Low temperature bonding of heterogeneous materials using Al2O3 as an intermediate layer

Direct wafer bonding is a key enabling technology for many current and emerging photonic devices. Most prior work on direct wafer bonding has, however, focused on the Si platform for fabrication of silicon-on-insulator (SOI) and micro-electromechanical systems (MEMS). As a result, a universal bonding solution for heterogeneous material systems has not yet been developed. This has been a roadblock in the realization of novel devices which need the integration of new semiconductor platforms such as III-V on Si, Ge on Sapphire, LiNbO3 on GaAs etc. The large thermal expansion coefficient mismatch in the hetero-material systems limits the annealing to low temperatures to avoid stressed films. This work explores the use of Al2O3 as an intermediate layer for bonding heterogeneous materials. The key to achieve a stronger bond is to maximize the hydroxyl group density of the bonding interfaces. The use of Al2O3 helps achieve that, since it has a high hydroxyl group density (around 18 OH/nm2 at RT) which is approximately 4 times that of a Si surface. This work optimizes the bonding process using Al2O3 by studying the contribution of Al2O3 deposition parameters. An optimized process is presented and applied to bond GaAs on Sapphire and InP on SiO2/Si.
Low temperature bonding of heterogeneous materials using $\text{Al}_2\text{O}_3$ as an intermediate layer

Integration of heterogeneous materials is crucial for many nanophotonic devices. The integration is often achieved by bonding using polymer adhesives or metals. A much better and cleaner option is direct wafer bonding, but the high annealing temperatures required make it a much less attractive option. Direct wafer bonding relies on a high density of hydroxyl groups on the surfaces, which may be difficult to achieve depending on the materials. Thus, it is a challenge to design a universal wafer bonding process. However, using an intermediate layer between the bonding surfaces reduces the dependence on the bonding materials, and thus, the bonding mechanism essentially remains the same. The authors present a systematic study on the use of $\text{Al}_2\text{O}_3$ as an intermediate layer for bonding of heterogeneous materials. The ability to achieve high hydroxyl group density and well-controlled films makes atomic layer deposited $\text{Al}_2\text{O}_3$ an excellent choice for the intermediate layer. The authors have optimized the bonding process to achieve a high interface energy of $1.7 \text{ J/m}^2$ for a low temperature annealing of $300 \degree\text{C}$. The authors also demonstrate wafer bonding of InP to $\text{SiO}_2$ on Si and GaAs to sapphire using the $\text{Al}_2\text{O}_3$ interlayer. Published by the AVS.
Pulse carving using nanocavity-enhanced nonlinear effects in photonic crystal Fano structures

We experimentally demonstrate the use of a photonic crystal Fano resonance for carving-out short pulses from long-duration input pulses. This is achieved by exploiting an asymmetric Fano resonance combined with carrier-induced nonlinear effects in a photonic crystal membrane structure. The use of a nanocavity concentrates the input field to a very small volume leading to an efficient nonlinear resonance shift that carves a short pulse out of the input pulse. Here, we demonstrate shortening of ~500 ps and ~100 ps long pulses to ~30 ps and ~20 ps pulses, respectively. Furthermore, we demonstrate error-free low duty cycle return-to-zero signal generation at 2 Gbit/s with energy consumption down to ~1 pJ/bit and power penalty of ~2 dB. The device physics and limitations are analyzed using nonlinear coupled-mode theory.

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Scopus rating (2012): SJR 2.577 SNIP 1.92 CiteScore 3.52
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Web of Science (2012): Indexed yes

BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.519 SNIP 2.453 CiteScore 3.69
ISI indexed (2011): ISI indexed yes
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Web of Science (2009): Indexed yes

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Scopus rating (2008): SJR 3.354 SNIP 2.384
Web of Science (2008): Indexed yes

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Web of Science (2003): Indexed yes

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Web of Science (2002): Indexed yes

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signal reshaping and noise suppression using photonic crystal Fano structures

