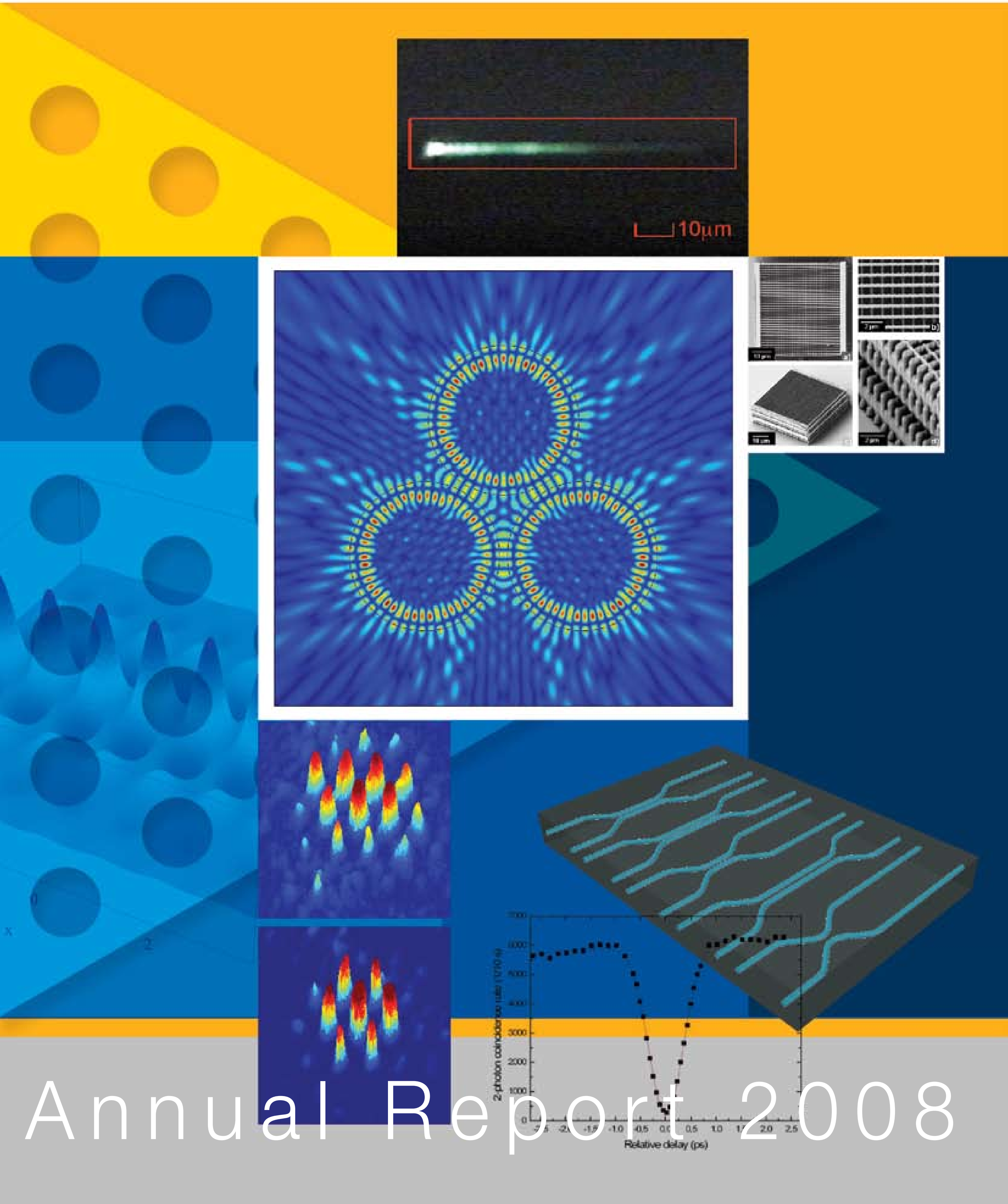
CUDOS

The Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS)



