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Michael J Steel

Michael Steel was awarded a BSc(Hons) and PhD (1996) from the University of Sydney for research in multiple wavelength interactions in nonlinear optical fibre Bragg gratings. After postdoctoral work in quantum optics at the University of Auckland and photonic crystals at Columbia University, he joined the photonics software company RSoft Design Group, Inc. In seven years at RSoft, he designed and developed a number of widely used photonics modelling software packages, including BandSOLVE, the world's first commercial photonic band structure analysis tool, now used widely in laboratories and companies around the world. He was appointed an Associate Professor in the Department of Physics and Astronomy at Macquarie University in 2007. His research interests include quantum light sources and logic circuits in integrated waveguides, light polarisation in nanooptics, linear and nonlinear optics of periodic structures and guided wave magneto-optics.

Key Areas of Research Contribution

A/Prof Steel is the Science Leader of the Quantum Integrated Photonics project coordinating the programs in both correlated photon pair generation and reconfigurable quantum circuits. He jointly supervises PhD student Thomas Meany who is developing 3-D quantum walk structures using the laser direct write technology. A/Prof Steel's own research in this area is focused on theoretical calculations of photon generation rates and the optical quantum states generated by spontaneous processes in highly nonlinear waveguides. The group's achievements in this area are discussed under the summary of the Quantum Integrated Photonics project. A/Prof Steel is studying the classical and quantum properties of waveguide structures written in glass using the laser direct write process. In collaboration with Dr Alex Judge, Professor Martijn de Sterke, and Partner Investigator Professor John Sipe of the University of Toronto, he is also developing a Hamiltonian formalism for describing nonlinear processes in metamaterials that fully accounts for the strong dispersion and loss observed in these systems. He supervises CUDOS PhD students involved in quantum circuits, and laser-written waveguide structures for gratings, lasers and optical isolators.

2011 Achievements

Waveguides composed of metamaterials and especially negative index media are a promising arena for improving the efficiency of a range of nonlinear optical processes such as frequency conversion. The natural theoretical language of these systems is coupled mode theory. While the general form of the relevant coupled mode equations can be obtained by ad hoc methods, the strong dispersion and absorption associated with metamaterials mean that identifying the correct form for the dispersive and nonlinear coefficients requires some care. Building on previous theories that introduced a Hamiltonian for electrodynamics in absorbing dielectrics fully consistent with causality, A/Prof Steel and his team obtained the generalisation that includes the strong magneto-electric cross coupling characteristic of metamaterials. They fully diagonalised the quantum version of this Hamiltonian, providing a new theory of quantum electrodynamics in metamaterials [1]. From this basis they can proceed to find rigorous coupled mode equations for a range of frequency conversion processes in metamaterials in both classical and quantum regimes.

Building on work from the first CUDOS program and in collaboration with Friedrich-Schiller University (Jena, Germany), the group reported two interesting applications of fibre Bragg gratings created by the laser direct write systems at Macquarie University. Both results exploited the strongly-localised high-contrast index modifications that comprise these gratings. Previously these gratings have been restricted to uniform structures showing strong sidebands and limiting their application for filtering. Student Robert Williams [2] showed that by dragging the writing laser across the fibre core a range of apodised (smoothed) gratings with reduced sidebands could be obtained. Jena student Jens Thomas developed a detailed model of grating coupling between the core and cladding modes in three layer fibres. The strong modifications unique to these gratings displayed enhanced coupling to modes of higher azimuthal order, normally inaccessible in conventional gratings, with the measured results matching our full-vector theory very closely. Such structures could be useful for excitation of individual cladding modes of specific order and polarisation.

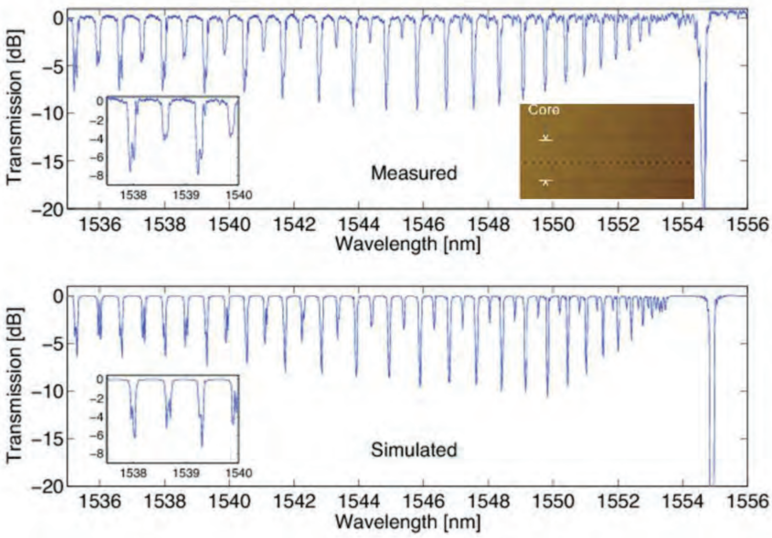

Fig. 1.: Measured and calculated cladding-mode spectra for a laser written fibre Bragg grating. Insets show an image of the grating and the polarisation splitting predicted by the vector theory.

Recognition

A/Prof Steel is currently serving as the technical program chair of the Australian Optical Society component at the Australian Institute of Physics Congress for 2012. He serves on the editorial advisory board of the journal Optics Communications and this year delivered an invited colloquium on quantum light sources at the University of Melbourne.

References

1. A. Judge, J. E. Sipe, M. J. Steel and C.M. de Sterke, in preparation.
2. R. J. Williams, C. Voigtländer, G. D. Marshall, A. Tünnermann, S. Nolte, M. J. Steel, and M. J. Withford, "Point-by-point inscription of apodized fiber Bragg gratings," *Optics Letters* 36, 2988–2990 (2011).
3. J. Thomas, N. Jovanovic, R. G. Becker, G. D. Marshall, M. J. Withford, A. Tünnermann, S. Nolte and M. J. Steel, "Cladding mode coupling in highly localized fiber Bragg gratings: modal properties and transmission spectra," *Optics Express* 19, 325–341 (2011).