We experimentally demonstrate the use of photonic crystal Fano resonances for reshaping optical data signals. We show that the combination of an asymmetric Fano resonance and carrier-induced nonlinear effects in a nanocavity can be used to realize a nonlinear power transfer function, which is a key functionality for optical signal regeneration, particularly for suppression of amplitude fluctuations of data signals. The experimental results are explained using simulations based on coupled-mode theory and also compared to the case of using conventional Lorentzian-shaped resonances. Using indium phosphide photonic crystal membrane structures, we demonstrate reshaping of 2 Gbit/s and 10 Gbit/s return-to-zero on-off keying (RZ-OOK) data signals at telecom wavelengths around 1550 nm. Eye diagrams of the reshaped signals show that amplitude noise fluctuations can be significantly suppressed. The reshaped signals are quantitatively analyzed using bit-error ratio (BER) measurements, which show up to 2 dB receiver sensitivity improvement at a BER of 10⁻⁹ compared to a degraded input noisy signal. Due to efficient light-matter interaction in the high-quality factor and small mode-volume photonic crystal nanocavity, low energy consumption, down to 104 fJ/bit and 41 fJ/bit for 2 Gbit/s and 10 Gbit/s, respectively, has been achieved. Device perspectives and limitations are discussed.
The Internet today transmits hundreds of terabits per second, consumes 9% of all electricity worldwide and grows by 20-30% per year (1,2). To support capacity demand, massively parallel communication links are installed, not scaling favourably concerning energy consumption. A single frequency comb source may substitute many parallel lasers and improve system energy-efficiency (3,4). We present a frequency comb realized by a non-resonant aluminium-gallium-arsenide-on-insulator (AlGaAsOI) nanowaveguide with 66% pump-to-comb conversion efficiency, which is significantly higher than state-of-the-art resonant comb sources. This enables unprecedented high data-rate transmission for chip-based sources, demonstrated using a single-mode 30-core fibre. We show that our frequency comb can carry 661 Tbit s⁻¹ of data, equivalent to more than the total Internet traffic today. The comb is obtained by seeding the AlGaAsOI chip with 10-GHz picosecond pulses at a low pump power (85 mW), and this scheme is robust to temperature changes, is energy efficient and facilitates future integration with on-chip lasers or amplifiers (5,6).

Single-source chip-based frequency comb enabling extreme parallel data transmission
The Internet today transmits hundreds of terabits per second, consumes 9% of all electricity worldwide and grows by 20-30% per year (1,2). To support capacity demand, massively parallel communication links are installed, not scaling favourably concerning energy consumption. A single frequency comb source may substitute many parallel lasers and improve system energy-efficiency (3,4). We present a frequency comb realized by a non-resonant aluminium-gallium-arsenide-on-insulator (AlGaAsOI) nanowaveguide with 66% pump-to-comb conversion efficiency, which is significantly higher than state-of-the-art resonant comb sources. This enables unprecedented high data-rate transmission for chip-based sources, demonstrated using a single-mode 30-core fibre. We show that our frequency comb can carry 661 Tbit s⁻¹ of data, equivalent to more than the total Internet traffic today. The comb is obtained by seeding the AlGaAsOI chip with 10-GHz picosecond pulses at a low pump power (85 mW), and this scheme is robust to temperature changes, is energy efficient and facilitates future integration with on-chip lasers or amplifiers (5,6).

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Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Nanophotonic Devices, Fujikura Ltd., Technical University of Denmark
Wavelength tunable MEMS VCSELs for OCT imaging

MEMS VCSELs are one of the most promising swept source (SS) lasers for optical coherence tomography (OCT) and one of the best candidates for future integration with endoscopes, surgical probes and achieving an integrated OCT system. However, the current MEMS-based SS are processed on the III-V wafers, which are small, expensive and challenging to work with. Furthermore, the actuating part, i.e., the MEMS, is on the top of the structure which causes a strong dependence on packaging to decrease its sensitivity to the operating environment. This work addresses these design drawbacks and proposes a novel design framework. The proposed device uses a high contrast grating mirror on a Si
MEMS stage as the bottom mirror, all of which is defined in an SOI wafer. The SOI wafer is then bonded to an InP III-V wafer with the desired active layers, thereby sealing the MEMS. Finally, the top mirror, a dielectric DBR (7 pairs of TiO2 - SiO2), is deposited on top. The new device is based on a silicon substrate with MEMS defined on a silicon membrane in an enclosed cavity. Thus the device is much more robust than the existing MEMS VCSELs. This design also enables either a two-way actuation on the MEMS or a smaller optical cavity (pull-away design), i.e., wider FSR (Free Spectral Range) to increase the wavelength sweep. Fabrication of the proposed device is outlined and the results of device characterization are reported.

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, Nanophotonics Theory and Signal Processing, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Experimental Surface and Nanomaterials Physics, Department of Micro- and Nanotechnology, Silicon Microtechnology, OCTLIGHT ApS
Authors: Sahoo, H. K. (Intern), Ansbæk, T. (Ekstern), Ottaviano, L. (Intern), Semenova, E. (Intern), Hansen, O. (Intern), Yvind, K. (Intern)
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An ultra-efficient nonlinear planar integrated platform for optical signal processing and generation
This paper will discuss the recently developed integrated platform: AlGaAs-on-insulator and its broad range of nonlinear applications. Recent demonstrations of broadband optical signal processing and efficient frequency comb generations in this platform will be reviewed.

