(United States)

Efficient generation of cascaded four-wave mixing processes using a concatenation of dispersion-optimized nonlinear optical fibers is reported. Two tunable lasers (with frequency spacing ranging from 100GHz to 1THz) are combined to create a sinusoidal beat note, which is subsequently adiabatically compressed to generate a train of pulses with a width of several tens of femtoseconds and exhibiting high peak power (>1kW). Adiabatic compression is optimized by adjusting the fiber dispersion and input power. Subsequent propagation of the generated pulses through a dispersion flattened fiber results in broadband and equalized optical frequency comb generation. The measured optical frequency comb (with 300 GHz spacing) spans over 900 nm centered at 1560 nm. We analyze linewidth broadening as a function of several parameters: comb mode spacing, power, and dispersion. The nonlinear Schrodinger equation was numerically solved using a split Step algorithm and considering the experimental parameters, and we found very good agreement with the experimental results. Numerical simulations give guidelines to optimize the bandwidth, the flatness and the noise performance of the generated optical frequency comb as a function of the mode spacing, power, and fiber dispersion. In summary, we investigated in detail octave spanning optical frequency combs with an essentially arbitrary mode spacing that are generated by a cascade of four-wave mixing processes in dispersion optimized fibers. The mode spacings accessible with the proposed approach (>100GHz) are not accessible with state-of-the-art comb technology (based on mode-locked lasers) that are limited to separations < 5GHz.

7582-10, Session 3

Two-stage bulk compressor for the generation of 10-MW few-cycle pulses at MHz repetition rates

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220-nJ, 42-fs, 5.25-MHz pulses from a long-cavity Ti:Sapphire chirped pulse oscillator were spectrally broadened by nonlinear propagation in a Sapphire plate. The dispersion was subsequently compensated with dispersive mirrors. After far-field spatial filtering the compressor delivered 80-nJ, sub-15-fs pulses at 5.25 MHz.

A novel 500-nJ Oscillator has been developed to demonstrate the energy-scaling potential of this compression scheme, calculations indicating the feasibility of 200-nJ, sub 15-fs pulse generation. A second compression stage has been designed in order to reduce the pulse duration down to <10fs.

7582-11, Session 3

Modal coupling of supercontinuum generation in a tapered fiber

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Generation of broadband supercontinuum has many practical applications, and a certain length of submicrometer-diameter wires are needed to generate a wideband spectra from tapered fiber in the literature. However, long submicrometer wires are impossible to produce by use of simple tapering techniques, and these longer tapered fibers are fragile for high-power laser experiment. In this work, by properly tuning the center wavelength of femtosecond Ti:sapphire laser, relatively wide spectra from above 400 nm to below 1200 nm can be generated. The excited tapered fiber is 1 micrometer in diameter and only 1-cm long. After connecting two optical fiber tapers by fusing standard fibers on either side, we can lower down the exciting wavelength for supercontinuum generation. Additionally, numerical simulation is performed to study the nonlinear effects and fiber loss inside the tapered fiber. Spatial modal coupling effect is investigated numerically in order to analyze the spectral response of supercontinuum generation phenomenon.

7582-12, Session 3

Tunable broadband optical generation via giant Rabi shifting in micro-plasmas

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Broadband, tunable radiation in optical frequency range is generated in atmospheric gases. Giant, self-induced Rabi-shifted radiation is observed when a probe laser interacts with a weakly ionized, cooling atomic or molecular micro-plasma. A micro-plasma is created in a gas at atmospheric pressure by an intense femtosecond laser pulse. A picosecond probe pulse then interacts with this plasma channel, producing red- and blue-shifted sidebands. These coherent sidebands arise from the self-action of the probe beam via induced Rabi oscillation between coupled of excited states populated in the process of the plasma cooling evolution. Maximum shifting of side bands > 90 meV from the carrier frequency is observed resulting in an effective bandwidth of 200 meV. The sidebands are controlled by the intensity and shape of the probe pulse with amplitude and shift predicted by a generalized Rabi-shifting model. Moreover, the characteristic fringe pattern exhibited in the sidebands indicates a high degree of coherence. The coherent broadband light can be shaped and manipulated for applications such as control experiments and short pulse generation.

