Electrical breakdown phenomena of dielectric elastomers

Silicone elastomers have been heavily investigated as candidates for dielectric elastomers and are as such almost ideal candidates with their inherent softness and compliance but they suffer from low dielectric permittivity. This shortcoming has been sought optimized by many means during recent years. However, optimization with respect to the dielectric permittivity solely may lead to other problematic phenomena such as premature electrical breakdown. In this work, we investigate the electrical breakdown phenomena of various types of permittivity-enhanced silicone elastomers. Two types of silicone elastomers are investigated and different types of breakdown are discussed. Furthermore the use of voltage stabilizers in silicone-based dielectric elastomers is investigated and discussed.

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Organisations: Center for Electron Nanoscopy, Department of Chemical and Biochemical Engineering, The Danish Polymer Centre
Contributors: Mateiu, R. V., Yu, L., Skov, A. L.
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Master/slave: A better tool for Gabor filtering optical coherence tomography imaging instruments

In this report, the benefits that the Master/Slave (MS) implementation of optical coherence tomography (OCT) can bring to a Gabor filtering (GF) imaging instrument are illustrated. The MS allows simultaneous display of three categories of images in one frame: multiple depth en-face OCT images, two B-scan OCT and a confocal like image. The power of MS is illustrated here by showing 3D images of constant transversal resolution from different objects, obtained by merging sub-volumes collected for four different focus positions. By combining the two techniques, GF and MS, a powerful imaging instrument is demonstrated. We show that when more than four focus positions are required, MS can produce fused volumes faster than the conventional FT based procedure.

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Organisations: Department of Photonics Engineering, Fiber Sensors & Supercontinuum, University of Kent, Universite de Bretagne Occidentale, Moorfields Eye Hospital NHS Foundation Trust
Contributors: Cernat, R., Bradu, A., Israelsen, N. M., Bang, O., Rivet, S., Keane, P. A., Heath, D. G., Rajendram, R., Podoleanu, A.
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Towards an integrated squeezed light source

Since its first generation more than 30 years ago, squeezed light has developed towards a tool for high precision measurements as well as a tool for quantum information tasks like quantum key distribution. Miniaturization of sensors is an active field of research with the prospect of many applications. The precision of optical sensors based on interferometric measurements is often limited by the fundamental shot noise. While shot noise can be reduced by increasing the employed light power, integrated sensors pose limitations on the maximum possible amount due to damaging effects of high intensity as well as power consumption. Bright quadrature squeezed light produced by the optical Kerr effect in a nonlinear medium offers an opportunity to overcome these limitations. Here, we present first steps towards a bright quadrature squeezed light source produced by the optical Kerr effect in race-track resonators in silicon nitride by presenting characterizations of the chip. Using standard fabrication techniques this source will have the potential of seamless integration into on-chip optical sensors.

On-chip RF-to-optical transducer

Recent advances in the fabrication of nano- and micromechanical elements enable the realization of high-quality mechanical resonators with masses so small that the forces from optical photons can have a significant impact on their motion. This facilitates a strong interaction between mechanical motion and light, or phonons and photons. This interaction is the cornerstone of the field of optomechanics and allows, for example, for ultrasensitive detection and manipulation of mechanical motion using laser light. Remarkably, today these techniques can be extended into the quantum regime, in which fundamental fluctuations of light and mechanics govern the system’s behavior. Micromechanical elements can also interact strongly with other physical systems, which is the central aspect of many micro-electro-mechanical based sensors. Micromechanical elements can therefore act as a bridge between these diverse systems, plus technologies that utilize them, and the mature toolbox of optical techniques that routinely operates at the quantum limit.
In a previous work [1], we demonstrated such a bridge by realizing simultaneous coupling between an electronic LC circuit and a quantum-noise limited optical interferometer. The coupling was mediated by a mechanical oscillator forming a mechanically compliant capacitor biased with a DC voltage. The latter enhances the electromechanical interaction all the way to the strong coupling regime. That scheme allowed optical detection of electronic signals with effective noise temperatures far below the actual temperature of the mechanical element. On-chip integration of the electrical, mechanical and optical elements is necessary for an implementation of the transduction scheme that is viable for commercial applications. Reliable assembly of a strongly coupled electromechanical device, and inclusion of an optical cavity for enhanced optical readout, are key features of the new platform. Both can be achieved with standard cleanroom fabrication techniques. We will furthermore present ongoing work to couple our transducer to an RF or microwave antenna, for low-noise detection of electromagnetic signals, including sensitive measurements of magnetic fields in an MRI detector.

Suppression of thermomechanical noise is a key feature of electro-optomechanical transducers, and, more generally, hybrid systems involving mechanical degrees of freedom. We have shown that engineering of the phononic density of states allows improved isolation of the relevant mechanical modes from their thermal bath [2], enabling coherence times sufficient to realize quantum-coherent optomechanical coupling. This proves the potential of the employed platform for complex transducers all the way into the quantum regime.

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Organisations: Department of Micro- and Nanotechnology, Nanoprobes, University of Copenhagen
Contributors: Simonsen, A., Tsaturyan, Y., Seis, Y., Schmid, S., Schliesser, A., Polzik, E. S.
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Industrial characterization of nano-scale roughness on polished surfaces

We report a correlation between the scattering value “Aq” and the ISO standardized roughness parameter Rq. The Aq value is a measure for surface smoothness, and can easily be determined from an optical scattering measurement. The correlation equation extrapolates the Aq value from a narrow measurement range of ±16° from specular to a broader range of ±80°, corresponding to spatial surface wavelengths of 0.8 μm to 25 μm, and converts the Aq value to the Rq value for the surface.

Furthermore, we present an investigation of the changes in scattering intensities, when a surface is covered with a thin liquid film. It is shown that the changes in the angular scattering intensities can be compensated for the liquid film, using empirically determined relations. This allows a restoration of the “true” scattering intensities which would be measured from a corresponding clean surface. The compensated scattering intensities provide Aq values within 5.7 % ± 6.1 % compared to the measurements on clean surfaces.

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Organisations: Department of Micro- and Nanotechnology, Polymer Micro & Nano Engineering, Department of Mechanical Engineering, Manufacturing Engineering, Dansk Fundamental Metrology AVS
Contributors: Feidenhans'l, N. A., Hansen, P., Pilny, L., Madsen, M. H., Bissacco, G., Petersen, J. C., Taboryski, R. J.
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Publication information
130-nm tunable grating-mirror VCSEL

We have reported that a combination of the high-index-contrast grating (HCG) mirror as movable mirror and the extended cavity configuration with an antireflection layer can provide a tuning wavelength range of 100 nm for tunable VCSELs. Here, we report that using the air-coupled cavity configuration instead of the extended cavity configuration can bring 130-nm tuning range around 1330-nm wavelength. The air-coupled cavity is known to reduce the quantum confinement factor in VCSELs, increasing threshold. In our air-coupled cavity HCG VCSEL case, the very short power penetration length in the HCG minimizes this reduction of the quantum confinement factor, not as significant as in the air-coupled cavity DBR VCSEL.

Accurate and Simple Calibration of DLP Projector Systems

Much work has been devoted to the calibration of optical cameras, and accurate and simple methods are now available which require only a small number of calibration targets. The problem of obtaining these parameters for light projectors has not been studied as extensively and most current methods require a camera and involve feature extraction from a known projected pattern. In this work we present a novel calibration technique for DLP Projector systems based on phase shifting profilometry projection onto a printed calibration target. In contrast to most current methods, the one presented here does not rely on an initial camera calibration, and so does not carry over the error into projector calibration. A radial interpolation scheme is used to convert features coordinates into projector space, thereby allowing for a very accurate procedure. This allows for highly accurate determination of parameters including lens distortion. Our implementation acquires printed planar calibration scenes in less than 1s. This makes our method both fast and convenient. We evaluate our method in terms of reprojection errors and structured light image reconstruction quality.
Demonstration of a variable plasmonic beam splitter
In this contribution, we excite surface plasmon polaritons propagating along a silver nano-wire by a single nitrogen-vacancy center located in a diamond nano-crystal. By using the tip of an atomic force microscope, a second nano-wire is brought into the evanescent field of the first wire such that surface plasmons can evanescently couple. In our experiment, we are able to tune the coupling strength from one nano-wire to another by adjusting the gap with the aid of the atomic force microscope. Numerical calculations of the coupling strength are carried out, which support the values found in the experiment.

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Organisations: Department of Physics, Quantum Physics and Information Technology
Contributors: Kumar, S., Israelsen, N. M., Andersen, U. L., Huck, A.
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DLP technology application: 3D head tracking and motion correction in medical brain imaging
In this paper we present a novel sensing system, robust Near-infrared Structured Light Scanning (NIRSL) for three-dimensional human model scanning application. Human model scanning due to its nature of various hair and dress appearance and body motion has long been a challenging task. Previous structured light scanning methods typically emitted visible coded light patterns onto static and opaque objects to establish correspondence between a projector and a camera for triangulation. In the success of these methods rely on scanning objects with proper reflective surface for visible light, such as plaster, light colored cloth. Whereas for human model scanning application, conventional methods suffer from low signal to noise ratio caused by low contrast of visible light over the human body. The proposed robust NIRSL, as implemented with the near infrared light, is capable of recovering those dark surfaces, such as hair, dark jeans and black shoes under visible illumination. Moreover, successful structured light scan relies on the assumption that the subject is static during scanning. Due to the nature of body motion, it is very time sensitive to keep this assumption in the case of human model scan. The proposed sensing system, by utilizing the new near-infrared capable high speed LightCrafter DLP projector, is robust to motion, provides accurate and high resolution three-dimensional point cloud, making our system more efficient and robust for human model reconstruction. Experimental results demonstrate that our system is effective
and efficient to scan real human models with various dark hair, jeans and shoes, robust to human body motion and produces accurate and high resolution 3D point cloud.

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Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Copenhagen University Hospital
Contributors: Olesen, O. V., Wilm, J., Paulsen, R. R., Højgaard, L., Larsen, R.
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Epitaxial growth of quantum dots on InP for device applications operating at the 1.55 μm wavelength range
The development of epitaxial technology for the fabrication of quantum dot (QD) gain material operating in the 1.55 μm wavelength range is a key requirement for the evolution of telecommunication. High performance QD material demonstrated on GaAs only covers the wavelength region 1-1.35 μm. In order to extract the QD benefits for the longer telecommunication wavelength range the technology of QD fabrication should be developed for InP based materials. In our work, we take advantage of both QD fabrication methods Stranski-Krastanow (SK) and selective area growth (SAG) employing block copolymer lithography. Due to the lower lattice mismatch of InAs/InP compared to InAs/GaAs, InP based QDs have a larger diameter and are shallower compared to GaAs based dots. This shape causes low carrier localization and small energy level separation which leads to a high threshold current, high temperature dependence, and low laser quantum efficiency. Here, we demonstrate that with tailored growth conditions, which suppress surface migration of adatoms during the SK QD formation, much smaller base diameter (13.6nm versus 23nm) and an improved aspect ratio are achieved. In order to gain advantage of non-strain dependent QD formation, we have developed SAG, for which the growth occurs only in the nano-openings of a mask covering the wafer surface. In this case, a wide range of QD composition can be chosen. This method yields high purity material and provides significant freedom for reducing the aspect ratio of QDs with the possibility to approach an ideal QD shape.

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, Center for Electron Nanoscopy, Programmable Phase Optics, Department of Micro- and Nanotechnology, Nanointegration, Amphiphilic Polymers in Biological Sensing, University of Rome La Sapienza
Contributors: Semenova, E., Kulkova, I., Kadkhodazadeh, S., Barettin, D., Kopylov, O., Cagliani, A., Almdal, K., Willatzen, M., Yvind, K.
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Finger image quality based on singular point localization

Singular points are important global features of fingerprints and singular point localization is a crucial step in biometric recognition. Moreover the presence and position of the core point in a captured fingerprint sample can reflect whether the finger is placed properly on the sensor. Therefore, the displacement given by detected core points is investigated. We propose pattern-based filters to eliminate the false detection given by state of the art approaches. The experimental results show improvement using different databases. Based on the improved singular point localization algorithm, we explore and analyze the importance of singular points on biometric accuracy. The experiment is based on large scale databases and conducted by relating the measured quality of a fingerprint sample, given by the positions of core points, to the biometric performance. The experimental results show the positions of core points do have influence on the comparison algorithms, but are not as relevant as other benchmarked quality metrics.

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Organisations: Department of Applied Mathematics and Computer Science, Center for Advanced Security Research Darmstadt, Høgskolen i Gjøvik
Contributors: Wang, J., Olsen, M. A., Busch, C.
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Geometry optimization of tubular dielectric elastomer actuators with anisotropic metallic electrodes

This paper presents an experimentally verified static three-dimensional model for core free tubular dielectric elastomer actuators with anisotropic compliant metal electrodes. Due to the anisotropy of the electrodes, the performance (force versus voltage, force versus stroke, and stroke versus voltage) of the actuators depends strongly on their geometry. Based on the three-dimensional model, the performance of the actuators is optimized by means of the length of the axes of their inner elliptical cross section and their wall thickness.

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Organisations: Department of Photonics Engineering, University of Southern Denmark, Danfoss AS
Contributors: Rechenbach, B., Willatzen, M., Sarban, R., Liang, C., Lassen, B.
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Impact of primary aberrations on coherent lidar performance
In this work we investigate the performance of a monostatic coherent lidar system in which the transmit beam is under the influence of primary phase aberrations: spherical aberration (SA) and astigmatism. The experimental investigation is realized by probing the spatial weighting function of the lidar system using different optical transceiver configurations. A rotating belt is used as a hard target. Our study shows that the lidar weighting function suffers from both spatial broadening and shift in peak position in the presence of aberration. It is to our knowledge the first experimental demonstration of these tendencies. Furthermore, our numerical and experimental results show good agreement. We also demonstrate how the truncation of the transmit beam affects the system performance. It is both experimentally and numerically proven that aberration effects have profound impact on the antenna efficiency, the optimum truncation of the transmit beam and the spatial sensitivity of a CW coherent lidar system. Under strong degree of aberration, the spatial confinement is significantly degraded. However for SA, the degradation of the spatial confinement can be reduced by tuning the truncation of the transmit beam, which results from the novel finding in this work, namely, that the optimum truncation ratio depends on the degree of SA.

Modeling of ultrafast THz interactions in molecular crystals
In this paper we present a numerical study of terahertz pulses interacting with crystals of cesium iodide. We model the molecular dynamics of the cesium iodide crystals with the Density Functional Theory software CASTEP, where ultrafast terahertz pulses are implemented to the CASTEP software to interact with molecular crystals. We investigate the molecular dynamics of cesium iodide crystals when interacting with realistic terahertz pulses of field strengths from 0 to 50 MV/cm. We find nonlinearities in the response of the CsI crystals at field strengths higher than 10 MV/cm.
Modeling the leakage of LCD displays with local backlight for quality assessment

The recent technique of local backlight dimming has a significant impact on the quality of images displayed with a LCD screen with LED local dimming. Therefore it represents a necessary step in the quality assessment chain, independently from the other processes applied to images. This paper investigates the modeling of one of the major spatial artifacts produced by local dimming: leakage. Leakage appears in dark areas when the backlight level is too high for LC cells to block sufficiently and the final displayed brightness is higher than it should. A subjective quality experiment was run on videos displayed on LCD TV with local backlight dimming viewed from a 0° and 15° angles. The subjective results are then compared objective data using different leakage models: constant over the whole display or horizontally varying and three leakage factor (no leakage, measured at 0° and 15° respectively). Results show that for dark sequences accounting for the leakage artifact in the display model is definitely an improvement. Approximating that leakage is constant over the screen seems valid when viewing from a 15° angle while using a horizontally varying model might prove useful for 0° viewing.

Non-collinear upconversion of incoherent light: designing infrared spectrometers and imaging systems

Upconversion of incoherent mid-infrared radiation to near visible wavelengths, offers very attractive sensitivity compared to conventional means of infrared detection. Incoherent light, focused into a nonlinear crystal, results in noncollinear phase matching of a narrow range of wavelengths for each angle of propagation. Non-collinear phase matching has been an area of limited attention for many years due to inherent incompatibility with tightly focused laser beams typically used for most second order processes in order to achieve acceptable conversion efficiency. The development of periodically poled crystals have allowed for non-critical collinear phase matching of most wavelengths, virtually eliminating the need for non-collinear phase matching. When considering upconversion of thermal light, spectral radiance is limited due to the finite temperature of the Planck radiation source. It is, however, straightforward to increase the incoherent power by increasing the receiving aperture of the upconversion unit i.e. the diameter of the upconversion laser beam. Hence, the optimal conversion efficiency for incoherent light is not achieved by tightly focused beams. In this paper we show that filling the nonlinear crystal with as large a pump beam as possible yields the best conversion as this allows for upconversion of large angles of incoming incoherent light. We present results of non-collinear mixing and how it affects spectral and spatial resolution in the image and compare against experiments. We finally discuss how it can be used to design and predict system performance and how incoherent upconversion can be used for mid-IR spectroscopy and imaging.
Non-planar nanoselective area growth of InGaAs/InP

In this study, we have investigated metal-organic vapor phase epitaxial nano-patterned selective area growth of InGaAs/InP on non-planar (001) InP surfaces. Due to high etching resistance and the small molecular size of negative tone electron beam HSQ resist, the protection mask formed in HSQ has small feature sizes in ten nanometers scale and allow realization of in-situ etching. As was observed in the SAG regime, in-situ etching of InP by carbon tetrabromide leads to formation of self-limited structures. By altering etching time, the groove shape can be changed from a triangular trench to a trapeze. Another appealing aspect of in situ etching is that the shape of InGaAs can be tuned from a crescent to a triangular or a line by varying growth parameters. Quantum well wires can be fabricated by growing directly in the bottom of V-shaped groove. In addition, changes of mask orientations lead to anisotropic or isotropic character of etching. The investigated technique of nano-patterned selective area growth allows obtaining different profiles of structures and different quantum structures such as quantum well or wires in the same growth run. To investigate the shape and crystalline quality of the active material, the cross-sectional geometry was observed by field emission scanning electron microscopy and scanning transmission electron microscopy. The optical properties were carried out at room temperature using micro-photoluminescence setup. The results showed different deposition rates for openings oriented along [0-11] and [0-1-1] directions with higher rate along [0-1-1]. The fabricated active material was incorporated into photonic crystal waveguides.
Optical surface scanning for respiratory motion monitoring in radiotherapy: a feasibility study

Purpose. We evaluated the feasibility of a surface scanning system (Catalyst) for respiratory motion monitoring of breast cancer patients treated with radiotherapy in deep inspiration breath-hold (DIBH). DIBH is used to reduce the radiation dose to the heart and lung. In contrast to RPM, a competing marker-based system, Catalyst does not require an objectmarker on the patient's skin. Materials and Methods. Experiment 1: a manikin was used to simulate sinusoidal breathing. The amplitude, period and baseline (signal value at end-expiration) were estimated with RPM and Catalyst. Experiment 2 and 3: the Quasar phantom was used to study if the angle of the monitored surface affects the amplitude of the recorded signal. Results. Experiment 1: we observed comparable period estimates for both systems. The amplitudes were 8 ± 0.1 mm (Catalyst) and 4.9 ± 0.1 mm (RPM). Independent check with in-room lasers showed an amplitude of approximately 8 mm, supporting Catalyst measurements. Large baseline errors were seen with RPM. Experiment 2: RPM underestimated the amplitude if the object-marker was angled during vertical motion. This result explains the amplitude underestimation by RPM seen in Experiment 1. Experiment 3: an increased (fixed) surface angle during breathing motion resulted in an overestimated amplitude with RPM, while the amplitude estimated by Catalyst was unaffected. Conclusion. Our study showed that Catalyst can be used as a better alternative to the RPM. With Catalyst, the amplitude estimates are more accurate and do not depend on the angle of the tracked surface, and the baseline errors are smaller.

Preparing the optics technology to observe the hot universe

With the selection of "The hot and energetic Universe" as science theme for ESA's second large class mission (L2) in the Cosmic Vision programme, work is focusing on the technology preparation for an advanced X-ray observatory. The core enabling technology for the high performance mirror is the Silicon Pore Optics (SPO) [1 to 23], a modular X-ray optics technology, which utilises processes and equipment developed for the semiconductor industry. The paper provides an overview of the programmatic background, the status of SPO technology and gives an outline of the development roadmap and activities undertaken and planned by ESA on optics, coatings [24 to 30] and test facilities [31, 33].
Science requirements and optimization of the silicon pore optics design for the Athena mirror

The science requirements for the Athena X-ray mirror are to provide a collecting area of 2 m² at 1 keV, an angular resolution of ~5 arc seconds half energy eidth (HEW) and a field of view of diameter 40-50 arc minutes. This combination of area and angular resolution over a wide field are possible because of unique features of the Silicon pore optics (SPO) technology used. Here we describe the optimization and modifications of the SPO technology required to achieve the Athena mirror specification and demonstrate how the optical design of the mirror system impacts on the scientific performance of Athena.

Sparse and shrunken estimates of MRI networks in the brain and their influence on network properties

Estimation of morphometric relationships between cortical regions is a widely used approach to identify and characterize structural connectivity. The elevated number of regions that can be considered in a whole-brain correlation analysis might lead to overfitted models. However, the overfitting can be avoided by using regularization methods. We found that, as expected, non-regularized correlations had low variability when a scarce number of variables were considered. However, a slight increase of variables led to an increase of variance of several magnitude orders. On the other hand, the regularized approaches showed more stable results with a relative low variance at the expense of a little bias. Interestingly, topological properties as local and global efficiency estimated in networks constructed from traditional non-regularized correlations also showed higher variability when compared to those from regularized networks. Our findings suggest that a population-based connectivity study can achieve a more robust description of cortical topology through regularization of the correlation estimates. Four regularization methods were examined: Two with shrinkage (Ridge and Schäfer’s shrinkage), one with sparsity (Lasso) and one with both shrinkage and sparsity (Elastic net). Furthermore, the different regularizations resulted in different correlation estimates as well as network properties. The shrunken estimates resulted in lower variance of the estimates than the sparse estimates.
The Large Observatory For x-ray Timing

The Large Observatory For x-ray Timing (LOFT) was studied within ESA M3 Cosmic Vision framework and participated in the final down-selection for a launch slot in 2022-2024. Thanks to the unprecedented combination of effective area and spectral resolution of its main instrument, LOFT will study the behaviour of matter under extreme conditions, such as the strong gravitational field in the innermost regions of accretion flows close to black holes and neutron stars, and the supranuclear densities in the interior of neutron stars. The science payload is based on a Large Area Detector (LAD, 10 m² effective area, 2-30 keV, 4 steradian field of view, 1 arcmin source location accuracy, 300 eV spectral resolution). The WFM is equipped with an on-board system for bright events (e.g. GRB) localization. The trigger time and position of these events are broadcast to the ground within 30 s from discovery. In this paper we present the status of the mission at the end of its Phase A study.
Topology-optimized broadband surface relief transmission grating

We propose a design methodology for systematic design of surface relief transmission gratings with optimized diffraction efficiency. The methodology is based on a gradient-based topology optimization formulation along with 2D frequency domain finite element simulations for TE and TM polarized plane waves. The goal of the optimization is to find a grating design that maximizes diffraction efficiency for the -1st transmission order when illuminated by unpolarized plane waves. Results indicate that a surface relief transmission grating can be designed with a diffraction efficiency of more than 40% in a broadband range going from the ultraviolet region, through the visible region and into the near-infrared region.

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Organisations: Department of Mechanical Engineering, Solid Mechanics, Ibsen Photonics A/S
Contributors: Andkjær, J., Ryder, C. P., Nielsen, P. C., Rasmussen, T., Buchwald, K., Sigmund, O.
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Upconversion enhanced degenerate four-wave mixing in the mid-infrared for sensitive detection of acetylene in gas flows

We present a new background free method for in situ gas detection that combines degenerate four-wave mixing with an infra-red light detector based on parametric frequency upconversion of infra-red light. The system is demonstrated at mid infrared wavelengths for low concentration measurements of acetylene diluted in a N2 gas flow at ambient conditions. It is demonstrated that the system is able to cover more than 100 nm in scanning range and detect concentrations as low as 3 ppm based on the R9e line. A major issue in small signal measurements is scattered light and it is showed how a spatial analysis can be used to reduce this level.

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Contributors: Høgstedt, L., Dam, J. S., Sahlberg, A., Li, Z., Alden, M., Pedersen, C., Tidemand-Lichtenberg, P.
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3D terahertz beam profiling

We present a characterization of THz beams generated in both a two-color air plasma and in a LiNbO3 crystal. Using a commercial THz camera, we record intensity images as a function of distance through the beam waist, from which we extract 2D beam profiles and visualize our measurements into 3D beam profiles. For the two-color air-plasma, we measure a conical beam profile that is focused to a bell-shape at the beam waist, whereas we observe a Gaussian beam profile for the THz beam generated from the LiNbO3 crystal.

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Adapting an optical nanoantenna for high E-field probing applications to a waveguided optical waveguide (WOW)

In the current work we intend to use the optical nano-antenna to include various functionalities for the recently demonstrated waveguided optical waveguide (WOW) by Palima et al. (Optics Express 2012). Specifically, we intend to study a WOW with an optical nano-antenna which can block the guiding light wavelength while admitting other wavelengths of light which address certain functionalities, e.g. drug release, in the WOW. In particular, we study a bow-tie optical nano-antenna to circular dielectric waveguides in aqueous environments. It is shown with finite element computer simulations that the nanoantenna can be made to operate in a bandstop mode around its resonant wavelength where there is a very high evanescent strong electrical probing field close to the antennas, and additionally the fluorescence or Raman excitations will be be unpolluted by stray light from the WOW due to the band-stop characteristic. We give geometrical parameters necessary for realizing functioning nanoantennas. © (2013) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.

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Adaptive local backlight dimming algorithm based on local histogram and image characteristics

Liquid Crystal Display (LCDs) with Light Emitting Diode (LED) backlight is a very popular display technology, used for instance in television sets, monitors and mobile phones. This paper presents a new backlight dimming algorithm that exploits the characteristics of the target image, such as the local histograms and the average pixel intensity of each backlight segment, to reduce the power consumption of the backlight and enhance image quality. The local histogram of the pixels within each backlight segment is calculated and, based on this average, an adaptive quantile value is extracted. A classification into three classes based on the average luminance value is performed and, depending on the image luminance class, the extracted information on the local histogram determines the corresponding backlight value. The proposed method has been applied on two modeled screens: one with a high resolution direct-lit backlight, and the other screen with 16 edge-lit backlight segments placed in two columns and eight rows. We have compared the proposed algorithm against several known backlight dimming algorithms by simulations; and the results show that the proposed algorithm provides better trade-off between power consumption and image quality preservation than the other algorithms representing the state of the art among feature based backlight algorithms. © (2013) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.

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A new optical method improves fluorescence guided diagnosis of bladder tumor in the outpatient department and reveals significant photo bleaching problems in established inpatients PDD techniques

Photo dynamic diagnosis (PDD) is a convenient and well-documented procedure for diagnosis of bladder cancer and tumours using endoscopic techniques. At present, this procedure is available only for routine use in an operating room (OR) and often with substantial photobleaching effects of the photosensitizer. We present a novel optical design of the endoscopic PDD procedure that allows the procedure to be performed in the outpatient department (OPD) and not only in the OR. Thereby, inpatient procedures lasting 1-2 days may be replaced by a few hours lasting procedure in the OPD. Urine blurs the fluorescence during PDD used in the OPD. Urine contains fluorescent metabolites that are excited by blue light giving an opaque green fluorescence confounding the desired red fluorescence (PDD) from the tumour tissue. Measurements from the clinical situation has shown that some systems for PPD based on blue light illumination (PDD mode) and white light illumination used for bladder tumour diagnosis and surgery suffers some inherent disadvantages, i.e., photo bleaching in white light that impairs the possibility for PDD as white light usually is used before the blue light for PDD. Based on spectroscopic observations of urine and the photoactive dye Protoporphyrin IX used in PDD a novel optical system for use with the cystoscope has been devised that solves the problem of green fluorescence from urine. This and the knowledge of photo-bleaching pitfalls in established systems make it possible to perform PDD of bladder tumours in the OPD and to improve PDD in the OR. © 2013 SPIE.
A photonic nanowire trumpet for interfacing a quantum dot and a Gaussian free-space mode

Efficient coupling between a localized quantum emitter and a well defined optical channel represents a powerful route to realize single-photon sources and spin-photon interfaces. The tailored fiber-like photonic nanowire embedding a single quantum dot has recently demonstrated an appealing potential. However, the device requires a delicate, sharp needle-like taper with performance sensitive to minute geometrical details. To overcome this limitation we demonstrate the photonic trumpet, exploiting an opposite tapering strategy. The trumpet features a strongly Gaussian far-field emission. A first implementation of this strategy has lead to an ultra-bright single-photon source with a first-lens external efficiency of 0.75 ± 0.1 and a predicted coupling to a Gaussian beam of 0.61 ± 0.08.

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Bloch-wave engineered submicron-diameter quantum-dot micropillars for cavity QED experiments

The semiconductor micropillar is attractive for cavity QED experiments. For strong coupling, the figure of merit is proportional to Q/√V, and a design combining a high Q and a low mode volume V is thus desired. However, for the standard submicron diameter design, poor mode matching between the cavity and the DBR Bloch mode limits the Q. We present a novel adiabatic design where Bloch-wave engineering is employed to improve the mode matching, allowing the demonstration of a record-high vacuum Rabi splitting of 85 μeV and a Q of 13600 for a 850 nm diameter micropillar.

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Cellular scanning strategy for selective laser melting: Evolution of optimal grid-based scanning path & parametric approach to thermal homogeneity

Selective laser melting, as a rapid manufacturing technology, is uniquely poised to enforce a paradigm shift in the manufacturing industry by eliminating the gap between job- and batch-production techniques. Products from this process, however, tend to show an increased amount of defects such as distortions, residual stresses and cracks; primarily attributed to the high temperatures and temperature gradients occurring during the process. A unit cell approach towards the building of a standard sample, based on literature, has been investigated in the present work. A pseudo-analytical model has been developed and validated using thermal distributions obtained using different existing scanning strategies. Several existing standard and non-standard scanning methods have been evaluated and compared using the empirical model as well as a 3D-thermal finite element model. Finally, a new grid-based scan strategy has been developed for processing the standard sample, one unit cell at a time, using genetic algorithms, with an objective of reducing thermal asymmetries. © 2013 SPIE.

Coating optimization for the ATHENA+ mission

The ATHENA mission concept, now called ATHENA+, continues to be refined to address important questions in modern astrophysics. Previous studies have established that the requirement for effective area can be achieved using a combination of bi-layer coatings and/or simple graded multilayers. We find that further coating developments can improve on the baseline specifications and present here preliminary results on the optimization of coating design based on the new specifications of the ATHENA+ mission. The performances of several material combinations are investigated with the goal of maximizing the telescope effective area within the energy envelope of the mission and simulation of mirror performance is carried out. © (2013) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.
Connectorization of fibre Bragg grating sensors recorded in microstructured polymer optical fibre

We describe the production and characterization of FC/PC connectorised fibre Bragg grating sensors in polymer fibre. Sensors were recorded in few-moded and single mode microstructured fibre composed of poly (methyl methacrylate).

Continuous-wave near-photon counting spectral imaging detector in the mid-infrared by upconversion

Low noise upconversion of IR images by three-wave mixing, can be performed with high efficiency when mixing the object radiation with a powerful laser field inside a highly non-linear crystal such as periodically poled Lithium Niobate. Since IR cameras are expensive and have high levels of intrinsic noise, we suggest to convert the wavelength from the mid infrared to the visible/NIR wavelength for simple detection using CCD cameras. The intrinsic noise in cameras has two main contributions. First, read noise originating from the charge to signal read-out electronics. This noise source is usually measured in number of electrons. The second noise source is usually referred to as dark noise, which is the background signal generated over time. Dark noise is usually measured in electrons per pixel per second. For silicon cameras certain models like EM-CCD have close to zero read noise, whereas high-end IR cameras have read noise of hundreds of electrons. The dark noise for infrared cameras based on semiconductor materials is also substantially higher than for silicon cameras, typical values being millions of electrons per pixel per second for cryogenically cooled cameras whereas peltier cooled CCD cameras have dark noise measured in fractions of electrons per pixel per second. An ideal solution thus suggest the combination of an efficient low noise image wavelength conversion system combined with low noise silicon based cameras for low noise imaging in the IR region. We discuss image upconversion as a means to do low noise conversion of IR light to visible light. We demonstrate system noise performance orders of magnitude lower than existing
cryogenic cooled IR cameras.

**Cross-correlated imaging of distributed mode filtering rod fiber**

We analyze the modal properties of an 85μm core distributed mode filtering rod fiber using cross-correlated (C2) imaging. We evaluate suppression of higher-order modes (HOMs) under severely misaligned mode excitation and identify a single-mode regime where HOMs are suppressed by more than 20dB.

**Design and geometry of hybrid white light-emitted diodes for efficient energy transfer from the quantum well to the nanocrystals**
We demonstrate light color conversion in patterned InGaN light-emitting diodes (LEDs), which is enhanced via nonradiative exciton resonant energy transfer (RET) from the electrically driven diode to colloidal semiconductor nanocrystals (NCs). Patterning of the diode is essential for the coupling between a quantum well (QW) and NCs, because the distance between the QW and NCs is a main and very critical factor of RET. Moreover, a proper design of the pattern can enhance light extraction.

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Design of an 1800nm Raman amplifier
We present the experimental results for a Raman amplifier that operates at 1810 nm and is pumped by a Raman fiber laser at 1680 nm. Both the pump laser and the Raman amplifier is polarization maintaining. A challenge when scaling Raman amplifiers to longer wavelengths is the increase in transmission loss, but also the reduction in the Raman gain coefficient as the amplifier wavelength is increased. Both polarization components of the Raman gain is characterized, initially for linearly co-polarized signal and pump, subsequently linearly polarized orthogonal signal and pump. The noise performance of the amplifier is also investigated for both configurations. Our results show an on/off gain exceeding 20 dB at 1810 nm for which the obtained effective noise figure is below 3 dB.

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Design optimization of a linear actuator

The mechanical contacting of a dielectric elastomer actuator is investigated. The actuator is constructed by coiling the dielectric elastomer around two parallel metal rods, similar to a rubber band stretched by two index fingers. The goal of this paper is to design the geometry and the mechanical properties of a polymeric interlayer between the elastomer and the rods, gluing all materials together, so as to optimize the mechanical durability of the system. Finite element analysis is employed for the theoretical study which is linked up to experimental results performed by Danfoss PolyPower A/S.

Developing aircraft photonic networks for airplane systems

Achieving affordable high speed fiber optic communication networks for airplane systems has proved to be challenging. In this paper we describe a summary of the EU Framework 7 project DAPHNE (Developing Aircraft Photonic Networks). DAPHNE aimed to exploit photonic technology from terrestrial communications networks, and then develop and optimize aircraft photonic networks to take advantage of the potential cost savings. The main areas of emphasis were on: multiplexing networks; providing standard components; simplifying installation; and reducing through life support costs. DAPHNE (fifteen partners from seven nations) finished in February 2013; and was supported by the European Commission’s Seventh Framework Programme, although the consortium members are continuing with in-house developments.
Dynamically constrained pipeline for tracking neural progenitor cells

Large scale in vitro cell growth experiments require automated segmentation and tracking methods to construct cell lineages in order to aid cell biologists in further analysis. Flexible segmentation algorithms that easily adapt to the specific type of problem at hand and directly applicable tracking methods are fundamental building blocks of setting up multi-purposed pipelines. Segmentation by discriminative dictionary learning and a graph formulated tracking method constraining the allowed topology changes are combined here to accommodate for highly irregular cell shapes and movement patterns. A mitosis detector constructed from empirical observations of cells in a pre-mitotic state interacts with the graph formulation to dynamically allow for cell mitosis when appropriate. Track consistency is ensured by introducing pragmatic constraints and the notion of blob states. We validate the proposed pipeline by tracking pig neural progenitor cells through a time lapse experiment consisting of 825 images collected over 69 hours. Each step of the tracking pipeline is validated separately by comparison with manual annotations. The number of tracked cells increase from approximately 350 to 650 during the time period.