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Electronic, Optical and Magnetic Materials, Mechanics of Materials, Aluminum gallium arsenide, Gallium compounds, Nonlinear optics, Photonics, Signal processing, Frequency combs, Integrated platform, Nonlinear applications, Ultra-efficient, Optical signal processing
Characterization and optimization of a high-efficiency AlGaAs-On-Insulator-based wavelength converter for 64- and 256-QAM signals

In this paper, we demonstrate wavelength conversion of advanced modulation formats such as 10-GBd 64-QAM and 256-QAM with high conversion efficiency over a 29-nm spectral window by using four-wave mixing in an AlGaAs-On-Insulator (AlGaAsOI) nano-waveguide. A thorough characterization of the wavelength converter is reported, including the optimization of the AlGaAsOI nano-waveguide in terms of conversion efficiency and associated bandwidth and the analysis of the impact of the converter pump quality and power as well as the signal input power. The optimized converter enables generating idlers with optical signal-to-noise ratio (OSNR) above 30 dB over a 29-nm bandwidth leading to error-free conversion of 64-QAM and 256-QAM with OSNR penalty below 1.0 dB and 2.0 dB respectively. The generated idlers exhibit an OSNR margin to the chosen forward error correction thresholds of >3 dB and >7 dB for 64-QAM and 256-QAM, respectively, that can be used for transmission after conversion.
Fabrication and experimental demonstration of photonic crystal laser with buried heterostructure

Development of ultra-small and efficient laser sources for photonic integrated circuits is one of the main cornerstones in achieving the requirements imposed for on-chip optical interconnects [1]. The InP photonic crystal (PhC) platform with selectively embedded gain medium [2] is a promising way of separating active light amplification regions from passive regions for light propagation without induced absorption losses and surface recombination. The main focus of this work is the fabrication and experimental demonstration of a buried heterostructure (BH) photonic crystal laser bonded to a silicon wafer, illustrating the effective single-platform active-passive material integration method.

General information

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, Nanophotonics Theory and Signal Processing, DTU Danchip
Authors: Sakanas, A. (Intern), Yu, Y. (Intern), Semenova, E. (Intern), Ottaviano, L. (Intern), Sahoo, H. K. (Intern), Mørk, J. (Intern), Yvind, K. (Intern)
Lasers, switches and non-reciprocal elements based on photonic crystal Fano resonances

We discuss the realization of active photonic devices exploiting Fano resonances in photonic crystal membranes.

Optical Time Domain Demultiplexing using Fano Resonance in InP Photonic Crystals

We present a scheme of time-domain Fano resonances based demultiplexing in InP photonic crystals.
Parity control of Fano resonances and its application for signal regeneration and pulse carving

Parity control of Fano resonances in a photonic crystal waveguide coupled to a nanocavity is implemented by controlling the position of a partially transmitting element (PTE) in the waveguide. We experimentally demonstrate regeneration and pulse carving of optical signals by exploiting nonlinearity in the nanocavity in combination with the asymmetrical Fano shape.

Photonic crystal Fano lasers and Fano switches

We show that Fano resonances can be realized in photonic crystal membrane structures by coupling line-defect waveguides and point-defect nanocavities. The Fano resonance can be exploited to realize optical switches with very small switching energy, as well as Fano lasers, that can generate short optical pulses.

Photonic crystal Fano resonances for realizing optical switches, lasers and non-reciprocal elements

We present our work on photonic crystal membrane devices exploiting Fano resonance between a line-defect waveguide and a side coupled nanocavity. Experimental demonstration of fast and compact all-optical switches for wavelength-conversion is reported. It is shown how the use of an asymmetric structure in combination with cavity-enhanced nonlinearity can be used to realize non-reciprocal transmission at ultra-low power and with large bandwidth. A novel type of laser structure, denoted a Fano laser, is discussed in which one of the mirrors is based on a Fano resonance. Finally, the design, fabrication and characterization of grating couplers for efficient light coupling in and out of the indium phosphide photonic crystal platform is discussed.
Towards Polarization-Independent Four-Wave Mixing in Dispersion Engineered AlGaAs-on-Insulator Nano-Waveguide

We demonstrate a polarization-independent continuous wave four-wave mixing conversion bandwidth of 70 nm (1530-1600 nm) in a dispersion engineered high-index contrast AlGaAs-on-insulator nano-waveguide. We obtain constant conversion efficiency over 175 nm for the TE mode.

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, Centre of Excellence for Silicon Photonics for Optical Communications, DTU Danchip
Authors: Pu, M. (Intern), Ottaviano, L. (Intern), Semenova, E. (Intern), Yvind, K. (Intern)
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Publication date: 2017

Towards Ultra-High Q Microresonators in High-Index Contrast AlGaAs-On-Insulator

We demonstrate an AlGaAs-on-insulator microresonator with intrinsic Q as high as 690,000. We optimized the fabrication and investigated the impact of waveguide dimension on the Q in such a high-index contrast platform.