Annual Report 2008

CI Short biography

Yuri Kivshar received his PhD in 1984 from the USSR Academy of Science and was at the Institute for Low Temperature Physics and Engineering (Kharkov, Ukraine). From 1988 to 1993 he worked at different research centers in USA, France, Spain, and Germany. In 1993 he accepted an appointment at the Research School of Physical Sciences and Engineering of the Australian National University where presently he is Professor and Head of the Nonlinear Physics Center. Yuri Kivshar published more than 350 research papers in peer-reviewed journals including more than 15 book chapters and review articles and 2 books published in 2003 (Academic Press) and 2004 (Springer-Verlag), both translated to Russian. His interests include nonlinear guided waves, optical solitons, nonlinear atom optics, photonic crystals, and stability of nonlinear waves. Professor Yuri Kivshar was a recipient of the Medal and Award of the Ukrainian Academy of Science (1989), the International Pnevmatikos Prize in Nonlinear Physics (1995), the Pawsey Medal of the Australian Academy of Science (1998). In 1999 he was appointed as an (first Australian) Associate Editor of the Physical Review, and in 2002 he was elected to the Australian Academy of Science. He is a Fellow of Optical Society of America and the American Physical Society.

His recent awards include the Lyle Medal of the Australian Academy of Sciences ((the highest award of the AAS in physics), The Peter Baum Award of the Australian National University (the most distinguished award of ANU), Carl Zeiss Visiting Professor Award from the University of Jena and the Carl Zeiss Foundation, and Distinguish Professor Award from the Wenner-Gren Foundation in Sweden.

Key areas of research contribution within the Centre

Nonlinear optics, fiber optics, nanophotonics, photonic crystals, parametric processes and frequency conversion, all-optical devices and technologies

Awards, honours, major international visits

His recent awards include the The Peter Baum Award of the Australian National University, Carl Zeiss Visiting Professor Award from the University of Jena and the Carl Zeiss Foundation, and Distinguish Professor Award from the Wenner-Gren Foundation in Sweden.

In 2008 he visited more than 25 research laboratories (where presented colloqua or invited seminars) including 5 Universities in Sweden (in the framework of the Distinguish Professor Award from the Wenner-Gren Foundation) in Stockholm, Umea, Norchoping, Linchoping, and Goeteborg (Sweden); Complutense University (Madrid), University of Jena (Germany), University of Bonn (Germany), Institute of Technical Physics (Tashkent, Uzbekistan), University of Edinburgh (UK), University of Vigo (Spain), Institute of Technical Physics (Ukraine), University of Rome (Italy), Institute of Optics (Russia), Fudan University in Shanghai (China), SASTRA University (Tanjavur, India), Pondichery University (India), and many others.

Key areas of research activity

Yuri Kivshar leads several research projects within the CUDOS program. His main research activity aims to develop innovative concepts of all-optical communication and information technologies and to carry out both theoretical and experimental studies on the photonic-crystal physics and engineering, optical solitons, and microphotonic nonlinear switching devices in order to promote the new field of photonic crystals, to enhance its development in Australia and provide linkages between leading edge R&D and industry in an important emerging technology. In particular, his current research activities fits at least two CUDOS Flagship projects **Slow Light** and **Tunable Microphotonics**, and it involve the studies of spatiotemporal dynamics of light propagation, nonlinear interaction and control of light in periodic photonic structures, and theoretical studies of photonic crystals and related devises.

