UNIVERSITY OF TECHNOLOGY, SYDNEY
Phone: +61 2 9514 2247
Email: Lindsay.Botten@uts.edu.au

Lindsay Botten

Lindsay Botten, a graduate of the University of Tasmania, is Professor of Applied Mathematics at UTS and Director, National Computational Infrastructure (NCI) at ANU. He has made leading contributions in electromagnetic optics advancing the physical and mathematical understanding of periodic structures, particularly gratings and photonic crystals. He is a Fellow of the Optical Society of America, the Australian Institute of Physics, and the Australian Mathematical Society. His broad expertise in mathematical and computational techniques in electromagnetic theory has led to an international reputation in the development of semi-analytic models of propagation and radiation dynamics.

Professor Botten has a strong background in Scientific Computing, Computational Mathematics, and Physics, and has led the advancement of high-end, research computing nationally through contributions as University Services Director of ac3, membership of the APAC Board, and as Lead CI on many infrastructure grants for new HPC systems in NSW and at NCI. In 2008, he was appointed as Director, NCI– Australia's pre-eminent research computing service, a $20M per year operation. He is a member of the Editorial Board of Proceedings A, Royal Society and a reviewer for eight journals.

Key Areas of Research Contribution

Lindsay Botten leads a group at UTS comprising Dr Chris Poulton (Senior Lecturer), Research Associates, Dr Kokou Dossou and Dr Ara Asatryan, and PhD Student, Dougal Kan. The group contributes to the nanophotonics and functional metamaterial programs of CUDOS, and co-supervises a number of related projects involving Sydney University PhD students.

Kokou Dossou presented an invited paper on behalf of the group at the computational modelling conference NUSOD 2011 in Rome.

Research Achievements in 2011

Impedance Methods for Photonics—in 2D, 3D and for Metamaterials

In recent years, Botten, Dossou and Sydney PhD Student, Felix Lawrence with McPhedran and de Sterke, have generalised the concept of impedance to develop an effective and accurate tool in the modelling of the scattering properties of complex photonic structures.

During 2011 the abovementioned generalised their previous work to apply to 3D dimensional structures, commencing with photonic crystal slabs. In this work a semi-analytical approach was developed to the solution of a scattering problem of a PC slab and its inverse, an array of nanowires. The theory relies on the use of the finite-element method (FEM) to solve for modes of an infinite array involving a regular eigenvalue problem, followed by the calculation of generalised Fresnel reflection and transmission matrices for each of the structural interfaces [1]. The concept of impedance arises naturally through the overlap integrals between exterior (plane wave) and interior (modal) fields. This approach will be extended in 2012 to metamaterials, and also to anti-reflection coatings for metamaterial devices.

The computation of impedances relies on the ability to compute Bloch modes, and the subsequent calculation of overlap integrals. The tools developed by the UTS/Sydney group are accurate and efficient, but are bespoke and not broadly accessible. Accordingly, Lawrence implemented the impedance method using common, commercial tools, e.g., COMSOL, overlaid with code written in standard Python. The outcomes were good, with the method [2] able to calculate enough Bloch modes of accuracy sufficient for impedance calculations and anti-reflection coating simulations. The tool, BlochCode, is now in the public domain (https://launchpad.net/blochcode).

Three-dimensional finite element method for the analysis of diffracting 3D photonic structures

In preparation for the 2012 implementation of 3D impedance methods for metamaterials, Dossou and Botten developed a new, efficient and accurate, 3D vectorial FEM for analysing the diffraction properties of 3D multilayer photonic devices [3]. Tests so far have confirmed the accuracy of the method for a range of structures including 2D gratings and multi-layered woodpiles. In 2012 they will apply the method to metamaterial devices.

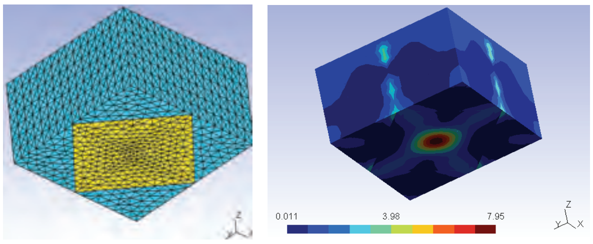

Figure 1: Chequerboard grating: 3D FEM unit cell mesh and contour plot of field intensity.

Optimisation of absorption in silicon nanowire array

Jointly with Sydney student Sturmberg and supervisors [4] de Sterke and McPhedran, Botten and his team analysed the absorption priorities and conversion efficiency of SiNW arrays. The UTS group led the theory and computational development using a semi-analytical modal formulation [1] that isolated the role and relationship of various effects (compared to purely numerical approaches). They optimised the absorption properties of the nanowire array and showed that the absorption is due to a few modes that couple well to the incident light by overlapping strongly with the absorbing silicon and exhibiting strong Fabry-Perot resonances.

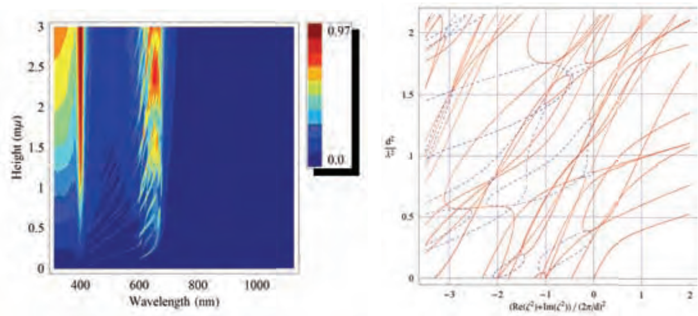

Figure 2: Contour plot of the absorptance of the nanowire array as a function of the wavelength and the wire length, and Bloch mode dispersion curves of a lossless cylinder array.

Photonic woodpiles

In the final part of the work for his PhD, UTS student Dougal Kan studied woodpile surface states, characterising their highly complex nature [5]. He also generalised of the fictitious source superposition method and applied it to 2D/3D structures to model a waveguide in a 3D woodpile [6].

References

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