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Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Technical University of Denmark, University of Copenhagen
Contributors: Vestergaard, J. S., Dahl, A., Holm, P., Larsen, R.
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EAP high-level product architecture
EAP technology has the potential to be used in a wide range of applications. This poses the challenge to the EAP component manufacturers to develop components for a wide variety of products. Danfoss Polypower A/S is developing an EAP technology platform, which can form the basis for a variety of EAP technology products while keeping complexity under control. High level product architecture has been developed for the mechanical part of EAP transducers, as the foundation for platform development. A generic description of an EAP transducer forms the core of the high level product architecture. This description breaks down the EAP transducer into organs that perform the functions that may be present in an EAP transducer. A physical instance of an EAP transducer contains a combination of the organs needed to fulfill the task of actuator, sensor, and generation. Alternative principles for each organ allow the function of the EAP transducers to
be changed, by basing the EAP transducers on a different combination of organ alternatives. A model providing an overview of the high level product architecture has been developed to support daily development and cooperation across development teams. The platform approach has resulted in the first version of an EAP technology platform, on which multiple EAP products can be based. The contents of the platform have been the result of multi-disciplinary development work at Danfoss PolyPower, as well as collaboration with potential customers and research institutions. Initial results from applying the platform on demonstrator design for potential applications are promising. The scope of the article does not include technical details. © 2013 SPIE.

Effects of nonlinear phase modulation on quantum frequency conversion using four-wave mixing Bragg scattering

Recently, we solved the coupled-mode equations for Bragg scattering (BS) in the low- and high-conversion regimes, but without the effects of nonlinear phase modulation (NPM). We now present solutions and Green functions in the low-conversion regime that include NPM. We find that NPM does not change the lowest-order conversion efficiency, but prevents complete separability (freedom from temporal entanglement). This problem is overcome to some degree by pre-chirping the pumps, which mitigates the effects of NPM. We conclude that arbitrary reshaping of the output modes and nearly complete separability are still possible, even when the effects of NPM are included. Finally, the effects of using different input signals are considered, and we conclude that using the natural input modes of the system drastically increases the efficiency. © (2013) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.
Efficient concept generating 3.9 W of diffraction-limited green light with spectrally combined tapered diode lasers

We propose an efficient concept increasing the power of diode laser systems in the visible spectral range. In comparison with second harmonic generation of single emitters, we show that spectral beam combining with subsequent sumfrequency generation enhances the available power significantly. Combining two 1060 nm distributed Bragg reflector tapered diode lasers (M 24σ ≤ 5.2), we achieve a 2.5-3.2 fold increase of green light with a maximum power of 3.9 Watts in a diffraction-limited beam (M 24σ ≤ 1.3). Without any further stabilization the obtained power stability is within ± 2.6 %. The electro-optical and nonlinear conversion efficiencies at maximum performance are 5.7 % and 2.6 %/W, respectively. Due to the intrinsic wavelength stabilization of the diodes we achieve single-mode emission with a sidemode suppression <15 dB and a spectral width as narrow as 5 pm. These results increase the application potential of green diode laser systems, for example, within the biomedical field. In order to enhance the power even further, our proposed concept can be expanded combining multiple diode lasers.

Efficient formation of extended line intensity patterns using matched-filtering generalized phase contrast

We demonstrate the efficient generation of line patterns using matched-filtering Generalized Phase Contrast (mGPC). So far, the main emphasis of mGPC light addressing has been on the creation of rapidly reconfigurable focused spots. This has recently been extended to encoding extended line patterns for structured light applications and advanced microscopy. © (2013) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.
Electrical injection schemes for nanolasers

The performance of injection schemes among recently demonstrated electrically pumped photonic crystal nanolasers has been investigated numerically. The computation has been carried out at room temperature using a commercial semiconductor simulation software. For the simulations two electrical injection schemes have been compared: vertical p-n junction through a current post structure as in1 and lateral p-i-n junction with either uniform material as in2 or with a buried heterostructure (BH) as in3. To allow a direct comparison of the three schemes the same active material composition consisting of 3 InGaAsP QWs on an InP substrate has been chosen for the modeling. In the simulations the main focus is on the electrical and optical properties of the nanolasers i.e. electrical resistance, threshold voltage, threshold current and wallplug efficiency. In the current flow evaluation the lowest threshold current has been achieved with the lateral electrical injection through the BH; while the lowest resistance has been obtained from the current post structure even though this model shows a higher current threshold because of the lack of carrier confinement. Final scope of the simulations is the analyses of advantages and disadvantages of different electrical injection schemes for the development of the optimal device design for the future generation of electrically pumped nanolasers for terabit communication.

Engineering the propagation of high-k bulk plasmonic waves in multilayer hyperbolic metamaterials by multiscale structuring

Propagation of large-wavevector bulk plasmonic waves in multilayer hyperbolic metamaterials (HMMs) with two levels of structuring is theoretically studied. It is shown that when the parameters of a subwavelength metal-dielectric multilayer (substructure) are modulated (superstructured) on a larger, wavelength scale, the propagation of bulk plasmon polaritons in the resulting multiscale HMM is subject to photonic band gap phenomena. A great degree of control over such plasmons can be exerted by varying the superstructure geometry. As an example, Bragg reflection and Fabry-Pérot
resonances are demonstrated in multiscale HMMs with periodic superstructures. More complicated, aperiodically ordered superstructures are also considered, with fractal Cantor-like multiscale HMMs exhibiting characteristic self-similar spectral signatures in the high-k band. The multiscale HMM concept is shown to be a promising platform for using high-k bulk plasmonic waves as a new kind of information carriers, which can be used in far-field subwavelength imaging and plasmonic communication.

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Fabrication and optical trapping of handling structures for reconfigurable microsphere magnifiers
We demonstrate the use of microfabricated supporting structures for maneuvering and supporting polystyrene microspheres for use as magnifying lenses in imaging applications. The supporting structure isolates the trapping light from the magnifier, hence avoiding direct radiation to the sample being observed which could be damaging, especially for biological specimens. Using an optical trapping setup, we demonstrate the actuation of a microsphere not held by optical traps, and show the possibility of imaging through such microspheres. © (2013) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.

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Hard X-ray/soft gamma-ray telescope designs for future astrophysics missions

We present several concept designs of hard X-ray/soft γ-ray focusing telescopes for future astrophysics missions. The designs are based on depth graded multilayer coatings. These have been successfully employed on the NuSTAR mission for energies up to 80 keV. Recent advances in demonstrating theoretical reflectivities for candidate multilayer material combinations up to 400 keV including effects of incoherent scatter has given an experimental base for extending this type of designs to the soft X-ray range. At the same time, the calibration of the in-flight performance of the NuSTAR mission has given a solid understanding and modelling of the relevant effects influencing the performance, including optical constants, roughness, scatter, non-uniformities and figure error. This allows for a realistic extension for designs going to much higher energies. Similarly, both thin slumped glass and silicon pore optics has been developed to a prototype stage which promises imaging resolution in the sub 10 arcsecond range. We present designs based on a 20 m and 50 m focal lengths with energy ranges up to 200 keV and 600 keV. © (2013) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.

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High resolution mid-infrared spectroscopy based on frequency upconversion

We present high resolution upconversion of incoherent infrared radiation by means of sum-frequency mixing with a laser followed by simple CCD Si-camera detection. Noise associated with upconversion is, in strong contrast to room temperature direct mid-IR detection, extremely small, thus very faint signals can be analyzed. The obtainable frequency resolution is usually in the nm range where sub nm resolution is preferred in many applications, like gas spectroscopy. In this work we demonstrate how to obtain sub nm resolution when using upconversion. In the presented realization one object point is imaged through the upconverter. Assuming homogeneous spherical emission from the object point, the upconverted radiation will carry the spectral information as con-centric rings. From the optical path length and dispersion properties of the nonlinear material, the acceptance bandwidth of the upconversion process is calculated. It is then straightforward to deduce the spectral information of the light emitted from the object point by a simple analysis of the upconverted radiation. In order to increase resolution, a scanning Fabry-Perot etalon is inserted in a collimated geometry of the upconverted light generated by the crystal. The etalon is designed with a free-spectral range larger than the bandwidth of the upconversion process. Hence, the spectral resolution is now set by the finesse of the etalon. Based on this approach a spectral resolution of 0.2 nm has been reached around 2.9 μm. We demonstrate high resolution spectral performance by observing emission from hot water vapor in a butane gas burner.

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Contributors: Dam, J. S., Hu, Q., Tidemand-Lichtenberg, P., Pedersen, C.
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Imprinted and injection-molded nano-structured optical surfaces

Inspired by nature, nano-textured surfaces have attracted much attention as a method to realize optical surface functionality. The moth-eye antireflective structure and the structural colors of Morpho butterflies are well-known examples used for inspiration for such biomimetic research. In this paper, nanostructured polymer surfaces suitable for up-scalable polymer replication methods, such as imprinting/embossing and injection-molding, are discussed. The limiting case of injection-moulding compatible designs is investigated. Anti-reflective polymer surfaces are realized by replication of Black Silicon (BSi) random nanostructure surfaces. The optical transmission at normal incidence is measured for wavelengths from 400 nm to 900 nm. For samples with optimized nanostructures, the reflectance is reduced by 50% compared to samples with planar surfaces. The specular and diffusive reflection of light from polymer surfaces and their implication for creating structural colors is discussed. In the case of injection-moulding compatible designs, the maximum reflection of nano-scale textured surfaces cannot exceed the Fresnel reflection of a corresponding flat polymer surface, which is approx. 4% for normal incidence. Diffraction gratings provide strong color reflection defined by the diffraction orders. However, the appearance varies strongly with viewing angles. Three different methods to address the strong angular-dependence of diffraction grating based structural color are discussed.

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Research output: Contribution to journal › Journal article – Annual report year: 2013 › Research › peer-review
Light-driven robotics for nanoscopy

The science fiction inspired shrinking of macro-scale robotic manipulation and handling down to the micro- and nanoscale regime opens new doors for exploiting the forces and torques of light for micro- and nanoscopic probing, actuation and control. Advancing light-driven micro-robotics requires the optimization of optical forces and torques that, in turn, requires optimization of the underlying light-matter interaction. This report is two-fold describing the new use of proprietary strongholds we currently are harnessing in the Programmable Phase Optics in Denmark on new means of sculpting of both light and matter for robotically probing at the smallest biological length scales.

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Light quality and efficiency of consumer grade solid state lighting products

The rapid development in flux and efficiency of Light Emitting Diodes (LED) has resulted in a flooding of the lighting market with Solid State Lighting (SSL) products. Many traditional light sources can advantageously be replaced by SSL products. There are, however, large variations in the quality of these products, and some are not better than the ones they are supposed to replace. A lack of quality demands and standards makes it difficult for consumers to get an overview of the SSL products.

Here the results of a two year study investigating SSL products on the Danish market are presented. Focus has been on SSL products for replacement of incandescent lamps and halogen spotlights. The warm white light and good color rendering properties of these traditional light sources are a must for lighting in Denmark and the Nordic countries. 266 SSL replacement lamps have been tested for efficiency and light quality with respect to correlated color temperature and color rendering properties.

This shows a trade-off between high color rendering warm white light and energy efficiency. The lumen and color maintenance over time has been investigated and results for products running over 11000 h will be presented. A new internet based SSL product selection tool will be shown. Here the products can be compared on efficiency, light quality parameters, thus providing a better basis for the selection of SSL products for consumers.

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Contributors: Dam-Hansen, C., Corell, D. D., Thorseth, A., Poulsen, P. B.
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Publication information
Modal instability of rod fiber amplifiers: a semi-analytic approach

The modal instability (MI) threshold is estimated for four rod fiber designs by combining a semi-analytic model with the finite element method. The thermal load due to the quantum defect is calculated and used to numerically determine the mode distributions on which the expression for the onset of MIs is highly dependent. The relative intensity noise of the seed laser in an amplifier setup is used to seed the mode coupling between the fundamental and higher order mode, and lead to MI threshold values of 174 W – 348 W of extracted output power for the four rod fibers having core diameters in the range 53 μm – 95 μm.

Multispectral mid-infrared imaging using frequency upconversion

It has recently been shown that it is possible to upconvert infrared images to the near infrared region with high quantum efficiency and low noise by three-wave mixing with a laser field [1]. If the mixing laser is single-frequency, the upconverted image is simply a band-pass filtered version of the infrared object field, with a bandwidth corresponding given by the acceptance parameter of the conversion process, and a center frequency given by the phase-match condition. Tuning of the phase-matched wavelengths has previously been demonstrated by changing the temperature [2] or angle [3] of the nonlinear material. Unfortunately, temperature tuning is slow, and angle tuning typically results in alignment issues. Here we present a novel approach where the wavelength of the mixing field is used as a tuning parameter, allowing for fast tuning and hence potentially fast image acquisition, paving the way for upconversion based real time multispectral imaging. In the present realization the upconversion module consists of an external cavity tapered diode laser in a Littrow configuration with a...
Multi-THz spectroscopy of mobile charge carriers in P3HT:PCBM on a sub-100 fs time scale
The dynamics of mobile charge carrier generation in polymer bulk heterojunction films is of vital importance to the development of more efficient organic photovoltaics. As with conventional semiconductors, the optical signatures of mobile carriers lie in the far-infrared (1-30 THz) although the electrodynamics deviate strongly from the Drude model. The key time scales for the process are sub-100 fs to picoseconds, and is a challenge to perform low energy spectroscopy on these time scales as it is less than the period of oscillation for the probing light. In this work, we demonstrate sub-100 fs spectroscopy of a polymer bulk heterojunction film P3HT:PCBM using a single-cycle, phase-locked and coherently detected multi-THz transient as a probe pulse following femtosecond excitation at 400 nm. By observing changes to the reflected THz transients from the film surface following photoexcitation, we can extract the complex optical conductivity spectrum for the film in snapshots of 40 fs following photoexcitation. We find that for our excitation conditions mobile charges are created in less than 120 fs and are characterized by a spectrum which is characteristic of a two dimensional delocalized polaron. A large fraction of mobile carriers relax to a localized state on a 1 ps time scale. Pump energy dependent photon-to-mobile carrier conversion efficiency supports hot exciton dissociation as a mechanism for such fast mobile carrier generation.
New horizons for Supercontinuum light sources: from UV to mid-IR
Commercially available supercontinuum sources continue to experience a strong growth in a wide range of industrial and scientific applications. In addition, there is a significant research effort focused on extending the wavelength coverage both towards UV and Mid-IR. Broadband sources covering these wavelength regions have received significant attention from potential users, as there is a wide array of applications for which there are few suitable alternative light sources – if any. Our developments in the field of Mid-IR supercontinuum sources have been based on radical approaches; such as soft glasses and novel pumping schemes, whereas shifting the spectrum further towards the UV has been based on sophisticated microstructure fiber designs. Here we present our latest developments in tailoring the power and spectral coverage of spatially coherent broadband supercontinuum sources.

Nonlinear spatial mode imaging of hybrid photonic crystal fibers
Degenerate spontaneous four wave mixing is studied for the rst time in a large mode area hybrid photonic crystal ber, where light con nement is achieved by combined index- and bandgap guiding. Four wave mixing products are generated on the edges of the bandgaps, which is veri ed by numerical and experimental results. Since the core mode is in resonance with cladding modes near the bandedges an unconventional measurement technique is used, in this work named nonlinear spatial mode imaging.
Nonlocal modification and quantum optical generalization of effective-medium theory for metamaterials

A well-known challenge for fabricating metamaterials is to make unit cells significantly smaller than the operating wavelength of light, so one can be sure that effective-medium theories apply. But do they apply? Here we show that nonlocal response in the metal constituents of the metamaterial leads to modified effective parameters for strongly subwavelength unit cells. For infinite hyperbolic metamaterials, nonlocal response gives a very large finite upper bound to the optical density of states that otherwise would diverge. Moreover, for finite hyperbolic metamaterials we show that nonlocal response affects their operation as superlenses, and interestingly that sometimes nonlocal theory predicts the better imaging. Finally, we discuss how to describe metamaterials effectively in quantum optics. Media with loss or gain have associated quantum noise, and the question is whether the effective index is enough to describe this quantum noise effectively. We show that this is true for passive metamaterials, but not for metamaterials where loss is compensated by linear gain. For such loss-compensated metamaterials we present a quantum optical effective medium theory with an effective noise photon distribution as an additional parameter. Interestingly, we find that at the operating frequency, metamaterials with the same effective index but with different amounts of loss compensation can be told apart in quantum optics.

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Photonic wires and trumpets for ultrabright single photon sources

Photonic wires have recently demonstrated very attractive assets in the field of high-efficiency single photon sources. After presenting the basics of spontaneous emission control in photonic wires, we compare the two possible tapering strategies that can be applied to their output end so as to tailor their radiation diagram in the far-field. We highlight the novel "photonic trumpet" geometry, which provides a clean Gaussian beam, and is much less sensitive to fabrication imperfections than the more common needle-like taper geometry. S4Ps based on a single QD in a PW with integrated bottom mirror and tapered tip display jointly a record-high efficiency (0.75±0.1 photon per pulse) and excellent single photon purity. Beyond single photon sources, photonic wires and trumpets appear as a very attractive resource for solid-state quantum optics experiments.

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Plasmonic modulator based on thin metal-semiconductor-metal waveguide with gain core

We focus on plasmonic modulators with a gain core to be implemented as active nanodevices in photonic integrated circuits. In particular, we analyze metal–semiconductor–metal (MSM) waveguides with InGaAsP-based active material layers. A MSM waveguide enables high field localization and therefore high modulation speed. The modulation is achieved by changing the gain of the core that results in different transmittance through the waveguide. Dependences on the waveguide core size and gain values of various active materials are studied. The effective propagation constants in the MSM waveguides are calculated numerically. We optimize the structure by considering thin metal layers. A thin single metal layer supports an asymmetric mode with a high propagation constant. Implementing such layers as the waveguide claddings allows to achieve several times higher effective indices than in the case of a waveguide with thick (>50 nm) metal layers. In turn, the high effective index leads to enhanced modulation speed. We show that a MSM waveguide with the electrical current control of the gain incorporates compactness and deep modulation along with a reasonable level of transmittance.

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Platform based design of EAP transducers in Danfoss PolyPower A/S

Electroactive Polymer (EAP) has gained increasing focus, in research communities, in last two decades. Research within the field of EAP has, so far, been mainly focused on material improvements, characterization, modeling and developing demonstrators. As the EAP technology matures, the need for a new area of research namely product development emerges. Product development can be based on an isolated design and production for a single product or platform design where a product family is developed. In platform design the families of products exploits commonality of platform modules while satisfying a variety of different market segments. Platform based approach has the primary benefit of being cost efficient and short lead time to market when new products emerges. Products development based on EAP technology is challenging both technologically as well as from production and processing point of view. Both the technological and processing challenges need to be addressed before a successful implementation of EAP technology into products. Based on this need Danfoss PolyPower A/S has, in 2011, launched a EAP platform project in collaboration with three Danish universities and three commercial organizations. The aim of the project is to develop platform based designs and product family for the EAP components to be used in variety of applications. This paper presents the structure of the platform project as a whole and specifically the platform based designs of EAP transducers. The underlying technologies, essential for EAP transducers, are also presented. Conceptual design and solution for the concepts are presented as well. © 2013 SPIE.

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Contributors: Sarban, R., Guðlaugsson, T. V.
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Propagation and excitation of graphene plasmon polaritons

We theoretically investigate the propagation of graphene plasmon polaritons in graphene nanoribbon waveguides and experimentally observe the excitation of the graphene plasmon polaritons in a continuous graphene monolayer. We show that graphene nanoribbon bends do not induce any additional loss and nanofocusing occurs in a tapered graphene nanoribbon, and we experimentally demonstrate the excitation of graphene plasmon polaritons in a continuous graphene monolayer assisted by a two-dimensional subwavelength silicon grating.
Quantum-dot micropillars for parametric THz emission

We report on the design, fabrication and optical investigation of AlGaAs microcavities for THz Difference Frequency Generation (DFG) between Whispering Gallery Modes (WGMs), where the pump and DFG wavelengths ($\lambda \approx 1.3 \mu m$ and $\lambda \approx 75-150 \mu m$, respectively) lie on opposite sides of the Restrahlen band. For the pump modes, we demonstrate CW lasing of quantum-dot layers under electrical injection at room temperature. We control the number of lasing WGMs via vertical notches on the pillars sidewalls, providing a selection mechanism for funneling the power only to the modes contributing to DFG. In parallel with the optimization of the pump lasers and in order to validate design and material parameters before the DFG experiments, we have performed linear measurements on two sets of passive samples. For the telecom range, the micropillars have been integrated with waveguides for distributed coupling and characterized via transmission measurements. In the THz range we have measured reflectivity spectra on 2D arrays of identical cylinders. In both cases, we demonstrate a good agreement between experimental results and simulations. On a more speculative note, we numerically show that etching a hole along the pillar axis can facilitate phase matching, while single-lobe farfield pattern can be obtained for the THz mode by micro-structuring the metallic ground plane around the microcavity. Finally, we suggest a real-time fine-tuning mechanism for the forthcoming active devices.
Spatial properties of a terahertz beam generated from a two-color air plasma
We present a spatial characterization of terahertz (THz) beams generated from a two-color air plasma under different conditions by measuring full 3D beam profiles using a commercial THz camera. We compare two THz beam profiles emitted from plasmas generated by 35 fs and 100 fs laser pulses, and show that the spatial properties of the two THz beams do not change significantly. For the THz beam profile generated by the 35 fs pulse, the spatial effect of eliminating the lower frequencies is investigated by implementing two crossed polarizers working as a high-pass filter. We show that this reduces the beam waist, and that the beam spot shape changes from Lorentzian to Gaussian. Finally, we observe a forward-propagating Gaussian THz beam by spatially filtering away the conical off-axis radiation with a 1 cm aperture.

Speed enhancement in VCSELs employing grating mirrors
In recent years, various approaches to improve the speed of directly modulated vertical-cavity surface-emitting lasers (VCSELs) have been reported and demonstrated good improvement. In this paper, we propose and numerically investigate a new possibility of using high-index-contrast grating (HCG) as mirror for VCSELs. By changing the grating design, one can control the reflection delay of the grating mirror, enabling the control of cavity photon lifetime. On the other hand, short energy penetration depth of the HCG results in smaller modal volume, compared to DBR VCSELs. An example structure shows that the HCG VCSEL has a 30-% higher 3-dB bandwidth than the DBR VCSEL.
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Systematic investigation of the temperature behavior of InAs/InP quantum nanostructure passively mode-locked lasers
This paper aims to investigate the effects of the temperature on the mode-locking capability of two section InAs/InP quantum nanostructure (QN) passively mode locked lasers. Devices are made with multi-layers of self-assembled InAs QN either grown on InP(100) (5 quantum dashes (QDashes) layers) or on InP (311)B (6 quantum dots (QDs) layers).
Using an analytical model, the mode-locking stability map is extracted for the two types of QN as a function of optical absorption, cavity length, current density and temperature. We believe that this study is of first importance since it reports for the first time a systematic investigation of the temperature-dependence on the mode-locking properties of InAs/InP QN devices. Beside, a rigorous comparison between QDashes and QDs temperature dependence is proposed through a proper analysis of the mode-locking stability maps. Experimental results also show that under some specific conditions the mode-locking operation can be temperature independent.

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, Universite europeenne de Bretagne
Contributors: Klaime, K., Piron, R., Grillot, F., Dontabactouny, M., Loualiche, S., Le Corre, A., Yvind, K.
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Terahertz semiconductor nonlinear optics
In this proceedings we describe our recent results on semiconductor nonlinear optics, investigated using single-cycle THz pulses. We demonstrate the nonlinear absorption and self-phase modulation of strong-field THz pulses in doped semiconductors, using n-GaAs as a model system. The THz nonlinearity in doped semiconductors originates from the near-instantaneous heating of free electrons in the ponderomotive potential created by electric field of the THz pulse, leading to ultrafast increase of electron effective mass by intervalley scattering. Modification of effective mass in turn leads to a decrease of plasma frequency in semiconductor and produces a substantial modification of THz-range material
dielectric function, described by the Drude model. As a result, the nonlinearity of both absorption coefficient and refractive index of the semiconductor is observed. In particular we demonstrate the nonlinear THz pulse compression and broadening in n-GaAs, as well as an intriguing effect of coexisting positive and negative refractive index nonlinearity within the broad spectrum of a single-cycle THz pulse. Based on Drude analysis we demonstrate that the spectral position of zero index nonlinearity is determined by (but not equal to) the electron momentum relaxation rate. Single cycle pulses of light, irrespective of the frequency range to which they belong, inherently have an ultrabroadband spectrum covering many octaves of frequencies. Unlike the single-cycle pulses in optical domain, the THz pulses can be easily sampled with sub-cycle resolution using conventional femtosecond lasers. This makes the THz pulses accessible model tools for direct observation of general nonlinear optical phenomena occurring in the single-cycle regime.

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The impact of external optical feedback on the degradation behavior of high-power diode lasers
The impact of external feedback on high-power diode laser degradation is studied. For this purpose early stages of gradual degradation are prepared by accelerated aging of 808-nm-emitting AlGaAs-based devices. While the quantum well that actually experiences the highest total optical load remains unaffected, severe impact is observed to the cladding layers and the waveguide. Consequently hardening of diode lasers for operation under external optical feedback must necessarily involve claddings and waveguide, into which the quantum well is embedded.

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Contributors: Hempel, M., Chi, M., Petersen, P. M., Zeimer, U., Weyers, M., Tomm, J. W.
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The photonic nanowire: an emerging platform for highly efficient single-photon sources for quantum information applications

Efficient coupling between a localized quantum emitter and a well defined optical channel represents a powerful route to realize single-photon sources and spin-photon interfaces. The tailored fiber-like photonic nanowire embedding a single quantum dot has recently demonstrated an appealing potential. However, the device requires a delicate, sharp needle-like taper with performance sensitive to minute geometrical details. To overcome this limitation we demonstrate the photonic trumpet, exploiting an opposite tapering strategy. The trumpet features a strongly Gaussian far-field emission. A first implementation of this strategy has lead to an ultra-bright single-photon source with a first-lens external efficiency of $0.75 \pm 0.1$ and a predicted coupling to a Gaussian beam of $0.61 \pm 0.08$.

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Thermal effect-resilient design of large mode area double-cladding Yb-doped photonic crystal fibers

The effects of thermally-induced refractive index change on the guiding properties of different large mode area fibers have been numerically analyzed. A simple but accurate model has been applied to obtain the refractive index change in the fiber cross-section, and a full-vector modal solver based on the finite-element method has been used to calculate the guided modes of the fibers operating at high power levels. The results demonstrate that resonant structures added to the fiber cross-section can be exploited to provide efficient suppression of high-order modes with a good resilience to thermal effects.

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Contributors: Coscelli, E., Poli, F., Johansen, M. M., Alkeskjold, T. T., Leick, L., Broeng, J., Sozzi, M., Candiani, A., Cucinotta, A., Selleri, S.
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Publication information
Thermal-recovery of modal instability in rod fiber amplifiers

We investigate the temporal dynamics of Modal instabilities (MI) in ROD fiber amplifiers using a 100 μm core rod fiber in a single-pass amplifier configuration, and we achieve ~200W of extracted output power before the onset of MI. Above the MI threshold, we investigate the temporal dynamics of beam fluctuations in both the transient and chaotic regime. We identify a set of discrete frequencies in the transient regime and a white distribution of frequencies in the chaotic regime. We test three identical rods using a multiple ramp-up procedure, where each rod is tested in three test series and thermally annealed between each test series. We find that the MI threshold degrades as it is reached multiple times, but is recovered by thermal annealing. We also find that the test history of the rods affects the temporal dynamics.

General information

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Contributors: Jørgensen, M. M., Laurila, M., Noordegraaf, D., Tanggaard Alkeskjold, T., Lægsgaard, J.
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Tunable Resonant-Cavity-Enhanced Photodetector with Double High-Index-Contrast Grating Mirrors

In this paper, we propose a broadband-tunable resonant-cavity-enhanced photodetector (RCE-PD) structure with double high-index-contrast grating (HCG) mirrors and numerically investigate its characteristics. The detector is designed to operate at 1550-nm wavelength. The detector structure consists of a top InP HCG mirror, a p-i-n photodiode embedding multiple quantum wells, and a Si HCG mirror formed in the Si layer of a silicon-on-insulator wafer. The detection wavelength can be changed by moving the top InP HCG mirror suspended in the air. High reflectivity and small penetration length of HCGs lead to a narrow absorption linewidth of 0.38 nm and a broad tuning range of 111 nm. The peak absorption efficiency is 76-84% within the tuning range. This broadband-tunable and narrow-absorption-linewidth RCE-PD is desirable for applications where selective wavelength demultiplexing is required. Furthermore, the fact that it can be fabricated on a silicon platform offers us a possibility of integration with electronics.

Tunable Resonant-Cavity-Enhanced Photodetector with Double High-Index-Contrast Grating Mirrors

In this paper, we propose a broadband-tunable resonant-cavity-enhanced photodetector (RCE-PD) structure with double high-index-contrast grating (HCG) mirrors and numerically investigate its characteristics. The detector is designed to operate at 1550-nm wavelength. The detector structure consists of a top InP HCG mirror, a p-i-n photodiode embedding multiple quantum wells, and a Si HCG mirror formed in the Si layer of a silicon-on-insulator wafer. The detection wavelength can be changed by moving the top InP HCG mirror suspended in the air. High reflectivity and small penetration length of HCGs lead to a narrow absorption linewidth of 0.38 nm and a broad tuning range of 111 nm. The peak absorption efficiency is 76-84% within the tuning range. This broadband-tunable and narrow-absorption-linewidth RCE-PD is desirable for applications where selective wavelength demultiplexing is required. Furthermore, the fact that it can be fabricated on a silicon platform offers us a possibility of integration with electronics.
VCSELs with a high-index-contrast grating for mode-division multiplexing

A novel vertical-cavity surface-emitting laser (VCSEL) structure for space division multiplexing (SDM) is proposed and numerically investigated. This laser structure employs a high-index-contrast grating (HCG) as a light-emitting mirror. The reflectivity of the HCG mirror is spatially modulated to excite a specific transverse mode, while its transmission phase is kept spatially constant. This laser can provide the selective excitation of a specific transverse mode, leading to a high coupling efficiency to a few mode fiber. Compared to the phase plate approach in current SDM systems, the HCG-integrated VCSEL approach can be a much more compact and cheaper alternative.
Wyner-Ziv Coding of Depth Maps Exploiting Color Motion Information

Distributed Video Coding of multi-view data and depth maps is an interesting and challenging research field, whose interest is growing thanks to the recent advances in depth estimation and the development of affordable devices able to acquire depth information. In applications like video surveillance and object tracking, the availability of depth data can be beneficial and allow for more accurate processing. In these scenarios, the encoding complexity is typically limited and therefore distributed coding approaches are desirable. In this paper a novel algorithm for distributed compression of depth maps exploiting corresponding color information is proposed. Due to the high correlation of the motion in color and corresponding depth videos, motion information from the decoded color signal can effectively be exploited to generate accurate side information for the depth signal, allowing for higher rate-distortion performance without increasing the delay at the decoder side. The proposed scheme has been evaluated against state-of-the-art distributed video coding techniques applied on depth data. Experimental results show that the proposed algorithm can provide PSNR improvement between 2.18 dB and 3.40 dB on depth data compared to the reference DISCOVER decoder, for GOP 2 and QCIF resolution. © (2013) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.

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X-ray optics developments at ESA

Future high energy astrophysics missions will require high performance novel X-ray optics to explore the Universe beyond the limits of the currently operating Chandra and Newton observatories. Innovative optics technologies are therefore being developed and matured by the European Space Agency (ESA) in collaboration with research institutions and industry, enabling leading-edge future science missions.

Silicon Pore Optics (SPO) [1 to 21] and Slumped Glass Optics (SGO) [22 to 29] are lightweight high performance X-ray optics technologies being developed in Europe, driven by applications in observatory class high energy astrophysics missions, aiming at angular resolutions of 5" and providing effective areas of one or more square meters at a few keV.

This paper reports on the development activities led by ESA, and the status of the SPO and SGO technologies, including progress on high performance multilayer reflective coatings [30 to 35]. In addition, the progress with the X-ray test facilities and associated beam-lines is discussed [36].
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X-ray optics for axion helioscopes

A method of optimizing grazing incidence x-ray coatings in ground based axion helioscopes is presented. Software has been developed to find the optimum coating when taking both axion spectrum and Micromegas detector quantum efficiency into account. A comparison of the relative effective area in the telescope using different multilayer material combinations is produced. Similar methods are used for IAXO, a planned axion helioscope. Additionally, the optimal focal length is modelled while taking into account the least possible background contribution from the detector. © (2013) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.

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Contributors: Jakobsen, A. C., Pivovaroff, M. J., Christensen, F. E.
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3D shape measurement using deterministic phase retrieval and a partially developed speckle field

For deterministic phase retrieval, the problem of insignificant axial intensity variations upon defocus of a smooth object wavefront is addressed. Our proposed solution is based on the use of a phase diffuser facilitating the formation of a partially-developed speckle field (i.e., a field with both scattered-wave and unperturbed-wave components). The smooth test wavefront impinges first on the phase diffuser producing the speckle field. Then two speckle patterns with different defocus are recorded at the output plane of a 4f-optical filtering setup with a spatial light modulator (SLM) in the common
Fourier domain. The local variations of the recorded speckle patterns and the defocus distance approximate the axial intensity derivative which, in turn, is required to recover the wavefront phase via the transport of intensity equation (TIE). The SLM setup reduces the speckle recording time and the TIE allows direct (i.e., non-iterative) calculation of the phase. The pre-requisite partially-developed speckle field in our technique facilitates high image contrast and significant axial intensity variation. Wavefront reconstruction for the 3D refractive test object used demonstrates the effectiveness of the technique.

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Contributors: Almoro, P. F., Waller, L., Agour, M., Falldorf, C., Pedrini, G., Osten, W., Hanson, S. G.
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A 3D CZT hard x-ray polarimeter for a balloon-borne payload
Today it is widely recognised that a measurement of the polarization status of cosmic sources high energy emission is a key observational parameter to understand the active production mechanism and its geometry. Therefore new instrumentation operating in the hard X/soft γ rays energy range should be optimized also for this type of measurement. In this framework, we present the concept of a small high-performance spectrometer designed for polarimetry between 100 and 1000 keV suitable as a stratospheric balloon-borne payload dedicated to perform an accurate and reliable measurement of the polarization status of the Crab pulsar, i.e. the polarization level and direction. The detector with 3D spatial resolution is based on a CZT spectrometer in a highly segmented configuration designed to operate as a high performance scattering polarimeter. We discuss different configurations based on recent development results and possible improvements currently under study. Furthermore we describe a possible baseline design of the payload, which can be also seen as a pathfinder for a high performance focal plane detector in new hard X and soft gamma ray focussing telescopes and/or advanced Compton instruments. Finally we present preliminary data from Montecarlo undergoing studies to determine the best trade-off between polarimetric performance and detector design complexity.

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Absorption enhancement in metal nanoparticles for photoemission current for solar cells

In order to improve the photoconversion efficiency, we consider the possibility of increasing the photocurrent in solar cells exploiting the electron photoemission from small metal nanoparticles into a semiconductor. The effect is caused by the absorption of photons and generation of local surface plasmons in the nanoparticles with optimized geometry. An electron photoemission from metal into semiconductor occurs if photon energy is larger than Schottky barrier at the metal-semiconductor interface. The photocurrent resulting from the absorption of photons with energy below the bandgap of the semiconductor added to the solar cell photocurrent can extend spectral response range of the device. We study the effect on a model system, which is a Schottky barrier n-GaAs solar cell, with an array of Au nanoparticles positioned at the interface between the semiconductor and the transparent top electrode. Based on the simulations, we chose to study disk-shaped Au nanoparticles with sizes ranging from 25nm to 50nm using electron beam lithography. Optical characterization of the fabricated devices shows the presence of LSP resonance around the wavelength of 1250nm, below the bandgap of GaAs.