Research achievements during 2008

Prediction and observation of novel types of surface modes in modulated photonics lattices

We predict that interfaces of periodically curved waveguide arrays can support a novel type of surface states which exist in a certain region of modulation parameters associated with the band flattening. Such linear surface states appear in truncated but otherwise perfect (defect-free) lattices as a direct consequence of the periodic modulation of the lattice potential. We show that the existence of these modes in different band gaps can be flexibly controlled by selecting the modulation profile, with no restrictions on Bloch wave symmetries characteristic of Shockley states. We report on the experimental observation of novel defect-free surface modes predicted theoretically for modulated photonic lattices.We generate the linear surface modes in truncated arrays of periodically curved optical waveguides created in fused silica by a laser direct-writing technique. Our results demonstrate that the degree of surface wave localization can be controlled by selecting the waveguide bending amplitude. This work was highlighted in the special issue of Optics and Photonics News "Optics in 2008" [I. Garanovich et al., Phys. Rev. Lett. **100**, 203904 (2008); A. Szameit et al., Phys. Rev. Lett. **101**, 203902 (2008)]

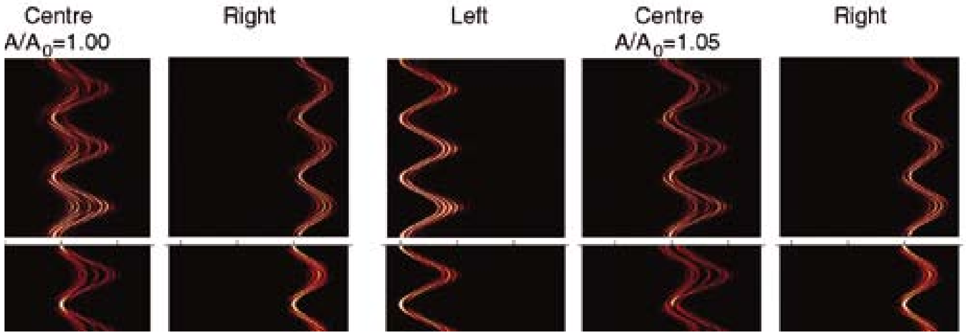


Fig 1. (a,b) Light propagation in the two curved arrays with different bending amplitude A. In each of the two blocks experimental fluorescent images are shown on the top, and corresponding numerical simulations are shown at the bottom. Light is launched into the left edge waveguide of the array (left), center waveguide (center), and right edge waveguide (right).

Observation of Multivortex Solitons in Photonic Lattices

We reported on the first observation of topologically stable spatially localized multivortex solitons generated in optically induced hexagonal photonic lattices. We demonstrate that topological stabilization of such nonlinear localized states can be achieved through self-trapping of truncated two-dimensional Bloch waves and confirm our experimental results by numerical simulations of the beam propagation in weakly deformed lattice potentials in anisotropic photorefractive media. [B. Terhalle et al., Phys. Rev. Lett. **101**, 013903 (2008)]

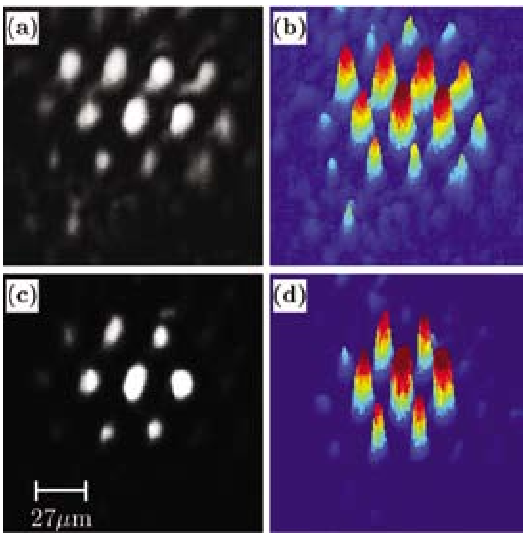


Fig 2. Output intensity distributions and corresponding three-dimensional surface plots of the probe beam for (a,b) low input intensities and (c,d) high input intensities.

