Deep-UV to Mid-IR Supercontinuum Generation driven by Mid-IR Ultrashort Pulses in a Gas-filled Hollow-core Fiber

Supercontinuum (SC) generation based on ultrashort pulse compression constitutes one of the most promising technologies towards ultra-wide bandwidth, high-brightness, and spatially coherent light sources for applications such as spectroscopy and microscopy. Here, multi-octave SC generation in a gas-filled hollow-core antiresonant fiber (HC-ARF) is reported spanning from 200 nm in the deep ultraviolet (DUV) to 4000 nm in the mid-infrared (mid-IR) having an output energy of 5 μJ. This was obtained by pumping at the center wavelength of the first anti-resonant transmission window (2460 nm) with ~100 fs pulses and an injected pulse energy of ~8 μJ. The mechanism behind the extreme spectral broadening relies upon intense soliton-plasma nonlinear dynamics which leads to efficient soliton self-compression and phase-matched dispersive wave (DW) emission in the DUV region. The strongest DW is observed at 275 nm which corresponds to the calculated phase-matching wavelength of the pump. Furthermore, the effect of changing the pump pulse energy and gas pressure on the nonlinear dynamics and their direct impact on SC generation was investigated. This work represents another step towards gas-filled fiber-based coherent sources, which is set to have a major impact on applications spanning from DUV to mid-IR.
Wavelength scaling of terahertz pulse energies delivered by two-color air plasmas

We address the long-standing problem of anomalous growth observed in the terahertz (THz) energy yield from air plasmas created by two-color laser pulses, as the fundamental wavelength $\lambda_0$ is increased. Using two distinct optical parametric amplifiers (OPAs), we report THz energies scaling like $\lambda^{\alpha_0}$ with large exponents $5.6 \leq \alpha \leq 14.3$, which departs from the growth in $\lambda^2$ expected from photocurrent theory. By means of comprehensive 3D simulations, we demonstrate that the changes in the laser beam size, pulse duration, and phase-matching conditions in the second-harmonic generation process when tuning the OPA’s carrier wavelength can lead to these high scaling powers. The value of the phase angle between the two colors reached at the exit of the doubling crystal turns out to be crucial and even explains non-monotonic behaviors in the measurements.

Terahertz time-domain spectroscopy of zone-folded acoustic phonons in 4H and 6H silicon carbide

We investigate the dielectric properties of the 4H and 6H polytypes of silicon carbide in the 0.1-19 THz range, below the fundamental transverse-optical phonons. Folding of the Brillouin zone due to the specific superlattice structure of the two polytypes leads to activation of acoustic phonon modes. We use a combination of ultrabroadband terahertz time-domain spectroscopy and simulations based on density-functional perturbation theory to observe and characterize these modes, including band splitting due to the dissimilar carbon and silicon sublattices of the structures, and an indirect measurement of the anisotropic sound velocities in the two polytypes.
Resonant effects in terahertz generation with laser-induced gas plasmas

High-efficiency Sub-single-cycle THz Wave Generation by Three-color Air Plasma

High-efficiency Sub-single-cycle THz Wave Generation by Three-color Air Plasma
Plasmonic Resonances Affecting Terahertz Generation in Laser-Induced Gas-Plasmas

We demonstrate that plasmonic resonances can be used to broaden the terahertz emission spectrum from two-color laser-driven gas-plasmas. This effect can be controlled by changing the polarization properties of elliptically shaped driving laser-pulses.

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Terahertz emission from laser-driven gas plasmas: A plasmonic point of view

We disclose an unanticipated link between plasmonics and nonlinear frequency down-conversion in laser-induced gas-plasmas. For two-color femtosecond pump pulses, a plasmonic resonance is shown to broaden the terahertz emission spectra significantly. We identify the resonance as a leaky mode, which contributes to the emission spectra whenever electrons are excited along a direction where the plasma size is smaller than the plasma wavelength. As a direct consequence, such resonances can be controlled by changing the polarization properties of elliptically shaped driving laser pulses. Both experimental results and 3D Maxwell consistent simulations confirm that a significant terahertz pulse shortening and spectral broadening can be achieved by exploiting the transverse driving laser beam shape as an additional degree of freedom. © 2018 Optical Society of America under the terms of the OSA Open Access Publishing Agreement.

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Volume: 5
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Ultra-broadband THz spectroscopy for sensing and identification for security applications

Ultra-broadband THz data recorded by air-plasma based systems, as well as synchrotron data will be presented for sensing and identification applications. The evolution from a precursor to home-made explosives can be nicely resolved using THz-TDS. Modelling these spectra by ab-initio DFT and molecular crystal simulation tools allows to identify the different inter- and intra-molecular character of the vibrational modes in this frequency range.

Bridging the gap between the THz and IR frequency regime

THz air photonics allow for the generation and detection of single-cycle sub-40 fs THz transients, which we use in a THz time-domain spectrometer to investigate the transmission properties of molecular crystalline materials in the ultrabroadband frequency window from 0.3 THz to more than 40 THz. We compare the obtained results with FTIR measurements to validate the THz-TDS results at large frequencies and compare the performance of these two techniques.
Influence of dispersion of nonlinearity on coherent supercontinuum generation bandwidth in photonic crystal fibers pumped at 2 μm

Sources of spectrally broadband and coherent light are necessary for frequency metrology and ultrashort pulse generation. Near-infrared (NIR) wavelengths are practical for such devices because of the emergence of robust and reasonably priced femtosecond lasers operating in this part of spectrum. This further enabled pulse preserving and coherent, so called all-normal dispersion supercontinuum (ANDi SC), covering over a full octave of around 600–1600 nm with pulse duration post-compressed down to single optical cycles [1]. When using the new erbium (1560 nm) or thulium (around 2000 nm) femtosecond lasers as pump sources, exceeding the 2400 nm barrier has proved a challenge. ANDi SC requires strong nonlinear response of the optical material, since self-phase modulation (SPM) and optical wave breaking (OWB) mediated four-wave mixing (FWM) are almost exclusively shaping the ANDi SC pulses. Flatness of the normal dispersion profile is also important, because FWM in this case is not phase-matched and takes place at the instance of the temporal overlap of the OWB components. Here we investigate and explain the bandwidth limitation of NIR pulse-preserving coherent SC by confronting ANDi SC generation performance in two types of photonic crystal fibers (PCFs) — Fig. 1(a, b) [2]. One type (NC21 series) has a flat NIR dispersion profile at the cost of nonlinearity, due to low nonlinear refractive index n2 the glasses forming the PCF lattice. The other type (NC38 series) features weaker dependence of the effective mode area Aeff on wavelength and much higher nonlinearity, albeit at the cost of flatness of the engineered normal dispersion profile.

Octave-spanning supercontinuum generation in a silicon-rich nitride waveguide: Erratum

We update the simulations presented in Opt. Lett. 41, 2719 (2016) [CrossRef] using a corrected value for the material nonlinearity.