7582-13, Session 4

LiInSe2 nanosecond optical parametric oscillator tunable from 4.7 to 8.7 µm

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Although room temperature lasing has been reported up to ~5 µm, practical solid-state-lasers have an upper limit of ~3 µm. The spectral range above 3 µm in the mid-IR can be continuously covered by nonlinear frequency down-conversion using powerful (femtosecond to nanosecond) laser sources in the near-IR. While oxide crystals start to absorb above 4 µm, at practical pump intensities, most of the chalcogenide mid-IR nonlinear crystals will suffer two-photon absorption (TPA) at 1064 nm because of their low band-gap. Being free of limitations related to spectral acceptance or higher order dispersion and nonlinear effects, nanosecond optical parametric oscillators (OPOs) possess the best potential for achieving high power / energy. Operation of such OPOs, pumped near 1 µm, at idler wavelengths exceeding 4.4 µm, apart from the archive Ag3AsS3, has been demonstrated only with AgGaS2 (AGS). The interest in LiInSe2 (LISe) whose band-gap is large enough (2.86 eV), is motivated by its superior thermo-mechanical properties: isotropic expansion, thermal conductivity ~5 Wm-1K-1 (~3 times higher than in AGS), and smaller thermo-optic coefficients as well as higher damage threshold than AGS. In this work we report broadband operation of a 1064 nm pumped LISe OPO, tunable from 4.7 to 8.7 µm. Pumping at a repetition rate of 100 Hz and the absence of thermal effects allowed to increase the average power by more than an order of magnitude at wavelengths much longer than in the initial demonstration (3.3-3.78 µm). We report also extensive damage studies of LISe with the same pump source.

7582-14, Session 4

3.2-watt single-frequency CW source at 790 nm based on frequency conversion of a fiber laser

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Many promising demonstrations of single pass frequency doubling of fiber lasers have recently been performed, providing a simple, robust method to generate multi-Watt power output in the green and near-infrared. However such sources are limited to operating wavelengths within the relatively narrow gain bandwidths defined by the fiber dopants. For many applications in spectroscopy and atomic physics, a fiber-laser based source with similar output providing continuous tunability in the 700 nm to 1000nm range would be highly attractive to provide a source of comparable capability to single frequency Ti: Sapphire lasers. We have demonstrated 3.2 Watts of single frequency output by single-pass frequency-doubling of a fiber-laser-pumped CW OPO. 25% efficient frequency doubling was demonstrated by focusing 13 Watts of 1580nm input into a 50mm length MgO:PPLN crystal. The single frequency 1580nm input was generated as the resonant signal wavelength in a CW OPO based on MgO:PPLN. The OPO was pumped by a 30 Watt Ytterbium-doped fiber laser operating at 1064nm, with a spectral bandwidth of ~0.6nm. 300mW of output at 980nm was also generated by the same technique using MgO:PPLN crystals of different poling periods.

7582-15, Session 4

Synchronously pumped at 1064 nm OPO based on CdSiP2 for generation of high-power picosecond pulses in the mid-infrared near 6.4 µm

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Synchronously pumped optical parametric oscillators (SPOPOs) are potentially efficient sources of high repetition rate (~100 MHz) ultrashort pulses at wavelengths not available from conventional mode-locked lasers. The use of chalcogenide crystals, transparent in the mid-IR, has been reported only in a few cases but preserving the high repetition rate was possible only by cascaded operation of two SPOPOs.

The only chalcogenide crystal directly pumped at 1064 nm, remains AgGaS2 (AGS), but it exhibits poor thermo-mechanical characteristics like thermal conductivity, anisotropy of thermal expansion and damage threshold. In all cases the pump systems were pulsed (either by using a modulator, Q-switching or pulsed excitation).