Accelerator experiments with soft protons and hyper-velocity dust particles: application to ongoing projects of future X-ray missions

We report on our activities, currently in progress, aimed at performing accelerator experiments with soft protons and hyper-velocity dust particles. They include tests of different types of X-ray detectors and related components (such as filters) and measurements of scattering of soft protons and hyper-velocity dust particles off X-ray mirror shells. These activities have been identified as a goal in the context of a number of ongoing space projects in order to assess the risk posed by environmental radiation and dust and qualify the adopted instrumentation with respect to possible damage or performance degradation. In this paper we focus on tests for the Silicon Drift Detectors (SDDs) used aboard the LOFT space mission. We use the Van de Graaff accelerators at the University of Tübingen and at the Max Planck Institute for Nuclear Physics (MPIK) in Heidelberg, for soft proton and hyper-velocity dust tests respectively. We present the experimental set-up adopted to perform the tests, status of the activities and some very preliminary results achieved at present time.
Active resonance tuning of stretchable plasmonic structures

Active resonance tuning is highly desired for the applications of plasmonic structures, such as optical switches and surface enhanced Raman substrates. In this paper, we demonstrate the active tunable plasmonic structures, which composed of monolayer arrays of metallic semishells with dielectric cores on stretchable elastic substrates. These composite structures support Bragg-type surface plasmon resonances whose frequencies are sensitive to the arrangement of the metallic semishells. Under uniaxial stretching, the lattice symmetry of these plasmonic structures can be reconfigured from hexagonal to monoclinic lattice, leading to not only large but also polarization-dependent shifts of the resonance frequency. The experimental results are supported by the numerical simulations. Our structures fabricated using simple and inexpensive self-assembly and lift-transfer techniques can open up applications of the stretch-tunable plasmonic structures in sensing, switching, and filtering.
An integrated payload design for the Exoplanet Characterisation Observatory (EChO)

The Exoplanet Characterisation Observatory (EChO) is a space mission dedicated to undertaking spectroscopy of transiting exoplanets over the widest wavelength range possible. It is based around a highly stable space platform with a 1.2 m class telescope. The mission is currently being studied by ESA in the context of a medium class mission within the Cosmic Vision programme for launch post 2020. The payload suite is required to provide simultaneous coverage from the visible to the mid-infrared and must be highly stable and effectively operate as a single instrument. In this paper we describe the integrated spectrometer payload design for EChO which will cover the 0.4 to 16 micron wavelength band. The instrumentation is subdivided into 5 channels (Visible/Near Infrared, Short Wave InfraRed, 2 x Mid Wave InfraRed; Long Wave InfraRed) with a common set of optics spectrally dividing the input beam via dichroics. We discuss the significant design issues for the payload and the detailed technical trade-offs that we are undertaking to produce a payload for EChO that can be built within the mission and programme constraints and yet which will meet the exacting scientific performance required to undertake transit spectroscopy. © 2012 SPIE.

Antisymmetric hybrid photonic crystal fibers with enhanced filtering and bending properties

A novel design of Yb-doped double-cladding hybrid photonic crystal fibers, with three rows of high-index inclusions on each side of the core, has been numerically analyzed with a full-vector modal solver based on the finite element method. Simulation results have demonstrated that a stronger filtering effect and a higher bending tolerance can be obtained with an increased number of high-index resonators. Moreover, the unique bending properties of hybrid fibers with antisymmetric design have been investigated and explained through the comparison with the ones of hybrid symmetric fibers, with high-index inclusions of the same dimension on both sides of the core.
Application of an EMCCD camera for calibration of hard X-ray telescopes

Recent technological innovations make it feasible to construct efficient hard x-ray telescopes for space-based astronomical missions. Focusing optics are capable of improving the sensitivity in the energy range above 10 keV by orders of magnitude compared to previously used instruments. The last decade has seen focusing optics developed for balloon experiments and they are implemented in approved space missions such as the Nuclear Spectroscopic Telescope Array (NuSTAR). The full characterization of x-ray optics for astrophysical missions, including measurement of the point spread function (PSF) as well as scattering and reactivity properties of substrate coatings, requires a large area detector with very high spatial resolution and sensitivity, photon counting and energy discriminating capability. Novel back-Thinned Electron Multiplying Charge-Coupled Devices (EMCCDs) are suitable detectors for ground-based calibrations if combined with a scintillating material. This optical coupling of the EMCCD chip to a microcolumnar CsI(Tl) scintillator can be achieved via a fiberoptic taper. Not only does this detector system exhibit low noise and high spatial resolution inherent to CCDs, but the EMCCD is also able to handle high frame rates. Additionally, thick CsI(Tl) yields high detection efficiency for x-rays. In this paper, we discuss the advantages of using an EMCCD to calibrate hard x-ray optics. We will illustrate the promising features of this detector solution using examples of data obtained during the ground calibration of the NuSTAR telescopes performed at Columbia University during 2010/2011. Finally, we give an outlook on latest development and optimizations. © 2012 SPIE.
and our numerical implementation for arbitrary geometries, and address computational issues related to the several length scales involved.

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**ATHENA optimized coating design**
The optimization of coating design for the ATHENA mission is described and the possibility of increasing the telescope effective area in the range between 0.1 and 10 keV is investigated. An independent computation of the on-axis effective area based on the mirror design of ATHENA is performed in order to review the current coating baseline. The performance of several material combinations, considering a simple bi-layer, simple multilayer and linear graded multilayer coatings are tested and simulation of the mirror performance considering both the optimized coating design and the coating baseline including on- and off-axis effective area curves are presented. We find that the use of linear graded multilayers can increase by 37% the integrated effective area of ATHENA in the energy range between 0.1 keV and 15 keV. © (2012) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.

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Avoided-crossing based modal cut-off analysis of 19-cell double-cladding photonic crystal fibers

The modal cut-off properties of Yb-doped Double-Cladding Photonic Crystal Fibers (DC-PCFs) with 19-cell core have been analyzed considering an innovative approach, where the avoided crossing between the guided modes and the highest-index cladding mode of the real fiber is taken as the cut-off condition. A finite element-based full-vector modal solver has been applied to calculate the modes of DC-PCFs with different normalized air-hole size and core refractive index. Simulations have shown the possibility to find generalized results for the modal cut-off wavelengths of 19-cell DC-PCFs.

Bio Optofluidics Cell Sorter – cell-BOCS Concept and Applications

The cell-BOCS is a novel microfluidics based cell-sorting instrument utilizing next generation optical trapping technology developed at the Technical University of Denmark. It is targeted emerging bio-medical research and diagnostics markets where it for certain applications offers a number of advantages over conventional fluorescence activated cell-sorting (FACS™) technology. Advantages include gentle handling of cells, sterile sorting, easy operation, small footprint and lower cost allowing out-of-core-facility use. Application examples are found within sorting of fragile transfected cells, high value samples and primary cell lines, where traditional FACS technology has limited application due to it’s droplet-based approach to cell-sorting. In the diagnostics field, in particular applying the cell-BOCS for isolating pure populations of circulating tumor cells is an area that has generated a lot of interest.
Broadband Fourier domain mode-locked laser for optical coherence tomography at 1060 nm

Optical coherence tomography (OCT) in the 1060nm range is interesting for in vivo imaging of the human posterior eye segment (retina, choroid, sclera) due to low absorption in water and deep penetration into the tissue. Rapidly tunable light sources, such as Fourier domain mode-locked (FDML) lasers, enable acquisition of densely sampled three-dimensional datasets covering a wide field of view. However, semiconductor optical amplifiers (SOAs)-the typical laser gain media for swept sources-for the 1060nm band could until recently only provide relatively low output power and bandwidth. We have implemented an FDML laser using a new SOA featuring broad gain bandwidth and high output power. The output spectrum coincides with the wavelength range of minimal water absorption, making the light source ideal for OCT imaging of the posterior eye segment. With a moderate SOA current (270 mA) we achieve up to 100nm total sweep range and 12 μm depth resolution in air. By modulating the current, we can optimize the output spectrum and thereby improve the resolution to 9 μm in air (~6.5 μm in tissue). The average output power is higher than 20mW. Both sweep directions show similar performance; hence, both can be used for OCT imaging. This enables an A-scan rate of 350 kHz without buffering the light source output.

Classification of Polarimetric SAR Data Using Dictionary Learning

This contribution deals with classification of multilook fully polarimetric synthetic aperture radar (SAR) data by learning a dictionary of crop types present in the Foulum test site. The Foulum test site contains a large number of agricultural fields, as well as lakes, forests, natural vegetation, grasslands and urban areas, which make it ideally suited for evaluation of classification algorithms.

Dictionary learning centers around building a collection of image patches typical for the classification problem at hand. This requires initial manual labeling of the classes present in the data and is thus a method for supervised classification.
Sparse coding of these image patches aims to maintain a proficient number of typical patches and associated labels. Data is consecutively classified by a nearest neighbor search of the dictionary elements and labeled with probabilities of each class.

Each dictionary element consists of one or more features, such as spectral measurements, in a neighborhood around each pixel. For polarimetric SAR data these features are the elements of the complex covariance matrix for each pixel. We quantitatively compare the effect of using different representations of the covariance matrix as the dictionary element features. Furthermore, we compare the method of dictionary learning, in the context of classifying polarimetric SAR data, with standard classification methods based on single-pixel measurements.

Coherent fiber supercontinuum laser for nonlinear biomedical imaging
Nonlinear biomedical imaging has not benefited from the well-known techniques of fiber supercontinuum generation for reasons such as poor coherence (or high noise), insufficient controllability, low spectral power intensity, and inadequate portability. Fortunately, a few techniques involving nonlinear fiber optics and femtosecond fiber laser development have emerged to overcome these critical limitations. These techniques pave the way for conducting point-of-care nonlinear biomedical imaging by a low-maintenance cost-effective coherent fiber supercontinuum laser, which covers a broad emission wavelength of 350-1700 nm. A prototype of this laser has been demonstrated in label-free multimodal nonlinear imaging of cell and tissue samples.© (2012) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.
Combined Characterization Techniques to Understand the Stability of a Variety of Organic Photovoltaic Devices - the ISOS-3 inter-laboratory collaboration

This work is part of the inter-laboratory collaboration to study the stability of seven distinct sets of state-of-the-art organic photovoltaic (OPVs) devices prepared by leading research laboratories. All devices have been shipped to and degraded at the Danish Technical University (DTU, formerly RISO-DTU) up to 1830 hours in accordance with established ISOS-3 protocols under defined illumination conditions. In this work we present a summary of the degradation response observed for the NREL sample, an inverted OPV of the type ITO/ZnO/P3HT:PCBM/PEDOT:PSS/Ag/Al, under full sun stability test. The results reported from the combination of the different characterization techniques results in a proposed degradation mechanism. The final conclusion is that the failure of the photovoltaic response of the device with time under full sun solar simulation, is mainly due to the degradation of the electrodes and not to the active materials of the solar cell.

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Comparative study of the performance of semiconductor laser based coherent Doppler lidars
Coherent Doppler Lidars (CDLs), operating at an eye-safe 1.5-micron wavelength, have found promising applications in the optimization of wind-power production. To meet the wind-energy sector's impending demand for more cost-efficient industrial sensors, we have focused on the development of continuous-wave CDL systems using compact, inexpensive semiconductor laser (SL) sources. In this work, we compare the performance of two candidate emitters for an all-semiconductor CDL system: (1) a monolithic master-oscillator-power-amplifier (MOPA) SL and (2) an external-cavity tapered diode laser (ECTDL).
CW and pulsed performance of Tm-doped photonic crystal fiber lasers
We demonstrate single-mode, highly polarized output from a thulium-doped photonic crystal fiber (PCF) with 50 μm core diameter and an ultra-large mode area >1000 μm². To our knowledge, this is the largest mode area of any flexible PCF and is capable of enabling the generation of high peak powers. In a Q-switched oscillator configuration, this fiber produces peak powers as high as 8.9 kW with 435 μJ, 49 ns pulses, >15 dB polarization extinction ratio and quasi diffraction-limited beam quality. The pulse energy was scaled to >1 mJ in amplifier configuration.

Design optimization of the distributed modal filtering rod fiber for increasing single mode bandwidth
High-power fiber amplifiers for pulsed applications require large mode area (LMA) fibers having high pump absorption and near diffraction limited output. This improves the limiting factor of nonlinear effects, while maintaining good beam quality. Photonic crystal fibers allow realization of short LMA fiber amplifiers having high pump absorption through a pump cladding that is decoupled from the outer fiber. However, achieving ultra low NA for single-mode (SM) guidance is challenging, and thus different design strategies must be applied to filter out higher order modes (HOMs). The novel distributed modal filtering (DMF) design presented here enables SM guidance, and previous results have shown a SM
mode field diameter of 60 μm operating in a 20 nm SM bandwidth. The DMF rod fiber has high index ring-shaped inclusions acting as resonators enabling SM guidance through modal filtering of HOMs. Large preform tolerances are compensated during the fiber draw resulting in ultra low NA fibers with very large cores. In this paper, design optimization of the SM bandwidth of the DMF rod fiber is presented. Analysis of band gap properties results in a fourfold increase of the SM bandwidth compared to previous results, achieved by utilizing the first band of cladding modes. This covers of a large fraction of the Yb emission band, where wavelengths of 1030 nm and 1064 nm can be included.

Development and characterization of coatings on Silicon Pore Optics substrates for the ATHENA mission

We present description and results of the test campaign performed on Silicon Pore Optics (SPO) samples to be used on the ATHENA mission. We perform a pre-coating characterization of the substrates using Atomic Force Microscopy (AFM), X-ray Reflectometry (XRR) and scatter measurements. X-ray tests at DTU Space and correlation between measured roughness and pre-coating characterization are reported. For coating development, a layer of Cr was applied underneath the Ir/B4C bi-layer with the goal of reducing stress, and the use of N2 during the coating process was tested in order to reduce the surface roughness in the coatings. Both processes show promising results. Measurements of the coatings were carried out at the 8 keV X-ray facility at DTU Space and with synchrotron radiation in the laboratory of PTB at BESSY II to determine reactivity at the grazing incidence angles and energies of ATHENA. Coating development also included a W/Si multilayer coating. We present preliminary results on X-ray Reflectometry and Cross-sectional Transmission Electron Microscopy (TEM) of the W/Si multilayer.
Development of a compact Bio-Optofluidic Cell Sorter

We develop an active cell sorter that utilizes machine vision for cell identification. Particles are identified based on visual features such as shape, size and color using image processing. The sorter shares features from our previously developed BioPhotonics Workstation. Hence, it benefits from the extended axial manipulation range provided by the low numerical aperture geometry. Detected particles are catapulted axially by several hundred microns, allowing them to be moved from one laminar flow region to another. As the sorting motion is transverse to the viewing plane, multiple particles can be catapulted at the same time, therefore enabling parallel sorting. The sorter is developed with a minimal footprint such that it can operate as a table top device, an advantage over flow cytometry or FACS systems.

Development status of a CZT spectrometer prototype with 3D spatial resolution for hand x-ray astronomy

The development of new focusing optics based on wide band Laue lenses operating from ~60 keV up to several hundred keV is particularly challenging. This type of hard X-ray or gamma ray optics requires a high performance focal plane detector in order to exploit to the best their intrinsic capabilities. We describe a three dimensional (3D) position sensitive detector prototype suitable as the basic module for a high efficiency Laue lens focal plane detector. This detector configuration is currently under study for use in a balloon payload dedicated to performing a high significance measurement of the polarization status of the Crab between 100 and 500 keV. The prototype is made by packing 8 linear modules, each composed of one basic sensitive unit bonded onto a thin supporting ceramic layer. Each unit is a drift strip detector based on a CZT crystal, irradiated transversally to the electric field direction. The anode is segmented into 8 detection cells, each comprising one collecting strip and 8 surrounding drift strips. The drift strips are biased by a voltage divider. The cathode is divided into 4 horizontal strips for the reconstruction of the Z interaction position. The detector readout electronics is based on RENA-3 ASIC and the data handling system uses a custom electronics based on FPGA to provide the ASIC setting, the event handling logic, and the data acquisition. This paper mainly describes the components and the status of the undergoing activities for the construction of the proposed 3D CZT prototype and shows the results of the electronics tests.
Effects of nonlocal response on the density of states of hyperbolic metamaterials

Metamaterials with a hyperbolic dispersion curve, called hyperbolic metamaterials, exhibit an amazing broad-band singularity in the photonic density of states in the usual local-response approximation. In this paper, under the framework of the hydrodynamic Drude model, we discuss the effects of the nonlocal response of the electron gas in the metal on the hyperbolic metamaterials. By using mean field theory, we derive the effective material parameters of the hyperbolic metamaterials. The original unbounded hyperbolic dispersion is found to be cut off at the wavevector inverse to the Fermi velocity. By expanding the Green function in a plane-wave basis and using the transfer matrix method to calculate the reflection coefficients, we study the local density of states (LDOS) of hyperbolic metamaterials. We show that the nonlocal response of the electron gas in the metal removes the singularity of both radiative and non-radiative local density of states, and also sets up a finite maximal value. We also briefly discuss the effects of the nonlocal response on other plasmonic structures, such as a metallic semi-infinite substrate and a metallic slab.
Enhanced light absorption in an ultrathin silicon solar cell utilizing plasmonic nanostructures

Nowadays, bringing photovoltaics to the market is mainly limited by high cost of electricity produced by the photovoltaic solar cell. Thin-film photovoltaics offers the potential for a significant cost reduction compared to traditional photovoltaics. However, the performance of thin-film solar cells is generally limited by poor light absorption. We propose an ultrathin-film silicon solar cell configuration based on SOI structure, where the light absorption is enhanced by use of plasmonic nanostructures. By placing a one-dimensional plasmonic nanograting on the bottom of the solar cell, the generated photocurrent for a 200 nm-thickness crystalline silicon solar cell can be enhanced by 90% in the considered wavelength range. These results are paving a promising way for the realization of high-efficiency thin-film solar cells.

Exploiting the Error-Correcting Capabilities of Low Density Parity Check Codes in Distributed Video Coding using Optical Flow

We consider Distributed Video Coding (DVC) in presence of communication errors. First, we present DVC side information generation based on a new method of optical flow driven frame interpolation, where a highly optimized TV-L1 algorithm is used for the flow calculations and combine three flows. Thereafter methods for exploiting the error-correcting capabilities of the LDPCA code in DVC are investigated. The proposed frame interpolation includes a symmetric flow constraint to the standard forward-backward frame interpolation scheme, which improves quality and handling of large motion. The three flows are combined in one solution. The proposed frame interpolation method consistently outperforms an overlapped block motion compensation scheme and a previous TV-L1 optical flow frame interpolation method with an average PSNR improvement of 1.3 dB and 2.3 dB respectively. For a GOP size of 2, an average bitrate saving of more than 40% is achieved compared to DISCOVER on Wyner-Ziv frames. In addition we also exploit and investigate the internal error-correcting capabilities of the LDPCA code in order to make it more robust to errors. We investigate how to achieve this goal by only modifying the decoding. One of approaches is to use bit flipping; alternatively one can modify the parity check matrix of the LDPCA. Different schemes known from LDPC codes are considered and evaluated in the LDPCA setting. Results show that the performance depend heavily on the type of channel used and on the quality of the Side Information.
External-cavity high-power dual-wavelength tapered amplifier with tunable THz frequency difference

A tunable 800 nm high-power dual-wavelength diode laser system with double-Littrow external-cavity feedback is demonstrated. The two wavelengths can be tuned individually, and the frequency difference of the two wavelengths is tunable from 0.5 to 5.0 THz. A maximum output power of 1.54 W is achieved with a frequency difference of 0.86 THz, the output power is higher than 1.3 W in the 5.0 THz range of frequency difference, and the amplified spontaneous emission intensity is more than 20 dB suppressed in the range of frequency difference. The beam quality factor M2 is 1.22±0.15 at an output power of 1.35 W. The simultaneous oscillation of the two wavelengths is under test by the sum-frequency generation experiment in a bismuth triborate (BIBO) nonlinear crystal.

Fiber design and realization of point-by-point written fiber Bragg gratings in polymer optical fibers

An increasing interest in making sensors based on fiber Bragg gratings (FBGs) written in polymer optical fibers (POFs) has been seen recently. Mostly microstructured POFs (mPOFs) have been chosen for this purpose because they are easier to fabricate compared, for example, to step index fibers and because they allow to tune the guiding parameters by modifying the microstructure. Now a days the only technique used to write gratings in such fibers is the phase mask technique with UV light illumination. Despite the good results that have been obtained, a limited flexibility on the grating design and the very long times required for the writing of FBGs raise some questions about the possibility of exporting POF FBGs and the sensors based on them from the laboratory bench to the mass production market. The possibility of arbitrary design of fiber Bragg gratings and the very short time required to write the gratings make the point-by-point grating writing technique very interesting and would appear to be able to fill this technological gap. On the other end this technique is hardly applicable for microstructured fibers because of the writing beam being scattered by the air-holes. We
report on the design and realization of a microstructured polymer optical fiber made of PMMA for direct writing of FBGs. The fiber was designed specifically to avoid obstruction of the writing beam by air-holes. The realized fiber has been used to point-by-point write a 5 mm long fourth order FBG with a Bragg wavelength of 1518 nm. The grating was inspected under Differential Interferometric Contrast microscope and the reflection spectrum was measured. This is, to the best of our knowledge, the first FBGs written into a mPOF with the point-by-point technique and also the fastest ever written into a polymer optical fiber, with less than 2.5 seconds needed.

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**Fluorescent SiC with pseudo-periodic moth-eye structures**
White light-emitting diodes (LEDs) consisting of a nitride-based blue LED chip and phosphor are very promising candidates for the general lighting applications as energy-saving sources. Recently, donor-acceptor doped fluorescent SiC has been proven as a highly efficient wavelength converter material much superior to the phosphors in terms of high color rendering index value and long lifetime. The light extraction efficiency of the fluorescent SiC based all semiconductor LED light sources is usually low due to the large refractive index difference between the semiconductor and air. In order to enhance the extraction efficiency, we present a simple method to fabricate the pseudo-periodic moth-eye structures on the surface of the fluorescent SiC. A thin gold layer is deposited on the fluorescent SiC first. Then the thin gold layer is treated by rapid thermal processing. After annealing, the thin gold layer turns into discontinuous nano-islands. The average size of the islands is dependent on the annealing condition which could be well controlled. By using the reactive-ion etching, pseudo-periodic moth-eye structures would be obtained using the gold nano-islands as a mask layer. Reactive-ion etching conditions are carefully optimized to obtain the lowest surface reflection performance of the fabricated structures. Significant omnidirectional luminescence enhancement (226.0 %) was achieved from the angle-resolved photoluminescence measurement, which proves the pseudo-periodic moth-eye structure as an effective and simple method to enhance the extraction efficiency of fluorescent SiC based white LEDs. © (2012) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.

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Frequency-doubled diode laser for direct pumping of Ti:sapphire lasers
A single-pass frequency doubled high-power tapered diode laser emitting nearly 1.3 W of green light suitable for direct pumping of Ti:sapphire lasers generating ultrashort pulses is demonstrated. The pump efficiencies reached 75 % of the values achieved with a commercial solid-state pump laser. However, the superior electro-optical efficiency of the diode laser improves the overall efficiency of the Ti:sapphire laser by a factor > 2. The optical spectrum emitted by the Ti:sapphire laser shows a spectral width of 112 nm (FWHM). Based on autocorrelation measurements, pulse widths of less than 20 fs are measured. These results open the opportunity of establishing diode laser pumped Ti:sapphire lasers for e.g. biophotonic applications like retinal optical coherence tomography or pumping of photonic crystal fibers for CARS microscopy.

Highly efficient high power single-mode fiber amplifier utilizing the distributed mode filtering bandgap rod fiber
We report on an ytterbium doped single mode distributed mode filtering rod fiber in an amplifier configuration delivering high average output power, up to 292 watts, using a mode-locked 30ps source at 1032nm with good power conversion efficiency. We study the modal stability of the output beam at high average output power levels and demonstrate a 44% power improvement before the threshold-like onset of mode instabilities by operating the rod fiber in a leaky waveguide regime. We investigate the guiding dynamics of the rod fiber and explain the improved performance by thermally induced refractive index profile change.
High-power single-frequency photonic bandgap fiber amplifier at 1178 nm

1178 nm single-frequency amplification by Yb-doped photonic bandgap fiber has been demonstrated. 24.6 W output was obtained without stimulated Brillouin scattering. 1.8 dB suppression of Brillouin gain by an acoustic antiguiding effect has been found in the low-index core antiresonant reflecting optical waveguide.

High-speed polarization-sensitive OCT at 1060 nm using a Fourier domain mode-locked swept source

Optical coherence tomography (OCT) in the 1060nm range is interesting for in vivo imaging of the human posterior eye segment (retina, choroid, sclera), as it permits a long penetration depth. Complementary to structural images, polarization-sensitive OCT (PS-OCT) images visualize birefringent, polarization-maintaining or depolarizing areas within the sample. This information can be used to distinguish retinal layers and structures with different polarization properties. High imaging speed is crucial for imaging ocular structures in vivo in order to minimize motion artifacts while acquiring sufficiently large datasets. Here, we demonstrate PS-OCT imaging at 350 kHz A-scan rate using a two-channel PS-OCT system in conjunction with a Fourier domain mode-locked laser. The light source spectrum spans up to 100nm around the water absorption minimum at 1060 nm. By modulating the laser pump current, we can optimize the spectrum and achieve a depth resolution of 9 μm in air (6.5 μm in tissue). We acquired retinal images in vivo with high resolution and deep
penetration into choroid and sclera, and features like the depolarizing RPE or an increasing phase retardation at the chorio-scleral interface are clearly visualized.

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Contributors: Marschall, S., Torzicky, T., Klein, T., Wieser, W., Pircher, M., Gotzinger, E., Zotter, S., Bonesi, M., Biedermann, B., Pedersen, C., Huber, R., Hitzenberger, C., Andersen, P. E.  
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**Improved space bandwidth product in image upconversion**

We present a technique increasing the space bandwidth product of a nonlinear image upconversion process used for spectral imaging. The technique exploits the strong dependency of the phase-matching condition in sum frequency generation (SFG) on the angle of propagation of the interacting fields with respect to the optical axis. Appropriate scanning of the phase-match condition (Δk=0) while acquiring images, allow us to perform monochromatic image reconstruction with a significantly increased space bandwidth product. We derive the theory for the image reconstruction process and demonstrate acquisition of images with >10 fold increase in space bandwidth product, i.e. the number of pixel elements, when compared to upconversion of images using fixed phase-match conditions.

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Influence of micro- and nanofillers on electro-mechanical performance of silicone EAPs

The effect of different fillers on the mechanical and dielectric properties of soft elastomers has been investigated. It was found that the addition of a small amount of silica fillers would increase the Young’s modulus significantly but not simultaneously increase the tear strength sufficiently for processing as thin films. Addition of nanoclay and barium titanate nanoparticles to the soft elastomers was shown to be very favorable for the enhancement of the dielectric properties without increasing the Young’s modulus significantly and could be used for DEAP material in e.g. micromanufacturing, where the tear strength is not crucial for processing. However, for elastomer film processing it is suggested that a combination of the nanoclay or barium titanate with either silica particles or bimodal networks would give the right tear strength together with the desired increased dielectric permittivity.

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Large amplitude oscillatory measurements as mechanical characterization methods for soft elastomers

Mechanical characterization of soft elastomers is usually done either by traditional shear rheometry in the linear viscoelastic (LVE) regime (i.e. low strains) or by extensional rheology in the nonlinear regime. However, in many commercially available rheometers for nonlinear extensions the measurements rely on certain assumptions such as a predefined shape alteration and are very hard to perform on soft elastomers in most cases. The LVE data provides information on important parameters for DEAP purposes such as the Young’s modulus and the tendency to viscous dissipation (at low strains only) but provides no information on the strain hardening or softening effects at larger strains, and the mechanical breakdown strength. Therefore it is obvious that LVE can not be used as the single mechanical characterization tool in large strain applications. We show how the data set of LVE, and large amplitude oscillating elongation (LAOE) and planar elongation make the ideal set of experiments to evaluate the mechanical performance of DEAPs. We evaluate the mechanical performance of several soft elastomers applicable for DEAP purposes such as poly(propyleneoxide) (PPO) networks and traditional unfilled silicone (PDMS) networks.

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Contributors: Skov, A. L.
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Lasing in Thulium doped Polarizing Photonic Crystal Fibers (PCF)

We describe lasing in polarizing thulium doped PCF fiber for the first time. The ~4 m long fiber had 50/250 μm core/cladding diameters and hole-diameter to pitch ratio of 0.18. CW lasing was achieved by end pumping with a 793 nm diode in an oscillator configuration. Slope efficiencies of ~35 % have been obtained with single mode beam quality (M2 13 dB without any intra-cavity polarizing elements. This fiber, with MFD of ~36 μm and ~5.8 dB/m cladding pump absorption, is an attractive option for high energy pulsed amplifiers in the 2 μm wavelength regime.

LOFT - The large observatory for x-ray timing

The LOFT mission concept is one of four candidates selected by ESA for the M3 launch opportunity as Medium Size missions of the Cosmic Vision programme. The launch window is currently planned for between 2022 and 2024. LOFT is designed to exploit the diagnostics of rapid X-ray flux and spectral variability that directly probe the motion of matter down to distances very close to black holes and neutron stars, as well as the physical state of ultradense matter. These primary science goals will be addressed by a payload composed of a Large Area Detector (LAD) and a Wide Field Monitor (WFM). The LAD is a collimated
Metamaterials modelling, fabrication, and characterisation techniques

Metamaterials are artificially designed media that show averaged properties not yet encountered in nature. Among such properties, the possibility of obtaining optical magnetism and negative refraction are the ones mainly exploited but epsilon-near-zero and sub-unitary refraction index are also parameters that can be obtained. Such behaviour enables unprecedented applications. Within this work, we will present various aspects of metamaterials research field that we deal with at our department. From the modelling part, we will present our approach for determining the field enhancement in slits that have dimensions in the 10^4 times smaller than the incident wavelength. This huge difference makes it almost impossible for commercial software to handle thus analytical approaches have to be employed. From the fabrication point of view, various 2D and 3D high resolution patterning techniques are used. The talk will describe the ones available within our group. We will present the electron-beam lithography approach for fabricating nano-antennae to be used in coupling of plasmonics waveguides to/from free space. Also, a 3D technique based on two-photon-polymerisation and isotropic metal deposition to fabricate metal-covered 3D photonic crystals will be discussed. From the measuring side we will present two THz based setups for obtaining material's characteristics, both in the low as well as in the high THz range, thus having the possibility of describing a material from 0.1 to 10THz. © 2012 SPIE.
Micromanipulation and microfabrication for optical microrobotics

Robotics can use optics feedback in vision-based control of intelligent robotic guidance systems. With light’s miniscule momentum, shrinking robots down to the microscale regime creates opportunities for exploiting optical forces and torques in microrobotic actuation and control. Indeed, the literature on optical trapping and micromanipulation attests to the possibilities for optical microrobotics. This work presents an optical microrobotics perspective on the optical microfabrication and micromanipulation work that we performed. We designed different three-dimensional microstructures and fabricated them by two-photon polymerization. These microstructures were then handled using our biophotonics workstation (BWS) for proof-of-principle demonstrations of optical actuation, akin to 6DOF actuation of robotic micromanipulators. Furthermore, we also show an example of dynamic behavior of the trapped microstructure that can be achieved when using static traps in the BWS. This can be generalized, in the future, towards a structural shaping optimization strategy for optimally controlling microstructures to complement approaches based on lightshaping. We also show that light channeled to microfabricated, free-standing waveguides can be used not only to redirect light for targeted delivery of optical energy but can also for targeted delivery of optical force, which can serve to further extend the manipulation arms in optical robotics. Moreover, light deflection with waveguide also creates a recoil force on the waveguide, which can be exploited for controlling the optical force.
Museum lighting for golden artifacts, with low correlated color temperature, high color uniformity and high color rendering index, using diffusing color mixing of red, cyan, and white-light-emitting diodes

Museum lighting presents challenges mainly due to the demand for precise color rendering and the damaging effects of radiation. Golden objects must normally be illuminated by the non-standard CCT of 2200 K. An LED system that conforms to these requirements has been developed and implemented at the Royal Danish Collection at Rosenborg Castle. Color mixing of red, cyan, and white LEDs was employed to achieve the spectral power distribution needed for the required CCT and a CRI above 90. Color uniformity is achieved by the use of a highly diffusing reflector. The system has shown energy saving above 70%.

Nonlinear propagation of strong-field THz pulses in doped semiconductors

We report on nonlinear propagation of single-cycle THz pulses with peak electric fields reaching 300 kV/cm in n-type semiconductors at room temperature. Dramatic THz saturable absorption effects are observed in GaAs, GaP, and Ge, which are caused by the nonlinear electron transport in THz fields. The semiconductor conductivity, and hence the THz absorption, is modulated due to the acceleration of carriers in strong THz fields, leading to an increase of the effective mass of the electron population, as the electrons are redistributed from the low-momentum, low-effective-mass states to the high-momentum, high-effective-mass states in the energy-momentum space of the conduction band. Further, we observe the typical accompanying effects of saturable absorption on the THz pulses, such as an increase of the group delay, as the peak electric field of the pulse increases. In this paper we present the results of nonlinear THz time-domain spectroscopy, and of THz pump - THz probe spectroscopy.
Nonperturbative cavity-QED between a single quantum dot and a metal nanoparticle

We investigate the quantum optical properties of an excited single photon emitter (quantum dot) near the surface of a finite-size metal nanoparticle using a photon Green function technique that rigorously quantizes the electromagnetic fields. We obtain Purcell factors of up to $5 \times 10^4$ due to higher order plasmon modes for both a 7-nm and 20-nm radius metal nanoparticle, and show the failure of employing a dipole approximation in regimes where useful quantum optical interactions occur. We also calculate enormous photonic Lamb shifts of up to 40 meV giving a normalized frequency shift up to $|\Delta \omega|_{\text{max}} / \omega_d = 1.28 \times 10^{-2}$. Considering a small quantum-dot, positioned 2-nm from the metal nanoparticle surface, we demonstrate that the strong coupling regime should be observable in the far-field spontaneous emission spectrum, even at room temperature and despite the non-propagating nature of the higher order modes. The vacuum Rabi doublet becomes a rich spectral quartet with two of the four peaks anticrossing, and surviving in spite of significant non-radiative decays. We also discuss the role of optical quenching and highlight the importance of accounting for photon transport from the dot to the detector. Our formalism is quite general and can easily be extended to include interactions between multiple quantum dots and multiple metal nanoparticles.

Optical fiber sensors fabricated by the focused ion beam technique

Focused ion beam (FIB) is a highly versatile technique which helps to enable next generation of lab-on-fiber sensor technologies. In this paper, we demonstrate the use application of FIB to precisely mill the fiber taper and end facet of both conventional single mode fiber (SMF) and photonic crystal fiber (PCF). Using this technique we fabricate a highly compact fiber-optic Fabry-Perot (FP) refractive index sensor near the tip of fiber taper, and a highly sensitive in-line temperature sensor in PCF. We also demonstrate the potential of using FIB to selectively fill functional fluid into desired air holes of PCF.
Optical telescope BIRT in ORIGIN for gamma ray burst observing

The ORIGIN concept is a space mission with a gamma ray, an X-ray and an optical telescope to observe the gamma ray bursts at large Z to determine the composition and density of the intergalactic matter in the line of sight. It was an answer to the ESA M3 call for proposal. The optical telescope is a 0.7-m F/1 with a very small instrument box containing 3 instruments: a slitless spectrograph with a resolution of 20, a multi-imager giving images of a field in 4 bands simultaneously, and a cross-dispersed Echelle spectrograph giving a resolution of 1000. The wavelength range is 0.5 μm to 1.7 μm. All instruments fit together in a box of 80 mm x 80 mm x 200 mm. The low resolution spectrograph uses a very compact design including a special triplet. It contains only spherical surfaces except for one tilted cylindrical surface to disperse the light. To reduce the need for a high precision pointing, an Advanced Image Slicer was added in front of the high resolution spectrograph. This spectrograph uses a simple design with only one mirror for the collimator and another for the camera. The Imager contains dichroics to separate the bandwidths and glass thicknesses to compensate the differences in path length. All 3 instruments use the same 2k x 2k detector simultaneously so that telescope pointing and tip-tilt control of a fold mirror permit to place the gamma ray burst on the desired instrument without any other mechanism.