Bloch Cavity Solitons in Nonlinear Resonators with Photonic Crystals

We predict a novel type of cavity solitons, Bloch cavity solitons, existing in nonlinear resonators with the refractive index modulated in both longitudinal and transverse directions and for both focusing (at normal diffraction) and defocusing (at anomalous diffraction) nonlinearities. We develop a modified mean-field theory and analyze the properties of these novel cavity solitons demonstrating, in particular, their substantial narrowing in the zero-diffraction regime [K. Staliunas et al, Phys. Rev. Lett. **101**, 153903 (2008)]

Coupled-resonator-induced reflection in photonic-crystal waveguide structures

We studied the resonant transmission of light in a coupled resonator optical waveguide interacting with two nearly identical side cavities. We reveal and describe a novel effect of the coupled-resonator induced reflection (CRIR) characterized by a very high and easily tunable quality factor of the reflection line, for the case of the inter-site coupling between the cavities and the waveguide. This effect differs sharply from the coupled-resonator-induced transparency (CRIT) – an all-optical analogue of the electromagnetically-induced transparency – which has recently been studied theoretically and experimentally for the structures based on micro-ring resonators and photonic crystal cavities. Both CRIR and CRIT effects have the same physical origin which can be attributed to the Fano-Feshbach resonances in the systems exhibiting more than one resonance. We discussed the applicability of the novel CRIR effect to the control of the slow-light propagation and low-threshold all-optical switching [S. Mingaleev et al, Opt. Express 16, 11647 (2008)]

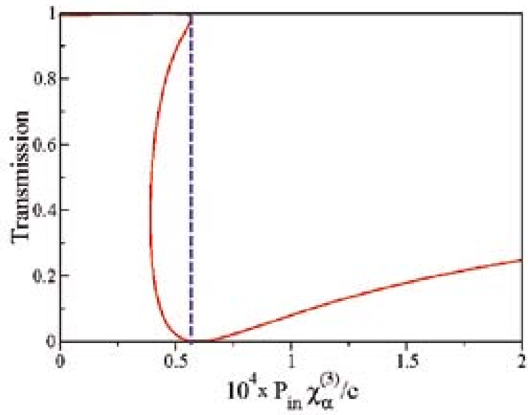


Fig 3. Nonlinear transmission and bistability for the case of the waveguide coupling with two nearly identical cavities.

Dispersionless tunneling of slow light in antisymmetric photonic crystal couplers

We suggested a novel and general approach to the design of photonic-crystal directional couplers operating in the slow-light regime. We predict, based on a general symmetry analysis, that robust tunneling of slow-light pulses is possible between antisymmetrically coupled photonic crystal waveguides. We demonstrate, through Bloch mode frequency domain and finite-difference time-domain (FDTD) simulations that, for all pulses with strongly reduced group velocities at the photonic band-gap edge, complete switching occurs at a fixed coupling length of just a few unit cells of the photonic crystal [Sangwoo Ha et al., Opt. Express **16**, 1104 (2008)].

Light Scattering by a Finite Obstacle and Fano Resonances

We found the conditions for observing Fano resonances at elastic light scattering by a single finite-size obstacle. General arguments have been illustrated by consideration of the scattering by a small (relative to the incident light wavelength) spherical obstacle based upon the exact Mie solution of the diffraction problem. The most attention was paid to recently discovered anomalous scattering. We also introduced an exactly solvable one-dimensional discrete model with nonlocal coupling for simulating diffraction in wave scattering in systems with reduced spatial dimensionality. We have revealed deep connections between the resonances in the continuous and discrete systems. This work was highlighted in the special issue of Optics and Photonics News "Optics in 2008" [M.I. Tribelsky et al., Phys. Rev. Lett. **100**, 043903 (2008)]