General information
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Authors: Pu, M. (Intern), Kamel, A. N. (Intern), Stassen, E. (Intern), Ottaviano, L. (Intern), Semenova, E. (Intern), Yvind, K. (Intern)
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An Ultra-Efficient Nonlinear Platform: AlGaAs-On-Insulator

The combination of nonlinear and integrated photonics enables applications including optical signal processing, multi-wavelength lasers, metrology, spectroscopy, and quantum information science. Silicon-on-insulator (SOI) has emerged as a promising platform [1, 2] due to its high material nonlinearity and its compatibility with the CMOS industry. However, silicon suffers two-photon absorption (TPA) in the telecommunication wavelength band around 1.55 µm, which hampers its applications. Different platforms have been proposed to avoid TPA in the telecom wavelength range such as Si3N4 and Hydex [3]. Though tremendous technological work in those platforms have greatly improved device performances, the relatively low intrinsic material nonlinearities of those materials limit device performances concerning efficiency. Therefore, an integrated nonlinear platform that combines a high material nonlinearity, a high-index contrast as SOI, and low linear and nonlinear losses is highly desired. Aluminium gallium arsenide (AlGaAs) was early identified as a promising candidate and even nominated as “the silicon of nonlinear optical material” [4] when operated just below half its bandgap energy. It offers a nonlinear index (n2) on the order of 10−17 W/m2 and a high refractive index (n ≈3.3), a large transparency window (from near- to mid-infrared), and the ability to engineer the material bandgap to mitigate TPA [5]. In this presentation, we introduce AlGaAs-on-insulator (AlGaAsOI) platform which combines both strong nonlinear light-matter interaction induced by high-index contrast layout and the potential to fabricate complex designs similar to what is done in silicon-on-insulator photonics. We demonstrate low loss (~1.4 dB/cm) nanowaveguides with an ultra-high nonlinear coefficient (~650W−1m−1) and microring resonators with quality factors on the order of 105 [6]. The large effective nonlinearity of such platform enables efficient nonlinear processes such as high-speed optical signal processing [7], supercontinuum generation, and Kerr frequency comb generation [8]. Moreover, the required operation power for signal generation processes such as optical parametric oscillation in the AlGaAsOI platform is well within the range of standard on-chip light sources. In line with the fast-growing hybrid integration trend to combine different materials in multiple levels on a single CMOS compatible chip, the AlGaAsOI platform is very promising for realizing a compact fully-integrated multi-wavelength light source for high bandwidth optical interconnects.

Broadband and Efficient Dual-Pump Four-Wave Mixing in AlGaAs-On-Insulator Nano-Waveguide

We characterize dual-pump four-wave-mixing in AlGaAs-on-insulator nano-waveguides and demonstrate an output conversion efficiency as high as -8.5 dB at 155-mW pump power. The idler optical signal-to-noise ratio is above 25 dB over a 26-nm bandwidth.
Broadband and efficient dual-pump four-wave-mixing in AlGaAs-on-insulator nano-waveguides

We characterize dual-pump four-wave-mixing in AlGaAs-on-insulator nano-waveguides and demonstrate an output conversion efficiency as high as −8.5 dB at 155-mW pump power. The idler optical signal-to-noise ratio is above 25 dB over a 26-nm bandwidth.

Characterization of a Wavelength Converter for 256-QAM Signals Based on an AlGaAs-On-Insulator Nano-waveguide

High efficiency and broadband wavelength conversion in a 9-mm AlGaAs-On-Insulator waveguide is shown to provide high-quality (OSNR > 30 dB) idler generation over a 28-nm bandwidth enabling error-free conversion of 10-GBd 256-QAM with OSNR penalty below 2.5 dB.
Efficient frequency comb generation in AlGaAs-on-insulator
The combination of nonlinear and integrated photonics enables Kerr frequency comb generation in stable chip-based microresonators. Such a comb system will revolutionize applications, including multi-wavelength lasers, metrology, and spectroscopy. Aluminum gallium arsenide (AlGaAs) exhibits very high material nonlinearity and low nonlinear loss. However, difficulties in device processing and low device effective nonlinearity made Kerr frequency comb generation elusive. Here, we demonstrate AlGaAs-on-insulator as a nonlinear platform at telecom wavelengths with an ultra-high device nonlinearity. We show high-quality-factor (Q > 105) micro-resonators where optical parametric oscillations are achieved with milliwatt-level pump threshold powers, which paves the way for on-chip pumped comb generation.