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Optimal local dimming for LED-backlit LCD displays via linear programming

LED-backlit LCD displays hold the promise of improving the image quality while reducing the energy consumption with signal-dependent local dimming. To fully realize such potentials we propose a novel local dimming technique that jointly optimizes the intensities of LED backlights and the attenuations of LCD pixels. The objective is to minimize the distortion in luminance reproduction due to the leakage of LCD and the coarse granularity of the LED lights. The optimization problem is formulated as one of linear programming, and both exact and approximate algorithms are proposed. Simulation results demonstrate superior performances of the proposed algorithms over the existing local dimming algorithms.

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Contributors: Shu, X., Wu, X., Forchhammer, S.
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Optimization of light quality from color mixing light-emitting diode systems for general lighting

To address the problem of spectral light quality from color mixing light-emitting diode systems, a method for optimizing the spectral output of multicolor LED system with regards to standardized quality parameters has been developed. The composite spectral power distribution from the LEDs are simulated using radiometrically measured single LED spectra. The method uses electrical input powers as input parameters and optimizes the resulting spectral power distribution with regard to color rendering index, correlated color temperature and chromaticity distance. The results indicate Pareto optimal boundaries mapping the capabilities of the simulated lighting system.

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Photonic crystal fibers for supercontinuum generation pumped by a gain-switched CW fiber laser
Supercontinuum generation in photonic crystal fibers (PCFs) pumped by CW lasers yields high spectral power density and average power. However, such systems require very high pump power and long nonlinear fibers. By on/off modulating the pump diodes of the fiber laser, the relaxation oscillations of the laser can be exploited to enhance the broadening process. The physics behind the supercontinuum generation is investigated by sweeping the fiber length, the zero dispersion wavelength, and the fiber nonlinearity. We show that by applying gain-switching a high average output power of up to 30 W can be maintained and the spectral width can be improved by 90%. The zero dispersion wavelength should be close to but below the pump wavelength to achieve the most visible light. By increasing the nonlinearity the fiber length can be reduced from 100 m to 25 m and the efficiency of visible light generation is improved by more than 200%.

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Quantum optics with quantum dots in photonic nanowires
Besides microcavities and photonic crystals, photonic nanowires have recently emerged as a novel resource for solidstate quantum optics. We will review recent studies which demonstrate an excellent control over the spontaneous emission of InAs quantum dots (QDs) embedded in single-mode GaAs photonic wires. On the basic side, we have demonstrated a strong inhibition (x 1/16) of QD SpE in thin wires (d0.95 for d~λ/n), and polarization control in elliptical nanowires. A single QD in a photonic wire is thus an attractive system to explore the physics of the "one-dimensional atom" and build novel quantum optoelectronic devices. Quite amazingly, this approach has for instance permitted (unlike microcavity-based approaches) to combine for the first time a record-high efficiency (72%) and a negligible g(2) in a QD single photon source.

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Reducing dephasing in coupled quantum dot-cavity systems by engineering the carrier wavefunctions

We demonstrate theoretically how photon-assisted dephasing by the electron-phonon interaction in a coupled cavity-quantum dot system can be significantly reduced for specific QD-cavity detunings. Our starting point is a recently published theory, which considers longitudinal acoustic phonons, described by a non-Markovian model, interacting with a coupled quantum dot-cavity system. The reduction of phonon-induced dephasing is obtained by placing the cavity-quantum dot system inside an infinite slab, assuming spherical electronic wavefunctions. Based on our calculations, we expect this to have important implications in single-photon sources, allowing the indistinguishability of the photons to be improved.

Sampling conditions for gradient-magnitude sparsity based image reconstruction algorithms

We seek to characterize the sampling conditions for iterative image reconstruction exploiting gradient-magnitude sparsity. We seek the number of views necessary for accurate image reconstruction by constrained, total variation (TV) minimization, which is the optimization problem suggested in the compressive sensing (CS) community for this type of sparsity. The preliminary finding here, based on simulations using images of realistic sparsity levels, is that necessary sampling can go as low as N/4 views for an NxN pixel array. This work sets the stage for fixed-exposure studies where the number of projections is balanced against the X-ray intensity per projection.
**Selectivity of spatial filtering velocimetry of objective speckles for measuring out-of-plane motion**

We probe the dynamics of objective laser speckles as the axial distance between the object and the observation plane changes. With the purpose of measuring out-of-plane motion in real time, we apply optical spatial filtering velocimetry to the speckle dynamics. To achieve this, a rotationally symmetric spatial filter is designed. The spatial filter converts the speckle dynamics into a photocurrent with a quasi-sinusoidal response to the out-of-plane motion. Our contribution presents the technology and discusses the selectivity of the spatial filter. Specifically, we discuss how the selectivity of the spatial filter with regard to radial speckle motion is influenced by a concurrent in-plane speckle motion. The spatial filter is emulated with a CCD camera, and is tested on speckle acquisitions obtained from a controlled set-up. Experiments with the emulated filters illustrate performance and potential applications of the technology.

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**Silicon pore optics developments and status**

Silicon Pore Optics (SPO) is a lightweight high performance X-ray optics technology being developed in Europe, driven by applications in observatory class high energy astrophysics missions. An example of such application is the former ESA science mission candidate ATHENA (Advanced Telescope for High Energy Astrophysics), which uses the SPO technology for its two telescopes, in order to provide an effective area exceeding 1 m² at 1 keV, and 0.5 m² at 6 keV, featuring an angular resolution of 10" or better [1 to 24]. This paper reports on the development activities led by ESA, and the status of the SPO technology. The technology development programme has succeeded in maturing the SPO further and achieving important milestones, in each of the main activity streams: environmental compatibility, industrial production and optical performance. In order to accurately characterise the increasing performance of this innovative optical technology, the associated X-ray test facilities and beam-lines have been refined and upgraded. © 2012 SPIE.
Slow-light enhancement of gain

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Slow-light enhancement of spontaneous emission in active photonic crystal waveguides

Photonic crystal defect waveguides with embedded active layers containing single or multiple quantum wells or quantum dots have been fabricated. Spontaneous emission spectra are enhanced close to the bandedge, consistently with the enhancement of gain by slow light effects. These are promising results for future compact devices for terabit/s communication, such as miniaturised semiconductor optical amplifiers and mode-locked lasers.

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Organisations: Department of Photonics Engineering, Quantum and Laser Photonics, Nanophotonic Devices
Spectral Design Flexibility of LED Brings Better life

Light-emitting diodes (LEDs) are penetrating into the huge market of general lighting because they are energy saving and environmentally friendly. The big advantage of LED light sources, compared to traditional incandescent lamps and fluorescent light tubes, is the flexible spectral design to make white light using different color mixing schemes. The spectral design flexibility of white LED light sources will promote them for novel applications to improve the life quality of human beings. As an initial exploration to make use of the spectral design flexibility, we present an example: ‘no blue’ white LED light source for sufferers of disease Porphyria. An LED light source prototype, made of high brightness commercial LEDs applying an optical filter, was tested by a patient suffering from Porphyria. Preliminary results have shown that the sufferer could withstand the light source for much longer time than the standard light source. At last future perspectives on spectral design flexibility of LED light sources improving human being’s life will be discussed, with focus on the light and health. The good health is ensured by the spectrum optimized so that vital hormones (melatonin and serotonin) are produced during times when they support human daily rhythm.
Speedup of optimization-based approach to local backlight dimming of HDR displays

Local backlight dimming in Liquid Crystal Displays (LCD) is a technique for reducing power consumption and simultaneously increasing contrast ratio to provide a High Dynamic Range (HDR) image reproduction. Several backlight dimming algorithms exist with focus on reducing power consumption, while other algorithms aim at enhancing contrast, with power savings as a side effect. In our earlier work, we have modeled backlight dimming as a linear programming problem, where the target is to minimize the cost function measuring the distance between ideal and actual output. In this paper, we propose a version of the abovementioned algorithm, speeding up execution by decreasing the number of input variables. This is done by using a subset of the input pixels, selected among the ones experiencing leakage or clipping distortions. The optimization problem is then solved on this subset. Sample reduction can also be beneficial in conjunction with other approaches, such as an algorithm based on gradient descent, also presented here. All the proposals have been compared against other known approaches on simulated edge- and direct-lit displays, and the results show that the optimal distortion level can be reached using a subset of pixels, with significantly reduced computational load compared to the optimal algorithm with the full image.

Stability and degradation of organic photovoltaics fabricated, aged, and characterized by the ISOS 3 inter-laboratory collaboration

Seven distinct sets (n > 12) of state of the art organic photovoltaic devices were prepared by leading research laboratories in a collaboration planned at the Third International Summit on Organic Photovoltaic Stability (ISOS-3). All devices were shipped to DTU and characterized simultaneously up to 1830 h in accordance with established ISOS-3 protocols under three distinct illumination conditions: accelerated full sun simulation; low level indoor fluorescent lighting; and dark storage with daily measurement under full sun simulation. Three nominally identical devices were used in each experiment both to provide an assessment of the homogeneity of the samples and to distribute samples for a variety of post soaking analytical measurements at six distinct laboratories enabling comparison at various stages in the degradation of the devices. Characterization includes current-voltage curves, light beam induced current (LBIC) imaging, dark lock-in thermography (DLIT), photoluminescence (PL), electroluminescence (EL), in situ incident photon-to-electron conversion efficiency (IPCE), time of flight secondary ion mass spectrometry (TOF-SIMS), cross sectional electron microscopy (SEM), UV visible spectroscopy, fluorescence microscopy, and atomic force microscopy (AFM). Over 100 devices with more than 300 cells were used in the study. We present here design of the device sets, results both on individual devices and uniformity of device sets from the wide range of characterization methods applied at different stages of aging under the three illumination conditions. We will discuss how these data can help elucidate the degradation mechanisms as well as the benefits and challenges associated with the unprecedented size of the collaboration.
Stereo side information generation in low-delay distributed stereo video coding

Distributed Video Coding (DVC) is a technique that allows shifting the computational complexity from the encoder to the decoder. One of the core elements of the decoder is the creation of the Side Information (SI), which is a hypothesis of what the to-be-decoded frame looks like. Much work on DVC has been carried out: often the decoder can use future and past frames in order to obtain the SI exploiting the time redundancy. Other work has addressed a Multiview scenario; exploiting the frames coming from cameras close to the one we are decoding (usually a left and right camera) it is possible to create SI exploiting the inter-view spatial redundancy. A careful fusion of the two SI should be done in order to use the best part of each SI. In this work we study a Stereo Low-Delay scenario using only two views. Due to the delay constraint we use only past frames of the sequence we are decoding and past and present frames of the other. This is done by using Extrapolation, to exploit the time redundancy and well known techniques for stereo error concealment. This allows us to create good quality SI even if we are only using two views. In this work we have also used a new method in order to fuse the two SIs, inspired by Multi-Hypothesis decoding. In this work the multiple hypotheses are used to fuse the SIs. Preliminary results show improvements up to 1 dB.
Structure-mediated micro-to-nano coupling using sculpted light and matter

The synergy between photonics, nanotechnology and biotechnology is spawning the emerging fields of nanobiotechnology and nano-biophotonics. Photonic innovations already hurdle the diffraction barrier for imaging with nanoscopic resolutions. However, scientific hypothesis testing demands tools, not only for observing nanoscopic phenomena, but also for reaching into and manipulating nanoscale constituents in this domain. This report is twofold describing the new use of proprietary strongholds we currently are establishing at DTU Fotonik on new means of sculpting of both light and matter for bio-probing at the smallest scales.

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Supercontinuum - broad as a lamp, bright as a laser, now in the mid-infrared

Based on the experience gained developing our market leading visible spectrum supercontinuum sources NKT Photonics has built the first mid-infrared supercontinuum source based on modelocked picosecond fiber lasers. The source is pumped by a ≈ 2 µm laser based on a combination of erbium and thulium and use ZBLAN fibers to generate a 1.75-4.4 µm spectrum. We will present results obtained by applying the source for mid-infrared microscopy where absorption spectra can be used to identify the chemical nature of different parts of a sample. Subsequently, we discuss the possible application of a mid-IR supercontinuum source in other areas including infrared countermeasures.

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Surface plasmon polariton modulator with optimized active layer

A multilayered waveguide, which supports surface plasmon polaritons, is considered as an absorption modulator. The waveguide core consists of a silicon nitride layer and ultrathin layer with the varied carrier density embedded between two silver plates, which also serve as electrodes. Under applying voltage to electrodes the carrier density in the transparent conducting oxide layer (we study indium tin oxide - ITO) changes according to the Thomas-Fermi screening theory. We employ analytical solutions for a multilayered system as well as numerical simulations with the commercial software package CST Microwave Studio in the frequency domain. We explore different permittivities of the ITO layer, which can be achieved by utilizing different anneal conditions. To increase transmittance and enhance modulation depth or efficiency, we propose to pattern the continuous active layer. Dependence from the pattern size and filling factor of the active material are analyzed for tuned permittivity of the ITO layer. Direct simulation of the device functionality validates optimization design.

Temperature compensated, humidity insensitive, high-Tg TOPAS FBGs for accelerometers and microphones

In this paper we present our latest work on Fiber Bragg Gratings (FBGs) in microstructured polymer optical fibers (mPOFs) and their application as strain sensing transducers in devices, such as accelerometers and microphones. We demonstrate how the cross-sensitivity of the FBG to temperature is eliminated by using dual-FBG technology and how mPOFs fabricated from different grades of TOPAS with glass transition temperatures around 135 degrees C potentially allow high-temperature humidity insensitive operation. The results bring the mPOF FBG closer to being a viable technology for commercial applications requiring high sensitivity due to the low Young's Modulus of polymer.
The LOFT wide field monitor

LOFT (Large Observatory For x-ray Timing) is one of the four missions selected in 2011 for assessment study for the ESA M3 mission in the Cosmic Vision program, expected to be launched in 2024. The LOFT mission will carry two instruments with their prime sensitivity in the 2-30 keV range: a 10 m² class large area detector (LAD) with a <1° collimated field of view and a wide field monitor (WFM) instrument based on the coded mask principle, providing coverage of more than 1/3 of the sky. The LAD will provide an effective area ~20 times larger than any previous mission and will by timing studies be able to address fundamental questions about strong gravity in the vicinity of black holes and the equation of state of nuclear matter in neutron stars. The prime goal of the WFM will be to detect transient sources to be observed by the LAD. However, with its wide field of view and good energy resolution of <300 eV, the WFM will be an excellent monitoring instrument to study long term variability of many classes of X-ray sources. The sensitivity of the WFM will be 2.1 mCrab in a one day observation, and 270 mCrab in 3s in observations of in the crowded field of the Galactic Center. The high duty cycle of the instrument will make it an ideal detector of fast transient phenomena, like X-ray bursters, soft gamma repeaters, terrestrial gamma flashes, and not least provide unique capabilities in the study of gamma ray bursts. A dedicated burst alert system will enable the distribution to the community of ~100 gamma ray burst positions per year with a ~1 arcmin location accuracy within 30 s of the burst. This paper provides an overview of the design, configuration, and capabilities of the LOFT WFM instrument.

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The LOFT wide field monitor simulator

We present the simulator we developed for the Wide Field Monitor (WFM) aboard the Large Observatory For Xray Timing (LOFT) mission, one of the four ESA M3 candidate missions considered for launch in the 2022–2024 timeframe. The WFM is designed to cover a large FoV in the same bandpass as the Large Area Detector (LAD, almost 50% of its accessible sky in the energy range 2–50 keV), in order to trigger follow-up observations with the LAD for the most interesting sources. Moreover, its design would allow to detect transient events with fluxes down to a few mCrab in 1-day exposure, for which good spectral and timing resolution would be also available (about 300 eV FWHM and 10 μs, respectively). In order to investigate possible WFM configurations satisfying these scientific requirements and assess the instrument performance, an end-to-end WFM simulator has been developed. We can reproduce a typical astr

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The readout system and the trigger algorithm implementation for the UFFO Pathfinder

Since the launch of the SWIFT, Gamma-Ray Bursts (GRBs) science has been much progressed. Especially supporting many measurements of GRB events and sharing them with other telescopes by the Gamma-ray Coordinate Network (GCN) have resulted the richness of GRB events, however, only a few of GRB events have been measured within a minute after the gamma ray signal. This lack of sub-minute data limits the study for the characteristics of the UV-optical light curve of the short-hard type GRB and the fast-rising GRB. Therefore, we have developed the telescope named the Ultra-Fast Flash Observatory (UFFO) Pathfinder, to take the sub-minute data for the early photons from GRB. The UFFO Pathfinder has a coded-mask X-ray camera to search the GRB location by the UBAT trigger algorithm. To determine the direction of GRB as soon as possible it requires the fast processing. We have ultimately implemented all algorithms in field programmable gate arrays (FPGA) without microprocessor. Although FPGA, when compared with microprocessor, is generally estimated to support the fast processing rather than the complex processing, we have developed the implementation to overcome the disadvantage and to maximize the advantage. That is to measure the location as accurate as possible and to determine the location within the sub-second timescale. In the particular case for a accuracy of the X-ray trigger, it requires special information from the satellite based on the UFFO central control system. We present the implementation of the UBAT trigger algorithm as well as the readout system of the UFFO Pathfinder
The slewing mirror telescope of the Ultra Fast Flash Observatory Pathfinder

The Slewing Mirror Telescope (SMT) is a key telescope of Ultra-Fast Flash Observatory (UFFO) space project to explore the first sub-minute or sub-seconds early photons from the Gamma Ray Bursts (GRBs) afterglows. As the realization of UFFO, 20kg of UFFO-Pathfinder (UFFO-P) is going to be on board the Russian Lomonosov satellite in November 2012 by Soyuz-2 rocket. Once the UFFO Burst Alert & Trigger Telescope (UBAT) detects the GRBs, Slewing mirror (SM) will slew to bring new GRB into the SMT’s field of view rather than slewing the entire spacecraft. SMT can give a UV/Optical counterpart position rather moderated 4arcsec accuracy. However it will provide a important understanding of the GRB mechanism by measuring the sub-minute optical photons from GRBs. SMT can respond to the trigger over 35 degree x 35 degree wide field of view within 1 sec by using Slewing Mirror Stage (SMS). SMT is the reflecting telescope with 10cm Ritchey-Chretien type and 256 x 256 pixilated Intensified Charge-Coupled Device (ICCD). In this paper, we discuss the overall design of UFFO-P SMT instrument and payloads development status.© (2012) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.
THz quantum-confined Stark effect in semiconductor quantum dots

We demonstrate an instantaneous all-optical manipulation of optical absorption at the ground state of InGaAs/GaAs quantum dots (QDs) via a quantum-confined Stark effect (QCSE) induced by the electric field of incident THz pulses with peak electric fields reaching 200 kV/cm in the free space. As a result, a THz signal with the full bandwidth of 3 THz can be directly encoded onto an optical signal probing the ground state absorption in QDs, resulting in the encoded temporal features as fast as 460 fs. The optical absorption modulation at highest THz fields reaches about 30% of the total optical absorption in QDs at the ground state. The dependency of electro-absorption modulation depth on the peak THz field is found to be strongly nonlinear, as expected from the QCSE. From this dependency we conclude that the dominant contribution to the observed electro-absorption modulation in our sample is made by the overall optical absorption quenching via a reduction of the overlap integral and hence the probability of inter-band transition, rather than by the Stark shift of the QD absorption peak away from the spectrum of the optical probe. As expected from the three-dimensional geometry of a QD, the THz QCSE was found to be independent of the polarization of the THz field. The instantaneous nature of THz QCSE in QDs enables femtosecond all-optical switching at very high repetition rates. This allowed us to demonstrate the potential for applications in THz-range wireless communication systems with the data rate of at least 0.5 Tbit/s.

Truly single-mode polarization maintaining hollow core PCF

Fabrication of a truly single mode, low loss and polarization maintaining HC-PCF is reported. This fiber has a 50 nm wide strictly single mode region with good polarization holding (h-parameter below 10-4 m-1) and low loss (<20 dB/km).
Ultra-Fast Flash Observatory for observation of early photons from gamma ray bursts

We describe the space project of Ultra-Fast Flash Observatory (UFFO) which will observe early optical photons from gamma-ray bursts (GRBs) with a sub-second optical response, for the first time. The UFFO will probe the early optical rise of GRBs, opening a completely new frontier in GRB and transient studies, using a fast response Slewing Mirror Telescope (SMT) that redirects optical path to telescope instead of slewing of telescopes or spacecraft. In our small UFFO-Pathfinder experiment, scheduled to launch aboard the Lomonosov satellite in 2012, we use a motorized mirror in our Slewing Mirror Telescope instrument to achieve less than one second optical response after X-ray trigger. We describe the science and the mission of the UFFO project, including a next version called UFFO-100. With our program of ultra-fast optical response GRB observatories, we aim to gain a deeper understanding of GRB mechanisms, and potentially open up the z<10 universe to study via GRB as point source emission probes. © (2012) COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.
Using pico-LCoS SLMs for high speed cell sorting

We propose the use of consumer pico projectors as cost effective spatial light modulators in cell sorting applications. The matched filtering Generalized Phase Contrast (mGPC) beam shaping method is used to produce high intensity optical spots for trapping and catapulting cells. A pico projector's liquid crystal on silicon (LCoS) chip was used as a binary phase spatial light modulator (SLM) wherein correlation target patterns are addressed. Experiments using the binary LCoS phase SLM with a fabricated Pyrex matched filter demonstrate the generation of intense optical spots that can potentially be used for cell sorting. Numerical studies also show mGPC’s robustness to phase aberrations in the LCoS device, and its ability to outperform a top hat beam with the same power.

VCSELs and silicon light sources exploiting SOI grating mirrors

In this talk, novel vertical-cavity laser structure consisting of a dielectric Bragg reflector, a III-V active region, and a high-index-contrast grating made in the Si layer of a silicon-on-insulator (SOI) wafer will be presented. In the Si light source version of this laser structure, the SOI grating works as a highly-reflective mirror as well as routes light into a Si in-plane output waveguide connected to the grating. In the vertical-cavity surface-emitting laser (VCSEL) version, there is no in-plane output waveguide connected to the grating. Thus, light is vertically emitted through the Bragg reflector. Numerical simulations show that both the silicon light source and the VCSEL exploiting SOI grating mirrors have superior performances, compared to existing silicon light sources and long wavelength VCSELs. These devices are highly adequate for chip-level optical interconnects as well as conventional short-distance optical connections. In the talk, device physics will be discussed in detail.
Wave-front-engineered grating mirrors for VCSELs
High-index-contrast grating mirrors featuring beam steering abilities for the transmitted beam as well as high reflectivity over a broad bandwidth are suggested. Gratings designed to provide control over the wave front of the transmitted beam are numerically investigated. The proposed structures are then fabricated for experimental characterization. The measurements performed show the beam steering ability of the suggested HCG designs and are also in good agreement with the theoretical predictions. General design rules to engineer these HCG structures for different applications are derived. These grating mirrors would have a significant impact on low cost laser sources fabrication, since a more efficient integration of optoelectronic modules can be achieved by avoiding expensive external lens systems.

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WOW: light print, light propel, light point
We are presenting so-called Wave-guided Optical Waveguides (WOWs) fabricated by two-photon polymerization and capable of being optically manipulated into any arbitrary orientation. By integrating optical waveguides into the structures we have created freestanding waveguides which can be positioned anywhere in a sample at any orientation using real-time 3D optical micromanipulation with six degrees of freedom. One of the key aspects of our demonstrated WOWs is the change in direction of in-coupled light and the marked increase in numerical aperture of the out-coupled light. Hence, each light propelled WOW can tap from a relatively broad incident beam and generate a much more tightly confined light at its tip. The presentation contains both numerical simulations related to the propagation of light through a WOW and preliminary experimental demonstrations on our BioPhotonics Workstation. In a broader context, this research shows that optically trapped micro-fabricated structures can potentially help bridge the diffraction barrier. This structure-mediated paradigm may be carried forward to open new possibilities for exploiting beams from far-field optics down to the sub-wavelength domain.

General information
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Ytterbium-doped large-mode-area photonic crystal fiber amplifier with gain shaping for use at long wavelengths

A large-mode-area Ytterbium-doped photonic crystal fiber amplifier with efficient suppression of amplified spontaneous emission is presented. The fiber cladding consists of a hexagonal lattice of air holes, where three rows are replaced with circular high-index inclusions. Seven missing air holes define the large-mode-area core. Light confinement is achieved by combined index and bandgap guiding, which allows for single-mode operation and distributed spectral filtering of amplified spontaneous. The fiber properties give control of the gain shape and are ideal for amplification in the long wavelength regime of the Ytterbium gain spectrum above 1100 nm.

870nm Bragg grating in single mode TOPAS microstructured polymer optical fibre

We report the fabrication and characterization of a fiber Bragg grating (FBG) with 870 nm resonance wavelength in a single-mode TOPAS microstructured polymer optical fiber (mPOF). The grating has been UV-written with the phase-mask technique using a 325 nm HeCd laser. The static tensile strain sensitivity has been measured as 0.64 pm/μstrain, and the temperature sensitivity was -60 pm/°C. This is the first 870nm FBG and the first demonstration of a negative temperature response for the TOPAS FBG, for which earlier results have indicated a positive temperature response. The relatively low material loss of the fiber at this wavelength compared to that at longer wavelengths will considerably enhance the potential utility of the TOPAS FBG.
Advanced simulations of x-ray beam propagation through CRL transfocators using ray-tracing and wavefront propagation methods

Compound refractive lenses (CRL) are widely used to manipulate synchrotron radiation beams. Accurate modelling of X-ray beam propagation through individual lenses and through "transfocators" composed of a large number of CRLs is of high importance, since it allows for comprehensive optimization of X-ray beamline designs for particular user experiments. In this work we used the newly developed McXtrace ray-tracing package and the SRW wave-optics code to simulate the beam propagation of X-ray undulator radiation through such a "transfocator" as implemented at ID-11 at ESRF. By applying two complementary simulation methods, we were able to obtain comparable results (e.g. the beam's focused properties) and also to provide a complete description of X-ray beam propagation through the CRLs and other optical components. However, some discrepancies between the results acquired by both methods (e.g. broader monochromatization degree obtained with the McXtrace code) brought a meaningful insight into further development strategies for the McXtrace package.
All-fiber 7x1 signal combiner for incoherent laser beam combining

We demonstrate an all-fiber 7x1 signal combiner for incoherent laser beam combining. This is a potential key component for reaching several kW of stable laser output power. The combiner couples the output from 7 single-mode (SM) fiber lasers into a single multi-mode (MM) fiber. The input signal fibers have a core diameter of 17 μm and the output MM fiber has a core diameter of 100 μm. In a tapered section light gradually leaks out of the SM fibers and is captured by a surrounding fluorine-doped cladding. The combiner is tested up to 2.5 kW of combined output power and only a minor increase in device temperature is observed. At an intermediate power level of 600 W a beam parameter product (BPP) of 2.22 mm x mrad is measured, corresponding to an M2 value of 6.5. These values are approaching the theoretical limit dictated by brightness conservation.

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All-solid birefringent hybrid photonic crystal fiber based interferometric sensor for measurement of strain and temperature

A highly sensitive fiber-optic interferometric sensor based on an all-solid birefringent hybrid photonic crystal fiber (PCF) is demonstrated for measuring strain and temperature. A strain sensitivity of similar to 23.8 pm/με and a thermal sensitivity of similar to -1.12 nm/°C are demonstrated in the experiment.

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A Monte Carlo approach for simulating the propagation of partially coherent x-ray beams

Advances at SR sources in the generation of nanofocused beams with a high degree of transverse coherence call for effective techniques to simulate the propagation of partially coherent X-ray beams through complex optical systems in order to characterize how coherence properties such as the mutual coherence function (MCF) are propagated to the exit plane. Here we present an approach based on Monte Carlo sampling of the Green function. A Gauss-Shell Stochastic Source with arbitrary spatial coherence is synthesized by means of the Gaussian copula statistical tool. The Green function is obtained by sampling Huygens-Fresnel waves with Monte Carlo methods and is used to propagate each source realization to the detector plane. The sampling is implemented with a modified Monte Carlo ray tracing scheme where the optical path of each generated ray is stored. Such information is then used in the summation of the generated rays at the observation plane to account for coherence properties. This approach is used to simulate simple models of propagation in free space and with reflective and refractive optics. © 2011 COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.

A simple model for 2D image upconversion of incoherent light

We present a simple theoretical model for 2 dimensional (2-D) image up-conversion of incoherent light. While image upconversion has been known for more than 40 years, the technology has been hindered by very low conversion quantum efficiency (~10^-7). We show that our implementation compared to previous work can result in a feasible system: Using intracavity upconversion and Quasi Phase Matching (QPM) nonlinear materials provide increased conversion efficiency. Using a QPM crystal and choosing the wavelengths so the first order term in the phasematch wavelength acceptance vanishes, results in very large wavelength acceptance. This work describes how the bandwidth acceptance can be predicted and designed. This gives promise of a new way to make infrared imaging devices with tunable spectral sensitivity.
BioPhotonics Workstation: a university tech transfer challenge

Conventional optical trapping or tweezing is often limited in the achievable trapping range because of high numerical aperture and imaging requirements. To circumvent this, we are developing a next generation BioPhotonics Workstation platform that supports extension modules through a long working distance geometry. This geometry provides three dimensional and real time manipulation of a plurality of traps facilitating precise control and a rapid response in all sorts of optical manipulation undertakings. We present ongoing research and development activities for constructing a compact next generation BioPhotonics Workstation to be applied in three-dimensional studies on regulated microbial cell growth including their underlying physiological mechanisms, in vivo characterization of cell constituents and manufacturing of nanostructures and new materials.
Cavity quantum electrodynamics studies with site-controlled InGaAs quantum dots integrated into high quality microcavities

Semiconductor quantum dots (QDs) are fascinating nanoscopic structures for photonics and future quantum information technology. However, the random position of self-organized QDs inhibits a deterministic coupling in devices relying on cavity quantum electrodynamics (cQED) effects which complicates, e.g., the large scale fabrication of quantum light sources. As a result, large efforts focus on the growth and the device integration of site-controlled QDs. We present the growth of low density arrays of site-controlled In(Ga)As QDs where shallow etched nanoholes act as nucleation sites. The nanoholes are located relative to cross markers which allows for a precise spatial alignment of the site-controlled QDs (SCQDs) and the photonic modes of high quality microcavities with an accuracy better than 50 nm. We also address the optical quality of the SCQDs in terms of the single SCQD emission mode linewidth, the oscillator strength and the quantum efficiency. A stacked growth of strain coupled SCQDs forming on wet chemically etched nanoholes provide the smallest linewidth with an average value of 210 μeV. Using time resolved photoluminescence studies on samples with a varying thickness of the capping layer we determine a quantum efficiency of the SCQD close to 50% and an oscillator strength of about 10. Finally, single photon emission with associated with g(2)(0) = 0.12 of a weakly coupled SCQD-micropillar system will be presented.

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Coatings for the NuSTAR mission

The NuSTAR mission will be the first mission to carry a hard X-ray (5-80 keV) focusing telescope to orbit. The optics are based on the use of multilayer coated thin slumped glass. Two different material combinations were used for the flight optics, namely W/Si and Pt/C. In this paper we describe the entire coating effort including the final coating design that was used for the two flight optics. We also present data on the performance verification of the coatings both on Si witness samples as well as on individual flight mirrors.

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Deposition of sol-gel sensor spots by nanoimprint lithography and hemi-wicking

We present a method for homogeneous deposition of sol-gel sensor materials, which enable fabrication of sensor spots for optical pH and oxygen measurements inside plastic containers. A periodic pattern of posts is imprinted into a polycarbonate substrate and, using the principle of hemi-wicking, a deposited droplet spreads, guided by the posts, to automatically fill the imprinted structure, not being sensitive to alignment as long as it is deposited inside the patterned area. Hemi-wicking is an effective method to immobilize a low viscosity liquid material in well-defined spots on a surface, when conventional methods such as screen- or stamp-printing do not work. On length scales of the order of the microstructure period, surface tension will govern the shape of the liquid-air interface, and the liquid will climb up the pillars to keep a fixed contact angle with the sidewalls. The surface to volume ratio is therefore constant all over the surface of the liquid spread by hemi-wicking, when considering length scales larger than the microstructure period. Material redistribution caused by solvent evaporation, i.e., the "coffee ring effect", can therefore be avoided because the evaporation rate does not vary on length scales larger than the periodic pattern.

General information
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Organisations: Department of Micro- and Nanotechnology, DELTA - a Part of FORCE Technology
Contributors: Mikkelsen, M. B. L., Marie, R., Hansen, J. H., Nielsen, H. O., Kristensen, A.
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Design, fabrication, and characterization of silicon pore optics for ATHENA/IXO

Silicon pore optics is a technology developed to enable future large area X-ray telescopes, such as the International X-ray Observatory (IXO) or the Advanced Telescope for High ENergy Astrophysics (ATHENA), an L-class candidate mission in the ESA Space Science Programme 'Cosmic Visions 2015-2025'. ATHENA/IXO use nested mirrors in Wolter-I configuration to focus grazing incidence X-ray photons on a detector plane. The x-ray optics will have to meet stringent performance requirements including an effective area of a few m² at 1.25 keV and angular resolution between 5(IXO) and 9(ATHENA) arc seconds. To achieve the collecting area requires a total polished mirror surface area close to 1000 m² with a surface roughness better than 0.5 nm rms. By using commercial high-quality 12" silicon wafers which are diced, structured, wedged, coated, bent and stacked, the stringent performance requirements can be met without any costly polishing steps. Two of such stacks are then assembled into a co-aligned mirror module, which is a complete X-ray imaging system. Included in the mirror module are the isostatic mounting points, providing a reliable interface to the telescope. Hundreds of such mirror modules are finally integrated into petals, and mounted onto the spacecraft to form an X-ray optic. In this paper we will present the silicon pore optics mass manufacturing process and latest X-ray test results.

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Organisations: Astrophysics, National Space Institute, Cosine Measurement Systems, European Space Agency - ESA, Micronit Microfluidics B.V., SRON Netherlands Institute for Space Research, Physikalisch-Technische Bundesanstalt, Max-Planck-Institut für extraterrestrische Physik
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Developing our Next Generation BioPhotonics Workstation
Optical trapping and manipulation have established a track record for cell handling in small volumes. However, this cell handling capability is often not simultaneously utilized in experiments using other methods for measuring single cell properties such as fluorescent labeling. Such methods often limit the trapping range because of high numerical aperture and imaging requirements. To circumvent these issues, we are developing a BioPhotonics Workstation platform that supports extension modules through a long working distance geometry. Furthermore, a long range axial manipulation range is achieved by the use of counter-propagating beam traps coupled with the long working distance. This geometry provides three dimensional and real time manipulation of a plurality of traps - currently 100 independently reconfigurable - facilitating precise control and a rapid response in all sorts of optical manipulation undertakings. We present ongoing research activities for constructing a compact next generation BioPhotonics Workstation.
Development of nanostructured protective "sight glasses" for IR gas sensors

In this work protective "sight glasses" for infrared gas sensors showing a sub-wavelength nanostructure with random patterns have been fabricated by reactive ion etching (RIE) in an easy and comparable cheap single step mask-less process. By an organic coating, the intrinsic water repellent property of the surface could be enhanced, shown by contact angle and roll-off angle measurements. The "self-cleaning" surface property and chemical robustness towards aggressive environments are demonstrated. FT-IR spectroscopy concerning the optical properties of these nanostructured silicon windows revealed a stable anti-reflective "moth-eye" effect in certain wavelength ranges owing to the nanostructures.
**Differential thermal analysis microsystem for explosive detection**

A micro differential thermal analysis (DTA) system is used for detection of trace explosive particles. The DTA system consists of two silicon micro chips with integrated heaters and temperature sensors. One chip is used for reference and one for the measurement sample. The sensor is constructed as a small silicon nitride membrane incorporating heater elements and a temperature measurement resistor. In this manuscript the DTA system is described and tested by measuring calorimetric response of 3 different kinds of explosives (TNT, RDX and PETN). This project is carried out under the framework of the Xsense project at the Technical University of Denmark (DTU) which combines four independent sensing techniques, these micro DNT sensors will be included in handheld explosives detectors with applications in homeland security and landmine clearance.