Octave-spanning supercontinuum generation in a silicon-rich nitride waveguide

We update the simulations presented in Opt. Lett. 41, 2719 (2016) [CrossRef] using a corrected value for the material nonlinearity.
Parametrically tunable soliton-induced resonant radiation by three-wave mixing

We show that a temporal soliton can induce resonant radiation by three-wave mixing nonlinearities. This constitutes a new class of resonant radiation whose spectral positions are parametrically tunable. The experimental verification is done in a periodically poled lithium niobate crystal, where a femtosecond near-IR soliton is excited and resonant radiation waves are observed exactly at the calculated soliton phasematching wavelengths via the sum- and difference-frequency generation nonlinearities. This extends the supercontinuum bandwidth well into the mid IR to span 550–5000 nm, and the mid-IR edge is parametrically tunable over 1000 nm by changing the three-wave mixing phase-matching condition.

The results are important for the bright and broadband supercontinuum generation and for the frequency comb generation in quadratic nonlinear microresonators.

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Source-ID: 131211202
Research output: Contribution to journal › Journal article – Annual report year: 2017 › Research › peer-review

Tunable soliton-induced resonant radiation by three-wave mixing

A remarkable feature about the temporal optical soliton is that it can be phase-matched to new frequencies, emitting so-called resonant radiation (RR). This constitutes an efficient source of ultrafast pulses in emerging wavelength regimes, and plays a vital role in coherently extending the supercontinuum bandwidth [1]. RR waves are usually invoked by four-wave mixing (4WM) through the self-phase modulation (SPM) term $A|A|^2$, or more recently through the conjugate SPM term $A^*|A|^2$, or the third-harmonic generation (THG) term $A^3$ [2, 3]. We here show with theory and experiments that three-
wave mixing (3 WM) also supports soliton-induced RR waves [4].

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Research output: Chapter in Book/Report/Conference proceeding > Conference abstract in proceedings – Annual report year: 2017 > Research > peer-review

Ultra-broadband THz time-domain spectroscopy of energetic materials
Ultra-broadband THz spectroscopy based on photomixing in air plasma allows to exploit an extended frequency range, up to 20 THz and beyond. In this work, we investigate the potential of this technique for chemical recognition of illicit substances like explosives and compare the experimental spectra with ab-initio DFT simulation results to get deeper insight to the physical nature of the observed spectral features.

General information
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Organisations: Department of Photonics Engineering, Ultrafast Infrared and Terahertz Science, French-German Research Institute of Saint Louis
Contributors: Kaltenecker, K. J., Zhou, B., Engelbrecht, S., Fischer, B., Jepsen, P. U.
Number of pages: 2
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Publication date: 2017

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Source-ID: 2392118898
Research output: Chapter in Book/Report/Conference proceeding > Article in proceedings – Annual report year: 2017 > Research > peer-review

Ultrafast nonlinear response of silicon carbide to intense THz fields
We demonstrate ultrafast nonlinear absorption induced by strong, single-cycle THz fields in bulk, lightly doped 4H silicon carbide. A combination of Zener tunneling and intraband transitions makes the effect as at least as fast as the excitation pulse. The sub-picosecond recovery time makes the observed response the fastest nonlinear modulation scheme for THz signals reported so far.

General information
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Coherent supercontinuum bandwidth limitations under femtosecond pumping at 2 µm in all-solid soft glass photonic crystal fibers

Two all-solid glass photonic crystal fibers with all-normal dispersion profiles are evaluated for coherent supercontinuum generation under pumping in the 2.0 µm range. Inhouse boron-silicate and commercial lead-silicate glasses were used to fabricate fibers optimized for either flat dispersion, albeit with lower nonlinearity, or with larger dispersion profile curvature but with much higher nonlinearity. Recorded spectra at the redshifted edge reached 2500-2800 nm depending on fiber type. Possible factors behind these differences are discussed with numerical simulations. The fiber enabling the broadest spectrum is suggested as an efficient first stage of an all-normal dispersion cascade for coherent supercontinuum generation exceeding 3000 nm.

Multiple-octave spanning high-energy mid-IR supercontinuum generation in bulk quadratic nonlinear crystals

Bright and broadband coherent mid-IR radiation is important for exciting and probing molecular vibrations. Using cascaded nonlinearities in conventional quadratic nonlinear crystals like lithium niobate, self-defocusing near-IR solitons have been demonstrated that led to very broadband supercontinuum generation in the visible, near-IR, and short-wavelength mid-IR. Here we conduct an experiment where a mid-IR crystal is pumped in the mid-IR. The crystal is cut for noncritical interaction, so the three-wave mixing of a single mid-IR femtosecond pump source leads to highly phase-mismatched second-harmonic generation. This self-acting cascaded process leads to the formation of a self-defocusing soliton at the mid-IR pump wavelength and after the self-compression point multiple octave-spanning supercontinua are observed. The results were recorded in a commercially available crystal LiInS2 pumped in the 3-4 µm range with 85 fs 50 µJ pulse energy, with the broadest supercontinuum covering 1.6-7.0 µm. We measured up 30 µJ energy in the supercontinuum, and the energy promises to scale favorably with an increased pump energy. Other mid-IR crystals can readily be used as well to cover other pump wavelengths and target other supercontinuum wavelength ranges.
Multiple-μJ mid-IR supercontinuum generation in quadratic nonlinear crystals

Pumping a quadratic nonlinear crystal in the mid-IR we observe octave-spanning mid-IR supercontinua. A self-acting cascaded process leads to the formation of a self-defocusing nonlinearity, allowing formation of filament-free octave-spanning supercontinua in the 2.0–7.0 μm range with 10s of μJ pulse energies, much higher than filament-based techniques. This allows to use the supercontinuum as ultra-broadband excitation pulses in nonlinear optical applications.

Octave-spanning supercontinuum generation in a silicon-rich nitride waveguide

We experimentally show octave-spanning supercontinuum generation in a nonstoichiometric silicon-rich nitride waveguide when pumped by femtosecond pulses from an erbium fiber laser. The pulse energy and bandwidth are comparable to results achieved in stoichiometric silicon nitride waveguides, but our material platform is simpler to manufacture. We also observe wave-breaking supercontinuum generation by using orthogonal pumping in the same waveguide. Additional
analysis reveals that the waveguide height is a powerful tuning parameter for generating mid-infrared dispersive waves while keeping the pump in the telecom band.

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, Centre of Excellence for Silicon Photonics for Optical Communications, Department of Applied Mathematics and Computer Science, Department of Informatics and Mathematical Modeling, Risø National Laboratory for Sustainable Energy, Chalmers University of Technology
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**Octave-spanning supercontinuum generation in a silicon-rich nitride waveguide**
We generate supercontinuum (817–2250 nm at −30dB) in a dispersion-engineered silicon-rich nitride waveguide by pumping fs pulses with 82 pJ from an erbium-fiber oscillator. Spectral broadening mechanisms include soliton fission and dispersive wave generation.