The recently discovered CdSiP2 (CSP), is a negative uniaxial chalcopyrite that allows 1064 nm pumping without two-photon-absorption and possesses a useful transparency up to 6.5 µm. It outperforms all other mid-IR nonlinear materials that can be pumped near 1 µm in almost every aspect and is the only material which allows non-critical phase-matching, with a maximum effective nonlinearity of 84.5 pm/V.

In the present work CSP is employed in a picosecond SPOPO pumped at 1064 nm, to produce quasi-steady-state idler pulses near 6.4 µm with an energy as high as 2.8 µJ at 100 MHz. The train of 2 µs long macropulses, each consisting of 200 (picosecond) pulses, follows at a repetition rate of 25 Hz. This corresponds to an average power of 14 mW. The pump depletion (conversion efficiency) exceeds 40%. Without intracavity etalon, the 12.6 ps long mid-IR micropulses have a spectral width of 240 GHz.

7582-16, Session 4

A high peak power compact eye-safe optical parametric oscillator system

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We report the operation of an optical parametric oscillator (OPO) at 1574 nm using KTP, with output peak power of more than 5 megawatts, output pulse energy of up to 30 mJ per pulse, and pulse width of less than 6 nanoseconds at full width half maximum (FWHM). The OPO was pumped by a diode pumped Nd:YAG Q-switched laser, with pump energy of about 95 mJ and pulse width of approximately 7 ns. The conversion efficiency from 1064 nm Nd:YAG laser to OPO output at 1574 nm is more than 30%. The whole system including the Nd:YAG laser was compactly packed inside a case measuring 15" x 9" x 5.3". The complete Nd:YAG/OPO system was tested over an operating temperature range of ... C to +35 C and a storage temperature range of -40 C to +50 C ... significant power or performance variations, which makes it suit... field operation.

7582-17, Session 4

Excitation of individual Raman Stokes li... of up-to 10th order using rectangular sh... optical pulses at 530nm

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We demonstrated the selective excitation of individual Raman S... lines of up-to 10th order pumped by 100ns, rectangular-shaped pulses at 530nm. The rectangular shaped optical pulses were g... through frequency-doubling of an adaptively pulse shaped fiber... operating at 1060nm. This form of pulse shape is optimal for Ra... conversion processes since all parts of the pulse experience th... Raman gain. As a result, it is possible for a single pulse to trans... of its energy through sequential Raman frequency shifts to succ... order Stokes lines along a length of fiber - yielding a pulse at a s... selected Raman-order at the fiber output. A high extinction ratio... the selected line and all other Raman-orders can be achieved b... appropriate choice of the input peak power. We have achieved ... ratios as high as 15 dB between primary and adjacent Stokes li... this approach in a 1 km long SMF-28 fiber and launched pump ... up to 5 W at 100 kHz repetition frequency, obtaining wavelength... output at discrete wavelengths in the range 530-780 nm. Sourc... on such an approach have potential applications in the areas of... processing and bio-medical science amongst others.

7582-18, Session 5

Tunable nonlinear-optical devices for las... spectroscopic sensing

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Generating coherent light via nonlinear optics drives many of ou... spectroscopic sensing applications [1]. For instance, narrowbar... pulsed optical parametric oscillators (OPOs) controlled by inject... seeding are used extensively for cavity-ringdown and coherent-... spectroscopies [1-4]. In a high-precision OPO-based spectrosc... system [5-7], we employ a long-pulse (>25 ns) pump laser with ... heterodyne diagnostics to log instantaneous frequency and chi... pulse-by-pulse basis. In other work, we use photorefractive me... narrowband wavelength control of tunable diode lasers and pul... [8-10]. Prospective applications of pulsed OPOs include mid-inf... sensing of explosives or post-blast residues and coherent-Ram... spectroscopic screening, e.g., of pathogens.

[1] B.J.Orr, Y.He, R.T.White, "Spectroscopic Applications of Tun...