**General information**

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Organisations: Nanoprobes Group, NanoSystemsEngineering Section, Department of Micro- and Nanotechnology
Contributors: Olsen, J. K., Greve, A., Senesac, L., Thundat, T., Boisen, A.
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**Direct pumping of ultrashort Ti:sapphire lasers by a frequency doubled diode laser**

A simple and robust diode laser system emitting 1.28 W of green light suitable for pumping an ultrafast Ti:sapphire laser is presented. To classify our results, the diode laser is compared to a standard, commercially available diode pumped solid-state (DPSS) laser system pumping the same oscillator. When using our diode laser system, the optical conversion efficiencies from green to near-infrared light reduces to 75 % of the values achieved with the commercial pump laser. Despite this reduction the overall efficiency of the Ti: sapphire laser is still increased by a factor > 2 due to the superior electro-optical efficiency of the diode laser. Autocorrelation measurements show that pulse widths of less than 20 fs can be expected with an average power of 52 mW when using our laser. These results indicate the high potential of direct diode laser pumped Ti: sapphire lasers to be used in applications like retinal optical coherence tomography (OCT) or pumping of photonic crystal fibers for CARS (coherent anti-stokes Raman spectroscopy) microscopy.

**General information**

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Organisations: Diode Lasers and LED Systems, Department of Photonics Engineering, Terahertz Technologies and Biophotonics, Femtolasers Produktions GmbH, Ferdinand-Braun-Institut
Contributors: Müller, A., Jensen, O. B., Unterhuber, A., Le, T., Stingl, A., Hasler, K., Sumpf, B., Erbert, G., Andersen, P. E., Petersen, P. M.
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Earth-Affecting Solar Causes Observatory (EASCO): a mission at the Sun-Earth L5

Coronal mass ejections (CMEs) and corotating interaction regions (CIRs) as well as their source regions are important because of their space weather consequences. The current understanding of CMEs primarily comes from the Solar and Heliospheric Observatory (SOHO) and the Solar Terrestrial Relations Observatory (STEREO) missions, but these missions lacked some key measurements: STEREO did not have a magnetograph; SOHO did not have in-situ magnetometer. SOHO and other imagers such as the Solar Mass Ejection Imager (SMEI) located on the Sun-Earth line are also not well-suited to measure Earth-directed CMEs. The Earth-Affecting Solar Causes Observatory (EASCO) is a proposed mission to be located at the Sun-Earth L5 that overcomes these deficiencies. The mission concept was recently studied at the Mission Design Laboratory (MDL), NASA Goddard Space Flight Center, to see how the mission can be implemented. The study found that the scientific payload (seven remote-sensing and three in-situ instruments) can be readily accommodated and can be launched using an intermediate size vehicle; a hybrid propulsion system consisting of a Xenon ion thruster and hydrazine has been found to be adequate to place the payload at L5. Following a 2-year transfer time, a 4-year operation is considered around the next solar maximum in 2025.

Electrically pumped photonic nanowire single-photon source with an efficiency of 89%

We propose a new electrically-pumped single-photon source design based on a quantum dot in a photonic nanowire. For realistic parameters, the design features an efficiency of 89 % predicted by numerical simulations. Unlike cavity-based designs, our approach allows for broadband spontaneous emission control and has high tolerance towards surface roughness. In the nanowire, a geometrical effect ensures good coupling between the quantum dot and the optical mode, and an inverted tapering section is introduced to adiabatically expand the mode waist and control the far field emission profile while minimizing the relative modal overlap with the metal contacts.
Enhancing slow- and fast-light effects in quantum dot semiconductor waveguides through ultrafast dynamics

In this paper we review our theoretical work on slow and fast light effects in quantum dot semiconductor optical amplifiers (QD SOAs), in particular we investigate the carrier dynamical contributions to the dynamic gain grating and cross gain modulation induced by unique ultrafast inter-subband carrier dynamics between discrete QD bound states. Our calculations predict that by increasing the injection current density, additional ultra-fast coherent gain contributions around 100GHz arise in contrast to the slow sub-gigahertz carrier density pulsation (CDP) effects. For potential applications in microwave photonics, especially targeting the millimeter wave range, we propose that quantum dot devices might be used to realize an optically fed microwave phase shifter in the frequency range of 100GHz.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Quantum and Laser Photonics
Contributors: Chen, Y., Mørk, J.
Pages: 793709-11
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ESA-led ATHENA/IXO optics development status
The International X-ray Observatory (IXO) is a candidate mission in the ESA Space Science Programme Cosmic Vision 1525, and was studied as a joint mission with NASA and JAXA. Considering the programmatic evolution of the international context, the mission is being reformulated as an ESA-led mission, under the name of ATHENA (Advanced Telescope for High Energy Astrophysics), with possible participation of NASA and JAXA. The mission is building on the novel Silicon Pore Optics (SPO) technology to achieve the required performance for this demanding astrophysics observatory. This technology is being developed by an industrial consortium, and involves also several research institutes [1-12]. A second optics technology, slumped glass optics (SGO), which is being developed in Europe and the USA, was the backup technology for IXO, and additionally work is progressing on improved reflective coatings and X-ray test...
Extending JPEG-LS for low-complexity scalable video coding

JPEG-LS, the well-known international standard for lossless and near-lossless image compression, was originally designed for non-scalable applications. In this paper we propose a scalable modification of JPEG-LS and compare it with...
the leading image and video coding standards JPEG2000 and H.264/SVC intra for low-complexity constraints of some wireless video applications including graphics.

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Organisations: Coding and Visual Communication, Department of Photonics Engineering, St. Petersburg State University Of Aerospace Instrumentation
Contributors: Ukhanova, A., Sergeev, A., Forchhammer, S.
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**Fabrication and characterization of woodpile structures**
In this paper we present the whole fabrication and characterization cycle for obtaining 3D metal-dielectric woodpile structures. The optical properties of these structures have been measured using different setups showing the need of considering e.g. border effects when planning their use in real-life devices. It was found that the behavior of the structures close to the edge is very different from the one in the middle. The existence of special features in the former spectra still needs to be completely understood and explained.

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Organisations: Metamaterials, Department of Photonics Engineering
Contributors: Zalkovskij, M., Malureanu, R., Andryieuski, A., Lavrinenko, A.
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First results from the ground calibration of the NuSTAR flight optics

NuSTAR is a hard X-ray satellite experiment to be launched in 2012. Two optics with 10.15 m focal length focus X-rays with energies between 5 and 80 keV onto CdZnTe detectors located at the end of a deployable mast. The FM1 and FM2 flight optics were built at the same time based on the same design and with very similar components, and thus the performance of both is expected to be very similar. We provide an overview of calibration data that is being used to build an optics response model for each optic and describe initial results for energies above 10 keV from the ground calibration of the flight optics. From a preliminary analysis of the data, our current best determination of the overall HPD of both the FM1 and FM2 flight optics is 52", and nearly independent of energy. The statistical error is negligible, and a preliminary estimate of the systematic error is of order 4". The as-measured effective area and HPD meet the toplevel NuSTAR mission sensitivity requirements.

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Frequency Stepped Pulse Train Modulated Wind Sensing Lidar

In this paper a wind sensing lidar utilizing a Frequency Stepped Pulse Train (FSPT) is demonstrated. One of the advantages in the FSPT lidar is that it enables direct measurement of wind speed as a function of distance from the lidar. Theoretically the FSPT lidar continuously produces measurements as is the case with a CW lidar, but at the same time with a spatial resolution, and without the range ambiguity originating from e.g. clouds. The FSPT lidar utilizes a frequency sweeping source for generation of the FSPT. The source generates a pulse train where each pulse has an optical carrier frequency shifted a set quantity relative to the carrier frequency of the previous pulse. In the scheme presented here, the measured frequency depends on the distance from which the signal originates. The measured frequency is related to the Doppler frequency shift induced by the wind and an integer number of frequency shifts corresponding to a specific distance. The spatial resolution depends on the repetition rate of the pulses in the pulse train. Directional wind measurements are shown and compared to a CW lidar measurement. The carrier to noise ratio of the FSPT lidar compared to a CW lidar is discussed as well as the fundamental differences between the two systems. In the discussion we describe the most dominant noise sources in our system and what influences these have on the FSPT lidar's ability to measure under different scattering conditions.

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Organisations: Fiber Optics, Devices and Non-linear Effects, Department of Photonics Engineering
Contributors: Olesen, A. S., Pedersen, A. T., Rottwitt, K.
Pages: 81590O
Publication date: 2011
Functionalized 2PP structures for the BioPhotonics Workstation

In its standard version, our BioPhotonics Workstation (BWS) can generate multiple controllable counter-propagating beams to create real-time user-programmable optical traps for stable three-dimensional control and manipulation of a plurality of particles. The combination of the platform with microstructures fabricated by two-photon polymerization (2PP) can lead to completely new methods to communicate with micro- and nano-sized objects in 3D and potentially open enormous possibilities in nano-biophotonics applications. In this work, we demonstrate that the structures can be used as microsensors on the BWS platform by functionalizing them with silica-based sol-gel materials inside which dyes can be entrapped.

General information
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Organisations: Teraherts Technologies and Biophotonics, Department of Photonics Engineering, Kyoto University
Contributors: Matsuoka, T., Nishi, M., Sakakura, M., Miura, K., Hirao, K., Palima, D., Tauro, S., Bañas, A. R., Glückstad, J.
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High resolution 2D image upconversion of incoherent light
An optimized method for continuous wave 2-dimensional (2-D) upconversion of incoherent or thermal light is demonstrated and quantified. Using standard resolution targets a resolution of 200×1000 pixels is obtained. The suggested method is viewed in scope of modern CCD cameras operating in the near infrared (NIR) portion of the electromagnetic spectrum. The key is optimization of the upconversion process. This include Quasi-Phase-Matching leading to higher effective nonlinearities and elimination of walk-off, an intra-cavity design enhancing the upconversion process, and finally the use of modern NIR CCD detectors. Furthermore, we discuss the exceptionally good depth of field possible for imaging systems based on the proposed method.

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Organisations: Optical Sensor Technology, Department of Photonics Engineering
Contributors: Dam, J. S., Pedersen, C., Tidemand-Lichtenberg, P.
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Hybrid large mode area photonic crystal fiber for distributed spectral filtering and single-mode operation
The properties of a large mode area Yb-doped double-cladding hybrid photonic crystal fiber, with antisymmetric high-index inclusions, have been analyzed. Simulations, carried out through a finite-element based modal solver, and experimental measurements have demonstrated the narrow spectral filtering capability of this fiber, with a passband of about 80 nm in the Yb gain region. Moreover, high-order mode suppression has been demonstrated with a proper air-hole size. Finally, the stress-induced birefringence due to the Ge-doped rods used as high-index insets has been investigated, accounting for the polarization-maintaining behaviour of the manufactured fiber.

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Organisations: University of Parma, NKT Group
Contributors: Poli, F., Coscelli, E., Alkeskjold, T. T., Passaro, D., Cucinotta, A., Selleri, S., Leick, L., Broeng, J.
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Low-NA single-mode LMA photonic crystal fiber amplifier

Enabling Single-Mode (SM) operation in Large-Mode-Area (LMA) fiber amplifiers and lasers is critical, since a SM output ensures high beam quality and excellent pointing stability. In this paper, we demonstrate and test a new design approach for achieving ultra-low NA SM rod fibers by using a spatially Distributed Mode Filter (DMF). This approach achieves SM performance in a short and straight rod fiber and allows preform tolerances to be compensated during draw. A low-NA SM rod fiber amplifier having a mode field diameter of ~60μm at 1064nm and a pump absorption of 27dB/m at 976nm is demonstrated.

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Organisations: Department of Photonics Engineering, Fiber Optics, Devices and Non-linear Effects
Contributors: Alkeskjold, T. T., Laurila, M., Scolari, L., Broeng, J., Laurila, M.
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Peer-reviewed: Yes

McXtrace: A modern ray-tracing package for X-ray instrumentation

we present the developments of the McXtrace project, a free, open source software package based on Monte Carlo ray tracing for simulations and optimisation of complete X-ray instruments. The methodology of building a simulation is presented through an example beamline, namely Beamline 811 at MAX-lab, Lund, Sweden - a beamline dedicated to materials science. © 2011 COPYRIGHT Society of Photo-Optical Instrumentation Engineers (SPIE). Downloading of the abstract is permitted for personal use only.

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Organisations: Nano-Microstructures in Materials, Materials Research Division, Risø National Laboratory for Sustainable Energy, University of Copenhagen, Lund University, European Synchrotron Radiation Facility
Contributors: Bergbäck Knudsen, E., Prodi, A., Willendrup, P. K., Lefmann, K., Baltser, J., Gundlach, C., Del Río, M. S., Ferrero, C., Feidenhans'l, R.
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Modeling LCD Displays with Local Backlight Dimming for Image Quality Assessment
Traditionally, algorithm-based (objective) image and video quality assessment methods operate with the numerical presentation of the signal, and they do not take the characteristics of the actual output device into account. This is a reasonable approach, when quality assessment is needed for evaluating the signal quality distortion related directly to digital signal processing, such as compression. However, the physical characteristics of the display device also pose a significant impact on the overall perception. In order to facilitate image quality assessment on modern liquid crystal displays (LCD) using light emitting diode (LED) backlight with local dimming, we present the essential considerations and guidelines for modeling the characteristics of displays with high dynamic range (HDR) and locally adjustable backlight segments. The representation of the image generated by the model can be assessed using the traditional objective metrics, and therefore the proposed approach is useful for assessing the performance of different backlight dimming algorithms in terms of resulting quality and power consumption in a simulated environment. We have implemented the proposed model in C++ and compared the visual results produced by the model against respective images displayed on a real display with locally controlled backlight units.

MT_RAYOR: a versatile raytracing tool for X-ray telescopes
The prediction of the properties of X-ray telescopes is important for the planning of observations and the interpretation of data. The mirror quality in terms of micro-roughness scattering and deformations relative to the idealized shape plays a crucial role for the sensitivity of the telescope for detecting celestial X-ray sources. Monte-Carlo raytracing systems have been used in all X-ray telescope missions. MT RAYOR is a system that can be used to analyze any Wolter-1 optics including simulation of extended sources, celestial or in the laboratory, with position dependent spectral properties. Examples that explore the MT RAYOR capabilities have been chosen from the future missions NuSTAR and Astrosat.
Multi-colorimetric sensor array for detection of explosives in gas and liquid phase

In the framework of the research project "Xsense" at the Technical University of Denmark (DTU) we are developing a simple colorimetric sensor array which can be useful in detection of explosives like DNT, TATP, HMX, RDX and identification of reagents needed for making homemade explosives. The technology is based on an array of chemoselective compounds immobilized on a solid support. Upon exposure to the analyte in suspicion the colorimetric array changes color. Each chosen compound reacts chemo-selectively with analytes of interest. A change in a color signature indicates the presence of unknown explosives and volatile organic compounds (VOCs). We are working towards the selection of compounds that undergo color changes in the presence of explosives and VOCs, as well as the development of an immobilization method for the molecules. Digital imaging of the colorimetric array before and after exposure to the analytes creates a color difference map which gives a unique fingerprint for each explosive and VOCs. Such sensing technology can be used for screening relevant explosives in a complex background as well as to distinguish mixtures of volatile organic compounds distributed in gas and liquid phases. This sensor array is inexpensive, and can potentially be produced as single use disposable.
New elastomeric silicone based networks applicable as electroactive systems

Commercial elastomer materials are available for dielectric electroactive polymer (DEAP) purposes but the applied commercial elastomers have not been developed with the specific application in mind. It is therefore obvious that optimization of the elastomer material should be possible. In this study we focus on optimization of the mechanical properties of the elastomer and show that it is possible to lower the elastic modulus and still not compromise the other required mechanical properties such as fast response, stability, low degree of viscous dissipation and high extensibility. The elastomers are prepared from a vinyl-terminated polydimethyl siloxane (PDMS) and a 4-functional crosslinker by a platinum-catalyzed hydrosilylation reaction between the two reactants. Traditionally, elastomers based on hydrosilylation are prepared via a ‘one-step two-pot’ procedure (with a mix A and a mix B mixed in a given ratio). An alternative network formulation method is adopted in this study in order to obtain an elastomeric system with controlled topology – a so-called bimodal network. Bimodal networks are synthesized using a ‘two-step four-pot’ mixing procedure which results in a nonhomogeneous network structure which is shown to lead to novel mechanical properties due to the low extensibility of the short chains and the high extensibility of the long chains. The first ensures stability and the last retards the rupture process thereby combining two desired properties for DEAP purposes without necessarily compromising the viscous dissipation. Several elastomers are prepared and tested for the linear viscoelastic behaviour, i.e. behaviour in the small-strain limit (up to approximately 10% strain). The bimodal networks are, however, capable of extensions up to several times their initial length but the focus here is the small-strain limit.

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NuSTAR ground calibration: The Rainwater Memorial Calibration Facility (RaMCaF)
The Nuclear Spectroscopic Telescope Array (NuSTAR) is a NASA Small Explorer mission that will carry the first focusing hard X-ray (5-80 keV) telescope to orbit. The ground calibration of the three flight optics was carried out at the Rainwater Memorial Calibration Facility (RaMCaF) built for this purpose. In this article we present the facility and its use for the ground calibration of the three optics.

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Organisations: Astrophysics, National Space Institute, Columbia University, University of California, California Institute of Technology, Lawrence Livermore National Laboratory
Optical currents in vector fields
The influence of phase relations and the degree of mutual coherence of superimposing waves in the arrangements of twowave superposition on the characteristics of the microparticle's motion has been analyzed. The prospects of studying temporal coherence using the proposed approach are made. For the first time, we have shown experimentally the possibility of diagnostics the optical currents in liquids caused by polarization characteristics of an optical field alone, using test metallic particles of nanoscale.

Passive synchronized Q-switching between a quasi-three-level and a four-level laser
Synchronized Q-switching between quasi-three-level and four-level lasers is interesting for sum-frequency generation into the blue and ultraviolet. We report, for the first time, stable synchronized Q-switching between a quasi-three-level laser at
946 nm and a four-level laser at 1064 nm in an all passive approach. While timing jitter of the individual free-running lasers were on the order of 10 μs, the relative timing jitter, defined as one standard-deviation of the experimental data, was only 9 ns between the two synchronized pulses. The minimum delay between the two pulses was 64 ns during stable operation, which gave a 79% temporal overlap when normalized against the zero-delay scenario. Preliminary results show promise for non-linear frequency conversion, which could lead to high power pulsed blue and ultraviolet lasers.

**Polymer PCF Bragg grating sensors based on poly(methyl methacrylate) and TOPAS cyclic olefin copolymer**

Fibre Bragg grating (FBG) sensors have been fabricated in polymer photonic crystal fibre (PCF). Results are presented using two different types of polymer optical fibre (POF); first multimode PCF with a core diameter of 50μm based on poly(methyl methacrylate) (PMMA) and second, endlessly single mode PCF with a core diameter of 6μm based on TOPAS cyclic olefin copolymer. Bragg grating inscription was achieved using a 30mW continuous wave 325nm helium cadmium laser. Both TOPAS and PMMA fibre have a large attenuation of around 1dB/cm in the 1550nm spectral region, limiting fibre lengths to no longer than 10cm. However, both have improved attenuation of under 10dB/m in the 800nm spectral region, thus allowing for fibre lengths to be much longer. The focus of current research is to utilise the increased fibre length, widening the range of sensor applications. The Bragg wavelength shift of a grating fabricated in PMMA fibre at 827nm has been monitored whilst the POF is thermally annealed at 80°C for 7 hours. The large length of POF enables real time monitoring of the grating, which demonstrates a permanent negative Bragg wavelength shift of 24nm during the 7 hours. This creates the possibility to manufacture multiplexed Bragg sensors in POF using a single phase mask in the UV inscription manufacturing. TOPAS holds certain advantages over PMMA including a much lower affinity for water, this should allow for the elimination of cross-sensitivity to humidity when monitoring temperature changes or axial strain, which is a significant concern when using PMMA fibre.
Preliminary coating design and coating developments for ATHENA
We present initial novel coating design for ATHENA. We make use of both simple bilayer coatings of Ir and B4C and more complex constant period multilayer coatings to enhance the effective area and cover the energy range from 0.1 to 10 keV. We also present the coating technology used for these designs and present test results from coatings.

General information
Publication status: Published
Organisations: Astrophysics, National Space Institute, ESTEC, Cosine Measurement Systems
Contributors: Jakobsen, A. C., Ferreira, D. D. M., Christensen, F. E., Shortt, B., Collon, M., Ackermann, M. D.
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Publication date: 2011
Peer-reviewed: Yes

Quenched transmission of light through ultrathin metal films
We discuss optical properties of ultrathin metal films, with particular attention to the phenomenon of quenched transmission. Transmission of light through an optically ultrathin metal film with a thickness comparable to its skin depth is significant. We demonstrate the quenched transmission through the ultrathin metal films when they are periodically modulated. We also discuss the physics behind it and explain how this abnormal phenomenon is ascribed to surface plasmon resonance effects.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Structured Electromagnetic Materials
Contributors: Xiao, S., Mortensen, N. A.
Pages: 81040B
Sensing characteristics of birefringent microstructured polymer optical fiber

We experimentally studied several sensing characteristics of a birefringent microstructured polymer optical fiber. The fiber exhibits a birefringence of the order $2 \times 10^{-5}$ at 1.3 μm because of two small holes adjacent to the core. In this fiber, we measured spectral dependence of phase and group modal birefringence, bending losses, polarimetric sensitivity to strain and temperature. The sensitivity to strain was also examined for intermodal interference observed in the spectral range below 0.8 μm. Finally, we showed that the material transmission windows shift as function of the applied strain. This shift has an exponential character and saturates for greater strain.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Fiber Sensors & Supercontinuum, Wroclaw University of Science and Technology, Instituto de Engenharia de Sistemas e Computadores do Porto
Contributors: Szczurowski, M. K., Frazao, O., Baptista, J. M., Nielsen, K., Bang, O., Urbanczyk, W.
Pages: 7753
Publication date: 2011
Peer-reviewed: Yes
Single-mode 7-cell core hollow core photonic crystal fiber with increased bandwidth
We present two low-loss 7-cell core hollow-core photonic crystal fibers (HC-PCF) with intrinsic single mode properties around 1550 nm. By reducing the number of surface modes within the bandgap these fibers can be operated close to the short wavelength bandgap edge. It is well known that by omitting a core tube in HC-PCF fabrication of a surface mode free bandgap can be achieved. We found by experimental as well as numerical, investigation that using a core tube with a wall thickness reduced to between 60-70 % is sufficient to have a surface mode free short wavelength bandgap edge. The transmission and mode properties of the fabricated fibers are examined experimentally and compared to numerical calculations.

General information
Publication status: Published
Organisations: NKT Group
Contributors: Lyngsø, J. K., Jakobsen, C., Simonsen, H. R., Broeng, J.
Number of pages: 4
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Original language: English
DOIs: 10.1117/12.885151
Source: dtu
Source-ID: n::oai:DTIC-ART:spie/305478999::24133
Research output: Contribution to journal › Journal article – Annual report year: 2011 › Research › peer-review

Single-mode regime of 19-cell Yb-doped double-cladding photonic crystal fibers
The single-mode regime of 19-cell Yb-doped double-cladding photonic crystal fibers, successfully exploited for high-power applications due to their large mode area, has been studied. The first higher-order mode cut-off wavelength has been evaluated taking into account the crossing between its dispersion curve, obtained with a full-vector modal solver based on the finite element method, and the one of the fundamental space-filling mode, calculated for an infinite cladding. Moreover, the overlap integral on the doped core of the higher-order mode at cut-off condition has been calculated, in order to investigate its effective suppression in the gain competition with the fundamental mode, by applying a spatial and spectral amplifier model. 19-cell double-cladding photonic crystal fibers with different core diameter and refractive index values have been considered. Simulation results have shown that the approach based on the fundamental space-filling mode effective index is not suitable for the cut-off analysis of large core fibers with a finite cladding dimension.

General information
Publication status: Published
Organisations: NKT Group
Contributors: Coscelli, E., Poli, F., Alkeskjold, T. T., Passaro, D., Cucinotta, A., Selleri, S., Leick, L., Broeng, J.
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Original language: English
Sparse principal component analysis in hyperspectral change detection
This contribution deals with change detection by means of sparse principal component analysis (PCA) of simple
differences of calibrated, bi-temporal HyMap data. Results show that if we retain only 15 nonzero loadings (out of 126) in
the sparse PCA the resulting change scores appear visually very similar although the loadings are very different from their
usual non-sparse counterparts. The choice of three wavelength regions as being most important for change detection
demonstrates the feature selection capability of sparse PCA.

Spatial and spectral imaging of LMA photonic crystal fiber amplifiers
We demonstrate modal characterization using spatial and spectral resolved (S2) imaging, on an Ytterbium-doped large-
mode-area photonic crystal fiber (PCF) amplifier and compare results with conventional cut-off methods. We apply
numerical simulations and step-index fiber experiments to calibrate our mathematical and experimental routines of our S2
imaging system. We systematically analyze higher order mode (HOM) content of a polarizing 40μm core double-clad PCF
amplifier with various launching and coiling configurations. We demonstrate a HOM suppression of more than -24dB with
variance of 2.3dB.
Spectral narrowing of a 980 nm tapered diode laser bar

High power diode laser bars are interesting in many applications such as solid state laser pumping, material processing, laser trapping, laser cooling and second harmonic generation. Often, the free running laser bars emit a broad spectrum of the order of several nanometres which limit their scope in wavelength specific applications and hence, it is vital to stabilize the emission spectrum of these devices. In our experiment, we describe the wavelength narrowing of a 12 element 980 nm tapered diode laser bar using a simple Littman configuration. The tapered laser bar which suffered from a big smile has been "smile corrected" using individual phase masks for each emitter. The external cavity consists of the laser bar, both fast and slow axis micro collimators, smile correcting phase mask, 6.5x beam expanding lens combination, a 1200 lines/mm reflecting grating with 85% efficiency in the first order, a slow axis focusing cylindrical lens of 40 mm focal length and an output coupler which is 10% reflective. In the free running mode, the laser emission spectrum was 5.5 nm wide at an operating current of 30A. The output power was measured to be in excess of 12W. Under the external cavity operation, the wavelength spread of the laser could be limited to 0.04 nm with an output power in excess of 8 W at an operating current of 30A. The spectrum was found to be tunable in a range of 16 nm.

General information

Publication status: Published
Organisations: Department of Photonics Engineering, Diode Lasers and LED Systems, Universite Paris-Sud
Contributors: Vijayakumar, D., Jensen, O. B., Lucas Leclin, G., Petersen, P. M., Thstrup, B.
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Peer-reviewed: Yes

Publication information

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Research output: Contribution to journal › Conference article – Annual report year: 2011 › Research › peer-review

Studies of plasmonic hot-spot translation by a metal-dielectric layered superlens

We have studied the ability of a lamellar near-field superlens to transfer an enhanced electromagnetic field to the far side of the lens. In this work, we have experimentally and numerically investigated superlensing in the visible range. By using the resonant hot-spot field enhancements from optical nanoantennas as sources, we investigated the translation of these sources to the far side of a layered silver-silica superlens operating in the canalization regime. Using near-field scanning optical microscopy (NSOM), we have observed evidence of superlens-enabled enhanced-field translation at a wavelength of about 680 nm. Specifically, we discuss our recent experimental and simulation results on the translation of hot spots using a silver-silica layered superlens design. We compare the experimental results with our numerical simulations and discuss the perspectives and limitations of our approach.

Bibliographical note

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Research output: Contribution to journal › Conference article – Annual report year: 2011 › Research › peer-review
The mirror module design for the cryogenic x-ray imaging spectrometer on-board ORIGIN

ORIGIN is a medium size high-energy mission concept submitted to ESA in response to the Cosmic Vision call issued on July 2010. The mission will investigate the evolution of the Universe by performing soft X-ray high resolution spectroscopic measurements of metals formed in different astrophysical environments, from the first population III stars at z > 7 to the present large scale structures. The main instrument on-board ORIGIN will be a large format array of TES X-ray microcalorimeters covering a FOV of 30° at the focal plane of a grazing incidence optical module with a focal length of 2.5 m and an angular resolution of 30” HEW at 1 keV. We present the optical module design which is based on hybrid technologies, namely Silicon Pore Optics for the outer section and Ni electro-forming for the inner section, and we present the expected performances based on test measurements and ray-tracing simulations.
Unified approach for retrieval of effective parameters of metamaterials

We propose the method of effective parameters retrieval based on the Bloch mode analysis of periodic metamaterials. We perform the surface and volume averaging of the electromagnetic field of the dominating (fundamental) Bloch mode to determine the Bloch and wave impedances, respectively. We show that our method is able to retrieve both material and wave EPs for a wide range of materials, which can be lossy or lossless, dispersive, possess negative permittivity, permeability and refractive index values. It is simple and unambiguous, free of the "branch" problem, which is an issue for the reflection/transmission based method and has no limitations on a metamaterial slab thickness. The method does not require averaging different fields' components at various surfaces or contours. The retrieval of both wave and material EPs is performed within a single computational cycle, after exporting fields on the unit cells facets or in its volumes directly from Maxwell's equations solver.

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Publication status: Published
Organisations: Metamaterials, Department of Photonics Engineering, Australian National University
Contributors: Andryieuski, A., Ha, S., Sukhorukov, A. A., Kivshar, Y. S., Lavrinenko, A.
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Research output: Contribution to journal › Conference article – Annual report year: 2011 › Research › peer-review

Xsense: a miniaturised multi-sensor platform for explosives detection

Realizing that no one sensing principle is perfect we set out to combine four fundamentally different sensing principles into one device. The reasoning is that each sensor will complement the others and provide redundancy under various environmental conditions. As each sensor can be fabricated using microfabrication the inherent advantages associated with MEMS technologies such as low fabrication costs and small device size allows us to integrate the four sensors into one portable device at a low cost.

General information
Publication status: Published
Organisations: Department of Micro- and Nanotechnology, Cognitive Systems, Department of Informatics and Mathematical Modeling, University of Southern Denmark, University of Alberta
Pages: 803123-7
Publication date: 2011
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Publication information
Journal: Proceedings of SPIE, the International Society for Optical Engineering
10-GHz 1.59-μm quantum dash passively mode-locked two-section lasers

This paper reports the fabrication and the characterisation of a 10 GHz two-section passively mode-locked quantum dash laser emitting at 1.59 μm. The potential of the device's mode-locking is investigated through an analytical model taking into account both the material parameters and the laser geometry. Results show that the combination of a small absorbing section coupled to a high absorption coefficient can lead to an efficient mode-locking. Characterisation shows mode-locking operation though output pulses are found to be strongly chirped. Noise measurements demonstrate that the single side band phase noise does not exceed -80 dBc/Hz at 100 kHz offset leading to an average timing jitter as low as 800 fs. As compared to single QW lasers these results constitute a significant improvement and are of first importance for applications in optical telecommunications.

3D characterization of the forces in optical traps based on counter-propagation beams shaped by a spatial light modulator

An experimental characterization of the 3D forces, acting on a trapped polystyrene bead in a counter-propagating beam geometry, is reported. Using a single optical trap with a large working distance (in the BioPhotonics Workstation), we simultaneously measure the transverse and longitudinal trapping force constants. Two different methods were used: The Drag force method and the Equipartition method. We show that the counterpropagating beams traps are simple harmonic for small displacements. The force constants reveal a transverse asymmetry as = - 9.7 pN/μm and = 11.3 pN/μm (at a total laser power of 2x35 mW) for displacements in opposite directions. The Equipartition method is limited by mechanical noise and is shown to be applicable only when the total laser power in a single 10 μm counter-propagating trap is below 2x20 mW.
7+1 to 1 pump/signal combiner for air-clad fiber with 15 m MFD PM single-mode signal feed-through

A 7+1 to 1 pump/signal combiner with single-mode (SM) polarization maintaining (PM) 15 µm mode-field-diameter (MFD) signal feed-through is demonstrated. The combiner is designed for pulse amplification in an active Yb-doped air-clad fiber operated in backward pumped configuration. Signal coupling through the device is realized by a microstructured taper element allowing single-mode guidance and constant MFD at a taper ratio of 3.4.

80-nm-tunable high-index-contrast subwavelength grating long-wavelength VCSEL: Proposal and numerical simulations

A widely-tunable single-mode long wavelength vertical-cavity surface-emitting laser structure employing a MEMStunable high-index-contrast subwavelength grating (HCG) is suggested and numerically investigated. A very large 80- nm linear tuning range was obtained as the HCG was actuated by -220 to 250 nm. The large tuning range results from making the air gap part of the optical cavity, which was achieved by inserting an antireflection layer below the air gap and by the absence of partial top DBR for current spreading. The single mode operation was maintained throughout the tuning range, thanks to the selective pumping of the fundamental mode and the moderate mode selection by the HCG itself. Analytic expressions for tuning range and tuning sensitivity were derived, using the penetration depth of the HCG for the first time.
A closer look at dynamic speckles and the use of their fine-structure for object measurements

The possibility to “dress up” the speckles and thereby providing them with a fine structure will be discussed. As these speckles arise from scattering off solid targets, the dynamics of the speckles and their inherent fine structure might vary, providing information on different aspects of the surface displacement. This is achieved by illuminating the object with structured light, and observing the speckle field as it passes an optical system. In this way, simultaneous measurement of displacement (e.g. 2-D) and rotation can be performed. The application of this concept with a system based on spatial filtering velocimetry and ordinary speckle correlation will be discussed.

A highly efficient single-photon source based on a quantum dot in a photonic nanowire

General information
Publication status: Published
Organisations: Quantum and Laser Photonics, Department of Photonics Engineering, French Alternative Energies and Atomic Energy Commission, Laboratoire Charles Fabry de l'Institut d'Optique
Alleviate photo darkening by single-mode RMO fiber design
In this work we propose and demonstrate a single mode fiber design that alleviates photo darkening. The fiber design is based on a reduced signal mode to gain material overlap which is found to reduce the induced losses of PD. For the fiber, saturated photo darkening operation is observed after 1500 hours operation with less than 7% reduction in slope efficiency from 350 W output power in Yb/Al co-doped material. Power scalability up to 5 kW of the RMO fiber design is theoretically predicted.

Analysis of laser speckle patterns from fingertips

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Research output: Contribution to journal › Conference article – Annual report year: 2010 › Research › peer-review

General information
Publication status: Published
Organisations: Diode Lasers and LED Systems, Department of Photonics Engineering, Optical Sensor Technology
Contributors: Iversen, T. F. Q., Hanson, S. G.
Pages: 772621
Publication date: 2010
Peer-reviewed: Yes
Analytic expressions for level crossing for stochastic signals with relevance in optics

General information
Publication status: Published
Organisations: Optical Sensor Technology, Department of Photonics Engineering, The Aerospace Corporation
Contributors: Hanson, S. G., Yura, H.
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Scopus rating (2010): SJR 0.208 SNIP 0.225
Web of Science (2010): Indexed yes
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http://www.speckle10.ufsc.br/index.php
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Research output: Contribution to journal › Conference article – Annual report year: 2010 › Research › peer-review

Antenna-assisted enhanced transmission through subwavelength nanoholes
By structural engineering of sub-wavelength apertures, we numerically demonstrate that transmission through apertures can be significantly enhanced. Based on equivalent circuit theory analysis, structured apertures are obtained with a 1900-fold transmission enhancement factor. We show that the enhancement is due to the excitation of the strong localized resonant modes of the structured apertures.