**General information**
Publication status: Published
Organisations: Department of Photonics Engineering, Department of Applied Mathematics and Computer Science, Department of Informatics and Mathematical Modeling, Risø National Laboratory for Sustainable Energy, Chalmers University of Technology
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10.1364/CLEO_SI.2016.SW1Q.3

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Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2016 › Research › peer-review
Widely tunable mid-IR femtosecond resonant radiation induced by self-defocusing solitons in a quadratic nonlinear medium
We experimentally observe widely tunable mid-IR femtosecond pulses by resonant radiation, generated by direct three-wave-mixing from a soliton in PPLN. The poling pitch gives a parametrically tunable resonant radiation, a feature absent in Kerr media.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Terahertz Science & Technology, Shanghai University, National Central University
Number of pages: 2
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ISBN (Print): 978-1-943580-11-8
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Collision between soliton and dispersive wave in phase-mismatched quadratic nonlinear crystals

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group
Contributors: Liu, X., Zhou, B., Guo, H., Bache, M.
Number of pages: 1
Publication date: 2015

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Source-ID: 112085915
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report year: 2015 › Research › peer-review

Dispersive waves induced by self-defocusing temporal solitons in a beta-barium-borate crystal.
We experimentally observe dispersive waves in the anomalous dispersion regime of a beta-barium-borate (BBO) crystal, induced by a self-defocusing few-cycle temporal soliton. Together the soliton and dispersive waves form an energetic octave-spanning supercontinuum. The soliton was excited in the normal dispersion regime of BBO through a negative cascaded quadratic nonlinearity. Using pump wavelengths from 1.24 to 1.4 μm, dispersive waves are found from 1.9 to 2.2 μm, agreeing well with calculated resonant phasematching wavelengths due to degenerate four-wave mixing to the soliton. We also observe resonant radiation from nondegenerate four-wave mixing between the soliton and a probe wave, which was formed by leaking part of the pump spectrum into the anomalous dispersion regime. We confirm the experimental results through simulations.

General information
Publication status: Published
Organisations: Department of Photonics Engineering
Contributors: Zhou, B., Bache, M.
Pages: 4257-4260
Publication date: 2015
Peer-reviewed: Yes
Efficient supercontinuum generation in quadratic nonlinear waveguides without quasi-phase-matching

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group, Friedrich Schiller University Jena, National Central University
Contributors: Guo, H., Zhou, B., Steinert, M., Setzpfandt, F., Pertsch, T., Chung, H., Chen, Y., Bache, M.
Number of pages: 1
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Research output: Chapter in Book/Report/Conference proceeding → Conference abstract in proceedings – Annual report year: 2015 → Research → peer-review

Energetic mid-IR femtosecond pulse generation by self-defocusing soliton-induced dispersive waves in a bulk quadratic nonlinear crystal

Generating energetic femtosecond mid-IR pulses is crucial for ultrafast spectroscopy, and currently relies on parametric processes that, while efficient, are also complex. Here we experimentally show a simple alternative that uses a single pump wavelength without any pump synchronization and without critical phase-matching requirements. Pumping a bulk quadratic nonlinear crystal (unpoled LiNbO3 cut for noncritical phase-mismatched interaction) with sub-mJ near-IR 50-fs pulses, tunable and broadband (∼ 1,000 cm−1) mid-IR pulses around 3.0 μm are generated with excellent spatio-temporal pulse quality, having up to 10.5 μJ energy (6.3% conversion). The mid-IR pulses are dispersive waves phase-matched to near-IR self-defocusing solitons created by the induced self-defocusing cascaded nonlinearity. This process is filament-free and the input pulse energy can therefore be scaled arbitrarily by using large-aperture crystals. The technique can readily be implemented with other crystals and laser wavelengths, and can therefore potentially replace current ultrafast frequency-conversion processes to the mid-IR.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group
Contributors: Zhou, B., Guo, H., Bache, M.
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BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.78 SJR 2.186 SNIP 1.664
Experimental observation of dispersive wave generation by self-defocusing nonlinearity in BBO crystal

High-energy compression of mid-IR pulses in a bulk nonlinear crystal

Mid-infrared supercontinuum generation spanning more than 11 μm in a chalcogenide step-index fiber
Mid-IR femtosecond frequency conversion by soliton-probe collision in phase-mismatched quadratic nonlinear crystals

We show numerically that ultrashort self-defocusing temporal solitons colliding with a weak pulsed probe in the near-IR can convert the probe to the mid-IR. A near-perfect conversion efficiency is possible for a high effective soliton order. The near-IR self-defocusing soliton can form in a quadratic nonlinear crystal (beta-barium borate) in the normal dispersion regime due to cascaded (phase-mismatched) second-harmonic generation, and the mid-IR converted wave is formed in the anomalous dispersion regime between $\lambda = 2.2-2.4 \mu m$ as a resonant dispersive wave. This process relies on nondegenerate four-wave mixing mediated by an effective negative cross-phase modulation term caused by cascaded soliton-probe sum-frequency generation. © 2015 Optical Society of America
Tunable mid-infrared radiations in quadratic media through near-infrared soliton interactions with second-harmonic resonances

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group
Number of pages: 1
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Source: PublicationPreSubmission
Source-ID: 112087378
Research output: Chapter in Book/Report/Conference proceeding – Conference abstract in proceedings – Annual report year: 2015

Efficient femtosecond mid-infrared pulse generation by dispersive wave radiation in bulk lithium niobate crystal

We experimentally demonstrate efficient mid-infrared pulse generation by dispersive wave radiation in bulk lithium niobate crystal. Femtosecond mid-IR pulses centering from 2.8–2.92 µm are generated using the single pump wavelengths from 1.25–1.45 µm.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group, Department of Applied Mathematics and Computer Science
Contributors: Zhou, B., Guo, H., Bache, M.
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Source: FindIt
Source-ID: 273345324
Research output: Chapter in Book/Report/Conference proceeding – Article in proceedings – Annual report year: 2014
Efficient Femtosecond Mid-infrared Pulse Generation by Dispersive Wave Radiation in Bulk Lithium Niobate Crystal

We experimentally demonstrate efficient mid-infrared pulse generation by dispersive wave radiation in bulk lithium niobate crystal. Femtosecond mid-IR pulses centering from 2.8-2.92 μm are generated using the single pump wavelengths from 1.25-1.45 μm. © 2014 Optical Society of America

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group
Contributors: Zhou, B., Guo, H., Bache, M.
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Publication date: 2014

Experiments on Cascaded Quadratic Soliton Compression in Unpoled LN Waveguide

Experiments on cascaded quadratic soliton compression in unpoled phasemismatched lithium niobate waveguides are presented. Pulse self-phasemodulation dominated by an overall self-defocusing nonlinearity is observed, with an variation of pump wavelength and waveguide core width. © 2014 Optical Society of America

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group, Shanghai University
Contributors: Guo, H., Zhou, B., Zeng, X.
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Publication date: 2014

Few-cycle solitons and supercontinuum generation with cascaded quadratic nonlinearities in unpoled lithium niobate ridge waveguides

Formation and interaction of few-cycle solitons in a lithium niobate ridge waveguide are numerically investigated. The solitons are created through a cascaded phase-mismatched second-harmonic generation process, which induces a dominant self-defocusing Kerr-like nonlinearity on the pump pulse. The inherent material self-focusing Kerr nonlinearity is overcome over a wide wavelength range, and self-defocusing solitons are supported from 1100 to 1900 nm, covering the whole communication band. Single cycle self-compressed solitons and supercontinuum generation spanning 1.3 octaves are observed when pumped with femtosecond nanojoule pulses at 1550 nm. The waveguide is not periodically poled, as quasi-phase-matching would lead to detrimental nonlinear effects impeding few-cycle soliton formation.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group
Contributors: Guo, H., Zeng, X., Zhou, B., Bache, M.
Generating Efficient Femtosecond Mid-infrared Pulse by Single Near-infrared Pump Wavelength in Bulk Nonlinear Crystal Without Phase-matching

