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Yuri Kivshar

Professor Yuri Kivshar received his PhD in 1984 from the Institute for Low Temperature Physics and Engineering (Kharkov, Ukraine). From 1988 to 1993 he worked at different research centres in USA, France, Spain, and Germany, and from 1993 was employed by the Australian National University where he currently holds the position of Professor and Head of Nonlinear Physics Center.

Professor Yuri Kivshar is a recipient of many awards including the Medal and Award of the Ukrainian Academy of Science (1989), the International Pnevmatikos Prize in Nonlinear Physics (1995), the Pawsey and Lyle Medals of the Australian Academy of Science (1998, 2007). He has extensive experience in nonlinear optics, optical communications, optical solitons, guided wave optics, and photonic crystals. His recent research is focused on nonlinear photonics and metamaterials, where he has already demonstrated a number of important achievements, including the first theoretical prediction and experimental studies of nonlinear metamaterials (widely highlighted by the media), the first experimental observation of polychromatic solitons in photonic lattices (highlighted in the OPN magazine), the first prediction and demonstration of self-collimation of white light (Nature Physics). His authority in nonlinear nanophotonics and metamaterials has led to many invitations to speak at national and international meetings.

Key Areas of Research Contribution

Professor Yuri Kivshar is the Deputy Director of CUDOS with a leadership role in the fundamental science programs including new programs in metamaterials and nonlinear nanophotonics. He shapes the fundamental science programs, establishing long-term strategy for aligning these new directions with overarching goals of the Centre. Professor Kivshar links strong theoretical capabilities of the Centre with capabilities of experimental groups, by assembling and leading world class physicists working on leading edge topics of Metamaterials. During 2011 Professor Kivshar was also involved in the research activities of Nanoplasmonics and Quantum Integrated Photonics.

2011 Achievements

Effective antiferromagnetism of hybrid metamaterials

Professor Kivshar and his research team analysed a metal-dielectric structure composed of a silicon nanoparticle coupled to a stack of split-ring resonators, and revealed the possibility of optically-induced antiferromagnetic response of such a hybrid meta-molecule. They showed that a hybrid metamaterial created by a periodic lattice of the meta-molecules supports antiferromagnetic modes with a checker-board pattern and the propagation of spin waves. This approach opens novel possibilities for the control of artificial anti-ferromagnetism at optical frequencies.

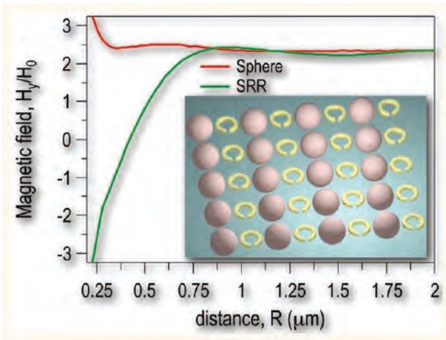

Figure 1: Magnetic response of a silicon sphere coupled to a multi-stack of split-ring resonators (SRRs). Dependence of the induced magnetization of the sphere and split-ring resonators on the distance between at the resonant frequency 257 THz. Below critical distance 1mm the ferromagnetic like magnetization switches to antiferromagnetic one; Insert shows a schematic of a hybrid metal-dielectric structure consisting of silicon spheres coupled to copper split-ring resonators.

Novel types of metamaterial invisibility cloaks

The ANU research group designed a novel type of electromagnetic cloak to conceal an object in a corner, and demonstrated its excellent performance. In their approach they designed a cloak of invisibility suitable for a non-flat surface, rather than just a perfectly flat mirror. By introducing a differential scattering coefficient, the performance of ideal and simplified cloaks was compared. For various angles of incidence, the ideal cloak shows consistently excellent performance, while the performance of the simplified cloak varies greatly. Further simulation indicates the loss in the cloak will degrade the cloaking performance. The design extends the repertoire of available cloaking geometries to include objects located in a corner. The group also studied a double-shell cloak for hiding objects with dimensions comparable with the radiation wavelength. They demonstrated that the structure consisting of a dielectric layer and a layer of an epsilon-near-zero material can suppress substantially the scattering from a sphere and at the same time shield its interiors. The double-layer coating cloaks different objects with various material and geometrical parameters.