General information
Publication status: Published
Organisations: Structured Electromagnetic Materials, Department of Photonics Engineering
Contributors: Xiao, S., Peng, L., Mortensen, A.
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Web of Science (2010): Indexed yes
Original language: English
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Source-ID: 267739
Research output: Contribution to journal › Conference article – Annual report year: 2010 › Research › peer-review
Autofluorescence of pigmented skin lesions using a pulsed UV laser with synchronized detection: clinical results

We report preliminary clinical results of autofluorescence imaging of malignant and benign skin lesions, using pulsed 355 nm laser excitation with synchronized detection. The novel synchronized detection system allows high signal-to-noise ratio to be achieved in the resulting autofluorescence signal, which may in turn produce high contrast images that improve diagnosis, even in the presence of ambient room light. The synchronized set-up utilizes a compact, diode pumped, pulsed UV laser at 355 nm which is coupled to a CCD camera and a liquid crystal tunable filter. The excitation and image capture is sampled at 5 kHz and the resulting autofluorescence is captured with the liquid crystal filter cycling through seven wavelengths between 420 nm and 580 nm. The clinical study targets pigmented skin lesions and evaluates the prospects of using autofluorescence as a possible means in differentiating malignant and benign skin tumors. Up to now, sixteen patients have participated in the clinical study. The autofluorescence images, averaged over the exposure time of one second, will be presented along with histopathological results. Initial survey of the images show good contrast and diagnostic results show promising agreement based on the histopathological results.

General information
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Organisations: Department of Photonics Engineering, Diode Lasers and LED Systems, Optical Sensor Technology, Terahertz Technologies and Biophotonics, Lund University
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Original language: English
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Cavity mode control in side-coupled periodic waveguides: theory and experiment

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Metamaterials
Contributors: Ha, S., Sukhorukov, A. A., Lavrinenko, A., Kivshar, Y. S.
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Research output: Contribution to journal › Conference article – Annual report year: 2010 › Research › peer-review
Counter-propagating patterns in the BioPhotonics Workstation: getting more out of light for trapping and manipulation
The counter-propagating geometry opens an extra degree of freedom for shaping light while subsuming single-sided illumination as a special case (i.e., one beam set turned off). In its conventional operation, our BioPhotonics Workstation (BWS) uses symmetric, co-axial counter-propagating beams for stable three-dimensional manipulation of multiple particles. In this work, we analyze counter-propagating shaped-beam traps that depart from this conventional geometry. We show that projecting shaped beams with separation distances previously considered axially unstable can, in fact, enhance the trap by improving axial and transverse trapping stiffness. We also show interesting results of trapping and micromanipulation experiments that combine optical forces with fluidic forces. These results hint about the rich potential of using patterned counter-propagating beams for optical trapping and manipulation, which still remains to be fully tapped.

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Organisations: Teraherts Technologies and Biophotonics, Department of Photonics Engineering
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Research output: Contribution to journal › Conference article – Annual report year: 2010 › Research › peer-review

Coupling of cavities - the way to impose control over their modes
In this work, we demonstrate that the compound mode properties of coupled photonic-crystal cavities can depend critically on the interplay of distance between cavities and their longitudinal shifts. Thus the robust control over the cavity modes can be imposed. The simple coupled-mode theory employed for such systems predicts a peculiar behavior of band dispersion in the slow light regime at the photonic band-edge. In particular, it reveals an interesting effect that the frequency detuning of the fundamental supermodes in the coupled cavities can be reduced down to zero. We anticipate that this property will be generic for side-coupled cavity systems irrespectively of the individual cavity design, e.g. point-defect cavities in a photonic crystal or linear cavities in one-dimensional arrays of elements (rods or holes). We report here about the finite-difference frequency-domain method (FDFD) developed by us to analyze nanocavities with a very high Q-factor. The method is utilized to confirm by simulations the coupled-mode theory predictions. As an example we choose coupled cavities in one-dimensional periodic arrays of holes in dielectric nanowires known also as nanobeams.

General information
Publication status: Published
Organisations: Metamaterials, Department of Photonics Engineering, Centre for Ultrahigh-bandwidth Devices for Optical Systems, Max Planck Institute
Contributors: Ivinskaya, A., Lavrinenko, A., Sukhorukov, A. A., Shyroki, D., Ha, S., Kivshar, Y. S.
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Web of Science (2010): Indexed yes
Original language: English
Development of a 3D CZT detector prototype for Laue Lens telescope

We report on the development of a 3D position sensitive prototype suitable as focal plane detector for Laue lens telescope. The basic sensitive unit is a drift strip detector based on a CZT crystal, (~19×8 mm² area, 2.4 mm thick), irradiated transversally to the electric field direction. The anode side is segmented in 64 strips, that divide the crystal in 8 independent sensor (pixel), each composed by one collecting strip and 7 (one in common) adjacent drift strips. The drift strips are biased by a voltage divider, whereas the anode strips are held at ground. Furthermore, the cathode is divided in 4 horizontal strips for the reconstruction of the third interaction position coordinate. The 3D prototype will be made by packing 8 linear modules, each composed by one basic sensitive unit, bonded on a ceramic layer. The linear modules readout is provided by a custom front end electronics implementing a set of three RENA-3 for a total of 128 channels. The front-end electronics and the operating logics (in particular coincidence logics for polarisation measurements) are handled by a versatile and modular multi-parametric back end electronics developed using FPGA technology.

General information
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Organisations: Astrophysics, National Space Institute, National Institute for Astrophysics, University of Coimbra, Università degli studi di Ferrara, Università di Parma
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Development of the colorimetric sensor array for detection of explosives and volatile organic compounds in air

In the framework of the research project 'Xsense' at the Technical University of Denmark (DTU) we are developing a simple colorimetric sensor array which can be useful in detection of explosives like DNT and TNT, and identification of volatile organic compounds in the presence of water vapor in air. The technology is based on an array of chemoresponsive dyes immobilized on a solid support. Upon exposure to the analyte in suspicion the dye array changes color. Each chosen dye reacts chemoselectively with analytes of interest. A change in a color signature indicates the presence of unknown explosives and volatile organic compounds (VOCs). We are working towards the selection of dyes that undergo color changes in the presence of explosives and VOCs, as well as the development of an immobilization method for the molecules. Digital imaging of the dye array before and after exposure to the analytes creates a color difference map which gives a unique fingerprint for each explosive and volatile organic compound. Such sensing technology can be used to screen for relevant explosives in a complex background as well as to distinguish mixtures of volatile organic compounds distributed in gas phase. This sensor array is inexpensive, and can potentially be produced as single use disposable.

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Dynamical performance for science-mode stationkeeping with an external occulter

An external occulter flown in precise formation with a telescope is being considered for high-contrast direct imaging of exoplanets as a viable mission scenario. In this paper, the dynamics about the Sun-Earth L2 region for an occulter-telescope constellation are considered in conjunction with fourth-body and solar radiation pressure acting as disturbing forces. An optimal observation window is defined in terms of both thrust required and the Sun-constellation geometry. By simulation, the effects of the stellar latitude and distance, the spacecraft separation, the magnitude of the disturbing forces, and
Dynamical properties of speckled speckles
We consider the dynamical properties of speckles observed through a second static diffuser arising from a linear or angularly displaced first diffuser. Analytical expressions are obtained for general situations where both the space between the displaced and the static diffuser and the space between the static diffuser and the plane of observation consist of an optical system that can be characterized by a complex-valued ABCD-matrix (e.g. simple and complex imaging systems, free space propagation in both the near-and far-field, and Fourier transform systems). The use of the complex ABCD-method means that diffraction due to inherent apertures is included. One of the diffusers is assumed to give rise to fully developed speckle, i.e. the scattered phase is assumed to be delta-correlated, whereas the second and dynamic diffuser has a finite lateral scale. The illumination of the displaced diffuser is assumed to be Gaussian but the derived expressions are not restricted to a plane incident beam. The results are applicable for speckle-based systems for determining mechanical displacements, especially for long-range systems, and for analyzing systems for measuring biological activity beyond a diffuse layer, e.g. blood flow measurements through human skin.

Efficient multi-mode to single-mode conversion in a 61 port photonic lantern
We demonstrate the fabrication of a multi-mode (MM) to 61 port single-mode (SM) splitter or "Photonic Lantern". Low port count Photonic Lanterns were first described by Leon-Saval et al. (2005). These are based on a photonic crystal fiber type design, with air-holes defining the multi-mode fiber (MMF) cladding. Our fabricated Photonic Lanterns are solid all-glass versions, with the MMF defined by a low-index tube surrounding the single-mode fibers (SMFs). We show experimentally that these devices can be used to achieve efficient and reversible coupling between a MMF and 61 SMFs, when perfectly matched launch conditions into the MMF are ensured. The total coupling loss from a 100 µm core diameter MM section to the ensemble of 61 SMFs and back to another 100 µm core MM section is measured to be as low as 0.76 dB. This demonstrates the feasibility of using the Photonic Lanterns within the field of astrophotonics for coupling MM star-light to an ensemble of SM fibers in order to perform fiber Bragg grating based spectral filtering.
Electrically tunable liquid crystal photonic bandgap fiber laser

We demonstrate electrical tunability of a fiber laser by using a liquid crystal photonic bandgap fiber. Tuning of the laser is achieved by combining the wavelength filtering effect of a liquid crystal photonic bandgap fiber device with an ytterbium-doped photonic crystal fiber. We fabricate an all-spliced laser cavity based on a liquid crystal photonic bandgap fiber mounted on a silicon assembly, a pump/signal combiner with single-mode signal feed-through and an ytterbium-doped photonic crystal fiber. The laser cavity produces a single-mode output and is tuned in the range 1040-1065nm by applying an electric field to the silicon assembly.
Eyjafjallajökull volcano ash plume detection in the frame of the new constituting lidar network Leonet

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FDML swept source at 1060 nm using a tapered amplifier
We present a novel frequency-swept light source working at 1060nm that utilizes a tapered amplifier as gain medium. These devices feature significantly higher saturation power than conventional semiconductor optical amplifiers and can thus improve the limited output power of swept sources in this wavelength range. We demonstrate that a tapered amplifier can be integrated into a fiber-based swept source and allows for high-speed FDML operation. The developed light source operates at a sweep rate of 116kHz with an effective average output power in excess of 30mW. With a total sweep range of 70 nm an axial resolution of 15 µm in air (~11µm in tissue) for OCT applications can be achieved.

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Contributors: Marschall, S., Klein, T., Wieser, W., Biedermann, B., Hsu, K., Sumpf, B., Hasler, K., Erbert, G., Jensen, O. B., Pedersen, C., Huber, R., Andersen, P. E.
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Bibliographical note
Fiber-optical microphones and accelerometers based on polymer optical fiber Bragg gratings: [invited]

Polymer optical fibers (POFs) are ideal for applications as the sensing element in fiber-optical microphones and accelerometers based on fiber Bragg gratings (FBGs) due to their reduced Young's Modulus of 3.2GPa, compared to 72GPa of Silica. To maximize the sensitivity and the dynamic range of the device the outer diameter and the length of the sensing fiber segment should be as small as possible. To this end we have fabricated 3mm FBGs in single-mode step-index POFs of diameter 115 micron, using 325nm UV writing and a phase-mask technique. 6mm POF sections with FBGs in the center have been glued to standard Silica SMF28 fibers. These POF FBGs have been characterized in terms of temperature and strain to find operating regimes with no hysteresis. Commercial fast wavelength interrogators (KHz) are shown to be able to track the thin POF FBGs and they are finally applied in a prototype accelerometer. The specs are compared to the specs obtained when using Silica FBGs.

Fractal THz metamaterials: design, fabrication and characterisation

The concept of metamaterials (MTMs) is acknowledged for providing new horizons for controlling electromagnetic radiations thus their use in frequency ranges otherwise difficult to manage (e.g. THz radiation) broadens our possibility to better understand our world as well as opens the path for new applications. THz radiation can be employed for various purposes, among them the study of vibrations in biological molecules, motion of electrons in semiconductors and propagation of acoustic shock waves in crystals. We propose here a new THz fractal MTM design that shows very high transmission in the desired frequency range as well as a clear differentiation between one polarisation and another. Based on theoretical predictions we fabricated and measured a fractal based THz metamaterial that shows more than 60% field transmission at around 1THz for TE polarized light while the TM waves have almost 80% field transmission peak at 0.6THz. One of the main characteristics of this design is its tunability by design: by simply changing the length of the fractal elements one can choose the operating frequency window. The modelling, fabrication and characterisation results will be presented in this paper. Due to the long wavelength of THz radiation, the resolution requirements for fabrication of metamaterials are within the optical lithography range. However, the high aspect ratio of such structures as well as the substrate thickness pose challenges in the fabrication process. The measurements were made using terahertz time domain spectroscopy (THz-TDS) that allows us to obtain both the amplitude and phase of the transmission function. The experimental results are in very good agreement with theoretical calculations based on finite-difference time-domain simulations.
Hexabundles: imaging fibre arrays for low-light astronomical applications

We demonstrate for the first time an imaging fibre bundle ("hexabundle") that is suitable for low-light applications in astronomy. The most successful survey instruments at optical-infrared wavelengths today have obtained data on up to a million celestial sources using hundreds of multimode fibres at a time fed to multiple spectrographs. But a large fraction of these sources are spatially extended on the celestial sphere such that a hexabundle would be able to provide spectroscopic information at many distinct locations across the source. Our goal is to upgrade single-fibre survey instruments with multimode hexabundles in place of the multimode fibres. We discuss two varieties of hexabundles: (i) closely packed circular cores allowing the covering fraction to approach the theoretical maximum of 91%; (ii) fused noncircular cores where the interstitial holes have been removed and the covering fraction approaches 100%. In both cases, we find that the cladding can be reduced to ~2μm over the short fuse length, well below the conventional ~10λ thickness employed more generally. We discuss the relative merits of fused/unfused hexabundles in terms of manufacture and deployment, and present our first on-sky observations.

Higher-order mode suppression in rod-type photonic crystal fibers with sectioned doping and enlarged core

Yb-doped rod-type photonic crystal fibers are double-cladding large-mode-area fibers with the outer dimension of few millimeters. The higher-order mode suppression through gain filtering has been demonstrated in these fibers, by enlarging the core radius from 30 μm to 40 μm, while keeping fixed the doped-area dimension. Sectioned core doping, obtained by adding a low refractive index ring in the fiber core, has been taken into account, in order to design fibers with an effective single-mode behaviour. Moreover, the gain competition among the guided modes in the enlarged-core rod-type PCFs has been analyzed with a spatial and spectral amplifier model, showing the positive effect of the gain filtering in improving the fundamental mode amplification, to the detriment of the higher-order mode one. Comparisons have been made with the
properties of rod-type fibers with 30 μm core radius, both with uniform and sectioned doping, in order to show the effectiveness of the down-doped ring in the enlarged core for the higher-order mode suppression.

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Contributors: Poli, F., Coscelli, E., Passaro, D., Cucinotta, A., Selleri, S., Lægsgaard, J., Broeng, J.
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**High-index-contrast subwavelength grating VCSEL**
In this article, we report our results on 980nm high-index-contrast subwavelength grating (HCG) VCSELs for optical interconnection applications. In our structure, a thin undoped HCG layer replaces a thick p-type Bragg mirror. The HCG mirror can feasibly achieve polarization-selective reflectivities close to 100%. The investigated structure consists of a HCG mirror with an underneath /4-thick oxide gap, four p-type GaAlAs/GaAs pairs for current spreading, three InGaAs/GaAs quantum wells, and an n-type GaAlAs/GaAs Bragg mirror. The HCG structure was defined by e-beam lithography and dry etching. The current oxide aperture and the oxide gap underneath the HCG were simultaneously formed by the selective wet oxidation process. Compared to air-gap high contrast grating mirrors demonstrated elsewhere, our grating mirrors are particular since they are supported by thinner /4 aluminium oxide layer, and thus are mechanically robust and thinner than usual designs. Sub-milliamp threshold currents and single-transverse-mode operation was obtained. A hero device exhibited maximum singlemode output power of more than 4 mW at room temperature and 1 mw at 70°C, which are the highest values ever reported from the HCG structures. These results build a bridge between a standard VCSEL and a hybrid laser on silicon, making them of potential use for the realization of silicon photonics.

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Contributors: Gilet, P., Olivier, N., Grosse, P., Gilbert, K., Chelnokov, A., Chung, I., Mørk, J.
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High-power FDML laser for swept source-OCT at 1060 nm

We present a novel frequency-swept light source working at 1060nm that utilizes a tapered amplifier as gain medium. These devices feature significantly higher saturation power than conventional semiconductor optical amplifiers and can thus improve the limited output power of swept sources in this wavelength range. We demonstrate that a tapered amplifier can be integrated into a fiber-based swept source and allows for high-speed FDML operation. The developed light source operates at a sweep rate of 116kHz with an effective average output power in excess of 30mW. With a total sweep range of 70 nm an axial resolution of 15 μm in air (~11μm in tissue) for OCT applications can be achieved.

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Contributors: Marschall, S., Klein, T., Wieser, W., Biedermann, B., Hsu, K., Sumpf, B., Hasler, K., Erbert, G., Jensen, O. B., Pedersen, C., Huber, R., Andersen, P. E.
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Linear and kernel methods for multi- and hypervariate change detection

The iteratively re-weighted multivariate alteration detection (IR-MAD) algorithm may be used both for unsupervised change detection in multi- and hyperspectral remote sensing imagery as well as for automatic radiometric normalization of multi- or hypervariate multitemporal image sequences. Principal component analysis (PCA) as well as maximum autocorrelation factor (MAF) and minimum noise fraction (MNF) analyses of IR-MAD images, both linear and kernel-based (which are nonlinear), may further enhance change signals relative to no-change background. The kernel versions are based on a dual formulation, also termed Q-mode analysis, in which the data enter into the analysis via inner products in the Gram matrix only. In the kernel version the inner products of the original data are replaced by inner products between nonlinear mappings into higher dimensional feature space. Via kernel substitution, also known as the kernel trick, these inner products between the mappings are in turn replaced by a kernel function and all quantities needed in the analysis are expressed in terms of the kernel function. This means that we need not know the nonlinear mappings explicitly. Kernel principal component analysis (PCA), kernel MAF and kernel MNF analyses handle nonlinearities by implicitly transforming data into high (even infinite) dimensional feature space via the kernel function and then performing a linear analysis in that space. In image analysis the Gram matrix is often prohibitively large (its size is the number of pixels in the image squared). In this case we may sub-sample the image and carry out the kernel eigenvalue analysis on a set of training data samples only. To obtain a transformed version of the entire image we then project all pixels, which we call the test data, mapped nonlinearly onto the primal eigenvectors. IDL (Interactive Data Language) implementations of IR-MAD, automatic radiometric normalization and kernel PCA/MAF/MNF transformations have been written which function as transparent and fully integrated extensions of the ENVI remote sensing image analysis environment. Also, Matlab code exists which allows for fast data exploration and experimentation with smaller datasets. Computationally demanding kernelization of test data with training data and kernel image projections have been programmed to run on massively parallel CUDA-enabled graphics processors, when available, giving a tenfold speed enhancement. The software will be available from the authors’ websites in the near future. A data example shows the application to bi-temporal RapidEye data covering the Garzweiler open pit mine in the Ruhr area in Germany.

General information
Metal-dielectric composites with tunable optical properties

General information
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Miniaturised optical sensors for industrial applications

When addressing optical sensors for use in e.g. industry, compactness, robustness and performance are essentials. Adhering to these demands, we have developed a suit of compact optical sensors for the specific purposes of measuring angular velocity and linear translations of rigid objects. The technology is based on compact and low-cost laser sources such as Vertical Cavity Surface Emitting Lasers (VCSELs). The methods characterise the object motion by speckle translation in the near field (imaging) or far field (optical Fourier transform) by optical spatial filtering velocimetry. The volume of the two optical solutions is less than 1 cm³, including the application specific integrated circuit (ASIC), which processes the data and interfaces a PC/Laptop directly via a USB driver. The sensors are designed for working distances of 2 and 12 mm for near field and far field, respectively. We will consider the requirements for the optical designs in order to optimize the two sensor concepts for their respective purpose. For the angular velocity sensor the phase curvature of the illuminating beam is important in order to avoid parasitic contributions from any linear (transverse, in-plane) translations. The linear translation sensor is based on an imaging system. Therefore, the optical solution requires some kind of a beam-combining device because the VCSEL and the photodetectors being located in separate areas on the ASIC. We will present these two optical sensor designs and measurements for evaluation of their performance.

General information
Monolithic Yb-fiber femtosecond laser with intracavity all-solid PBG fiber and ex-cavity HC-PCF

We demonstrate an all-fiber femtosecond master oscillator / power amplifier operating at the central wavelength of 1033 nm, based on Yb-doped fiber as gain medium, and two different kinds of photonic crystal fibers for dispersion control and stabilization. An all-solid (AS) polarization maintaining (PM) photonic bandgap fiber (PBG) is used in the cavity of the master oscillator for dispersion compensation and stabilization of modelocking. The final compression of an chirped-pulse-amplified laser signal is performed in a hollow PM PCF, yielding final fiber-delivered pulse energy of around 7 nJ, and pulse duration of around 297 fs. The self-stabilization mechanism of the oscillator, based on the optical nonlinearities in an AS PCF, results in excellent environmental and operational stability of our laser. Stable self-starting fundamental modelocking is maintained for at least 4 days of operation. During the 8-hour long observation of the output power, power fluctuations of less than 0.38 % are measured. Stable fundamental modelocking is maintained during temperature sweeps in the range 10 - 40 °C.
Nanoimprinted polymer chips for light induced local heating of liquids in micro- and nanochannels

A nanoimprinted polymer chip with a thin near-infrared absorber layer that enables light-induced local heating (LILH) of liquids inside micro- and nanochannels is presented. An infrared laser spot and corresponding hot-spot could be scanned across the device. Large temperature gradients yield thermophoretic forces, which are used to manipulate and stretch individual DNA molecules confined in nanochannels. The absorber layer consists of a commercially available phthalocyanine dye (Fujifilm), with a narrow absorption peak at approximately 775 nm, dissolved in SU-8 photosresist (Microchem Corp.). The 500 nm thick absorber layer is spin-coated on a transparent substrate and UV exposed. Microfluidic channels are defined by nanoimprint lithography in a 1.5 μm thick layer of low molecular weight polymethyl methacrylate (PMMA, Microchem Corp.), which is spin coated on top of the absorber layer. We have used a previously developed two-level hybrid stamp for replicating two V-shaped microchannels (width=50 μm and height = 900 nm) bridged by an array of 200 nanochannels (width and height of 250 nm). The fluidic channels are finally sealed with a lid using PMMA to PMMA thermal bonding. Light from a 785 nm laser diode was focused from the backside of the chip to a spot diameter down to 5 μm in the absorber layer, yielding a localized heating (Gaussian profile) and large temperature gradients in the liquid in the nanochannels. A laser power of 38 mW yielded a temperature of 40°C in the center of a 10 μm 1/e diameter. Fluorescence microscopy was performed from the frontside.

Nanoimprinted polymer photonic crystal dye lasers

Optically pumped polymer photonic crystal band-edge dye lasers are presented. The photonic crystal is a rectangular lattice providing laser feedback as well as an optical resonance for the pump light. The lasers are defined in a thin film of photodefinable Ormocore hybrid polymer, doped with the laser dye Pyromethene 597. A compact frequency doubled Nd:YAG laser (352 nm, 5 ns pulses) is used to pump the lasers from above the chip. The laser devices are 450 nm thick slab waveguides with a rectangular lattice of 100 nm deep air holes imprinted into the surface. The 2-dimensional rectangular lattice is described by two orthogonal unit vectors of length a and b, defining the P and X directions. The frequency of the laser can be tuned via the lattice constant a (187 nm - 215 nm) while pump light is resonantly coupled into the laser from an angle () depending on the lattice constant b (355 nm). The lasers are fabricated in parallel on a 10 cm diameter wafer by combined nanoimprint and photolithography (CNP). CNP relies on a UV transparent quartz nanoimprint stamp with an integrated metal shadow mask. In the CNP process the photonic crystal is formed by mechanical deformation (imprinting) while the larger features are defined by UV exposure through the combined mask/mold.
Optical twisters: beams having twists in both phase and amplitude [invited]

We describe a diffracting beam with orbital angular momentum (OAM) but with a helical profile in both phase and amplitude components of the beam. This is different from Laguerre-Gaussian (LG) beams where only the phase component has a helical profile. Such profile in LG beams introduces a phase singularity at the centre and produces a dark region surrounded by a ring-shaped light pattern. For LG-beams, the ring radius is proportional to the degree of helicity or topological charge of the beam. The beam we describe here is initially characterized with an apodized helical phase front at the outskirts and linearly scaled towards no phase singularity at the centre of the beam. At the focal volume, we show that our beam forms an intensity distribution that can be accurately described as an "optical twister" as it propagates in the forward direction. Unlike LG beams, an optical twister can have minimal changes in radius but with a scalable OAM. Furthermore, we characterize the OAM in terms of its capacity to introduce spiral motion on particles trapped along its orbit. We also show that our "optical twister" maintains a high concentration of photons at the focus even as the topological charge is increased. Such beams can be applied to fundamental studies of light and atoms such as in quantum entanglement of the OAM, toroidal traps for cold atoms and for optical manipulation of microscopic particles.

Performance of multilayer coated silicon pore optics

The requirements for the IXO (International X-ray Observatory) telescope are very challenging in respect of angular resolution and effective area. Within a clear aperture with $1.7 \, m > R > 0.25 \, m$ that is dictated by the spacecraft envelope, the optics technology must be developed to satisfy simultaneously requirements for effective area of $2.5 \, m^2$ at $1.25 \, keV$, $0.65 \, m^2$ at $6 \, keV$ and $150 \, cm^2$ at $30 \, keV$. The reflectivity of the bare mirror substrate materials does not allow these requirements to be met. As such the IXO baseline design contains a coating layout that varies as a function of mirror radius and in accordance with the variation in grazing incidence angle. The higher energy photon response is enhanced through the use of depth-graded multilayer coatings on the inner radii mirror modules. In this paper we report on the first reflectivity measurements of wedged ribbed silicon pore optics mirror plates coated with a depth graded W/Si multilayer. The measurements demonstrate that the deposition and performance of the multilayer coatings is compatible with the SPO production process.
Photonic integrated single-sideband modulator / frequency shifter based on surface acoustic waves

Optical frequency shifters are essential components of many systems. In this paper, a compact integrated optical frequency shifter is designed making use of the combination of surface acoustic waves and Mach-Zehnder interferometers. It has a very simple operation setup and can be fabricated in standard semiconductor materials. The performance of the device is analyzed in detail, and by using multi-branch interferometers, the sensitivity of the device to fabrication tolerances can be drastically reduced.
Plasmonic nanostructures: local versus nonlocal response

We study the importance of taking the nonlocal optical response of metals into account for accurate determination of optical properties of nanoplasmonic structures. Here we focus on the computational physics aspects of this problem, and in particular we report on the nonlocal-response package that we wrote for state-of-the-art numerical software, enabling us to take into account the nonlocal material response of metals for any arbitrarily shaped nanoplasmonic structures, without much numerical overhead as compared to the standard local response. Our method is a frequency-domain method, and hence it is sensitive to possible narrow resonances that may arise due to strong electronic quantum confinement in the metal. This feature allows us to accurately determine which geometries are strongly affected by nonlocal response, for example regarding applications based on electric field enhancement properties for which metal nanostructures are widely used.

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Polarization speckles and generalized Stokes vector wave: a review [invited]

We review some of the statistical properties of polarization-related speckle phenomena, with an introduction of a less known concept of polarization speckles and their spatial degree of polarization. As a useful means to characterize twopoint vector field correlations, we review the generalized Stokes parameters proposed by Korotkova and Wolf, and introduce its time-domain representation to describe the space-time evolution of the correlation between random electric vector fields at two different space-time points. This time-domain generalized Stokes vector, with components similar to those of the beam coherence polarization matrix proposed by Gori, is shown to obey the wave equation in exact analogy to a coherence function of scalar fields. Because of this wave nature, the time-domain generalized Stokes vector is referred to as generalized Stokes vector wave in this paper.

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Polymer-coated vertical-cavity surface-emitting laser diode vapor sensor

We report a new method for monitoring vapor concentration of volatile organic compounds using a vertical-cavity surface-emitting laser (VCSEL). The VCSEL is coated with a polymer thin film on the top distributed Bragg reflector (DBR). The analyte absorption is transduced to the electrical domain through modulation of the VCSEL output power as the polymer swell. We have investigated the responsivity of this technique experimentally using a plasma polymerized polystyrene coating and explain the results theoretically as a reflectance modulation of the top DBR.

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Research output: Contribution to journal » Conference article – Annual report year: 2010 » Research

Power-scalable long-wavelength Yb-doped photonic bandgap fiber sources

Ytterbium-doped photonic-bandgap fiber sources operationg at the long-wavelength edge of the ytterbium gain band are being investigated for high power amplification. Artificial shaping of the gain spectrum by the characteristic distributed filtering effect of the photonic bandgap enables spontaneous-emission-free power svaling. As high as 167 W power and 16 dB saturated gain at 1178 nm have been demonstrated
Real-time reconfigurable counter-propagating beam-traps

We present a versatile technique that enhances the axial stability and range in counter-propagating (CP) beam-geometry optical traps. It is based on computer vision to track objects in unison with software implementation of feedback to stabilize particles. In this paper, we experimentally demonstrate the application of this technique by real-time rapid repositioning coupled with a strongly enhanced axial trapping for a plurality of particles of varying sizes. Also exhibited is an interesting feature of this approach in its ability to automatically adapt and trap objects of varying dimensions which simulates biosamples. By working on differences rather than absolute values, this feedback based technique makes CP-trapping nullify many of the commonly encountered pertubations such as fluctuations in the laser power, vibrations due to mechanical instabilities and other distortions emphasizing its experimental versatility.

Recent advances in slow and fast light for applications in microwave photonics: [invited]

We discuss the recent advances in slow and fast light for applications in microwave photonics. We focus on the experimental results and theoretical predictions for slow and fast light in photonic crystal fibers and photonic bandgap fibers. We also discuss the applications of slow and fast light in microwave photonics, such as microwave signal processing and communication systems.
Rigorous analysis of non-magnetic cloaks
Nonmagnetic cloak offers a feasible way to achieve invisibility at optical frequencies using materials with only electric responses. In this letter, we suggest an approximation of the ideal nonmagnetic cloak and quantitatively study its electromagnetic characteristics using a full-wave scattering theory. It is demonstrated that the forward scattering of the impedance matched cloak increases dramatically as the thickness of the cloak decreases. Nevertheless, it is still possible to effectively reduce the total scattering cross section with a very thin cloak whose impedance is not matched to the surrounding material at the outer boundary. Our analysis also provides the flexibility of reducing the scattering in an arbitrary direction.

General information
Publication status: Published
Organisations: Structured Electromagnetic Materials, Department of Photonics Engineering, Imperial College London
Contributors: Zhang, J., Luo, Y., Mortensen, A.
Pages: 775428
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Spontaneous emission of quantum dots in disordered photonic crystal waveguides
We report on the enhancement of the spontaneous emission rate of single semiconductor quantum dots embedded in a photonic crystal waveguide with engineered disorder. Random high-Q cavities, that are signature of Anderson localization, are measured in photoluminescence experiments and appear in the slow light regime of the waveguide mode. Time resolved experiments show a 15-fold enhancement of the spontaneous emission rate, with coupling efficiencies of single photons into Anderson localized cavity modes of 94%. These results show that the performances of Anderson-localized cavities are comparable to state-of-the-art nano-cavities, proving the potentiality of disorder in light confinement.

General information
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Organisations: Quantum Photonics, Department of Photonics Engineering
Contributors: Sapienza, L., Nielsen, H. T., Stobbe, S., Garcia-Fernández, D., Smolka, S., Lodahl, P.
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Statistics of polarization speckle: theory versus experiment

In this paper, we reviewed our recent work on the statistical properties of polarization speckle, described by stochastic Stokes parameters fluctuating in space. Based on the Gaussian assumption for the random electric field components and polar-interferometer, we investigated theoretically and experimentally the statistics of Stokes parameters of polarization speckle, including probability density function of Stokes parameters with the spatial degree of polarization, autocorrelation of Stokes vector and statistics of spatial derivatives for Stokes parameters.

General information
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Organisations: Optical Sensor Technology, Department of Photonics Engineering, Heriot-Watt University, University of Electro-Communications, Yuriy Fedkovych Chernivtsi National University
Contributors: Wang, W., Hanson, S. G., Takeda, M., Angelsky, O. V. (ed.)
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Stimulated Raman scattering in microstructured polymer optical fibers

General information
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Organisations: Fiber Sensors & Supercontinuum, Department of Photonics Engineering, Fiber Optics, Devices and Non-linear Effects
Contributors: Nielsen, K., Brunetti, A. C., Pakarzadeh, H., Rottwitt, K.
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Structured light 3D tracking system for measuring motions in PET brain imaging

Patient motion during scanning deteriorates image quality, especially for high resolution PET scanners. A new proposal for a 3D head tracking system for motion correction in high resolution PET brain imaging is set up and demonstrated. A prototype tracking system based on structured light with a DLP projector and a CCD camera is set up on a model of the High Resolution Research Tomograph (HRRT). Methods to reconstruct 3D point clouds of simple surfaces based on phase-shifting interferometry (PSI) are demonstrated. The projector and camera are calibrated using a simple stereo vision procedure where the projector is treated as a camera. Additionally, the surface reconstructions are corrected for the non-linear projector output prior to image capture. The results are convincing and a first step toward a fully automated tracking system for measuring head motions in PET imaging.

Surface plasmon polariton excitation and extraordinary optical transmission in metallic grating structures with subwavelength slits

We explore structures composed of two gratings with subwavelength slits in silver films. We study the extraordinary transmission of electromagnetic wave in these structures and the conditions at which the transmittance is equal to zero. Dependences on various geometric parameters are analyzed. We show that the zero of transmittance i.e. the suppression of the extraordinary transmission is observed at wavelength that corresponds to the excitation of surface plasmon polariton in a gap between two gratings with subwavelength slits. We also research structures composed of arrays of slits in thick films set close to continuous thin films. We reveal that an efficiency of the transmission of the slit mode of the grating into the thin film is greater than an efficiency of the transmission of plane wave into the same film. The investigations are performed through numerical simulations with the Fourier modal method.
The Nuclear Spectroscopic Telescope Array (NuSTAR)

The Nuclear Spectroscopic Telescope Array (NuSTAR) is a NASA Small Explorer mission that will carry the first focusing hard X-ray (6 - 80 keV) telescope to orbit. NuSTAR will offer a factor 50 - 100 sensitivity improvement compared to previous collimated or coded mask imagers that have operated in this energy band. In addition, NuSTAR provides sub-arcminute imaging with good spectral resolution over a 12-arcminute eld of view. After launch, NuSTAR will carry out a two-year primary science mission that focuses on four key programs: studying the evolution of massive black holes through surveys carried out in elds with excellent multiwavelength coverage, understanding the population of compact objects and the nature of the massive black hole in the center of the Milky Way, constraining the explosion dynamics and nucleosynthesis in supernovae, and probing the nature of particle acceleration in relativistic jets in active galactic nuclei. A number of additional observations will be included in the primary mission, and a guest observer program will be proposed for an extended mission to expand the range of scientic targets. The payload consists of two co-aligned depth-graded multilayer coated grazing incidence optics focused onto a solid state CdZnTe pixel detectors. To be launched in early 2012 on a Pegasus rocket into a low-inclination Earth orbit, NuSTAR largely avoids SAA passage, and will therefore have low and stable detector backgrounds. The telescope achieves a 10.14-meter focal length through on-orbit deployment of an extendable mast. An aspect and alignment metrology system enable reconstruction of the absolute aspect and variations in the telescope alignment resulting from mast exure during ground data processing. Data will be publicly available at GSFC's High Energy Archive Research Center (HEASARC) following validation at the science operations center located at Caltech.