We experimentally demonstrate efficient mid-infrared pulse generation by dispersive wave radiation in bulk lithium niobate crystal. Femtosecond mid-IR pulses centering from 2.8-2.92 μm are generated using the single pump wavelengths from 1.25-1.45 μm. © 2014 Optical Society of America

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High-energy pulse compressor using self-defocusing spectral broadening in anomalously dispersive media

A new high-energy pulse compressor uses self-defocusing spectral broadening in anomalously dispersive quadratic nonlinear crystals, followed by positive group-delay-dispersion compensation. Compression to sub-50 fs is possible from Joule-class 1.03 μm femtosecond amplifiers in large-aperture KDP.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group
Contributors: Bache, M., Zhou, B.
Highly coherent mid-IR supercontinuum by self-defocusing solitons in lithium niobate waveguides with all-normal dispersion

We numerically investigate self-defocusing solitons in a lithium niobate (LN) waveguide designed to have a large refractive index (RI) change. The waveguide evokes strong waveguide dispersion and all-normal dispersion is found in the entire guiding band spanning the near-IR and the beginning of the mid-IR. Meanwhile, a self-defocusing nonlinearity is invoked by the cascaded (phase-mismatched) second-harmonic generation under a quasi-phase-matching pitch. Combining this with the all-normal dispersion, mid-IR solitons can form and the waveguide presents the first all-nonlinear and solitonic device where no linear dispersion (i.e. non-solitonic) regimes exist within the guiding band. Soliton compressions at 2 mm and 3 mm are investigated, with nano-joule single cycle pulse formations and highly coherent octave-spanning supercontinuum generations. With an alternative design on the waveguide dispersion, the soliton spectral tunneling effect is also investigated, with which few-cycle pico-joule pulses at 2 mm are formed by a near-IR pump. © 2014 Optical Society of America.

Low-energy Self-defocusing Soliton Compression at Optical Communication Wavelengths in Unpoled Lithium Niobate Ridge Waveguide

Self-defocusing soliton compression supported by the cascaded phase-mismatched second-harmonic generation process is numerically demonstrated in unpoled lithium niobate ridge waveguides where nano-joule pulses are operated and quasi-phase-matching is unnecessary. The soliton range is 1100-1800 nm.
Mid-infrared supercontinuum covering the 1.4–13.3 μm molecular fingerprint region using ultra-high NA chalcogenide step-index fibre

The mid-infrared spectral region is of great technical and scientific interest because most molecules display fundamental vibrational absorptions in this region, leaving distinctive spectral fingerprints. To date, the limitations of mid-infrared light sources such as thermal emitters, low-power laser diodes, quantum cascade lasers and synchrotron radiation have precluded mid-infrared applications where the spatial coherence, broad bandwidth, high brightness and portability of a supercontinuum laser are all required. Here, we demonstrate experimentally that launching intense ultra-short pulses with a central wavelength of either 4.5 μm or 6.3 μm into short pieces of ultra-high numerical-aperture step-index chalcogenide glass optical fibre generates a mid-infrared supercontinuum spanning 1.5 μm to 11.7 μm and 1.4 μm to 13.3 μm, respectively. This is the first experimental demonstration to truly reveal the potential of fibres to emit across the mid-infrared molecular ‘fingerprint region’, which is of key importance for applications such as early cancer diagnostics, gas sensing and food quality control.

Observation of an octave-spanning supercontinuum in the mid-infrared using ultrafast cascaded nonlinearities

An octave-spanning mid-IR supercontinuum is observed experimentally using ultrafast cascaded nonlinearities in a LiInS2 quadratic nonlinear crystal pumped with 70 fs energetic mid-IR pulses and cut for strongly phase-mismatched second-harmonic generation. ©OSA 2014.
Octave-Spanning Mid-IR Supercontinuum Generation with Ultrafast Cascaded Nonlinearities
An octave-spanning mid-IR supercontinuum is observed experimentally using ultrafast cascaded nonlinearities in an LiInS2 quadratic nonlinear crystal pumped with 70 fs energetic mid-IR pulses and cut for strongly phase-mismatched second-harmonic generation.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group
Contributors: Zhou, B., Guo, H., Liu, X., Bache, M.
Number of pages: 2
Publication date: 2014

Soliton-induced nonlocal resonances observed through high-intensity tunable spectrally compressed second-harmonic peaks
Experimental data of femtosecond thick-crystal second-harmonic generation show that when tuning away from phase matching, a dominating narrow spectral peak appears in the second harmonic that can be tuned over hundreds of nanometers by changing the phase-mismatch parameter. Traditional theory explains this as phase matching between a sideband in the broadband pump to its second harmonic. However, our experiment is conducted under high input intensities and instead shows excellent quantitative agreement with a nonlocal theory describing cascaded quadratic nonlinearities. This theory explains the detuned peak as a nonlocal resonance that arises due to phase matching between the pump and a detuned second-harmonic frequency, but where in contrast to the traditional theory the pump is assumed dispersion free. As a soliton is inherently dispersion free, the agreement between our experiment and the nonlocal theory indirectly proves that we have observed a soliton-induced nonlocal resonance. The soliton exists in the self-defocusing regime of the cascaded nonlinear interaction and in the normal dispersion regime of the crystal, and needs high input intensities to become excited.

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Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group
Contributors: Zhou, B., Guo, H., Bache, M.
Number of pages: 10
Publication date: 2014
Peer-reviewed: Yes
Nonlinear wave equation in frequency domain: accurate modeling of ultrafast interaction in anisotropic nonlinear media

We interpret the purely spectral forward Maxwell equation with up to third-order induced polarizations for pulse propagation and interactions in quadratic nonlinear crystals. The interpreted equation, also named the nonlinear wave equation in the frequency domain, includes quadratic and cubic nonlinearities, delayed Raman effects, and anisotropic nonlinearities. The full potential of this wave equation is demonstrated by investigating simulations of solitons generated in the process of ultrafast cascaded second-harmonic generation. We show that a balance in the soliton delay can be achieved due to competition between self-steepening, Raman effects, and self-steepening-like effects from cascading originating in the group-velocity mismatch between the pump and the second harmonic. We analyze the first-order contributions, and show that this balance can be broken to create fast or slow pulses. Through further simulations we demonstrate few-cycle compressed solitons in extremely short crystals, where spectral phenomena, such as blue/red shifting, nonstationary radiation in accordance with the nonlocal phase-matching condition, and dispersive-wave generation are observed and marked, which helps improve the experimental knowledge of cascading nonlinear soliton pulse compression.

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Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group
Contributors: Guo, H., Zeng, X., Zhou, B., Bache, M.
Pages: 494-504
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Peer-reviewed: Yes

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Web of Science (2013): Impact factor 1.806
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
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Source: Bibtex
Source-ID: urn:ae3188b283c149020bf6e304585b2f6a
Research output: Contribution to journal › Journal article – Annual report year: 2013 › Research › peer-review

Completely background free broadband coherent anti-Stokes Raman scattering spectroscopy
For the first time it was proposed a numerical approach to obtain non-NRB time-frequency coherent anti-Stokes Raman scattering (CARS) spectrograms. In order to evaluate the validity of the CARS spectrogram for background free broadband CARS spectroscopy, the authors numerically constructed a CARS spectrogram for an assumed Gaussian
probe pulse of 500 fs (FWHM).