Low-loss high-confinement waveguides and microring resonators in AlGaAs-on-insulator
AlGaAs is a promising material for integrated nonlinear photonics due to its intrinsic high nonlinearity. However, the challenging fabrication of deep etched AlGaAs devices makes it difficult to realize high-performance devices such as low-loss dispersion engineered waveguides and high quality microring resonators. Here, we report a process to make high-quality AlGaAs-on-insulator (AlGaAsOI) wafers where high confinement waveguides can be realized. Using optimized patterning processes, we fabricated AlGaAsOI waveguides with propagation losses as low as 1 dB/cm and microring resonators with quality factors up to 350,000 at telecom wavelengths. Our demonstration opens new prospects for AlGaAs devices in integrated nonlinear photonics.
Nonlinear Optics in AlGaAs on Insulator
AlGaAs on insulator is a powerful nonlinear platform sporting a high effective nonlinearity and the possibility to fabricate complex designs. We will present low loss waveguides enabling efficient optical signal processing and Kerr comb generation.

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Optically pumped 1550nm wavelength tunable MEMS VCSEL
The paper presents the design and fabrication of an optically pumped 1550nm tunable MEMS VCSEL with an enclosed MEMS. The MEMS is defined in SOI and the active material, an InP wafer with quantum wells are bonded to the SOI and the last mirror is made from the deposition of dielectric materials. The design brings flexibility to fabricate MEMS VCSELS over a wider range of wavelengths. The paper discusses results from the simulations and bonding results from fabrication. The device will push the boundaries for wavelength sweepspeed and bandwidth.

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, Centre of Excellence for Silicon Photonics for Optical Communications, Experimental Surface and Nanomaterials Physics, Department of Micro- and Nanotechnology, Silicon Microtechnology, OCTLIGHT ApS
Authors: Sahoo, H. K. (Intern), Ansbæk, T. (Ekstern), Ottaviano, L. (Intern), Semenova, E. (Intern), Hansen, O. (Intern), Yvind, K. (Intern)
Number of pages: 10
Publication date: 2016
Phase-sensitive Four-wave Mixing in AlGaAs-on-Insulator Nano-waveguides

Phase-sensitive four-wave mixing is experimentally demonstrated in a 5-mm long AlGaAsOI nano-waveguide. More than 7 dB of phase-sensitive extinction ratio are reported without neither using active biasing nor polarization-assisted schemes. Measurements show a good match with numerical predictions.

General information
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Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Nanophotonic Devices
Authors: Da Ros, F. (Intern), Pu, M. (Intern), Ottaviano, L. (Intern), Hu, H. (Intern), Semenova, E. (Intern), Galili, M. (Intern), Yvind, K. (Intern), Oxenløwe, L. K. (Intern)
Number of pages: 2
Publication date: 2016

Single-Source AlGaAs Frequency Comb Transmitter for 661 Tbit/s Data Transmission in a 30-core Fiber

We demonstrate an AlGaAs-on-insulator nano-waveguide-based frequency comb with high OSNR enabling a single-source to fully load a 9.6-km heterogeneous 30-core fibre with 661 Tbit/s data achieved by 30xcores, 80xWDM, 40 Gbaud, and PDM-16QAM

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Publication date: 2016
**Supercontinuum Generation in AlGaAs-On-Insulator Nano-Waveguide at Telecom Wavelengths**

We characterize pulse spectral broadening in an AlGaAs-on-insulator nano-waveguide at telecom wavelengths. We obtain a supercontinuum over 500 nm (30-dB bandwidth) with 410-fs pulses and self-phase modulation broadening covering the C-band with 1.1-ps pulses.

**Surface Plasmons on Highly Doped InP**

Silicon doped InP is grown by metal-organic vapor phase epitaxy (MOVPE) using optimized growth parameters to achieve high free carrier concentration. Reflectance of the grown sample in mid-IR range is measured using FTIR and the result is used to retrieve the parameters of the dielectric function. The derived dielectric function is used to simulate the excitation of surface plasmons by a diffraction grating made of the grown material. The grating structure is fabricated using standard nanofabrication techniques. Spectral features from the grating agree well with the simulations and show spp coupling at predicted angles of incidence and wavelengths.
Threshold Characteristics of Slow-Light Photonic Crystal Lasers

The threshold properties of photonic crystal quantum dot lasers operating in the slow-light regime are investigated experimentally and theoretically. Measurements show that, in contrast to conventional lasers, the threshold gain attains a minimum value for a specific cavity length. The experimental results are explained by an analytical theory for the laser threshold that takes into account the effects of slow light and random disorder due to unavoidable fabrication imperfections. Longer lasers are found to operate deeper into the slow-light region, leading to a trade-off between slow-light induced reduction of the mirror loss and slow-light enhancement of disorder-induced losses.

