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Editorial

Nonlinear Fibre-Based Photonic Technologies

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The field of photonics is one of the fastest growing research areas in modern science, having a direct and almost immediate impact on the development of new technologies in fields ranging from telecommunications to the biosciences. Photonics, effectively an interdisciplinary field at the interface of physics, material science, and engineering, is very strongly linked to the field of nonlinear science. Though nonlinear physics has a rather long history, beginning with the works of Newton and Huygens, science and technologies of the 19th and most of the 20th century have been dominated by linear mathematical models and linear physical phenomena. Over the last decades, there has been growing recognition of physical systems in which nonlinearity introduces a rich variety of fundamentally new properties that can never be observed in linear models or implemented in linear devices.

From a practical standpoint, nonlinearity adds to the difficulty of understanding and predicting the system properties. However, with suitable design and control, it is possible to master and exploit nonlinear physical interactions and processes to yield tremendous benefits. The understanding and mastering of nonlinear optical systems has the potential to enable a new generation of engineering concepts.

Although silica exhibits much lower optical nonlinearity than crystals of such materials as lithium niobate or beta barium borate, silica fibres can provide a comparatively enormous interaction length (more than 1 km) and tight confinement (less than 2 μm^2 mode area), which offers the long-recognized possibility of using optical fibres for nonlinear interactions. In high-speed optical communications such nonlinear effects generally degrade the integrity of the transmitted signal, but the same effects can be used to realize a variety of optical functions that have practical applications in the field of light-wave technology. Nonlinear processes that have been exploited in demonstrations and applications include stimulated Brillouin and Raman scattering, as well as aspects of the Kerr effect variously called self-phase modulation, cross-phase modulation, four-photon (four-wave) mixing, cross-polarization modulation, and parametric gain. Important examples of established and new emerging nonlinear fibre-based photonic technologies essentially relying on nonlinear phenomena include all-optical signal processing and regeneration in ultrafast telecommunications, optical gating, switching and frequency conversion, optical waveform generation and pulse shaping, optical parametric amplification, Raman amplifiers and lasers, high-power pulsed and continuous-wave lasers, broadband and supercontinuum (SC) light sources, and other applications. This is the area which is addressed in this special issue: the development of novel photonic approaches, techniques, systems, and devices exploiting nonlinear effects in optical fibres.

The use of nonlinear photonic technologies for managing signals in the all-optical domain has enabled applications in such diverse areas as optical telecommunications, metrology, optical sensing, microwave engineering, image processing, and optical computing, to name a few. Advantages of processing the information in the all-optical domain include the large available bandwidth and the parallelism intrinsic to the optical approach, which translate into high processing speeds. Although photonic technologies already play

an important role in the context of high-speed communications networks, their scope is, at present, largely restricted to the transport layer rather than being used for complex routing, processing and switching tasks which are performed in the electronic domain after an optical to electrical conversion which is costly and reduces system speed and latency. Today, electronic techniques of signal manipulation are advanced compared to all-optical processing devices which are still at the research stage rather than under commercial development. Hence, considerable knowledge still has to be accumulated, and new methodologies need to be explored before a true breakthrough can be achieved in this field, allowing the range of functions and operations currently accomplished electronically to be performed in the optical domain. Furthermore, by using optical rather than electronic processing, additional functionality may be possible.

Several textbooks exist that cover various aspects of nonlinear fibre-based optical technology. There are also several tutorial and invited papers devoted to the topic. The purpose of this special issue is to provide a flavor of the state-of-the-art, recent developments and trends in the field from both theoretical and experimental perspectives. The issue comprises eight papers submitted by distinguished researchers and their colleagues in their respective fields, who were invited to contribute with an overview of the latest advances in their own research area.

J. Azaña et al. review recent work on the design and fabrication of all-fibre (long-period grating-based) devices for optical pulse shaping, particularly picosecond and subpicosecond flat-top pulse generation, and their application in nonlinear optical telecommunication data processing, particularly switching (demultiplexing) of optical time-division multiplexed data signals in fibre-optic telecommunication links operating at bit rates up to 640 Gbit/s. S. Boscolo et al. review recent theoretical and experimental progress on the use of fibre nonlinearities for the generation and shaping of optical pulses and the applications of advanced pulse shapes in all-optical signal processing, with a focus on ultrahigh repetition rate pulse sources, parabolic and triangular pulse generation, coherent SC sources, and applications such as optical regeneration, linear distortion compensation, signal postprocessing in optical communication systems, optical signal doubling, and frequency conversion. I. O. Zolotovskii et al. report theoretical predictions of the generation of stable self-similar frequency-modulated optical pulses in a length-inhomogeneous fibre gain medium, which enables subpicosecond pulse amplification up to the nanojoule energies. O. Vanvincq et al. review recent theoretical and experimental work on manipulating the Raman gain-induced soliton self-frequency shift dynamics in special solid-core photonic band-gap fibres and its impact on SC generation, with the results showing efficient tailoring of the SC spectral extension as well as strong noise reduction at the SC long-wavelength edge. K. Krupa et al. discuss nonlinear frequency conversion based on Bragg-scattering four-wave mixing in highly nonlinear fibre using a novel cost-effective and partially coherent pumping scheme, with the experimental results demonstrating efficient and tunable conversion despite the large bandwidth and statistical independence of the pumps. E. Shlizerman et al. use the method of proper orthogonal decomposition (POD) to demonstrate that low-dimensional models generated by a POD analysis provide a good framework for characterizing the underlying dynamics and bifurcation behavior in mode-locked laser systems, and determining the optimal working regime for the laser (maximal suppression of the multipulsing instability). A. Komarov et al. present results of their research on multipulse operation of passive mode-locked fibre lasers, addressing in particular the formation of bound steady states of interacting solitons in the presence of different nonlinear loss shaping mechanisms, the possibility of information coding in soliton trains with various bounds between neighboring pulses, and the formation of bound-enhancing powerful soliton wings as a result of dispersive wave emission due to lumped nonlinear losses. Finally, L. K. Oxenløwe et al. review recent experimental advances in nonlinear optical signal processing for Ethernet applications, with a focus on 1.28 Tb/s data generation and demultiplexing.

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