**General information**

Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group, Shenzhen University
Contributors: Liu, X., Niu, H., Liu, W., Chen, D., Zhou, B., Bache, M.
Number of pages: 1
Publication date: 2013

**Host publication information**

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Source: dtu
Source-ID: u::8083
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report
year: 2013 › Research › peer-review

**Cross-correlation frequency-resolved optical gating by molecular vibration for ultrashort pulse**

**General information**

Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group, Shenzhen University
Contributors: Liu, X., Niu, H., Liu, W., Chen, D., Zhou, B., Bache, M.
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Publication date: 2013

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prod11373964127584.paper_3_.pdf
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10.1109/CLEOE-IQEC.2013.6801114
Source: dtu
Source-ID: u::8083
Research output: Chapter in Book/Report/Conference proceeding › Conference abstract in proceedings – Annual report
year: 2013 › Research › peer-review

**Few-cycle nonlinear mid-IR pulse generated with cascaded quadratic nonlinearities**

Generating few-cycle energetic and broadband mid-IR pulses is an urgent current challenge in nonlinear optics. Cascaded second-harmonic generation (SHG) gives access to an ultrafast and octave-spanning self-defocusing nonlinearity: when $\Delta k L > 2\pi$ the pump experiences a Kerr-like nonlinear index change $\Delta n = n_{cascl}$, where $n_{case} \propto -d_{eff}/\Delta k$, and $d_{eff}$ is the effective quadratic nonlinearity. Due to competing material nonlinearities $n_{Kerr}$ the total nonlinear refractive is $n_{cubic} = n_{cascl} + n_{Kerr}$. Interestingly $n_{cubic}$ can become negative (self-defocusing), elegantly avoiding self-focusing problems, and making it possible to excite solitons with normal dispersion [1].

**General information**

Publication status: Published
Organisations: Department of Photonics Engineering, Ultrafast Nonlinear Optics group
Contributors: Bache, M., Liu, X., Zhou, B.
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Peer-reviewed: Yes
Keywords: optical harmonic generation, optical Kerr effect, optical pulse generation, optical pumping, optical solitons, refractive index, Aerospace, Bioengineering, Communication, Networking and Broadcast Technologies, Components, Circuits, Devices and Systems, Engineered Materials, Dielectrics and Plasmas, Engineering Profession, Fields, Waves and Electromagnetics, General Topics for Engineers, Nuclear Engineering, Photonics and Electrooptics, Power, Energy
Generating mid-IR octave-spanning supercontinua and few-cycle pulses with solitons in phase-mismatched quadratic nonlinear crystals

We discuss a novel method for generating octave-spanning supercontinua and few-cycle pulses in the important mid-IR wavelength range. The technique relies on strongly phase-mismatched cascaded second-harmonic generation (SHG) in mid-IR nonlinear frequency conversion crystals. Importantly we here investigate the so-called noncritical SHG case, where no phase matching can be achieved but as a compensation the largest quadratic nonlinearities are exploited. A self-defocusing temporal soliton can be excited if the cascading nonlinearity is larger than the competing material self-focusing nonlinearity, and we define a suitable figure of merit to screen a wide range of mid-IR dielectric and semiconductor materials with large effective second-order nonlinearities $d_{eff}$. The best candidates have simultaneously a large bandgap and a large $d_{eff}$. We show selected realistic numerical examples using one of the promising crystals: in one case soliton pulse compression from 50 fs to 15 fs (1.5 cycles) at 3.0 μm is achieved, and at the same time a 3-cycle dispersive wave at 5.0 μm is formed that can be isolated using a long-pass filter. In another example we show that extremely broadband supercontinua can form spanning the near-IR to the end of the mid-IR (nearly 4 octaves).
The anisotropic Kerr nonlinear refractive index of the beta-barium borate (β-BaB₂O₄) nonlinear crystal

We study the anisotropic nature of the Kerr nonlinear response in a beta-barium borate (β-BaB₂O₄, BBO) nonlinear crystal. The focus is on determining the relevant \( \chi^{(3)} \) cubic tensor components that affect interaction of type I cascaded second-harmonic generation. Various experiments in the literature are analyzed and we correct the data from some of the experiments for contributions from cascading as well as for updated material parameters. We also perform an additional experimental measurement of the Kerr nonlinear tensor component responsible for self-phase modulation in cascading, and we show that the average value of 14 different measurements is considerably larger than what has been used to date. Our own measurements are consistent with this average value. We also treat data measurements for mixtures of tensor components, and by disentangling them we present for the first time a complete list that we propose as reference of the four major cubic tensor components in BBO. We finally discuss the impact of using the cubic anisotropic response in ultrafast cascading experiments in BBO.
Ultrafast and Broadband Optical Nonlinearities from Strongly Phase-Mismatched Second Harmonic Generation
All solid-state passively mode-locked ultrafast lasers based on Nd, Yb, and Cr doped media

Cascaded Soliton Compression of Energetic Femtosecond Pulses at 1030 nm

We discuss soliton compression with cascaded second-harmonic generation of energetic femtosecond pulses at 1030 nm. We discuss problems encountered with soliton compression of long pulses and show that sub-10 fs compressed pulses can be achieved.
Critical Boundary of Cascaded Quadratic Soliton Compression in PPLN
Cascaded quadratic soliton compression in PPLN is investigated and a general critical soliton number is found as the compression boundary. An optimal-parameter diagram for compression at 1550 nm is presented.

High-energy Few-cycle Pulses Directly Generated from Strongly Phase-mismatched Lithium Niobate Crystal
We show that effective soliton compression can be realized in strongly phase-mismatched quadratic media. Sub-15 fs pulses are experimentally generated directly from 10-mm-long bulk lithium niobate crystal by 120-fs input pulses at 1300 nm.