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A Highly Efficient Nonlinear Platform: AlGaAs-On-Insulator

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Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2015

AlGaAs-On-Insulator Nanowire with 750 nm FWM Bandwidth, -9 dB CW Conversion Efficiency, and Ultrafast Operation
Enabling Record Tbaud Wavelength Conversion

We present an AlGaAs-on-insulator platform for integrated nonlinear photonics. We demonstrate the highest reported conversion efficiency/length/pump-power, ultra-broadband fourwave mixing, and first-ever wavelength conversion of 1.28-Tbaud serial data signals in a 3-mm long dispersion-engineered AlGaAs nano-waveguide

General information
State: Published
Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication
Authors: Pu, M. (Intern), Ottaviano, L. (Intern), Semenova, E. (Intern), Vukovic, D. (Intern), Oxenløwe, L. K. (Intern), Yvind, K. (Intern)
AlGaAs-On-Insulator Nanowire with 750 nm FWM Bandwidth, -9 dB CW Conversion Efficiency, and Ultrafast Operation
Enabling Record Tbaud Wavelength Conversion

AlGaAs-On-Insulator nonlinear photonics
We present an AlGaAs-on-insulator platform for integrated nonlinear photonics. We demonstrate the highest reported conversion efficiency and ultra-broadband four-wave mixing for an integrated platform around 1550nm

Highly Efficient Four-Wave Mixing in an AlGaAs-On-Insulator (AlGaAsOI) Nano-Waveguide
We propose an AlGaAs-on-insulator platform for nonlinear integrated photonics. We demonstrate highly efficient four-wave mixing in a 3-mm long AlGaAs-on-insulator nanowaveguide. A conversion efficiency of -21.1 dB is obtained with only a 45-mW pump

Highly Sensitive Photonic Crystal Cavity Laser Noise Measurements using Bayesian Filtering
We measure for the first time the frequency noise spectrum of a photonic crystal cavity laser with less than 20 nW of fiber-coupled output power using a coherent receiver and Bayesian filtering.
**General information**

State: Published

Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Nanophotonics Theory and Signal Processing, Nanophotonic Devices, Metro-Access and Short Range Systems, Helmut-Schmidt-University


Number of pages: 3

Publication date: 2015

**Host publication information**

Title of host publication: Proceedings of 2015 Optical Fiber Communications Conference and Exhibition

Publisher: IEEE

Article number: W2A.28

ISBN (Electronic): 978-1-55752-937-4

Main Research Area: Technical/natural sciences

Conference: Optical Fiber Communications Conference and Exposition 2015, Los Angeles, CA, United States, 22/03/2015 - 22/03/2015

DOIs: 10.1364/OFC.2015.W2A.28

Source: PublicationPreSubmission

Source-ID: 110721203

Publication: Research - peer-review › Article in proceedings – Annual report year: 2015

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**Slow-light effects in photonic crystal membrane lasers**

In this paper, we present a systematic investigation of photonic crystal cavity laser operating in the slow-light regime. The dependence of lasing threshold on the effect of slow-light will be particularly highlighted.

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**Thermal analysis of line-defect photonic crystal lasers**

We report a systematic study of thermal effects in photonic crystal membrane lasers based on line-defect cavities. Two material platforms, InGaAsP and InP, are investigated experimentally and numerically. Lasers with quantum dot layers embedded in an InP membrane exhibit lasing at room temperature under CW optical pumping, whereas InGaAsP membranes only lase under pulsed conditions. By varying the duty cycle of the pump beam, we quantify the heating induced by optical pumping in the two material platforms and compare their thermal properties. Full 3D finite element simulations show the spatial temperature profile and are in good agreement with the experimental results concerning the thermal tolerance of the two platforms.

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**General information**

State: Published

Organisations: Department of Photonics Engineering, Nanophotonics Theory and Signal Processing, Nanophotonic Devices, Department of Micro- and Nanotechnology

Authors: Xue, W. (Intern), Yu, Y. (Intern), Ottaviano, L. (Intern), Semenova, E. (Intern), Yvind, K. (Intern), Mørk, J. (Intern)

Number of pages: 3

Pages: 1-3

Publication date: 2015

**Host publication information**

Title of host publication: 2015 Opto-Electronics and Communications Conference (OECC)

Publisher: IEEE

ISBN (Print): 9781467379441

Main Research Area: Technical/natural sciences

Conference: Opto Electronics and Communications Conference 2015, Shanghai, China, 28/06/2015 - 28/06/2015

Communication, Networking and Broadcast Technologies, Fields, Waves and Electromagnetics, Photonics and Electrooptics, Cavity resonators, Epitaxial growth, Integrated optics, Optical losses, Optical pumping, Photonics, Solids