General information
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Organisations: Astrophysics, National Space Institute, IT-Department, California Institute of Technology, University of California at Berkeley, Columbia University, NASA Jet Propulsion Laboratory, NASA Goddard Space Flight Center, Sonoma State University, McGill University, Stanford University, ASI Science Data Center, Lawrence Livermore National Laboratory
Publication date: 2010
Peer-reviewed: Yes
Theory of second-harmonic generation in silica nanowires

The possibility of second-harmonic generation based on surface dipole and bulk multipole nonlinearities in silica nanowires is investigated numerically. Both circular and microstructured nanowires are considered. Phase matching is provided by propagating the pump field in the fundamental mode, while generating the second harmonic in one of the modes of the LP11 multiplet. This is shown to work in both circular and microstructured nanowires, although only one of the LP11 modes can be phase-matched in the microstructure. The prospect of obtaining large conversion efficiencies in silica-based nanowires is critically discussed, based on simulations of second-harmonic generation in nanowires with a fluctuating phase-matching wavelength. It is concluded that efficient wavelength conversion will either require strong improvements in the nanowire uniformity, or an increase of the second-order nonlinearity by at least an order of magnitude by use of a different base material, or highly polarizable surface coatings.

General information
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Organisations: Department of Photonics Engineering, Fiber Optics, Devices and Non-linear Effects
Contributors: Lægsgaard, J.
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Web of Science (2010): Indexed yes
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Keywords: microstructured fibers, nanowires, second-harmonic generation
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Three-dimensional positioning with optofluidic microscope

This paper reports on-chip based optical detection with three-dimensional spatial resolution by integration of an optofluidic microscope (OFM) in a microfluidic pinched flow fractionation (PFF) separation device. This setup also enables on-chip particle image velocimetry (PIV). The position in the plane perpendicular to the flow direction and the velocity along the flow direction of separated fluorescent labeled polystyrene microspheres with diameters of 1 μm, 2.1 μm, 3 μm and 4 μm is measured using the OFM readout. These results are bench marked against those obtained with a PFF device using a conventional fluorescence microscope as readout. The size separated microspheres are detected by OFM with an accuracy of ≤ 0.92 μm. The position in the height of the channel and the velocity of the separated microspheres are detected with an accuracy of 1.4 μm and 0.08 mm/s respectively. Throughout the measurements of the height and velocity distribution, the microspheres are observed to move towards the center of the channel in regard to its height.

General information
Publication status: Published
Organisations: Department of Micro- and Nanotechnology, NSE-Optofluidics Group, NanoSystemsEngineering Section
Contributors: Vig, A. L., Marie, R., Jensen, E., Kristensen, A.
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Time-lens based optical packet pulse compression and retiming

This paper presents a new optical circuit that performs both pulse compression and frame synchronization and retiming. Our design aims at directly multiplexing several 10G Ethernet data packets (frames) to a high-speed OTDM link. This scheme is optically transparent and does not require clock recovery, resulting in a potentially very efficient solution. The scheme uses a time-lens, implemented through a sinusoidally driven optical phase modulation, combined with a linear dispersion element. As time-lenses are also used for pulse compression, we design the circuit also to perform pulse compression, as well. The overall design is: (1) Pulses are converted from NRZ to RZ; (2) pulses are synchronized, retimed and further compressed at the specially designed time-lens; and (3) with adequate optical delays, frames from different input interfaces are added, with a simple optical coupler, completing the OTDM signal generation. We demonstrate the effectiveness of the design by laboratory experiments.

Time-resolved terahertz spectroscopy of conjugated polymer/CdSe nanorod composites: [invited]

This paper reports ultrafast carrier dynamics in hybrid CdSe nanorod / poly(3-hexylthiophene) (P3HT) bulk heterojunction films measured by time-resolved terahertz spectroscopy, and compare to the well studied P3HT/phenyl-C61-butyric acid methyl ester (PCBM) blend. Both films show an improved peak photoconductivity compared to P3HT alone, consistent with efficient charge transfer. The photoconductivity dynamics show fast, picosecond trapping or recombination in the hybrid blend while the all-organic film shows no such loss of mobile charge over ns time scales. The ac conductivity for all samples is well described by a Kramers-Kronig compatible Jonscher-type power law with exponent between 0.5 and 1 suggesting that interchain hopping in the polymer or between nanorods occurs at frequencies higher than 3 THz immediately after photoexcitation.
Towards meta-devices

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Metamaterials, Purdue University
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Research output: Contribution to journal › Conference article – Annual report year: 2010 › Research › peer-review

Transform domain Wyner-Ziv video coding with refinement of noise residue and side information

Distributed Video Coding (DVC) is a video coding paradigm which mainly exploits the source statistics at the decoder based on the availability of side information at the decoder. This paper considers feedback channel based Transform Domain Wyner-Ziv (TDWZ) DVC. The coding efficiency of TDWZ video coding does not match that of conventional video coding yet, mainly due to the quality of side information and inaccurate noise estimation. In this context, a novel TDWZ video decoder with noise residue refinement (NRR) and side information refinement (SIR) is proposed. The proposed refinement schemes are successively updating the estimated noise residue for noise modeling and side information frame quality during decoding. Experimental results show that the proposed decoder can improve the Rate-Distortion (RD) performance of a state-of-the-art Wyner Ziv video codec for the set of test sequences.

General information
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Organisations: Coding and Visual Communication, Department of Photonics Engineering
Contributors: Huang, X., Forchhammer, S.
Pages: 7744
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Peer-reviewed: Yes
Ultrafast conductivity dynamics in optically excited InGaN/GaN multiple quantum wells, observed by transient THz spectroscopy

We investigate ultrafast carrier dynamics in photoexcited InGaN/GaN multiple quantum wells by time-resolved terahertz spectroscopy. The initially very strong built-in piezoelectric field is screened upon photoexcitation by the polarized carriers, and is gradually restored as the carriers recombine. The conductivity related to the presence of photoexcited carriers, sensed by the THz probe pulses, shows a non-exponential, slowing-down decay with time, which is explained by the gradual restoration of the built-in field in the QWs and consequent quenching of recombination. Screening and restoration of the built-in field are confirmed by the photoluminescence measurements.

Waveguide-based optofluidics: [invited]

Optofluidic devices exploit the characteristics of liquids to achieve a dynamic adaptation of their optical properties. The use of liquids allows for functionalities of optical elements to be created, reconfigured or tuned. We present an overview of our work on fluid-control of optical elements and highlight the benefits of an optofluidic approach, focusing on optofluidic cavities created in silicon photonic crystal (PhC) waveguide platforms. These cavities can be spatially and spectrally reconfigured, thus allowing a dynamic control of their optical characteristics. PhC cavities are major building blocks in many applications, from microlasers and biomedical sensor systems to optical switches and integrated circuits. In this paper, we show that PhC microcavities can be formed by infusing a liquid into a selected section of a uniform PhC waveguide and that the optical properties of these cavities can be tuned and adapted. By taking advantage of the negative
In an effort to produce a handheld explosives sensor the Xsense project has been initiated at the Technical University of Denmark in collaboration with a number of partners. Using micro- and nano technological approaches it will be attempted to integrate four detection principles into a single device. At the end of the project, the consortium aims at having delivered a sensor platform consisting of four independent detector principles capable of detecting concentrations of TNT at sub parts-per-billion (ppb) concentrations and with a false positive rate less than 1 parts-per-thousand. The specificity, sensitivity and reliability are ensured by the use of clever data processing, surface functionalisation and nanostructured sensors and sensor surfaces.
Amplification and ASE suppression in a polarization-maintaining ytterbium-doped solid-core photonic bandgap fibre

We demonstrate suppression of amplified spontaneous emission at the conventional ytterbium gain wavelengths around 1030 nm in a cladding-pumped polarization-maintaining ytterbium-doped solid core photonic crystal fibre. The fibre works through combined index and bandgap guiding. Furthermore, we show that the peak of the amplified spontaneous emission can be shifted towards longer wavelengths by rescaling the fibre dimensions. Thereby one can obtain lasing or amplification at longer wavelengths (1100 nm - 1200 nm) as the amount of amplification in the fibre is shown to scale with the power of the amplified spontaneous emission.

An experimental investigation of Fang's Ag superlens suitable for integration

We report on experimental realization of the Fang Ag superlens structure [1] suitable for further processing and integration in bio-chips by replacing PMMA with a highly chemical resistant cyclo-olefin copolymer, mr-I T85 (Micro Resist Technology, Berlin, Germany). The superlens was able to resolve 80 nm half-pitch gratings when operating at a free space wavelength of 365 nm. Fang et al. used PMMA since it enables the presence of surface plasmons at the PMMA/Ag interface at 365 nm and because it planarizes the quartz/chrome mask. If the superlens is to be integrated into a device where further processing is needed involving various organic polar solvents, PMMA cannot be used. We propose to use mr-I T85, which is highly chemically resistant to acids and polar solvents. Our superlens stack consists of a quartz/chrome grating mask, a 40 nm layer of mr-I T85, 35 nm Ag, and finally 70 nm of the negative photoresist mr-UVL 6000 (Micro Resist). A 50 nm layer of aluminium on top of the quartz/chrome mask reflected all light that did not penetrate through the mask openings thereby reducing waveguiding in the top resist layer. The exposures took place in a UV-aligner at 365 nm corresponding to the excitation wavelength of the surface plasmons at the mr-I T85/Ag interface. Supporting COMSOL simulations illustrate the field intensity distribution inside the resist as well as the presence of surface plasmons at the mr-I T85/Ag boundary. AFM scans of the exposed structure revealed 80 nm gratings.
Coating of silicon pore optics

For the International X-ray observatory (IXO), a mirror module with an effective area of 3 m² at 1.25 keV and at least 0.65 m² at 6 keV has to be realized. To achieve this goal, coated silicon pore optics has been developed over the last years. One of the challenges is to coat the Si plates and still to realize Si-Si bonding. It has been demonstrated that ribbed silicon plates can be produced and assembled into stacks. All previously work has been done using uncoated Si plates. In this paper we describe how to coat the ribbed Si plates with an Ir coating and a top C coating through a mask so that there will be coating only between the ribs and not in the area where bonding takes place. The paper includes description of the mounting jig and how to align the mask on top of the plate. We will also present energy scans from Si plates coated through a mask.

General information

Publication status: Published
Organisations: National Space Institute
Contributors: Cooper-Jensen, C. P., Ackermann, M., Christensen, F. E., Collon, M. J., Krumrey, M.
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Control of ultrafast pulse propagation in semiconductor components: [invited]

Time shifting of optical pulses with duration in the range from 100 fs to a few ps represents one extreme of slow light, where THz bandwidth for the slow down or speed up is necessary. The physics of the time shifting of such very short pulses involves the gain saturation of the optical medium and is different from the slow-light mechanisms responsible for time shifting of pulses of narrower bandwidth. Experimental and theoretical results with semiconductor components are presented, emphasizing the physics as well as the limitations imposed by the dynamical processes.

General information

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Organisations: Department of Photonics Engineering, Quantum and Laser Photonics
Contributors: Poel, M. V. D., Hansen, P. L., Mørk, J.
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Degradation and stability of R2R manufactured polymer solar cells

Polymer solar cells have many advantages such as light weight, flexibility, environmental friendliness, low thermal budget, low cost and most notably very fast modes of production by printing techniques. Production experiments have shown that it is highly feasible with existing technology to mass produce polymer solar cells at a very low cost. We have employed state-of-the-art analytical techniques to address the challenging issues of degradation and stability of R2R manufactured devices. We have specifically studied the relative effect of oxygen and water on the operational devices in regard to degradation.

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Organisations: Solar Energy Programme, Risø National Laboratory for Sustainable Energy
Contributors: Norrman, K., Krebs, F. C.
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Evaluation of epoxy for use on NuSTAR optics

The Nuclear Spectroscopic Telescope Array (NuSTAR) is a NASA Small Explorer (SMEX) mission which employs two focusing optics. The optics are composed of stacks of thin mirror shells and spacers. Epoxy is used to bond the mirror shells to the spacers and is a crucial component in determining the structural and optical performance of the telescopes. We describe the epoxy selection for NuSTAR optics, emphasizing those epoxy characteristics essential to obtaining good optical performance.

General information
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Organisations: Astrophysics, National Space Institute
Contributors: An, H., Christensen, F. E., Doll, M., Hailey, C. J., Cooper-Jensen, C. P., Koglin, J. E., Mori, K., Tajiri, G.
Publication date: 2009
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Inhibition of yeast growth during long term exposure to laser light around 1064 nm: [Invited paper]

We have studied the effect of a 1070 nm continuous wave Ytterbium fiber laser on exponentially growing Saccharomyces cerevisiae yeast cells over a span of 4 hours. The cells were immobilized onto Concanavalin A covered microscope slides and the growth was measured using the area increase of the cells in 2D. Using a continuous dual beam plane wave with a uniform spatial intensity distribution, we found that a continuous radiant flux through a single cell as low as 0.5 mW in 1.5 hours significantly changed the growth and division rate of S. cerevisiae. With the dual beam setup used we were able to successfully manipulate single S. cerevisiae cells in 3 dimensions with a minimum flux thorough the cell of 3.5 mW. In the regime investigated from 0.7 mW to 2.6 mW we found no threshold for the photo damage, but rather a continuous response to the increased accumulated dose.

Microsystem technology based diode lasers and Raman sensors for in situ food quality control

A microsystem based Raman sensor system for the in situ control of meat was realized. As excitation laser source a compact external cavity diode laser (ECDL) emitting at 671.0 nm mounted on a micro optical bench with a total dimension of (13 x 4 x 1) mm3 is implemented. An output power of 200 mW, a stable emission at 671.0 nm, and a narrow spectral width of about 80 pm, i.e. 2 cm-1, were measured. The device is well suited for Raman measurements of liquid and solid samples. The devices parameters and the stability will be reviewed. The micro-system laser device is implemented into a specifically laboratory prototype, including an optical bench with a diameter of 25 mm and a length of 170 mm. The probe is coupled fiber-optically to a polychromator with CCD detector for rapid spectral analysis. The Raman probe is characterized and first Raman measurements of porcine musculus longissimus dorsi through the package will be presented. The usefulness of Raman spectroscopy will be discussed with a view of integrating the sensor in a handheld laser scanner for food control.

Keyword: External cavity diode laser,Raman sensor,Food quality control,Microsystem technology
NuSTAR hard x-ray optics design and performance
The Nuclear Spectroscopic Telescope Array (NuSTAR) is a NASA satellite mission scheduled for launch in 2011. Using focusing optics with multilayer coating for enhanced reflectivity of hard X-rays (6-79 keV), NuSTAR will provide a combination of clarity, sensitivity and spectral resolution surpassing the largest observatories in this band by orders of magnitude. This advance will allow NuSTAR to test theories of how heavy elements are born, discover collapsed stars and black holes on all scales and explore the most extreme physical environments. We will present an overview of the NuSTAR optics design and production process and detail the optics performance.

General information
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Optimizations of Pt/SiC and W/Si multilayers for the Nuclear Spectroscopic Telescope Array
The Nuclear Spectroscopic Telescope Array, NuSTAR, is a NASA funded Small Explorer Mission, SMEX, scheduled for launch in mid 2011. The spacecraft will fly two co-aligned conical approximation Wolter-I optics with a focal length of 10 meters. The mirrors will be deposited with Pt/SiC and W/Si multilayers to provide a broad band reflectivity from 6 keV up to 78.4 keV. To optimize the mirror coating we use a Figure of Merit procedure developed for gazing incidence optics, which averages the effective area over the energy range, and combines an energy weighting function with an angular weighting function to control the shape of the desired effective area. The NuSTAR multilayers are depth graded with a power-law, $d_i = a/(b + i)c$, and we optimize over the total number of bi-layers, $N$, $c$, and the maximum bi-layer thickness, $d_{max}$. The result is a 10 mirror group design optimized for a flat even energy response both on and off-axis.

General information
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Organisations: Astrophysics, National Space Institute
Contributors: Madsen, K. K., Harrison, F. A., Mao, P. H., Christensen, F. E., Cooper-Jensen, C. P., Brejnholt, N., Koglin, J., Pivovaroff, M. J.
Publication date: 2009
Peer-reviewed: Yes
Photo darkening of ytterbium cw fiber lasers
A model description of photo darkening of ytterbium cw fiber lasers based on long term tested fiber lasers is presented. Photo darkening of Yb/Al co-doped silica fibres is found to saturate following prolonged exposure to pump and signal radiation. The observed slope efficiency of Al co-doping is compared with modeled slope efficiency of P co-doping.

Polymer photonic crystal dye lasers as label free evanescent cell sensors
Dye doped polymer photonic crystal band edge lasers are applied for evanescent wave sensing of cells. The lasers are rectangular shaped slab waveguides of dye doped polymer on a glass substrate, where a photonic crystal is formed by 100 nm deep air-holes in the surface of the 375 nm high waveguides. The lasers are fabricated by combined nanoimprint and photolithography (CNP) in Ormocore hybrid polymer doped with the laser dye Pyrromethene 597. The lasers emit in the chip plane at a wavelength around 595 nm when pumped with 5 ns pulses from a compact frequency doubled Nd:YAG laser. We investigate the sensitivity of photonic crystal band-edge lasers to partial coverage with HeLa cells. The lasers are chemically activated with a flexible UV activated anthraquinone based linker molecule, which enables selective binding of cells and molecules. When measuring in Phosphate Buffered Saline (PBS), which has a refractive index close to that of the cells, the emission wavelength depends linearly on the cell density on the sensor surface. Our results demonstrate that nanostructured hybrid polymer lasers, which are cheap to fabricate and very simple to operate, can be selectively chemically activated with UV sensitive photolinkers for further bioanalytical applications. This opens the possibility to functionalize arrays of optofluidic laser sensors with different bio-recognition molecules for multiplexed sensing. The linear relationship between cell coverage and wavelength indicates that the slight refractive index perturbation from the partial coverage of the sensor influences the entire optical mode, rather than breaking down the photonic crystal feedback.
Airclad fiber laser technology
High-power fiber lasers and amplifiers have gained tremendous momentum in the last five years, and many of the traditional manufactures of gas and solid-state lasers are pursuing the attractive fiber-based systems, which are now displacing the old technology in many areas. High-power fiber laser systems require specially designed fibers with large cores and good power handling capabilities - requirements that are all met by the airclad fiber technology. In the present paper we go through many of the building blocks needed to build high-power systems and we show an example of a complete airclad laser system. We present the latest advancements within airclad fiber technology including a new 70 μm single-mode polarization-maintaining rod-type fiber capable of amplifying to MW power levels. Furthermore we describe the novel airclad based pump combiners and their use in a completely monolithic 350 W CW fiber laser system with an M2 of less than 1.1. Finally, we briefly touch upon the subject of photo darkening and its origin.

A three-dimensional CZT detector as a focal plane prototype for a Laue Lens telescope

A three-dimensional CZT detector as a focal plane prototype for a Laue Lens telescope
Design and clinical results from a fibre optic manometry catheter for oesophageal motility studies

We report the design and operation of an optical fibre manometry catheter for measuring variation in pressure in the oesophagus during peristalsis. Catheters of this kind are used to help diagnose oesophageal disorders by recording the muscular contractions of the oesophageal wall in patients having difficulty swallowing. Traditional oesophageal catheters consist of an array of recording sites enabling pressure measurement from multiple locations along the oesophagus. However, these catheters tend to be bulky or complex to operate whereas our optical equivalent uses a series of Fibre Bragg Grating (FBG) pressure sensors on a single fibre, significantly reducing complexity and allowing the catheter diameter to be minimised. The data from each FBG was recorded using a solid state spectrometer in which the reflected peaks each covered a number of pixels of the spectrometer. This has enabled the FBG peaks to be tracked in wavelength with sub-nanometre precision resulting in pressure sensitivities of less than 1 mmHg. Results from a clinical trial carried out on 10 healthy subjects will be presented. For the trial, each subject was simultaneously intubated with the optical catheter and a commercially available solid-state catheter. Back-to-back readings were taken from both devices during a series of controlled water swallows. Ten swallows were recorded with the catheters sensors positioned in proximal, mid, and distal regions of the oesophagus and the data analysed statistically. The fibre optic device accurately picked up the dynamic variations in pressure, and can react at least as fast as the solid state device.

General information
Publication status: Published
Organisations: Commonwealth Scientific and Industrial Research Organisation, University of New South Wales
Pages: -
Publication date: 2008
Peer-reviewed: Yes

Design and clinical results from a fibre optic manometry catheter for oesophageal motility studies

Laser-induced plasma from pure and doped water-ice at high fluence by ultraviolet and infrared radiation - art. no. 70050X

Ice made of ultrapure water or water doped with 1% polymer (polyethylene glycol, "PEG") was irradiated by laser light with fluences between 2 and 80 J/cm² in the ultraviolet (UV) regime at 355 nm and in the infrared (IR) regime at 1064
nm in vacuum. In the UV regime there is a threshold for plasma formation at 3.5 J/cm², whereas the threshold is at 8.5 J/cm² in the IR regime. The ions from the plasma plume were studied by a Langmuir probe. The ion yield was much higher for UV laser irradiation than for IR laser irradiation. The peak of the time-of-flight spectra comprises ions of velocity from 60 to 110 km/s. Generally, the ion yield was slightly larger for ice samples doped with PEG than for pure ones. The threshold behavior was much more pronounced in the IR regime than in the UV regime. These results indicate that the behavior of the plasma current can be understood in terms of ionization breakdown at the ice surface.

**General information**

Publication status: Published
Organisations: Optical Microsensors and Micromaterials, Department of Photonics Engineering, Electroceramics, Fuel Cells and Solid State Chemistry Division, Risø National Laboratory for Sustainable Energy
Contributors: Schou, J., Matei, A., Rodrigo, K. A., Dinescu, M.
Pages: X50-X50
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Peer-reviewed: Yes

**Publication information**

Journal: High-power Laser Ablation VII, Pts 1-2
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Scopus rating (2008): SJR 0.222 SNIP 0.252
Web of Science (2008): Indexed yes
Original language: English
Keywords: MAPLE, polyethylene glycol, laser-produced plasma, water ice, ionization
DOIs: 10.1117/12.785427
Source: orbit
Source-ID: 238266
Research output: Contribution to journal » Conference article – Annual report year: 2008 » Research » peer-review

**Low atomic number coating for XEUS silicon pore optics**

We describe a set of measurements on coated silicon substrates that are representative of the material to be used for the XEUS High Performance Pore Optics (HPO) technology. X-ray angular reflectance measurements at 2.8 and 8 keV, and energy scans of reflectance at a fixed angle representative of XEUS graze angles are presented. Reflectance is significantly enhanced for low energies when a low atomic number over-coating is applied. Modeling of the layer thicknesses and roughness is used to investigate the dependence on the layer thicknesses, metal and over coat material choices. We compare the low energy effective area increase that could be achieved with an optimized coating design.

**General information**

Publication status: Published
Organisations: National Space Institute
Contributors: Lumb, D., Cooper-Jensen, C. P., Krumrey, M., Cibik, L., Christensen, F. E., Collon, M., Bavdaz, M.
Publication date: 2008
Peer-reviewed: Yes

**Publication information**

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Scopus rating (2008): SJR 0.222 SNIP 0.252
Web of Science (2008): Indexed yes
Original language: English
DOIs: 10.1117/12.789664
Source: orbit
Source-ID: 233871
Research output: Contribution to journal » Journal article – Annual report year: 2008 » Research » peer-review
Photonic crystal couplers for slow light

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Metamaterials
Contributors: Sukhorukov, A., Ha, S., Dossou, K., Botten, L., Lavrinenko, A., Chigrin, D., Kivshar, Y. S.
Pages: 1-10
Publication date: 2008
Peer-reviewed: Yes

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BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.222 SNIP 0.252
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Original language: English
DOIs:
10.1117/12.772232
Source: orbit
Source-ID: 219945
Research output: Contribution to journal › Conference article – Annual report year: 2008 › Research › peer-review

Single-polarization single-transverse-mode rod-type photonic crystal fiber with mode-field-area of 2300 μm²
We report on an ytterbium-doped single-transverse-mode rod-type photonic crystal fiber that combines the advantages of low nonlinearity and intrinsic polarization stability. The mode-field-area of the fundamental mode is as large as 2300 (im². An output power of up to 163 W with a degree of polarization better than 85% has been extracted from a simple fiber laser setup without any additional polarizing element within the cavity than the fiber itself. The beam quality has been characterized by a M value of 1.2. The single-polarization window ranges from 1030 to 1080 nm, hence possesses an excellent overlap with the gain profile of ytterbium-doped silica fibers. To the best of our knowledge this fiber design has the largest modefield-diameter ever reported for polarizing or even polarization maintaining rare-earth-doped double-clad fibers.

General information
Publication status: Published
Organisations: Friedrich Schiller University Jena, Crystal Fibre A/S
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Publication date: 2008
Peer-reviewed: Yes

Publication information
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Scopus rating (2008): SJR 0.222 SNIP 0.252
Web of Science (2008): Indexed yes
Original language: English
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Source: dtu
Source-ID: n:oai:DTIC-ART:compendex/107691717::24250
Research output: Contribution to journal › Conference article – Annual report year: 2008 › Research › peer-review

Wavelength converter placement in optical networks with dynamic traffic
We evaluate the connection provisioning performance of GMPLS-controlled wavelength routed networks under dynamic traffic load and using three different wavelength converter placement heuristics. Results show that a simple uniform placement heuristic matches the performance of complex heuristics under dynamic traffic assumptions.
Analysis of the dependence of the guided mode field distribution on the silica bridges in hollow-core Bragg fibers

The guiding properties of fabricated air-silica Bragg fibers with different geometric characteristics have been numerically investigated through a modal solver based on the finite element method. The method has been used to compute the dispersion curves, the loss spectra and the field distribution of the modes sustained by the Bragg fibers under investigation. In particular, the silica bridge influence on the fundamental mode has been analyzed, by considering structures with different cross sections, that is an ideal Bragg fiber, without the silica nonosupports, a squared air-hole one and, finally, a rounded air-hole one, which better describes the real fiber transverse section. Results have shown the presence of anti-crossing points in the effective index curves associated with the transition of the guided mode to a surface mode. Moreover, it has been verified that these surface modes are responsible of the loss peaks in the fiber transmission spectra, also experimentally measured. Surface modes are mainly localized in the regions of the cladding where the bridge supports join the cladding rings, forming silica islands where the field can focuses.

Birefringent hollow core fibers

Hollow core photonic crystal fiber (HC-PCF), fabricated according to a nominally non-birefringent design, shows a degree of un-controlled birefringence or polarization mode dispersion far in excess of conventional non polarization maintaining...
fibers. This can degrade the output pulse in many applications, and places emphasis on the development of polarization maintaining (PM) HC-PCF. The polarization cross-coupling characteristics of PM HC-PCF are very different from those of conventional PM fibers. The former fibers have the advantage of suffering far less from stress-field fluctuations, but the disadvantage of a higher loss figure and the presence of interface roughness induced modecoupling which increases in strength as birefringence reduces. Close to mode anti-crossing events of one polarization mode, the PM HC-PCF is characterized by high birefringence, a high polarization dependent loss and an increased overlap between the polarization modes at the glass interfaces. The interplay between these effects leads to a wavelength for optimum polarization maintenance, \( \lambda_{\text{PM}} \), which is detuned from the wavelength of highest birefringence. By a suitable fiber design involving antiresonance of the core-surround geometry, \( \lambda_{\text{PM}} \) may coincide with a low-loss wavelength for the signal carrying polarization mode.

**EDGE: Explorer of diffuse emission and gamma-ray burst explosions**

How structures of various scales formed and evolved from the early Universe up to present time is a fundamental question of astrophysics. EDGE1 will trace the cosmic history of the baryons from the early generations of massive stars by Gamma-Ray Burst (GRB) explosions, through the period of galaxy cluster formation, down to the very low redshift Universe, when between a third and one half of the baryons are expected to reside in cosmic filaments undergoing gravitational collapse by dark matter (the so-called warm hot intragalactic medium). In addition EDGE, with its unprecedented capabilities, will provide key results in many important fields. These scientific goals are feasible with a medium class mission using existing technology combined with innovative instrumental and observational capabilities by:

(a) observing with fast reaction Gamma-Ray Bursts with a high spectral resolution (R ~ 500). This enables the study of their (star-forming) environment and the use of GRBs as back lights of large scale cosmological structures; (b) observing and surveying extended sources (galaxy clusters, WHIM) with high sensitivity using two wide field of view X-ray telescopes (one with a high angular resolution and the other with a high spectral resolution). The mission concept includes four main instruments: a Wide-field Spectrometer with excellent energy resolution (3 eV at 0.6 keV), a Wide-Field Imager with high angular resolution (HPD 15”) constant over the full 1.4 degree field of view, and a Wide Field Monitor with a FOV of 1/4 of the sky, which will trigger the fast repointing to the GRB. Extension of its energy response up to 1 MeV will be achieved with a GRB detector with no imaging capability. This mission is proposed to ESA as part of the Cosmic Vision call. We will briefly review the science drivers and describe in more detail the payload of this mission.

**General information**

Publication status: Published
Organisations: National Space Institute, Astrophysics
Fabrication of plasmonic waveguides for device applications

We report on experimental realization of different metal-insulator geometries that are used as plasmonic waveguides guiding electromagnetic radiation along metal-dielectric interfaces via excitation of surface plasmon polaritons (SPPs). Three configurations are considered: metal strips, symmetric nanowires and nanowire pairs embedded in a dielectric, and metal V-shaped grooves. Planar plasmonic waveguides based on nm-thin and pm-wide gold strips embedded in a polymer that support propagation of long-range SPPs are shown to constitute an alternative for integrated optical circuits. Using uniform and thickness-modulated gold strips different waveguide components including reflecting gratings can be realized. For applications where polarization is random or changing, metal nanowire waveguides are shown to be suitable candidates for efficient guiding of arbitrary polarized light. Plasmonic waveguides based on metal V-grooves that offer subwavelength confinement are also considered. We focus on recent advances in manufacturing of nanostructured metal strips and metal V-grooves using combined UV, electron-beam and nanoimprint lithography.

Femtosecond laser-induced cavitations in the lens of the human eye

Ultrafast femtosecond lasers are used increasingly for a wide range of medical purposes. The immediate tissue response to pulses above a certain threshold is optically or laser induced breakdown, which is often visible as gas-filled cavities that persist for some time. In the present study, we attempted to define the cavitation threshold in the human lens in vitro using multiphoton effects base d on radiation from a femtosecond 800 nm Ti:Sapphire laser. Cavitations were observed from pulse energy densities exceeding 16 mJ/cm², but only after several minutes of exposure and not as a result of a single laser pulse. This suggests that cavitations were caused by a process which differs iTom the single-pulse cavitations
observed at higher intensities. To evaluate whether the release of gas was caused by ionization and plasma formation or by thermal effects, we introduced pauses into the pulse train, which did not change the total exposure time needed to form a cavitation. This suggests that local heating did not play a significant role in producing the observed phenomenon, suggesting that photochemical reactions may be involved. These results demonstrate that there are several types of ultrafast laser effects in the lens that have a potential for therapeutic application and treatment of eye disease though further studies are needed to shed light on the nature of the formation of delayed cavitations.

**General information**
Publication status: Published
Organisations: Department of Photonics Engineering, Nanophotonics, Fibers & Nonlinear Optics, Copenhagen University Hospital
Contributors: Kessel, L., Nymand, J., Harbst, M., Poel, M. V. D., Eskildsen, L., Larsen, M.
Pages: H6321-H6321
Publication date: 2007
Peer-reviewed: Yes

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Scopus rating (2007): SJR 0.227 SNIP 0.315
Web of Science (2007): Indexed yes
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Source: orbit
Source-ID: 209549
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**Charge transport in Fe2O3 films deposited on nanowire arrays**
The short diffusion length of photo-excited charge carriers in Fe2O3 is one of the factors limiting the water splitting efficiency of iron oxide based materials. To overcome this problem we are engineering transparent arrays of nanowires to act as conducting substrates for the Fe2O3. To help understand the charge transport characteristics of the Fe2O3 component we report transient photocurrent measurements performed on an absorbing thin film of Fe2O3 deposited by filtered arc deposition on conducting glass with a semi-transparent silver Schottky top contact. Ultraviolet laser pulses were used to generate charge carriers near the surface and the resulting current transients were measured. A simulation of this charge transport has also been developed. The sign of the observed transients was independent of applied bias, consistent with a fully depleted film. The measurements also suggest that recombination may play a significant factor in determining the transient shape. Further investigation is required to confidently predict mobilities.

**General information**
Publication status: Published
Organisations: Commonwealth Scientific and Industrial Research Organisation, University of Queensland
Contributors: Barnes, P. R. F., Blake, D., Glasscock, J., Plumb, I. C., Vohralik, P. F., Bendavid, A., Martin, P. J.
Pages: 63400P
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Original language: English
DOIs:
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Source: orbit
Source-ID: 281364
Research output: Contribution to journal › Conference article – Annual report year: 2006 › Research › peer-review
Laser doppler semiconductor anemometry of vortes flow behind the vane wheel rotor of the water turbine
For hydrodynamic examinations of the turbid three-phase streams with air bubbles and with a depth more than 500 mm for
the first time it is developed 2D Laser Doppler Semiconductor Anemometer LADOS-LMZ. Anemometer signal processor
base on > and new procedure of adaptive selection of Doppler frequency. Complex testing of method and measuring tools
have been done. Outcomes of full-scale experiments on diagnostic of nonstationary flow behind the vane wheel rotor in
draught tube of the Fresnis water turbine are presented from optimum regimes of activity to forced. Water discharge which
has been calculated from water turbine universal performance model and calculated by measuring axial velocity profiles
was compared. It is shown that the maximum aggregate error of definition of the consumption does not exceed 5%.

General information
Publication status: Published
Organisations: Russian Academy of Sciences, JSC Leningradsky Metallichesky Zavod
Contributors: Meledin, V., Anikin, Y., Bakakin, G., Glavniy, V., Dvoinishnikov, S., Kulikov, D., Naumov, I., Okulov, V.,
Pavlov, V., Rakhamanov, V., Sadbakov, O., Mostovskiy, N., Ilyin, S.
Pages: 62620G
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Scopus rating (2006): SJR 0.308 SNIP 0.644
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Bibliographical note
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Source: orbit
Source-ID: 274291
Research output: Contribution to journal › Conference article – Annual report year: 2006 › Research › peer-review

Photoelectrochemical hydrogen production using nanostructured alpha-Fe2O3 electrodes
We report the methodology and fabrication of α-Fe2O3 nanostructured photoelectrodes for water splitting applications.
Thin films of α-Fe2O3 (hematite) were deposited onto nanostructured substrates (ZnO nanowires and TiO2 nanotubes)
using filtered arc deposition (FAD). It is proposed that such nanostructured electrodes can overcome the poor absorption
and high charge carrier recombination of planar α-Fe2O3 films used for water splitting. Results of the characterization and
optimization of the α-Fe2O3 films and the nanostructured substrates are presented. The filtered arc deposition technique
is shown to produce high purity α-Fe2O3 films. Results of preliminary studies of silicon doping of the hematite films are
presented. The filtered arc deposition technique is shown to be suitable for coating highly structured substrates.

General information
Publication status: Published
Organisations: Commonwealth Scientific and Industrial Research Organisation
Contributors: Glasscock, J., Barnes, P. R., Plumb, I. C., Bendavid, A., Martin, P. J.
Pages: 63400N
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Peer-reviewed: Yes

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Source-ID: 281355
Research output: Contribution to journal › Conference article – Annual report year: 2006 › Research › peer-review
T-ray spectroscopy of biomolecules: from chemical recognition toward biochip analysis - horizons and hurdles

In the recent years, there has been an increased interest in the exploitation of the far-infrared spectral region for applications based on chemical recognition. The fact that on the one hand many packaging materials are transparent for THz radiation and on the other hand the THz-spectra of many pharmaceuticals, illicit drugs, and explosives show very specific fingerprints show the potential that THz spectroscopy holds for identification of concealed substances by comparing the spectral signatures with the entries in a database. Yet, due to the lack of appropriate techniques the far-infrared region had for a long time been relatively unexplored, and therefore a detailed study of the far-infrared spectra and the character of the molecular vibrations that give rise to the characteristic spectral signatures can help to evaluate the applicability of THz spectroscopy and imaging for quality control, chemical recognition and biomedical applications.