Improving Soliton Compression Quality with Cascaded Nonlinearities by Engineered Multi-section Quasi-phase-matching Design
In few-cycle soliton generation with large compression factors using cascaded nonlinearities the pulse quality can be improved by engineering quasi-phase-matching structures. The soliton-induced mid-IR optical Cherenkov wave is also enhanced.
Soliton compression to few-cycle pulses with a high quality factor by engineering cascaded quadratic nonlinearities

We propose an efficient approach to improve few-cycle soliton compression with cascaded quadratic nonlinearities by using an engineered multi-section structure of the nonlinear crystal. By exploiting engineering of the cascaded quadratic nonlinearities, in each section soliton compression with a low effective order is realized, and high-quality few-cycle pulses with large compression factors are feasible. Each subsequent section is designed so that the compressed pulse exiting the previous section experiences an overall effective self-defocusing cubic nonlinearity corresponding to a modest soliton order, which is kept larger than unity to ensure further compression. This is done by increasing the cascaded quadratic nonlinearity in the new section with an engineered reduced residual phase mismatch. The low soliton orders in each section ensure excellent pulse quality and high efficiency. Numerical results show that compressed pulses with less than three-cycle duration can be achieved even when the compression factor is very large, and in contrast to standard soliton compression, these compressed pulses have minimal pedestal and high quality factor.
Ultrafast and octave-spanning optical nonlinearities from strongly phase-mismatched cascaded interactions

Cascaded nonlinearities have attracted much interest, but ultrafast applications have been seriously hampered by the simultaneous requirements of being near phase matching and having ultrafast femtosecond response times. Here we show that in strongly phase-mismatched nonlinear frequency conversion crystals the pump pulse can experience a large and extremely broadband self-defocusing cascaded Kerrlike nonlinearity. The large cascaded nonlinearity is ensured through interaction with the largest quadratic tensor element in the crystal, and the strong phase mismatch ensures an ultrafast nonlinear response with an octave-spanning bandwidth. We verify this experimentally by showing few-cycle soliton compression with noncritical cascaded second-harmonic generation: Energetic 47 fs infrared pulses are compressed in a just 1-mm long bulk lithium niobate crystal to 17 fs (under 4 optical cycles) with 80% efficiency, and upon further propagation an octave-spanning supercontinuum is observed. Such ultrafast cascading is expected to occur for a broad range of pump wavelengths spanning the near- and mid-IR using standard nonlinear crystals.
Optical Cherenkov radiation by cascaded nonlinear interaction: an efficient source of few-cycle energetic near- to mid-IR pulses

When ultrafast noncritical cascaded second-harmonic generation of energetic femtosecond pulses occur in a bulk lithium niobate crystal optical Cherenkov waves are formed in the near- to mid-IR. Numerical simulations show that the few-cycle solitons radiate Cherenkov (dispersive) waves in the $\lambda = 2.2 - 4.5 \mu m$ range when pumping at $\lambda_1 = 1.2 - 1.8 \mu m$. The exact phase-matching point depends on the soliton wavelength, and we show that a simple longpass filter can separate the Cherenkov waves from the solitons. The Cherenkov waves are born few-cycle with an excellent Gaussian pulse shape, and the conversion efficiency is up to 25%. Thus, optical Cherenkov waves formed with cascaded nonlinearities could become an efficient source of energetic near- to mid-IR few-cycle pulses.

General information
Publication status: Published
Organisations: Ultrafast Nonlinear Optics group, Department of Photonics Engineering, Fiber Sensors & Supercontinuum, Massachusetts Institute of Technology, Cornell University
Contributors: Bache, M., Bang, O., Zhou, B., Moses, J., Wise, F. W.
Pages: 22557-22562
Publication date: 2011
Peer-reviewed: Yes

Optical Cherenkov radiation by cascaded nonlinear interaction: an efficient source of few-cycle near- to mid-IR pulses

Through cascaded second-harmonic generation, few-cycle solitons can form that resonantly emit strongly red-shifted optical Cherenkov radiation. Numerical simulations show that such dispersive waves can be an efficient source of near- to mid-IR few-cycle broadband pulses.

General information
Publication status: Published
Organisations: Ultrafast Nonlinear Optics group, Department of Photonics Engineering, Fiber Sensors & Supercontinuum, Massachusetts Institute of Technology, Cornell University
Contributors: Bache, M., Bang, O., Zhou, B., Moses, J., Wise, F. W.
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URLs:
http://www.osa.org/meetings/topical_meetings/NLO/default.aspx
Source: orbit
Source-ID: 281887
Sub-20 fs energetic near-IR pulses generated with cascaded soliton compression in short lithium niobate crystals

We show experimentally that sub-20 fs near-infrared pulses can be generated through soliton compression of energetic femtosecond pulses. e compression relies on cascaded type-0 second-harmonic generation in a just 1 mm long lithium niobate crystal.

General information
Publication status: Published
Organisations: Fiber Sensors & Supercontinuum, Department of Photonics Engineering, Cornell University
Contributors: Zhou, B., Chong, A., Wise, F. W., Bache, M.
Pages: CF1.6
Publication date: 2011

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Title of host publication: 2011 Conference on and 12th European Quantum Electronics Conference Lasers and Electro-Optics Europe (CLEO EUROPE/EQEC)
Publisher: IEEE
ISBN (Print): 978-1-4577-0532-8
DOIs:
10.1109/CLEOE.2011.5942872
URLs:
http://www.cleoeurope.org/
Source: orbit
Source-ID: 277240
Research output: Chapter in Book/Report/Conference proceeding » Article in proceedings – Annual report year: 2011 » Research » peer-review

Diode laser pumped efficient femtosecond Yb:YAG ceramic laser

A diode-pumped mode-locking ceramic Yb:YAG laser with slope efficiency of 76% was demonstrated, output power up to 1.9 W was obtained with pulse duration of 418 fs and central wavelength of 1048 nm.

General information
Publication status: Published
Organisations: Chinese Academy of Sciences, Ecole Polytechnique, Xidian University
Number of pages: 2
Publication date: 2010

Host publication information
Title of host publication: CLEO/QELS 2010 : Conference on Lasers and Electro-Optics and Conference on Quantum Electronics and Laser Science
Publisher: IEEE
ISBN (Print): 978-1-55752-890-2
Source: PublicationPreSubmission
Source-ID: 112202127
Research output: Chapter in Book/Report/Conference proceeding » Article in proceedings – Annual report year: 2010 » Research » peer-review

Few-cycle femtosecond optical pulses in the visible and near-infrared: [invited]

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Fiber Sensors & Supercontinuum
Contributors: Bache, M., Bang, O., Zhou, B., Krolikowski, W., Wise, F.
Publication date: 2010

Host publication information
Title of host publication: Proceedings WLMI
Source: orbit
Source-ID: 271744
Research output: Chapter in Book/Report/Conference proceeding » Article in proceedings – Annual report year: 2010 » Research » peer-review
Generating energetic few-cycle pulses at 800 nm using soliton compression with type 0 cascaded quadratic interaction in lithium niobate

General information
Publication status: Published
Organisations: Fiber Sensors & Supercontinuum, Department of Photonics Engineering
Contributors: Bache, M., Zhou, B., Chong, A., Wise, F.
Publication date: 2010

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Article number: 5499960
ISBN (Print): 9781557528902
Source: orbit
Source-ID: 273857
Research output: Chapter in Book/Report/Conference proceeding - Article in proceedings – Annual report year: 2010 - peer-review

Generating ultra-short energetic pulses with cascaded soliton compression in lithium niobate crystals
By launching energetic femtosecond pulses in a lithium niobate crystal, the phase mismatched second-harmonic generation process compresses the 50 fs input pulse at 1250 nm to 30 fs through a soliton effect.

General information
Publication status: Published
Organisations: Fiber Sensors & Supercontinuum, Department of Photonics Engineering
Contributors: Zhou, B., Bache, M., Chong, A., Wise, F.
Publication date: 2010

Host publication information
Title of host publication: Proceedings EOSAM
Source: orbit
Source-ID: 273853
Research output: Chapter in Book/Report/Conference proceeding - Article in proceedings – Annual report year: 2011 - peer-review

Generation of red light femtosecond pulses from an intra-cavity frequency-doubled Cr4+: Forsterite Laser
We demonstrate the generation of red light femtosecond laser pulses from an intra-cavity frequency-doubled Cr4+:forsterite laser. An average output power of 75 mW is obtained at the central wavelength of 647 nm with a pulse width of 55 fs by inserting a 500-μm-thick BBO crystal in the laser cavity. The bandwidth of the spectrum of second harmonic pulses is 9 nm, corresponding to a time-bandwidth product of 0.355.

