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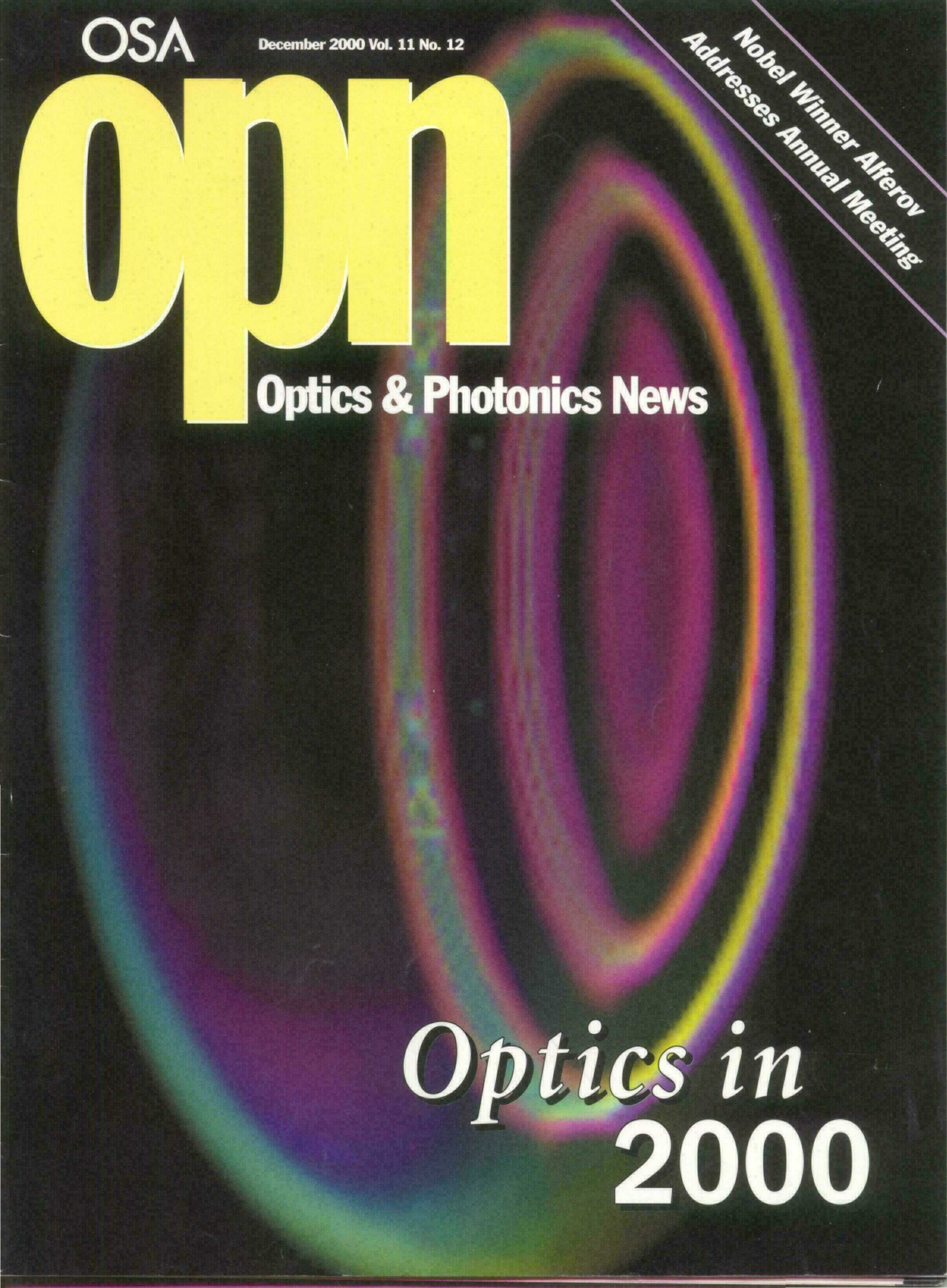
Nobel Winner Alferov Addresses Annual Meeting



Optics in 2000

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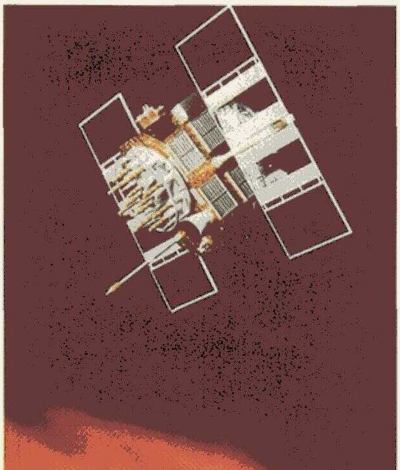
Physics Department, Duke University



Examples of the most significant recent research in optics and engineering are published each year in the December issue of OPN. This issue is comprised of short descriptions of the "hottest" topics in current optics research. Selection criteria applied to submissions are as follows:

- **the accomplishments described must have been published in a refereed journal in the year prior to publication in OPN;**
- **the work must be illustrated in a clear, concise manner, comprehensible to the at-large optics community;**
- **the topical area as a whole must be described, and the importance of the research must be detailed.**

There are no requirements in the selection process for inclusion of specific topical areas. When a large number of submissions are received for a specific area, this is taken as evidence that the topic has been fertile ground for activity and research over the course of the preceding year. OPN strives to ensure that engineering, science, and technology are all represented. The number of papers accepted overall is limited by space.