General information
Publication status: Published
Organisations: Nanophotonics, Department of Photonics Engineering, Center for Nanoteknologi, University of Freiburg
Contributors: Fischer, B. M., Helm, H., Jepsen, P. U.
Pages: 603809-1 - 603809-13
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Original language: English
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Invited paper
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Source-ID: 185457
Research output: Contribution to journal › Journal article – Annual report year: 2006 › Research › peer-review

Numerical investigations on the performance of external-cavity mode-locked semiconductor lasers

The performance of an external-cavity mode-locked semiconductor laser is analyzed theoretically and numerically. Passive mode-locking is described using a fully-distributed time-domain model including fast effects, spectral hole burning and carrier heating. We provide optimization rules in order to improve the mode-locking performance, such as reducing the pulsewidth and time-bandwidth product as much as possible. Timing jitter is determined by means of extensive numerical simulations of the model, demonstrating that an external modulation is required in order to maintain moderate timing-jitter and phase-noise levels at low frequencies. The effect of the driving conditions is investigated in order to achieve short pulses and low timing jitter. Our results are in qualitative agreement with reported experiments and predictions obtained from the master equation for mode-locking.

General information
Publication status: Published
Organisations: Department of Photonics Engineering
Contributors: Mulet, J., Mørk, J.
Pages: 571-582
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Proceedings of SPIE, the International Society for Optical Engineering
Volume: 5452-70
ISSN (Print): 0277-786X
Ratings:
Web of Science (2004): Indexed yes
Original language: English
DOIs:
10.1117/12.544978
Source: orbit
Source-ID: 61145
Optical frequency up-conversion in multimode and single-mode fibre radio systems
Using a novel optical frequency multiplication technique, microwave signal carriers up to 20-GHz are delivered to a significantly simplified remote radio access unit fed by a multimode fibre link having modal bandwidth below 1-GHz, as well as standard single mode fibre. Measurement results show that the remotely generated carriers have very narrow linewidths below 20-Hz, and exhibit much lower phase noise (< -90 dBc/Hz) than even a commercially available high frequency electronic signal generator. Thus by using optical frequency multiplication, existing in-building silica multimode fibre infrastructure, and the emerging polymer optical fibres may be used to not only transport fixed data services such as gigabit Ethernet but also to transparently distribute in-doors (and for short links), signals of present WLANs as well as future broadband WLAN services leading to significant system-wide cost reduction. It also enables the radio signal processing to be consolidated in a single central site, which is beneficial for advanced signal processing such as needed in multiple-input multiple output (MIMO) systems.

General information
Publication status: Published
Organisations: Eindhoven University of Technology
Pages: 169-177
Publication date: 2004
Peer-reviewed: No

Fabrication and performance of Constellation-X hard x-ray telescope prototype optics using segmented glass

General information
Publication status: Published
Organisations: Astrophysics, National Space Institute
Contributors: Hailey, C., Christensen, F. E., Craig, W., Harrison, F., Koglin, J., Petre, R., Yu, H., Zhang, W.
Pages: 90
Publication date: 2003
Peer-reviewed: Yes

The long duration flight of the TopHat experiment
The TopHat instrument was designed to operate on the top of a high altitude balloon. From this location, the experiment could efficiently observe using a clean beam with extremely low contamination from the far side lobes of the instrument beam. The experiment was designed to scan a large portion of the sky directly above it and to map the anisotropy of the Cosmic Microwave Background (CMB) and thermal emission from galactic dust. The instrument used a one-meter class telescope with a five-band single pixel radiometer spanning the frequency range from 150-600 GHz. The radiometer used bolometric detectors operating at ~250mK. Here, we report on the flight of the TopHat experiment over Antarctica in January, 2001 and describe the scientific goals, the operation, and in-flight performance.

General information
Publication status: Published
Organisations: National Space Institute
B-MINE, the balloon-borne microcalorimeter nuclear line explorer

B-MINE is a concept for a balloon mission designed to probe the deepest regions of a supernova explosion by detecting 44Ti emission at 68 keV with spatial and spectral resolutions that are sufficient to determine the extent and velocity distribution of the 44Ti emitting region. The payload introduces the concept of focusing optics and microcalorimeter spectroscopy to nuclear line emission astrophysics. B-MINE has a thin, plastic foil telescope multilayered to maximize the reflectivity in a 20 keV band centered at 68 keV and a microcalorimeter array optimized for the same energy band. This combination provides a reduced background, an energy resolution of 50 eV and a 3σ sensitivity in 106 s of 3.3 × 10-7 ph cm-2 s-1 at 68 keV. During the course of a long duration balloon flight. B-MINE could carry out a detailed study of the 44Ti emission line centroid and width in CASA.

Coating of the HEFT telescope mirrors. Methods and results

Coating of the HEFT telescope mirrors. Methods and results

General information
Publication status: Published
Organisations: Astrophysics, National Space Institute
Contributors: Jensen, C., Madsen, K., Chen, H., Christensen, F. E., Ziegler, E.
Pages: 724-733
Publication date: 2002
Peer-reviewed: Yes
Development and production of hard X-ray multilayer optics for HEFT
The High Energy Focusing Telescope (HEFT) will observe a wide range of objects including young supernova remnants, active galactic nuclei, and galaxy clusters at energies between 20 and 70 keV. Large collecting areas are achieved by tightly nesting layers of grazing incidence mirrors in a conic approximation Wolter-I design. The segmented mirrors that form these layers are made of thermally formed glass substrates coated with depth-graded multilayer films for enhanced reflectivity. The mirrors are assembled using an over-constraint method that forces the overall shape of the nominally cylindrical substrates to the appropriate conic form. We will present performance data on the HEFT optics and report the current status of the assembly production.

Development of precision hard X-ray multilayer optics with sub-arcminute performance

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Publication status: Published
Organisations: Astrophysics, National Space Institute
Contributors: Koglin, J., Chen, H., Christensen, F. E., Chonko, J., Craig, W., Decker, T., Jimenez-Grate, M., Hailey, C., Harrison, F., Jensen, C., Sileo, M., Windt, D., Yu, H.
Pages: 673-683
Publication date: 2002
Peer-reviewed: Yes

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Ratings:
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Original language: English
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Source-ID: 207410
Research output: Contribution to journal › Journal article – Annual report year: 2002 › Research › peer-review
High resolution spectroscopic imaging mission (HIS)

General information
Publication status: Published
Organisations: Astrophysics, National Space Institute
Contributors: Harrison, F., Boggs, S., Chen, H., Christensen, F. E., Craig, W., Gehrels, N., Grindlay, J., Hailey, C., Thorsett, S., Tueller, J., Woosley, S.
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Journal: Proceedings of SPIE, the International Society for Optical Engineering
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Ratings:
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Original language: English
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Source-ID: 207408
Research output: Contribution to journal › Journal article – Annual report year: 2002 › Research › peer-review

Overview of segmented glass optics development for the Constellation-X hard X-ray telescope

We report recent work on segmented glass optics for the Constellation-H hard x-ray telescope. This effort seeks to both improve the figure of the free-standing glass substrates, and to refine a newly-developed mounting technology for the substrates. We discuss metrology on recently characterized glass shells both unmounted and mounted. We also present plans for several prototype optics to be constructed in the upcoming year.

General information
Publication status: Published
Organisations: Astrophysics, National Space Institute
Contributors: Hailey, C., Christensen, F. E., Craig, W., Harrison, F., Petre, R., Koglin, J., Zhang, W., Windt, D.
Pages: 519-527
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Peer-reviewed: Yes

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Original language: English
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Research output: Contribution to journal › Journal article – Annual report year: 2002 › Research › peer-review

Radiation damage effects in CZT drift strip detectors

General information
Publication status: Published
Organisations: Astrophysics, National Space Institute
Contributors: Kuvvetli, I., Budtz-Jørgensen, C., Korsbech, U. C. C., Jensen, H.
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SAO balloon-borne microcalorimeter nuclear line explorer

General information
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Organisations: Astrophysics, National Space Institute
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Peer-reviewed: Yes

Semiconductor quantum-dot lasers and amplifiers
We have produced GaAs-based quantum-dot edge-emitting lasers operating at 1.16 μm with record-low transparency current, high output power, and high internal quantum efficiencies. We have also realized GaAs-based quantum-dot lasers emitting at 1.3 μm, both high-power edge emitters and low-power surface emitting VCSELs. We investigated the ultrafast dynamics of quantum-dot semiconductor optical amplifiers. The dephasing time at room temperature of the ground-state transition in semiconductor quantum dots is around 250 fs in an unbiased amplifier, decreasing to below 50 fs when the amplifier is biased to positive net gain. We have further measured gain recovery times in quantum dot amplifiers that are significantly lower than in bulk and quantum-well semiconductor optical amplifiers. This is promising for future demonstration of quantum dot devices with high modulation bandwidth
Antenna characteristics and air-ground interface deembedding methods for stepped-frequency ground-penetrating radar measurements

The result from field-tests using a Stepped-Frequency Ground Penetrating Radar (SF-GPR) and promising antenna and air-ground deembedding methods for a SF-GPR is presented. A monostatic S-band rectangular waveguide antenna was used in the field-tests. The advantages of the SF-GPR, e.g., amplitude and phase information in the SF-GPR signal, is used to deembed the characteristics of the antenna. We propose a new air-to-ground interface deembedding technique based on Principal Component Analysis which enables enhancement of the SF-GPR signal from buried objects, e.g., antipersonal landmines. The methods are successfully evaluated on field-test data obtained from measurements on a large-scale in-door test field.

Resolution requirements for thermal detection of buried land mines

Resolution requirements for thermal detection of buried land mines

Resolution requirements for thermal detection of buried land mines

Resolution requirements for thermal detection of buried land mines

Resolution requirements for thermal detection of buried land mines
A novel DC Magnetron sputtering facility for space research and synchrotron radiation optics

A new DC magnetron sputtering facility has been build up at the Danish Space Research Institute (DSRI), specially designed to enable uniform coatings of large area curved optics, such as Wolter-I mirror optics used in space telescopes and curved optics used in synchrotron radiation facilities. The paper is a brief description of this new facility and the future applications.

Calibration and modelling of the SODART-OXS Bragg spectrometer onboard the SRG satellite

The SODART X-ray telescope includes an Objective Crystal Spectrometer (OXS) providing a high energy resolving power by Bragg reflection upon crystals. To cover a wide energy range, 3 types of natural crystals (LiF, Si, RAP) and a Co/C multilayer structure upon Si are used in the ranges 5-11 keV, 2-5 keV, 0.5-1.2 keV, and 0.16-0.42 keV. All types of crystals besides Si being an ideal crystal (with parameters which were calculated) have been calibrated individually and after gluing onto the Bragg panel. The X-ray calibration procedures and results are discussed below. A ray-tracing program using the OXS calibration data and simulating the X-ray photon reflection on the mentioned crystals and the multilayers has been developed and is described also.

SODART optical block of the SRG satellite: Design and integration

This paper describes the design and the successful integration of the optical block of the SODART telescopes to be flown on the Spectrum Roentgen Gamma satellite. The integration involves both the integration of the two high throughput x-ray telescopes as well as the objective crystal spectrometer. The integrated unit meets all mechanical, thermal and optical
A synchrotron radiation facility for X-ray astronomy
A proposal for an X-ray optics test facility based at a synchrotron radiation source is presented. The facility would incorporate a clean preparation area, and a large evacuable test area. The advantages of using a synchrotron as the source of the test radiation are discussed. These include the ability to produce a highly parallel beam of monochromatic X-rays ranging from 200 eV to around 70 keV.

Development of grazing incidence multilayer mirrors for hard X-ray focusing telescopes
We are developing depth-graded, multilayer-coated mirrors for astrophysical hard X-ray focusing telescopes. In this paper, we discuss the primary technical challenges associated with the multilayer coatings, and report on progress to date. We have sputtered constant d-spacing and depth-graded W/Si multilayers onto 0.3-0.5 mm thick DURAN glass (AF45 and D263) and 0.4 mm thick epoxy replicated aluminum foils (ERAFs), both of which are potential mirror substrates. We have characterized the interfacial roughness, uniformity, and stress of the coatings. The average interfacial roughness of each multilayer was measured from specular reflectivity scans \( \theta_i = \theta_r \) using Cu Ka X-rays. The thin film stress was calculated from the change in curvature induced by the coating on flat glass substrates. Thickness and roughness uniformity were measured by taking specular reflectivity scans of a multilayer deposited on the inside surface of a quarter cylinder section. We found that interfacial roughness \( \sigma \) in the multilayers was typically between 3.5 and 4.0 Å on DESAG glass, and between 4.5 and 5.0 Å on the ERAFs. Also, we found that coatings deposited on glass that has been thermally formed into a cylindrical shape performed as well as flat glass. The film stress, calculated from Stoney’s equation, for a 200 layer graded multilayer was approximately 200 MPa. Our uniformity measurements show that with no baffles to alter the deposition profile on a curved optic, the layer thickness differs by \( \sim 20\% \) between the center and the edge of the optic. Interfacial roughness, however, remained constant, around 3.6 Å, throughout the curved piece, even as the layer spacing
dropped off.

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Organisations: National Space Institute, Astrophysics, California Institute of Technology, Osmic, Inc., Columbia University
Contributors: Mao, P. H., Harrison, F. A., Platonov, Y. Y., Broadway, D., DeGroot, B., Christensen, F. E., Craig, W. W., Hailey, C. J.
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**Integrated microfluidic - optical detection system on a chip**

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Organisations: Department of Micro- and Nanotechnology
Contributors: Leistiko, O.
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**Investigation of Substrates and Mounting Techniques for the High Energy Focusing Telescope (HEFT)**
The High Energy Focusing Telescope (HEFT) is a balloon-borne system for obtaining arcminute imagery in the 20-100 keV energy band. The hard X-ray optics are baselined to use thin epoxy-replicated aluminum foil substrates coated with graded-d multilayers, and we show some results on X-ray performance of prototype foil substrates. We also propose an extremely promising alternative substrate -thermally-formed glass. The advantages of thermally-formed glass substrates, their fabrication and preliminary metrology on sample pieces are discussed. Ifultimately feasible, the thermally-formed glass is a better substrate due to its superior hard X-ray reflectivity and scattering properties in comparison to similarly coated epoxyreplicated aluminum foil. We also discuss some preliminary work on the HEFT mirror mounting concept and the associated angular resolution error budget.

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Microfabricated flow system for manipulation and sorting of living cells

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Organisations: Department of Micro- and Nanotechnology
Contributors: Blankenstein, G., Larsen, U. D., Branebjerg, J.
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Novel Type of Highly Photosensitive Germanium Doped Silica Glass: Co-doping with Nitrogen

General information
Publication status: Published
Organisations: Department of Micro- and Nanotechnology
Contributors: Poulsen, C., Storgaard-Larsen, T., Hübner, J., Leistiko, O.
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The Objective Crystal Spectrometer OXS on the Spectrum-X-Γ Satellite Crystal Calibrations

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Organisations: Department of Physics
Contributors: Abdali, S.
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Ultrastrong UV-written gratings in PECVD-grown germanosilicate waveguides

General information
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Organisations: Department of Micro- and Nanotechnology
Contributors: Moss, D. J., Canning, J., Faith, M., Madden, S., Kemeny, P., Poladian, L., Ladouceur, F., Love, J. D., Poulsen, C., Leistiko, O.
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X-ray Calibration of the SODART Flight Telescopes

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Contributors: Abdali, S.
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Hard and soft x-ray study of the correlation between substrate quality and multilayer performance for Co/C coating produced by electron beam evaporation using ion polishing
Polished silicon crystals, lacquered aluminum foil, and float glass substrates with respect to surface roughness. Co/C multilayers were then deposited by electron-beam evaporation with in situ monitoring x-ray signal and ion polishing (Kr+) for the metal layer. The specular as well as the transverse scan have demonstrated different qualities, influenced by the different substrates. The investigations were performed with both hard x-ray (8.05 keV) as well as soft x-ray (0.25 keV). The reflectivity varies up to factor 3 between the best and the worst of these substrates. The results of these investigations and a comparison between the coating performances are discussed.

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Organisations: National Space Institute, Astrophysics
Contributors: Abdali, S., Christensen, F. E., Spiller, E., Louis, E.
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Multilayer x-ray mirrors for the objective crystal spectrometer on the Spectrum Roentgen Gamma satellite

We carried out experiments to determine the optimum parameters for the production of multilayer x-ray mirrors for the \( \lambda = 4.4 - 7.1 \) nm range using electron beam evaporation and ion-polishing. We report on the deposition of Co/C and Ni/C coatings, of which we polished the metal layers with Kr\(^+\) and Ar\(^+\) ions of 300, 500, and 1000 eV. We examined the effect of different polishing parameters on the smoothening of the Co- and Ni-layers. The in-situ reflectivity of \( \lambda = 3.16 \) nm during deposition and the ex-situ grazing incidence reflectivity of Cu-K(\( \alpha \)) radiation (\( \lambda = 0.154 \) nm) were used to analyze the coatings. We found optimum performance of the mirrors when applying polishing for 40 s with 500 eV Kr\(^+\)-ions at an angle of 20 degrees and an ion beam current of 20 mA. Using these parameters, we produced Co/C multilayer coatings on forty flat super-polished 6 \( \times \) 6 cm\(^2\) Si (111) crystals for the Objective Crystal Spectrometer on the Russian Spectrum Rontgen Gamma satellite. The coatings on the flight crystals have a period Lambda of 3.95 plus or minus 0.02 nm and a reflectivity of more than 8% averaged over s- and p-polarization over the entire wavelength range of interest. We present a detailed analysis of the coatings on the crystals.

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Contributors: Louis, E., Spiller, E., Abdali, S., Christensen, F. E.
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X-ray study of a SODART flight telescope using the expanded beam x-ray optics beamline at the Daresbury synchrotron

The on- and off-axis imaging properties of the first of two SODART flight telescopes have been studied using the expanded beam x-ray facility at the Daresbury synchrotron. From on- axis measurements the encircled power distribution and the point spread function at three energies 6.627 keV, 8.837 keV, and 11.046 keV have been measured using a one dimensional position sensitive detector. The data have been used to calculate the half power diameter (HPD) for three different SODART focal plane detectors, the high energy proportional counter (HEPC), the low energy proportional counter (LEPC) and the 19 element solid state array detector (SIXA). We found that the HPD decreases with increasing energy due to poorer figure error of the outermost mirrors. The HPD falls in the range from 2.3 to 3 arcmin for all detectors. Residual misalignment of the individual quadrants of the telescope was found to contribute to the HPD by approximately 10%. If 33% of the geometric telescope area near the edges of the quadrants are covered a reduction of 10% of the HPD can be obtained. On- and off-axis images generated from the one dimensional intensity distribution are presented. Finally the data have been used to calculate the variation of the effective area versus the off- axis angle.

General information
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Organisations: National Space Institute, Astrophysics, IT-Department
Contributors: Christensen, F. E., Hornstrup, A., Frederiksen, P. K., Abdali, S.
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Research output: Contribution to journal › Conference article – Annual report year: 1995 › Research › peer-review
Expanded beam x-ray optics calibration facility at the Daresbury Synchrotron
A facility for the calibration of X-ray Space Instrumentation has been established for the Daresbury Synchrotron. The facility provides a continuously tunable beam with (\Delta \lambda)/\lambda < 10^{-4} in the energy range from approximately 5 keV to more than 20 keV. At selected energies in the interval from 6 keV to 12 keV, the facility features a 1D sheet of X-rays, approximately 200 mm wide, obtained from an extremely asymmetric reflection in large perfect crystals of Si. The beam is collimated to < 20 arcsec. Data from tests using large (approximately 250 mm long) beam expander crystals in the energy range from 6 - 12 keV are presented. The planned calibration of the two X-ray telescopes (XSPECT/SODART and JET-X) will be described.

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Organisations: National Space Institute, Astrophysics, IT-Department
Contributors: Christensen, F. E., Hornstrup, A., FREDERIKSEN, P., ABDALI, S., Grundsøe, P., SCHNOPPER, H., LEWIS, R., HALL, C., BOROZDIN, K.
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Multilayer supermirrors: broadband reflection coatings for the 15- to 100-keV range
Supermirrors are multilayer structures where the thickness of the layers down through the structure changes so that wide-band reflection occurs. The principles were developed in the mid-70's and have been used extensively for neutron optics. Absorption in the upper layers limits the attainable reflectivity for X-rays. For hard X-rays (>= 15 keV), the absorption, however, is low enough that it is possible to design supermirrors with 10 - 70% reflectivity in a band approximately equals 3 times the width of the total reflection regime. Supermirrors of W/Si and Ni/C have been successfully fabricated and characterized. The measured X-ray reflectivities are well accounted for by the standard dynamical theories of multilayer reflection. Hard X-ray applications that could benefit from X-ray supermirror coatings include focusing and imaging instrumentation for astrophysics, and collimating and focusing device for synchrotron radiation.

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Contributors: Joensen, K. D., Gorenstein, P., Christensen, F. E., Hoeghoej, P.
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Preliminary results of a feasibility study for a hard x-ray Kirkpatrick-Baez telescope
Multilayers as coatings for grazing incidence telescopes have the potential of effectively improving the performance of telescopes coated with high-Z elements. For broad-band high energy (+10 keV) applications the multilayers, called supermirrors, are ideal. In this presentation we present the preliminary results of a feasibility study of a multifocus Kirkpatrick-Baez telescope. We can conclude that high quality multilayers can be performed on relevant thin large flat
substrate with adequate uniformity, and that existing deposition chambers can produce the multilayers at a rate of 0.42 m² per day, so that a coating reflectors for a 1200 cm² aperture telescope would take 8.5 months. The only remaining unanswered question is whether these thin supermirror-coated reflected can be configured to a 2 - 3' tolerance.

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Contributors: Joensen, K. D., Gorenstein, P., Wood, J. L., Christensen, F. E., Hoghoj, P.
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X-ray study of a test quadrant of the SODART telescopes using the expanded beam x-ray optics facility at the Daresbury synchrotron
The imaging properties of a test model of the SODART telescopes have been studied using an expanded beam X-ray facility at the Daresbury synchrotron. The encircled power and the point spread function at three energies 6.627 keV, 8.837 keV and 11.046 keV have been measured using 1D and 2D position sensitive detectors. The data have been used to calculate the Half Power Diameter (HPD) for three different SODART focal plane detectors. The High Energy Proportional Counter (HEPC), the Low Energy Proportional Counter (LEPC) and the 19 element solid state array detector (SIXA). At 6.627 keV and 8.837 keV the HPD is 2.5 - 3.0 arcmin for all detectors whereas it is somewhat larger at 11.046 keV for HEPC and LEPC but essentially unchanged for SIXA. Finally, the data are used to point to improvements that can be introduced during the manufacture of the flight telescopes.

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XSPECT telescopes on the SRG: optical performance
The XSPECT, thin foil, multiply nested telescope on SRG has been designed to achieve a large effective area at energies between 6 and 15 keV. The design goal for the angular resolution is 2 arcmin (HPD). Results of foil figure error measurements are presented. A ray tracing analysis was performed including results of earlier scattering measurements and the foil determination. The results of the analysis are compared with test measurements with X rays and show that there is a larger spread in the PSF than the model can account for. The decrease in effective area due to scattering is estimated to be 30% when the photons that scatter more than 6 arcmin are regarded as lost. The vignetting at off-axis angles leads to an effective area at the edge of the FOV which is 15% of that of an on-axis source.

General information
Analysis of rocking curve measurements of LiF flight crystals for the objective crystal spectrometer on SPECTRUM-X-GAMMA

The Objective Crystal Spectrometer on the SPECTRUM-X-GAMMA satellite will use three types of natural crystals LiF(220), Si(111), RAP(001), and a multilayer structure providing high-resolution X-ray spectroscopy of Fe, S, O, and C line regions of bright cosmic X-ray sources. 330 - 360 LiF(220) crystals of dimensions approximately 23 × 63 mm² are required to cover one side of a large (1000 × 600 mm²) panel, which is to be mounted in front of one of two high throughput X-ray telescopes. Rocking curves of 441 LiF(220) crystals measured by using an expanded Cu - Kα2 beam were analyzed to select the best ones for the flight model. An important parameter is the non-parallelity of the crystal lattice planes with respect to the rear side of the crystals, since it is of the same order of magnitude as the rocking curve width. By lapping the rear side to diminish the non-parallelity and selection the main parameters of the rocking curve averaged over all crystals can be improved at least by a factor of 1.6 both in full width half maximum and peak reflectivity.

High energy x-ray reflectivity and scattering study from spectrum-x-gamma flight mirrors

Line radiation from Fe K-alpha(1), Cu K-alpha(1), and Ag K-alpha(1) is used to study the high energy X-ray reflectivity and scattering behavior of flight-quality X-ray mirrors having various Al substrates. When both the specular and the scattered radiation are integrated, near theoretical reflectivities are found for all mirrors. Results of scattering studies show that scattering is strongly correlated with the Al foil type. Mirrors based on new 0.4 mm Al foil are found to have a typical scattering FWHM of about 1.1 arcmin, whereas mirrors based on 0.3 mm Al foil have an FWHM of greater than 1.5 arcmin. For all mirrors and for all energies, the scattering is found to exhibit the characteristic asymmetries predicted by a first order vector scattering theory.
High-resolution x-ray scatter and reflectivity study of sputtered IR surfaces

In recent years there has been an increased interest in the possible use of Ir as the reflecting surface in X-ray telescope programs. An X-ray study of such surfaces produced by sputtering of Ir on highly polished Zerodur flats is presented here. The study was performed using Fe K(α)1 (6.404 keV) and Cu K(α)1 (8.048 keV) and includes measurement of total external reflection and scattering. The scattering measurement was made with three different instruments arrangements; one employed a 1D position sensitive detector for low resolution studies giving approximately 30 arcsec resolution (FWHM), and the other two arrangements employed channel cut crystals providing resolutions (FWHM) of 5 arcsec and 1 arcsec, respectively at Cu K(α)1. The reflectivity study revealed a very close correspondence with a theoretical model based on recently published optical constants. This important result shows that an Ir coating can be produced with nominal bulk density.

High-resolution x-ray studies of an AXAF high-energy transmission grating

A triple axis X-ray diffractometer, designed and built at the Danish Space Research Institute, was used to make a high resolution study of the performance of a 2000 angstroms period, high energy X-ray transmission grating developed at MIT for one of the grating spectrometers on the Advanced X-ray Astrophysics Facility. Data was obtained at CuK(α)1 (8.048 keV) and, using single reflection asymmetric Si(044) crystals for both the monochromator and analyzer, an angular resolution of 1.5 arcsec FWHM was achieved. The efficiency of the grating in all orders up to the 15th was measured using a 12 kW rotating anode X-ray generator. These data provided the basis for a modelling of the grating structure.
Measurement of multilayer reflectivities from 8 keV to 130 keV

This paper presents measurements of specular and non-specular reflectivities of a W/Si multilayer with period d=135.1 Å. Angular dispersive measurements were performed at 8.05 keV and 59.3 keV, while energy dispersive measurements were made in the range of 17 keV to 130 keV. At an incidence angle of 1.57 mrad the fourth order Bragg-reflection is found at an energy of 120 keV with a reflectivity in excess of 50 % and a bandwidth (FWHM) of 3 %.

Medium-sized grazing incidence high-energy X-ray telescopes employing continuously graded multilayers

The authors present a concept of continuously graded multilayer structures for medium-sized X-ray telescopes which is based on several material combinations. They show that the theoretical reflectivity characteristics of these structures make them very advantageous when applied to high energy X-ray grazing incidence telescopes. They consider the performance of continuously graded Ni/C multilayers in a multi-focus, Kirkpatrick-Baez, geometry and show a significant improvement when compared to standard coatings of gold. For a total length of 3.3 m, a total aperture of 48 cm by 48 cm and 64 foci, an effective area of 250 cm² at 60 keV and a FWHM field of view of 6' is obtained. It is shown that a modular array of conical telescopes (conical approximation to a Wolter-I geometry), with the same length and aperture provides similar effective areas. Energy-dispersive X-ray reflectivity data (15-70 keV) is presented for the first continuously graded multilayer of this kind.
Multilayered supermirror structures for hard x-ray synchrotron and astrophysics instrumentation

By varying the thickness of the layers in a multilayer down through the structure, it is possible to produce wide-band reflectors. We report measurements and modeling of the reflectivity of Ni/C, Mo/Si and W/Si supermirrors, at energies ranging from 8 to 130 keV, and discuss the performance of two possible applications: a Kirkpatrick-Baez telescope, and a multiwavelength hard X-ray focusing reflector. The supermirrors perform as expected, and model-fits over the full range have been attempted with some success. We conclude that the supermirror coatings do indeed look very promising as hard x-ray optics for synchrotron applications, while some work on highly nested structures and supermirror coatings on very thin large substrates is necessary, before the feasibility of employing large-area supermirrors for hard X-ray astronomy is determined.

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A graded d-spacing multilayer telescope for high-energy x-ray astronomy

A high energy telescope design is presented which combines grazing incidence geometry with Bragg reflection in a graded d-spacing multilayer coating to obtain significant sensitivity up to \( \sim 60 \) keV. The concept utilizes total reflection and first order Bragg reflection in a graded d-spacing multilayer structure in a way that higher energies are reflected from the deepest layers in the stack. The specific design presented in this paper is based on Ni/C and Mo/C structures with d-spacings ranging from 25A to 100 A. X-ray reflectivity data obtained with Cu K\( \alpha_1 \) (8.05 keV) are presented from the first graded d-spacing structures of this kind.

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Organisations: National Space Institute, Astrophysics, IT-Department
Contributors: Christensen, F. E., Hornstrup, A., WESTERGAARD, N., SCHNOPPER, H., WOOD, J., PARKER, K.
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Qualification study of LiF flight crystals for the objective crystal spectrometer on the SPECTRUM-X-GAMMA satellite

The Objective Crystal Spectrometer (OXS) on the SPECTRUM-X-GAMMA satellite will carry these types of natural crystals LiF(220), Ge(111) and RAP(001). They will be used to study, among others, the H- and the He-like emission from the cosmically important elements Fe, S, Ar and O. More than 300 LiF-crystals of dimension approximately 23 \( \times \) 63 mm\(^2\) are required to cover one side of a large (approximately 1000 \( \times \) 600 mm\(^2\)) panel which is to be mounted in front of one of the high throughput X-ray telescopes. A qualification study, performed at the Danish Space Research Institute (DSRI), examined a large sample of LiF(220) crystals at Cu-K\( \alpha_2 \) (8.0278 keV). Data from 124 flight crystals yields an average FWHM of rocking curves of 2.3 arcmin with a standard deviation of 0.4 arcmin. For more than 80% of the crystals, angular deviation of the (220) planes from the actual crystal surface is less than 1.5 arcmin. These data will be used to select the best crystals for the flight panel and will determine precisely the orientation of the crystals mounted on the OXS. Eight crystals were glued onto a small test panel of the OXS and for only one crystal was there measured a significant deviation...
of the crystal properties, including alignment relative to the others.

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Contributors: Christensen, F. E., Rasmussen, I., Schnopper, H. W., Wiebicke, H., Halm, I., Geppert, U., Borozdin, K.
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**X-ray scattering measurements from thin-foil x-ray mirrors**
Thin foil X-ray mirrors are to be used as the reflecting elements in the telescopes of the X-ray satellites Spectrum-X-Gamma (SRG) and ASTRO-D. High resolution X-ray scattering measurements from the Au coated and dip-lacquered Al foils are presented. These were obtained from SRG mirrors positioned in a test quadrant of the telescope structure and from ASTRO-D foils held in a simple fixture. The X-ray data is compared with laser data and other surface structure data such as STM, atomic force microscopy (AFM), TEM, and electron micrography. The data obtained at Cu K-alpha(1), (8.05 keV) from all the mirrors produced on Al foils shows a scatter which limits the obtainable half-power width to above 1.5 arcmin. Mirrors based on electroformed Ni foils, however, show local regions with a factor of 4 better performance, and they are being developed for future applications.

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**Performance of microstrip proportional counters for x-ray astronomy on spectrum-roentgen-gamma**
DSRI will provide a set of four imaging proportional counters for the Danish-Soviet X-ray telescopes XSPECT/SODART. The sensor principle is based on the novel micro-strip proportional counter (MSPC), where the strip electrodes are deposited by photolithography onto a rigid substrate. The MSPC offers many advantages: A uniform gas gain, an excellent energy resolution, the possibility to match the strip pitch to the desired positron resolution, a fast charge collection and low operating voltages. However, a stable behaviour of the MSPC requires a careful choice of both substrate and strip electrode material. The low energy detectors will be equipped with polyimide windows of 0.5 pm thickness, providing a high quantum efficiency even at 200 eV with an energy resolution comparable to that of solid state detectors. The MSPC is capable of operating at high counting rates (10 ph s\(^{-1}\)) and the electronics is designed to match this capability.

**General information**
Measurements of X-ray reflectivities of Au-coatings at several energies

We present the results of an extensive study of X-ray reflectivities of dip lacquered and Au-coated Al foils. The measurements are performed at four different energies from 0.71 keV to 8.1 keV. The foils span a range of fabrication parameters. We show that two of three examined versions of a density variation model are able to explain the data. We find a strong dependence on the microroughness of thickness of the Au coating and of the Au deposition rates. We present data suggesting important correspondence between X-ray measurements and scanning tunneling microscopy measurements. We find no dependence on curing temperatures (70°C to 130°C). Finally, we have performed an energy scan of one of the foils in the range of 6 keV to 12 keV.

A Test Facility For Astronomical X-Ray Optics

Grazing incidence x-ray optics for x-ray astronomical applications are used outside the earth's atmosphere. These devices require a large collection aperture and the imaging of an x-ray source which is essentially placed at infinity. The ideal testing system for these optical elements has to approximate that encountered under working conditions, however the testing of these optical elements is notoriously difficult with conventional x-ray generators. Synchrotron Radiation (SR) sources are sufficiently brilliant to produce a nearly perfect parallel beam over a large area whilst still retaining a flux considerably higher than that available from conventional x-ray generators. A facility designed for the testing of x-ray optics, particularly in connection with x-ray telescopes is described below. It is proposed that this facility will be accommodated at the Synchrotron Radiation Source at the Daresbury Laboratory in the U.K.
Status Of The Development Of A Thin Foil High Throughput X-Ray Telescope For The Soviet Spectrum X-Gamma Mission

The first satellite in a planned series of Soviet X- and gamma ray satellites will be equipped with two high throughput telescopes to be delivered by the Danish Space Research Institute. The thin foil technology was originally developed by P. Serlemitsos at Goddard Space Flight Center, U.S.A. Our modification of this design is optimized with respect to high energy throughput of the telescope. The mechanical design and the status of the surface preparation technologies are described. Various X-ray and optical test facilities for the measurement of surface roughness, “orange peel”, and figure errors are described. An optical parallel beam has been established and results from the first mounted mirrors are discussed. The design goal is an angular resolution of 2 arcminutes (HEW). The first results seem to indicate that this is feasible and the possibility of going down to 1.5 arcminutes exits.

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X-Ray Measurements Of Total Reflectivity And Scattering From Au-Coated Foils.

We present X-ray measurements of total reflectivity and scattering from gold coated foils. The foils are two sorts of 0.3 mm thick lacquered aluminum, 0.125 mm thick plastic (Upilex) and 0.5 mm thick dip-lacquered nickel. The analysis of the data show a high reflectivity for all but the plastic foil, and only small microroughness (~10 Å at lengthscales below ~0.1 micron), evidenced by low resolution scattering measurements.

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