General information
Publication status: Published
Organisations: Chinese Academy of Sciences
Contributors: Xin, Z., Zhou, B., Zhan, M., Wei, Z.
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Peer-reviewed: Yes

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Scopus rating (2010): SJR 0.437 SNIP 0.551
Web of Science (2010): Impact factor 1.078
Web of Science (2010): Indexed yes
Original language: English
DOIs:
High-efficiency diode-pumped femtosecond Yb:YAG ceramic laser
A highly efficient diode-end-pumped femtosecond Yb:yttrium aluminum garnet (YAG) ceramic laser was demonstrated. Pumped by a 968 nm fiber-coupled diode laser, 1.9 W mode-locked output power at a repetition rate of 64.27 MHz was obtained with 3.5 W absorbed pump power, corresponding to a slope efficiency of 76%. Our measurement showed that the pulse duration was 418 fs with the central wavelength of 1048 nm.

Optical Cherenkov radiation in ultrafast cascaded second-harmonic generation
We show through theory and numerics that when few-cycle femtosecond solitons are generated through cascaded (phase-mismatched) second-harmonic generation, these broadband solitons can emit optical Cherenkov radiation in the form of linear dispersive waves located in the red part of the spectrum. The beating between the dispersive wave and the soliton generates trailing temporal oscillations on the compressed soliton. Insertion of a simple short-wave pass filter after the crystal can restore a clean soliton. On the other hand, bandpass filtering around the dispersive wave peak results in near-transform-limited ultrashort mid-IR pulses with pulse durations much shorter than the input near-IR pulse. The Cherenkov radiation for the crystal considered (β-barium borate) is found for pump wavelengths in the range λ = 0.95–1.45 μm, and is located in the regime λ = 1.5–3.5 μm. For shorter pump wavelengths, the phase-matching point is located in the absorption region of the crystal, effectively absorbing the generated dispersive wave. By calculating the phase-matching curves for typically used frequency conversion crystals, we point out that the mid-IR absorption in the crystal in many cases automatically will filter away the dispersive wave. Finally, an investigation of recent experimental results uncovers a four-wave-mixing phenomenon related to Cherenkov radiation that is an additional generation mechanism of long-wavelength radiation that can occur during soliton compression. We discuss the conditions that lead to this alternative
Diode-pumped passively mode-locked Yb:Y3Ga5O12 laser
We experimentally demonstrated femtosecond operation in a diode-pumped Yb:Y3Ga5O12 laser for the first time, to the best of our knowledge. By using Gires-Tournois interferometer mirrors for dispersion compensation and a semiconductor saturable absorber mirror for passive mode locking, pulses with a duration as short as 245 fs at the central wavelength of 1045 nm have been produced at a repetition rate of 64.3 MHz. Under the full pump power of 7 W, the maximum output power was 570 mW, with an average slope efficiency of 14.1%. (C) 2009 Optical Society of America

General information
Publication status: Published
Organisations: Chinese Academy of Sciences, Shandong University
Number of pages: 3
Pages: 3316-3318
Publication date: 2009
Peer-reviewed: Yes

Publication information
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Volume: 34
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ISSN (Print): 0146-9592
Ratings:
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Scopus rating (2009): SJR 2.963 SNIP 2.732
Web of Science (2009): Indexed yes
Original language: English
Keywords: Atomic and Molecular Physics, and Optics, Central wavelength, Diode-pumped, Femtosecond operation, Gires-Tournois interferometer mirrors, Maximum output power, Passive mode locking, Passively mode-locked, Pump power, Repetition rate, Semiconductor saturable absorber mirrors, Slope efficiencies, Fiber lasers, Mirrors, Semiconductor lasers, Ytterbium, Semiconductor diodes
DOIs:
10.1364/ol.34.003316
Source: FindIt
Source-ID: 5176714
Research output: Contribution to journal > Journal article – Annual report year: 2009 > Research > peer-review

Generation of 1053-nm femtosecond pulses by Yb:YAG laser
Femtosecond Yb:YAG laser at 1053 nm was realized by optimized crystal length and doping concentration, stable mode-locking power of 180 mW was achieved under 2W pump. Measurement shows 170fs pulse duration and 7nm spectrum bandwidth.

General information
Publication status: Published
Organisations: Chinese Academy of Sciences, Sorbonne Universités
Contributors: Zhou, B., Wei, Z., Li, D., Teng, H., Bourdet, G.
Number of pages: 2
Publication date: 2009

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Title of host publication: CLEO/QELS 2009 : Conference on Lasers and Electro-Optics and Conference on Quantum Electronics and Laser Science
Publisher: IEEE
ISBN (Print): 978-1-55752-869-8
Source: PublicationPreSubmission
Source-ID: 112202119
Generation of 170-fs laser pulses at 1053 nm by a passively mode-locked Yb:YAG Laser

A novel method is developed to obtain 1.05 μm laser operation with a Yb:YAG laser. By using a Yb:YAG crystal with proper length and doping concentration, a femtosecond Yb:YAG laser is realized at the central wavelength of 1053 nm. The measured pulse duration and spectral bandwidth (FWHM) are 170 fs and 7 nm; the repetition rate is 80 MHz. Under a power pump of 2 W, an average mode-locking power of 180 mW is achieved.

General information
Publication status: Published
Organisations: Chinese Academy of Sciences, Sorbonne Universités
Contributors: Zhou, B., Wei, Z., Li, D., Teng, H., Bourdet, G.
Number of pages: 4
Publication date: 2009
Peer-reviewed: Yes

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Volume: 26
Issue number: 5
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BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.483 SNIP 0.55
Web of Science (2009): Indexed yes
Original language: English
Keywords: Physics, Yb-YAG laser, Power, Output
DOI: 10.1088/0256-307X/26/5/054208
Source: FindIt
Source-ID: 144926069

Generation of 210 fs laser pulses at 1093 nm by a self-starting mode-locked Yb:GYSO laser

We report the first demonstration, to our knowledge, of the femtosecond laser operation by using a new alloyed Yb:GYSO crystal as the gain medium. With a 5 at. % Yb3+-doped sample and chirped mirrors for dispersion compensation, we obtained pulses as short as 210 fs at the center wavelength of 1093 nm. The average mode-locking power is 300 mW, and the pulse repetition frequency is 80 MHz.