DOIs: 10.1109/OECC.2015.7340132

Source: FindIt

Source-ID: 276911118

Publication: Research - peer-review › Article in proceedings – Annual report year: 2015

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**General information**

State: Published

Organisations: Department of Photonics Engineering, Nanophotonics Theory and Signal Processing, Nanophotonic Devices

Publication information
Journal: Optics Express
Volume: 23
Issue number: 14
ISSN (Print): 1094-4087
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.74 SJR 1.519 SNIP 1.567
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.48 SJR 1.532 SNIP 1.544
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.91 SNIP 1.674 CiteScore 3.78
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.313 SNIP 2.124 CiteScore 4.18
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.337 SNIP 2.196 CiteScore 4.38
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.562 SNIP 2.108 CiteScore 3.85
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.58 SNIP 2.572 CiteScore 4.04
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.906 SNIP 2.428
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 3.039 SNIP 2.679
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 3.204 SNIP 2.423
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 3.284 SNIP 2.11
Web of Science (2007): Indexed yes
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 3.313 SNIP 2.336
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.819 SNIP 2.472
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 2.669 SNIP 2.217
Web of Science (2003): Indexed yes

We present a record-low threshold power of 7 mW at ~1.55 µm for on-chip optical parametric oscillation using a high quality factor micro-ring-resonator in a new nonlinear photonics platform: AlGaAs-on-insulator

Tailored design of WDM filters in BCB embedded PhC membranes

We propose a design strategy for wavelength division multiplexing (WDM) filters in BCB embedded photonic crystal membranes. Due to the weaker vertical confinement determined by the material embedding the whole structure, accurate tailoring of the resonant cavity and of both bus and drop waveguides is necessary, in order to guarantee the required performance of the filter for WDM applications.
High-speed photodetectors in a photonic crystal platform

We demonstrate a fast photodetector (f3dB > 40GHz) integrated into a high-index contrast photonic crystal platform. Device design, fabrication and characterization are presented.
Strip detector for nanoscale resolution

General information
State: Published
Organisations: Metal Structures in Four Dimensions, Materials Research Division, Rise National Laboratory for Sustainable Energy, Department of Photonics Engineering, Nanophotonic Devices
Authors: Olsen, U. L. (Intern), Schmidt, S. (Intern), Poulsen, H. F. (Intern), Yvind, K. (Intern), Ottaviano, L. (Intern)
Publication date: 2009

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Materials characterization and modelling, Materials research
Electronic versions:
Detector_presentation.pdf
Source: orbit
Source-ID: 254907
Publication: Research - Sound/Visual production (digital) – Annual report year: 2009

Projects:

Fabrication and characterization of novel nanophotonic structures with electrical control

Department of Photonics Engineering
Period: 01/10/2016 → 30/09/2019
Number of participants: 4
PhD Student:
Marchevsky, Andrey (Intern)
Supervisor:
Mørk, Jesper (Intern)
Ottaviano, Luisa (Intern)
Main Supervisor:
Yvind, Kresten (Intern)

Financing sources
**Ultrahigh-speed Si-integrated on-chip laser**

Department of Photonics Engineering  
Period: 15/11/2015 → 14/11/2018  
Number of participants: 3  
Phd Student:  
Tandukar, Sushil (Intern)  
Supervisor:  
Ottaviano, Luisa (Intern)  
Main Supervisor:  
Chung, Il-Sug (Intern)  

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: Samfinansierede - Virksomhed  
Project: PhD

**Photonic crystal Fano structures**

Department of Photonics Engineering  
Period: 15/05/2015 → 14/07/2018  
Number of participants: 7  
Phd Student:  
Bekele, Dagmawi Alemayehu (Intern)  
Supervisor:  
Ottaviano, Luisa (Intern)  
Yvind, Kresten (Intern)  
Main Supervisor:  
Mørk, Jesper (Intern)  
Examiner:  
Frandsen, Lars Hagedorn (Intern)  
De Rossi, Alfredo (Ekstern)  
O’Faolain, Liam (Ekstern)  

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: Samfinansieret - Andet  
Project: PhD

**Ultrahigh-speed hybrid III-C-on-Si lasers**

Department of Photonics Engineering  
Period: 15/03/2015 → 29/10/2018  
Number of participants: 3  
Phd Student:  
Topic, Vladimir (Intern)  
Supervisor:  
Ottaviano, Luisa (Intern)  
Main Supervisor:  
Chung, Il-Sug (Intern)  

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: Samfinansieret - Andet  
Project: PhD
QUantum dot Energy level Engineering for laser applicatioNs on InP and Si platforms
This project is dedicated to the research of quantum dot (QD) epitaxial growth on both indium phosphide (InP) and silicon (Si) based platforms with the aim of creating superior gain material emitting in the 1.5-1.6 μm wavelength range. The majority of the proposed research is quite fundamental but will have noticeable impact to device applications for our everyday life in the near future. Diverse areas like telecommunication, optical coherence tomography including medical applications, sensing, computer and network clock-distribution, THz generation, and metrology can benefit from the materials investigated.