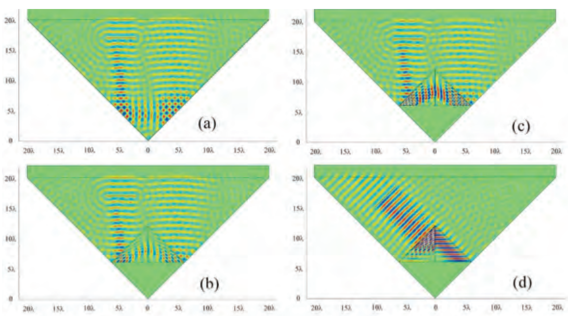

Figure 2. Functionalities of triangular corner cloak. Field distribution in the corner. (a) Empty, (b) covered with the ideal cloak, (c) covered with the simplified cloak, and (d) at oblique incidence to the simplified cloak. The obstacles here are modelled by PEC boundaries.

Spontaneous radiation in hyperbolic media and metamaterials

Professor Kivshar and his team developed the theory of the Purcell effect for spherical dipole emitters embedded in a special type of metamaterial described by the so-called hyperbolic effective media, taking into account a finite size of the emitter and losses in the surrounding medium. They obtained analytical expressions for the decay rates in the case when the emitter size is much smaller than the wavelength of radiation. The group revealed that, when the real parts of the longitudinal and transverse dielectric constants are of the opposite sign (i.e. for the hyperbolic media), the radiative decay rate depends strongly on the emitter size, and it diverges when the size vanishes. Their theory was developed for a simple model of homogeneous hyperbolic medium. However, due to its general character, it may also provide a qualitative insight into the peculiarities of the spontaneous emission in other types of metamaterials.

Metamaterials with conformational nonlinearity

Professor Kivshar and his research group demonstrated a novel principle in metamaterial assembly which integrates electromagnetic, mechanical, and thermal responses. Through these mechanisms, the conformation of the meta-molecules changes, providing a dual mechanism for nonlinearity and offering nonlinear chirality. Their proposal provides a starting platform for further analysis of the nonlinear phenomena in various metamaterials based on the flexible chiral particle, which can be made bi-isotropic, bi-anisotropic and even non-chiral, by choosing an appropriate lattice and alignment. While many peculiar features will be provided with the arising mutual interactions, the essence of nonlinear response is determined by the properties of an individual spiral particle, and therefore the above analysis forms a reliable basis for further research as well as the development of useful applications.

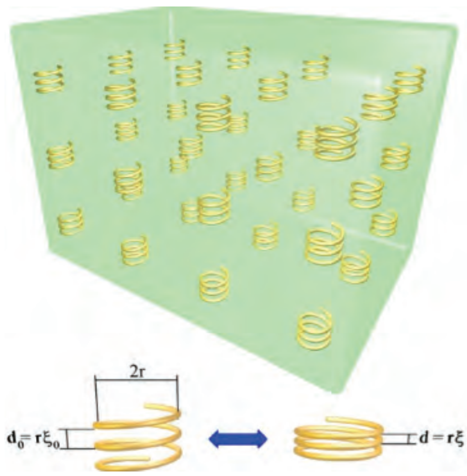

Figure 3 Schematic of a metamaterial composed of spiral meta-molecules. The structural units are electromagnetic resonators which can change their geometrical conformation: spiral pitch can vary, following a balance between the attractive force induced by magnetic field and the spring rigidity; and spiral radius r can change upon thermal expansion.

Recognition

Professor Kivshar delivered 12 invited conference talks in 2011 and on many occasions, was invited to address the media, including national and international interviews and commentaries. These are detailed later in the report. Professor Kivshar was selected as an ambassador of the Optical Society of America to represent the Society at several meetings, e.g. "Diffraction Days'11" (St. Petersburg, May 2011); one of his recent visits resulted in a critical overview of the optics activities in Chile ["Optics crosses the Andes" OPN 22, No. 2 (2011) 14-17]