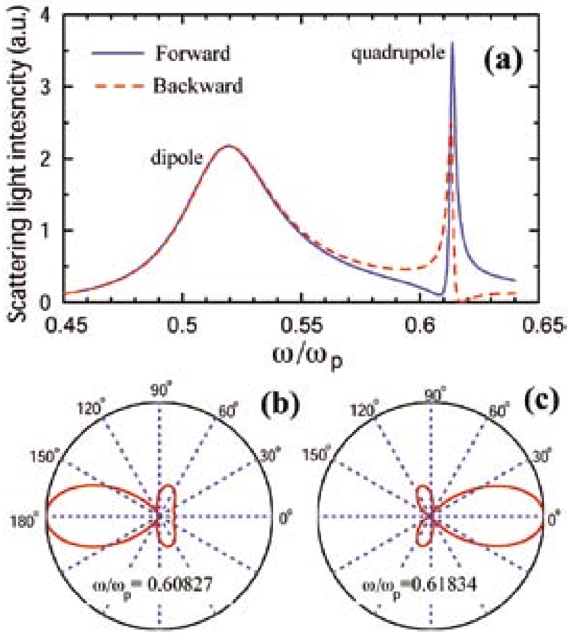


Fig 4. Exact Mie solution of the light scattering by a plasmonic nanoparticle. The radius of the nanoparticles is much smaller than the light wavelength. (a) Frequency dependence of the scattering light intensity in the vicinity of the dipole and quadrupole resonances. In the latter case both forward (solid lines) and backward (dashed lines) scattering profiles exhibit asymmetric Fano resonances; (b,c)

The angular dependence of the light scattering in the vicinity of the quadrupole resonance .

Dynamical nonlinear response of photonic structures with a liquid crystal defect

We demonstrate experimentally that a one-dimensional photonic crystal with a homeotropic nematic liquid crystal defect behaves as a polarization sensitive nonlinear all-optical device. We study statics and dynamics of the nonlinear optical response for linearly and circularly polarized beams and show enhanced sensitivity of the nonlinear optical response of liquid crystals and polarization self-modulation effects [U. Laudyn et al, Appl. Phys. Lett. **92**, 203304 (2008); A. Miroshnichenko, Appl. Phys. Lett. **92**, 253306 (2008)].

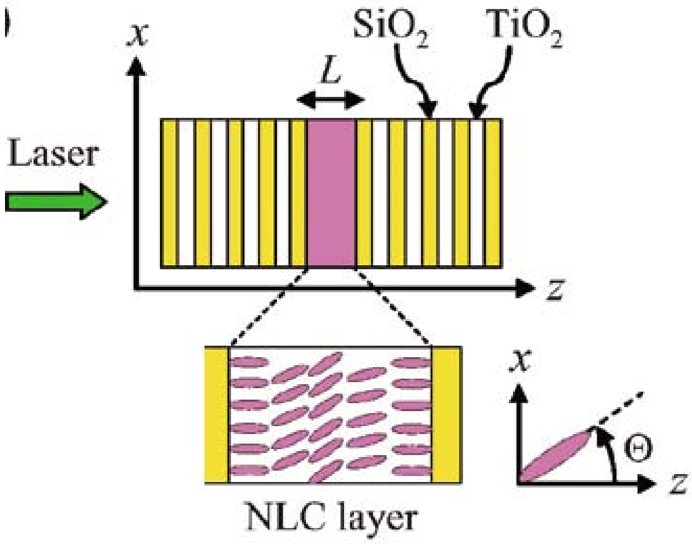


Fig 5. Sketch of the multilayers periodic structure with an embedded nonlinear liquid crystal defect.

In addition, together with Prof. Wieslaw Krolikowski, Yuri Kivshar leads the experimental studies of linear and nonlinear aspects of localization and control of light in periodic photonic structures, including the studies of nonlinear effects in fabricated photonic periodic structures. One of the major recent highlights of those projects is (see report by W Krolikowski for further details):

Generation of Second-Harmonic Conical Waves via Nonlinear Bragg Diffraction [S. Saltiel et al., Phys. Rev Lett. **100**, 103902 (2008)]. Observation of second-harmonic conical waves generated in a novel geometry of the transverse excitation of an annular periodically poled nonlinear photonic structure by a fundamental Gaussian beam, as a result of the higher-order nonlinear Bragg diffraction.