The projected research covers two directions. The first is the development of QDs which possess desired electronic and optical properties in the InP based material system, i.e. tailoring the energy level structure and wave functions in the dots. Manipulating the shape, chemical composition and surroundings of the nanostructures is the key to achieving the set goals. In the frame of the project I will implement two different approaches to design and grow high optical quality arrays of QDs. Those approaches are self-assembled quantum dot growth and selective area growth using block copolymer lithography. The second direction of the research is the deployment of the highly efficient QD gain material to a silicon platform. The development of epitaxial growth technology of III-V materials on Si combines the benefits of high optical quality III-V QD gain material with low cost silicon photonics, which is a key platform to push towards increased integration, higher speed and lower energy consumption.

Department of Photonics Engineering
Nanophotonic Devices
Center for Nanostructured Graphene
Department of Micro- and Nanotechnology
Amphiphilic Polymers in Biological Sensing
Center for Electron Nanoscopy

DTU Danchip
Period: 01/06/2013 → 31/08/2017
Number of participants: 9
Acronym: QUEENs
Number of related Ph.D. students: 2
Project participant:
Yvind, Kresten (Intern)
Almdal, Kristoffer (Intern)
Kadkhodazadeh, Shima (Intern)
Ottaviano, Luisa (Intern)
Willatzen, Morten (Intern)
Barettin, Daniele (Ekstern)
Phd Student:
Viazmitinov, Dmitrii (Intern)
Shikin, Artem (Intern)
Project Manager, academic:
Semenova, Elizaveta (Intern)

Compact Otdm/wdm opTical rEceiveRs based on photoNic crystal Integrated
COPERNICUS aims to develop compact demultiplexing receivers for 100 Gb/s optical time division multiplexed (OTDM) and wavelength division multiplexed (WDM) signals, based on photonic crystal technology. There is a pressing need for these devices for ultra-high bandwidth data links in server farms, optical storage networks and on-board internet/entertainment systems, where demand is driving the data bandwidth and technology integration level rapidly upwards. Next generation telecom systems will also benefit from these devices for OTDM and optical packet switching. Their high-speed and bandwidth, together with their ultra-low power consumption and extreme compactness, also make them a very promising technology for seamless cross-chip and off-chip data links for CMOS electronics. This approach has all the hallmarks of a highly disruptive technology with the potential to place Europe at the forefront of photonics. COPERNICUS targets advances in the physics, technology, modelling, and integration of photonic crystal devices. Key devices include high-speed all-optical gates, low-crosstalk wavelength drop filters, and high-speed integrated photodetectors. These devices rely on very strong light-matter interactions arising from the large, ultrafast nonlinear optical response of III-V semiconductors and the strong resonant field enhancement in photonic crystals. This is ideal for filters and all optical gates, enabling a dramatic reduction in size and switching energy. Their switching energy-delay product is two orders of magnitude smaller than that of competing technologies. Modelling will consider carrier plasma (spectral and spatial) contributions to the nonlinear optical response and develop a robust optical, thermal and electronic design tool for photonic crystal devices. New levels of photonic crystal integration will be pursued to combine these devices and achieve complex all-optical functions attractive to both medium- and long-term markets.
Nanophotonic Devices

Department of Photonics Engineering

Thales

University of Nottingham

Centre National de la Recherche Scientifique

Università degli studi di Ferrara

MergeOptics GMBH

Thales Systemes Aeroportes S.A.

Period: 01/07/2012 → 01/07/2015

Number of participants: 16

Acronym: COPERNICUS

Project ID: 70629

Contact person:

Prevotat, Olivier (Ekstern)

Traimond, Gilles (Ekstern)

Bujan, Gaelle (Ekstern)

Nielsen, Claus (Intern)

Pallesen, Lars (Intern)

Bianchi, Patrizio (Ekstern)

Ruggiero, Valeria (Ekstern)

Neumeuer, Dag (Ekstern)

Otte, Sven (Ekstern)

Christmann, Gérard (Ekstern)

Project participant:

Wynne-Jones, Martin (Ekstern)

Kristensen, Philip Trøst (Intern)

Mørk, Jesper (Intern)

Ottaviano, Luisa (Intern)

Schubert, Martin (Intern)

Yvind, Kresten (Intern)

Financing sources

Source: Forsk. EU - Andre EU-midler

Name of research programme: Forsk. EU - Andre EU-midler

Amount: 3,654,000.00 Danish Kroner

Project