With 33 papers accepted, 2000 has proven to be another successful year. OPN and OSA would like to thank the hundreds of researchers from all over the world who submitted summaries to Optics in 2000.

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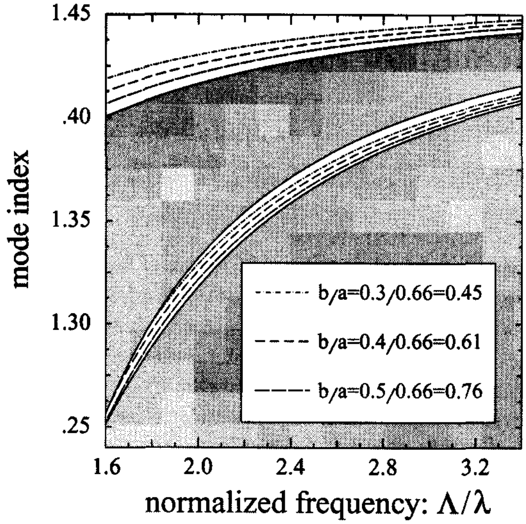

Guiding Mechanism in Photonic Crystal Fibers Figure 1. Modal dispersion curve for some donor-guided modes for three different defect radii. In all cases, the air-filling fraction of the PCF structure is $f = (2\pi/\sqrt{3})(a/\Lambda)^2$, where Λ denotes the pitch between consecutive holes.

ing mechanism is attributed to the inhibition of transverse radiation produced by the forbidden band of the photonic-crystal cladding. This mechanism is referred to as photonic bandgap guidance (PBG).

We accomplished an in-depth study of the guiding mechanism of PCFs. We introduced an irregularity in a perfectly periodic triangular structure of circular air holes (of radius a) by decreasing or increasing the size of the central hole (of radius b). The sign of the local variation of the refractive index determines the character of the defect, which acts as a donor impurity in an electron crystal for a positive index variation ($b < a$) and as an acceptor impurity for a negative index variation ($b > a$). For an acceptor defect ($b > a$), the localization mechanism causes a state to leave the upper conduction band and to enter the forbidden band located just below, as in a honeycomb PCF.

Alternatively, if we decrease the size of the defect ($b < a$), guided modes are promoted into the forbidden bands from neighboring conduction bands. However, unlike in the acceptor defect case, these guided modes originate in the immediately lower conduction bands. We have recognized several configurations in which guided modes appear simultaneously in both the upper and the lower forbidden bands of the triangular photonic crystal,[5] as shown in Fig. 1.

In light of the existence of these donor configurations that simultaneously present intraband and nonintraband guided modes, it seems unnatural to interpret PCF guidance by invoking two different physical principles to occur in the same structure at the same time. This is especially true when these guided modes are simultaneously promoted into the upper and the lower forbidden bands by an identical mechanism. In view of these results, we conclude that the guiding mechanism in PCFs is always provided by a unique phenomenon of multiple interference by the periodic structure, which does not distinguish between upper and lower forbidden band guidance.

Acknowledgment

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Nonlinear Localized Modes In Photonic Crystal Waveguides

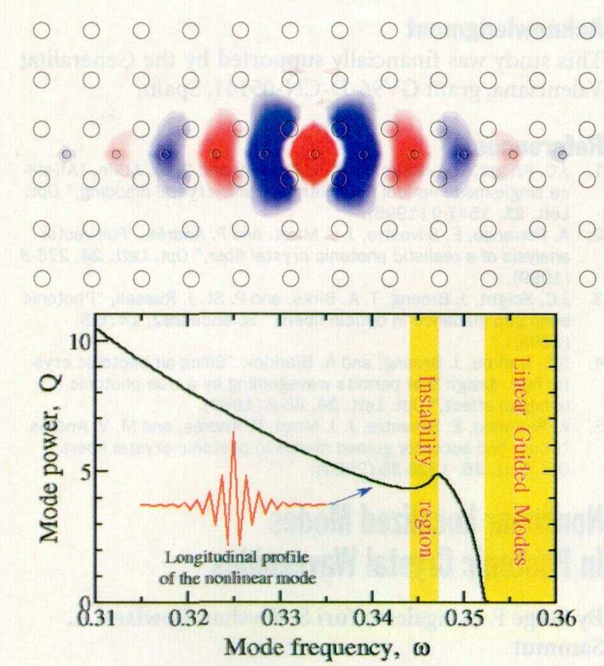
By Serge F. Mingaleev, Yuri S. Kivshar, Rowland A. Sammut

Photonic technology, by use of light instead of relatively slow electrons as the information carrier, is increasingly being proposed as a replacement for electronics in communication and information management systems. Among the most promising optical materials for achieving this goal are *photonic bandgap crystals,* in which periodic modulation of a dielectric constant controllably prohibits electromagnetic propagation throughout a specified frequency band.[1] Recent dramatic success in fabrication of photonic crystals with a bandgap at optical wavelengths[2] renders investigation of their properties a central problem.

