Introduction to the Feature Section on Optical Spatial Solitons

AMONG THE most striking and physically appealing manifestations of optical nonlinearity is the temporal or/and spatial self-localization of light, i.e., the formation of optical solitons being the result of a balance between linear dispersing, such as diffraction or dispersion, and nonlinear phase modulation effects. This Feature Section focuses on spatial solitons, or in a stricter sense, on spatially solitary waves which propagate without spreading as self-confined or self-trapped beams, i.e., the usually inevitable diffraction is arrested. Although this self trapping was reported in the early days of nonlinear optics by Chiao and co-workers in 1964, the study of temporal optical solitons in silica fibers, proposed in 1974 by Hasegawa and experimentally verified by Mollenauer in 1981, attracted much more interest, at least until the 1990s. In particular, this was due to the fact that, on the one hand, low-loss fibers allowed for interaction lengths of tens of kilometers and thus soliton formation, even for the extremely weak Kerr nonlinearity of silica, at very moderate powers. On the other hand, temporal solitons have an enormous potential as carriers of information in long-haul communications.

Spatial solitons, on the contrary, propagate in bulk media or film waveguides, thus requiring much stronger nonlinearities and/or optical powers for the restricted lengths available. But compared to their temporal counterparts, they are frequently considered physically more appealing because of: 1) their potential higher dimensionality (two dimensional in bulk media); 2) the diversity of nonlinear effects (off-resonant quadratic and cubic (Kerr) nonlinearity, photorefractive effects, reorientational nonlinearity in liquid crystals, carrier-induced nonlinearities in semiconductors, etc.) that they rely on; and 3) the different settings (continuous or discrete media, cavities) they can exist in.

The selection of contributions for this Feature Section was primarily based on these arguments. Thus, the surprisingly low power levels at which spatial solitons can form in photorefractive and liquid crystal materials will be shown. Moreover, it is interesting to understand soliton formation if the nonlinearity features a response encompassing saturation, nonlocality, strong polarization dependence, anisotropy, and threshold effects as it appears in liquid crystals.

It will be demonstrated that quadratic nonlinearities—usually employed for frequency conversion and parametric amplification—provide an interesting environment for symbiotic, i.e., dichromatic, soliton formation exhibiting many unique features.

Last, but not least, two contributions will focus on spatial soliton formation in transversally or longitudinally structured media as waveguide arrays (discrete solitons) or high-finesse cavities (cavity solitons), respectively. Both types of solitons have attracted a great deal of attention during the past several years. The peculiar features of discrete solitons illustrate how discreteness per se and nonlinearity may lead to an altogether new physical behavior. Cavity solitons are typical representatives of dissipative solitons and thus differ in various aspects from all other types discussed above, e.g., they do not form soliton families, but are completely determined by the parameters of the physical system.

Although in the near future, and in contrast to their temporal complements in fibers, spatial solitons are far from being applied in optical devices or systems, they possess a promising potential for all-optical signal routing, processing, and storage. In this respect, their stability, collision behavior, and reconfiguration is of particular interest and will be addressed in detail in the contributions to this Feature Section.

The authors of the invited papers have pioneered the field of spatial solitons in previous years. A primary goal was to shed light on the fundamentals of spatial soliton physics from both the experimental and the theoretical perspective.

It is hoped that this collection of papers will stimulate further work in spatial soliton physics and will attract even more young scientists to this field.

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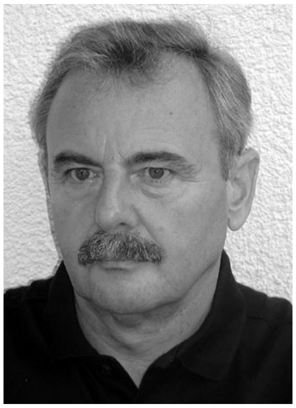

Falk Lederer received the Ph.D. degrees (Dr.rer.nat. and Dr.rer.nat.habil.) in 1977 and 1986, respectively, from the Friedrich-Schiller-Universitat, Jena, Germany. His work focused on scattering of electromagnetic fields in inhomogeneous media and nonlinear guided-wave phenomena, respectively.

He has been involved in integrated optics research since 1978, contributing to the understanding of guided-wave propagation in discontinuous waveguides. In 1980, he began work on nonlinear guided-wave optics. He was one of the pioneers in the theory and numerical modeling of strongly nonlinear guided waves, including several contributions to nonlinear wave propagation in one-dimensional photonic crystals. After working for several months during 1990 and 1991 as Guest Professor at the Université Paris-Sud, Orsay, France, he was appointed to the position of Professor of Solid-State Optics at the University of Jena, and became head of the Photonics Group in 1992. At that time, he became involved in soliton physics comprising discrete solitons, cavity solitons, and dissipative solitons in transmission lines. Important contributions of his group have included the prediction of quadratic cavity, Bragg, and discrete solitons, as well as the first experimental demonstration of photonic Bloch oscillations and anomalous refraction and diffraction in waveguide arrays. Currently, he is grant holder of several German research projects and is coordinator of the European research project "ROSA" dealing with all-optical signal processing in quadratic waveguide arrays.

Dr. Lederer is a member of the Optical Society of America and has been involved as Program Chair and General Co-Chair in the Topical Meetings on Nonlinear Guided Wave Phenomena. He was awarded the Ernst-Abbé Medal for his dissertation research.