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Organisations: Chinese Academy of Sciences
Number of pages: 3
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Publication date: 2009
Peer-reviewed: Yes

Publication information
Journal: Optics Letters
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Issue number: 1
ISSN (Print): 0146-9592
Ratings:
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.963 SNIP 2.732
Web of Science (2009): Indexed yes
Original language: English
Keywords: Atomic and Molecular Physics, and Optics, Center wavelengths, Chirped mirrors, Doped samples, Femtosecond lasers, Fs laser pulses, Gain mediums, Pulse Repetition frequencies, Laser pulses, Lasers, Ytterbium, Pulsed laser applications
Numerical and experimental investigation of a continuous-wave and passively mode-locked Yb:YAG laser at a wavelength of 1.05 μm

We present the results of a novel numerical and experimental investigation aimed at obtaining efficient 1.05 μm operation with a Yb:YAG laser. The model shows that the emitting wavelength of the Yb:YAG laser is affected by the combination of length and doping concentration of the gain medium. Efficient continuous-wave laser operation at the wavelength of 1050 nm was experimentally obtained in good agreement with the model predictions. Based on continuous-wave operation, generation of 1.8 ps laser pulses at the central wavelength of 1050 nm, as well as 170 fs laser pulses at the central wavelength of 1053 nm, were realized.

Short pulses give high speeds, precision and intensity

General information
Publication status: Published
Organisations: Chinese Academy of Sciences, CNRS
Contributors: Zhou, B., Wei, Z., Li, D., Teng, H., Bourdet, G. L.
Number of pages: 6
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Peer-reviewed: Yes

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ISSN (Print): 1559-128X
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Scopus rating (2009): SJR 1.191 SNIP 1.752
Web of Science (2009): Indexed yes
Original language: English
Keywords: Laser pulses, Lasers, Ytterbium, Central wavelength, Continuous wave operation, Continuous waves, Continuous-wave laser operation, Doping concentration, Emitting wavelengths, Experimental investigations, Fs laser pulse, Gain medium, Model prediction, Passively mode-locked, Yb:YAG laser, Pulsed laser applications, Atomic and Molecular Physics, and Optics
DOIs:
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Publisher: DTU Fotonik
Edition: 1
ISBN (Print): 87-92062-34-2
Source: orbit
Source-ID: 255225
Research output: Chapter in Book/Report/Conference proceeding › Book chapter – Annual report year: 2009 › Communication
**Synchronously pumped femtosecond optical parametric oscillator at 1053 nm**

A femtosecond optical parametric oscillator synchronously pumped by a Ti:Sapphire oscillator is reported. By the cavity length tuning, the signal wavelength is continuously tuned from 1000 to 1200 nm. The average output power of 32 mW is obtained at 1053 nm. The pulse width is measured to be 342 fs by intensity autocorrelation method. In addition, we observed bichromatic emission during the cavity length tuning process.

**General information**
- Publication status: Published
- Organisations: Chinese Academy of Sciences
- Number of pages: 4
- Pages: 1187-1190
- Publication date: 2009
- Peer-reviewed: Yes

**Publication information**
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- Issue number: 8
- ISSN (Print): 1672-1799
- Original language: English
- Keywords: Physics and Astronomy (all), Femtosecond, Optical parametric oscillator, Synchronously pump
- DOIs:
  - 10.1007/s11433-009-0160-8

**Highly Efficient Self-Starting Femtosecond Cr:Forsterite Laser**

We report a highly efficient and high power self-starting femtosecond Cr:forsterite laser pumped by a 1064-nm Yb doped fibre laser. Five chirped mirrors are used to compensate for the intra-cavity group-delay dispersion, and the mode-locking is initiated by a semiconductor saturable absorber mirror (SESAM). Under pump power of 7.9 W, stable femtosecond laser pulses with average power of 760 mW are obtained, yielding a pump power slope efficiency of 12.3%. The measured pulse duration and spectral bandwidth (FWHM) are 46 fs and 45 nm; the repetition rate is 82 MHz.

**General information**
- Publication status: Published
- Organisations: Chinese Academy of Sciences
- Number of pages: 3
- Pages: 3679-3681
- Publication date: 2008
- Peer-reviewed: Yes

**Publication information**
- Journal: Chinese Physics Letters
- Volume: 25
- Issue number: 10
- ISSN (Print): 0256-307X
- Ratings:
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  - Scopus rating (2008): SJR 0.342 SNIP 0.45
  - Web of Science (2008): Indexed yes
- Original language: English
- Keywords: Physics, Chromium-doped forsterite, Generation, Pulses, Dispersion
- DOIs:
  - 10.1088/0256-307X/25/10/044
Projects:

Supercontinuum generation with rugged femtosecond fibre lasers
Rao Delanthabettu Shivarama, S., PhD Student, Department of Photonics Engineering
Bache, M., Main Supervisor, Risø National Laboratory for Sustainable Energy
Moselund, P. M., Supervisor, Department of Photonics Engineering
Zhou, B., Supervisor, Department of Photonics Engineering
Bang, O., Main Supervisor, Department of Photonics Engineering
Anden EU-finansiering
15/02/2017 → 14/02/2020
Award relations: Supercontinuum generation with rugged femtosecond fibre lasers
Project: PhD

Novel ultrafast mid-IR laser source for spectroscopy
Bache, M., Project Participant, Department of Photonics Engineering, Ultrafast Infrared and Terahertz Science
Zhou, B., Project Participant, Department of Photonics Engineering, Ultrafast Infrared and Terahertz Science
Petersen, P. B., Project Participant
Ashihara, S., Project Participant
Project ID: 70885
01/01/2015 → 30/04/2016
Project: Research

Femtosecond few-cycle mid-infrared laser pulses
Liu, X., PhD Student, Department of Photonics Engineering
Bache, M., Main Supervisor
Zhou, B., Supervisor
Bang, O., Examiner
Minardi, S., Examiner
Jedrkiewicz, O., Examiner
Technical University of Denmark
15/10/2012 → 15/06/2016
Award relations: Femtosecond few-cycle mid-infrared laser pulses
Project: PhD

Cascaded Quadratic Soliton Compression in Waveguide Structures
Guo, H., PhD Student, Department of Photonics Engineering
Bache, M., Main Supervisor
Zeng, X., Supervisor
Zhou, B., Supervisor
Laegsgaard, J., Examiner
Phillips, C., Examiner
Gallo, K., Examiner
Technical University of Denmark
01/07/2011 → 26/09/2014
Award relations: Cascaded Quadratic Soliton Compression in Waveguide Structures
Project: PhD

Femto-midIR: Femtosecond few-cycle mid-infrared laser pulses
Bache, M., Project Manager, Department of Photonics Engineering
Zhou, B., Project Participant, Department of Photonics Engineering
Wise, Dept. of Applied & Engineering Physics, Cornell University, USA, F. W., Project Participant
Zeng, X., Project Participant, Department of Photonics Engineering
Project ID: 70694
Forskningsrådene - Andre: DKK5,757,437.00
01/06/2012 → 31/05/2015
Award relations: Femto-midIR: Femtosecond few-cycle mid-infrared laser pulses
Project: Research

Activities:
Generating ultra-short energetic pulses with cascaded soliton compression in lithium niobate crystals
Period: 1 Jan 2010 → …
Binbin Zhou (Speaker)
Department of Photonics Engineering
Fiber Sensors & Supercontinuum

Description
By launching energetic femtosecond pulses in a lithium niobate crystal, the phase mismatched second-harmonic generation process compresses the 50 fs input pulse at 1250 nm to 30 fs through a soliton effect.
Note: Paper ID 3371

Related external organisation
Unknown Organization
Activity: Talks and presentations › Conference presentations