Of special interest among the devices for microscopic light manipulation which have been proposed on the basis of photonic bandgap materials are carefully engineered line defects which could act as *waveguides* inside all-optical microchips. Very recently, Tokushima *et al.*[3] demonstrated highly efficient propagation of 1.55 μm wavelength light through a 120° sharply bent waveguide formed in a triangular lattice two-dimensional (2D) photonic crystal.

But to employ the high-tech potential of photonic crystal waveguides, it is important to achieve a dynamical tunability of their properties. This idea can be realized by changing the light intensity in the case of photonic crystals composed of a material with a *nonlinear response*[4] or photonic crystals with embedded *nonlinear impurities.* In this case the high-intensity light can propagate through the waveguide in the form of *nonlinear localized mode.*[5]

For instance, let us consider a 2D photonic crystal created by a square lattice of parallel, infinitely long dielectric rods in air, with a waveguide created by inserting an additional row of rods (the top view of such a structure is depicted at the top of Fig. 1). If the rods are fabricated from a Kerr-type nonlinear material, the electromagnetic field can be localized in the *waveguide direction,* totally due to the nonlinearity. At the top of Fig. 1 we plot the electric field E of the corresponding nonlin-



Nonlinear Localized Modes Figure 1. Electric field distribution of the nonlinear localized mode excited in the photonic crystal waveguide (top) and the dependence of the mode power on the frequency (bottom). The mode is unstable in the shaded region due to the effctive nonlocal interaction between waveguide rods.

ear localized mode. The most important physical characteristic of such a mode is its power Q (which is closely related to the mode energy) depicted at the bottom of Fig. 1 as a function of the mode frequency (all the frequencies in Fig. 1 lie inside the bandgap). Importantly, *stability* of such a localized mode is determined by the slope of the dependence Q(ω): the mode is stable when this slope is negative and unstable otherwise. One can see that there is an interval of the mode power Q where two stable nonlinear localized modes of different shape and frequency can coexist. As we show in Ref. 5 this *bistability phenomenon* occurs as a direct manifestation of the nonlocality of the effective (linear and nonlinear) interaction between the defect rods which form the waveguide.

Acknowledgments
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Propagating Fields

Modulation Instability of Spatially Incoherent Light Beams and Pattern Formation in Incoherent Wave Systems

By Detlef Kip, Marin Soljacic, Mordechai Segev, Evgenia Eugenieva, and Demetrios N. Christodoulides

Modulation instability (MI) is a universal process that appears in most nonlinear wave systems in nature. Because of MI, small amplitude and phase perturbations (from noise) grow rapidly under the combined effects of nonlinearity and diffraction (or dispersion, in the temporal domain). As a result, a broad optical beam (or a quasi-cw pulse) disintegrates during propagation, leading to filamentation or to break up into pulse trains. MI is generally considered as a precursor to solitons, because the filaments (or pulse trains) that emerge from the MI process are actually trains of almost ideal solitons. Over the years, MI has been systematically investigated in connection with numerous nonlinear processes. Yet, it was always believed that MI is inherently a coherent process and thus can appear only in nonlinear systems with a perfect degree of coherence. Earlier this year, however, we theoretically demonstrated[1] that MI can also exist in relation with partially incoherent wave packets or beams.

MI in nonlinear incoherent environments reveals several new features that have no counterpart in coherent wave systems. The most important new features are as follows. (1) The existence of a sharp threshold for nonlinear index change, below which perturbations (noise) on top of a uniform input beam decay and above which a quasi-periodic pattern forms. (2) The threshold depends on the coherence properties of the input beam: the threshold increases with decreasing correlation distance (decreasing spatial coherence). The intuition behind these features and the fundamental difference between MI in coherent and in incoherent wave systems can be understood in the following manner. A small periodic perturbation on a coherent beam remains periodic and maintains its modulation depth during linear diffraction. Thus, any self-focusing nonlinearity, no matter how small, increases the modulation depth and leads to instability, which is why coherent MI has no threshold. On the other hand, a perturbation on an incoherent beam diminishes its modulation depth during linear diffraction. The nonlinearity has to overcome this washout effect to gain instability, which is why incoherent MI has a threshold: it occurs only if the nonlinearity is strong enough to overcome the diffusive washout caused by diffraction. Furthermore, the more incoherent the beam, the higher the MI threshold.

Recently, we made the first experimental observation of incoherent MI.[2] We showed that, in a nonlinear partially coherent system (a nonlinear system of weakly correlated particles), patterns can form spontaneously (from noise) when the nonlinearity exceeds the threshold, and a periodic train of one-dimensional filaments