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Focus issue introduction: Nonlinear optics 2013

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Abstract: Nonlinear Optics has continued to develop over the last few years at an extremely fast pace, with significant advances being reported in nonlinear optical metamaterials, optical signal processing, quantum optics, nonlinear optics at subwavelength scale, and biophotonics. These exciting new developments have generated significant potential for a broad spectrum of technological applications in which nonlinear-optical processes play a central role.

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Impressive progress in nanofabrication techniques has led to unprecedented control of the materials and geometrical design parameters of metallic and dielectric nanostructures. These advances have facilitated important breakthroughs in relatively new areas of nonlinear optics, namely nonlinear-optical metamaterials and nonlinear plasmonics, and have generated a renewed drive towards increased device integration at the chip scale. We have witnessed equally exciting developments in more traditional areas of nonlinear optics as well, including new techniques for spectral and temporal optical pulse shaping, wavelength mixing and nonlinear-frequency generation, multi-wavelength broadband optical sources and frequency-comb generators, ultra-compact lasers, and nonlinear-optical switching.

This year’s Focus Issue consists of contributions from the authors of papers that have been accepted for presentation at this year’s Nonlinear Optics (NLO) 2013 conference held at The Fairmont Orchid, Kohala Coast, Hawaii, USA on 21-26 July 2013.

We start this feature with an exposé by Elsa Garmire, on how nonlinear optics is relevant for our daily life [1]. Much of the contemporary nonlinear optics research of today is devoted to optical frequency combs, and in this feature this is covered by three papers [2–4]. In [2] a mid-IR comb around 4300 nm is reported, with state-of-the-art power density. An analysis of the timing jitter of a Kerr-comb is reported in [3], and [4] provides a theoretical analysis of cross-phase modulation-induced comb.

Fiber optic nonlinearities [5–9] remain another important area, and nonlinearities in multimode fibers receive increasing interest. In [5,6] the modal dynamics of few-mode fibers are in focus, and in [7] a multimode junction is reported for mode locking. A theoretical analysis of Raman-induced quantum noise in fiber-based parametric amplifiers is given in [8], and [9] deals with the problem of carrier depletion in an active microstructured waveguide.

Nonlinear optical processes in which the interacting waves are surface plasmons are investigated in [10–12]. In [10] a three-wave mixing process is analyzed in which a photon and a surface plasmon are annihilated simultaneously to generate a photon, whose frequency is equal to the sum of the frequencies of the two incoming waves; the enhancement of transverse-magnetic second-harmonic generation (SHG) due to the excitation of surface plasmons is studied in [11]; whereas in [12], the enhancement of nonlinear optical effects due to the excitation of optical Tamm plasmon-polaritons in one-dimensional photonic crystal structures is reported.

A significant number of papers are devoted to harmonic generation and wavelength conversion [13–19]. In [13], parametric down-conversion from near-IR to mid IR (2-5 micrometers) is demonstrated. A periodically poled Lithium Niobate (PPLN) waveguide is used in [14], via SHG, to broadcast channels in the communication C-band around 1550 nm. A PPLN waveguide is also used in [15], as two tunable parametric-oscillator sources in the mid-IR range, which then are difference-frequency mixed to generate light in the 8-10 micrometer region. SHG generated from gold nanoparticles is demonstrated in [16], and in [17] by using Strontium Barium Niobate. The latter is used to obtain information of domain patterns and structures. The spectral properties of an aperiodic PPLN-based frequency doubler are investigated in [18]. In [19], a high-power microchip Nd:YAG laser is used to demonstrate

second and up to ninth-harmonic generation in various nonlinear media, and the first 118 nm UV generation is accomplished.

The role of optical nonlinearities in ultrafast laser sources is explored [20,21]. In [20], Kerr-lens modelocking of a vertical external-cavity surface-emitting laser (VECSEL) is analyzed and experimentally demonstrated, while in [20], the chaotic regime of chirped-pulse oscillators having significant third-order dispersion is investigated experimentally. In this second case, the chaotic regime is found to have long-term stability and is accompanied by a characteristic spectral shape and may be recognized by using special filters and by second-harmonic or two-photon absorption detectors. A new development in Raman spectroscopy is being pursued with the goal of suppressing the nonresonant background signal in coherent anti-Stokes Raman scattering (CARS) spectroscopy by the investigation of the relationship between four-wave mixing (FWM) and cascaded second-order wavelength conversion [22]. Finally special materials are also being explored for their roles in the control of light and nonlinear-optical processes [23,24]. In [23], spatial light modulators are used to implement fully randomized nondiffracting beams of variable structural size, to control the modulation length (photonic grain size) as well as the depth (disorder strength) of a random potential induced within a photorefractive crystal; Anderson localization is demonstrated and analyzed in the ensuing optically induced randomized potential. In [24], slabs of materials with near-zero permittivity display greatly enhanced nonlinear optical processes. The field enhancement arises from the continuity of the normal component of the displacement field relative to the surface, which in turn, drastically enhances nonlinear optical processes such as second- and third-harmonic generation.

To summarize, the set of topics in this year's Focus Issue reflect the most recent advances in the field of nonlinear optics. We believe that these current advances will stimulate future research that will further knowledge and understanding, as well as future breakthroughs in nonlinear optical phenomena.

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