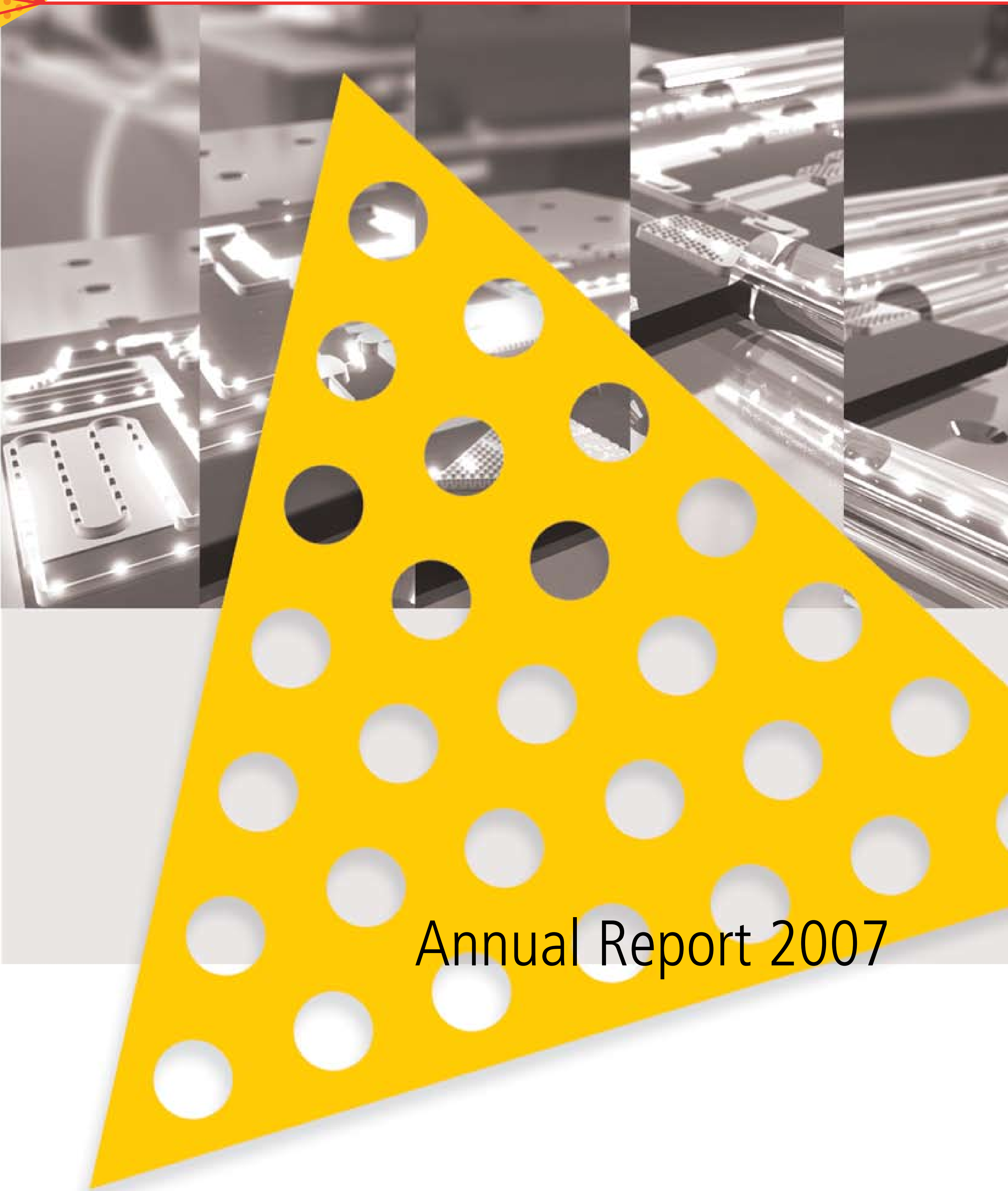
CUDOS

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

An Australian Research Council Centre of Excellence



Annual Report 2007

Professor Martijn de Sterke

Martijn de Sterke received the M.Eng degree from the University of Delft in the Netherlands and his PhD in Optics from the University of Rochester in the USA. After postdoctoral work at the University of Toronto, he joined the School of Physics at the University of Sydney, where he is now a Professor in Physics working in the area of optics and photonics. During 2001-2006 he was an Associate Editor of Optics Express. He was appointed as Editor in Chief of this journal on 1 January 2007.

Martijn de Sterke was the 1999 winner of the Pawsey Medal of the Australian of Sciences. He is a Fellow of the Optical Society of America.

Key areas of research contribution within the Centre

I contribute to the following Flagship projects: Slow Light (as Science Leader), Three-Dimensional Photonic Bandgap Materials, and Chalcogenide Photonic Crystal All-Optical Switch. He also works on the general theoretical description of wave propagation in complicated media, be they waveguide, nonlinear, periodic, or random.

Researchers and students

During 2007 I worked directly with Research Fellows Kokou Dossou, Snjezana Tomljenovic-Hanic and Eduard Tsoy, PhD students Neil Baker, Sam Campbell, Mike Lamont, Joe Mok, Paul Steinvurzel, and Jamie Vahn, and with honours students Felix Lawrence and Sahand Mahmoodian. I also work closely with Lindsay Botten, Ben Eggleton, and Ross McPhedran.

Research achievements during 2006

Much of my research was carried in the context of one of the Flagship Projects, particularly Slow Light and All-Optical Switching. This work is well described in the associated part of this Annual Report and is not mentioned here. Rather, I will here describe some of the work not covered elsewhere in this report.

In collaboration with Prof Marc Dignam from Queen's University and Prof Stewart Aitchison from the University of Toronto, both in Canada, and members of their group, we finished a major experimental investigation on Dynamic Localization in curved waveguide arrays. This work involves an array of waveguides with specially designed, periodically varying curvature. The aim of the work is to show that light which is coupled into one of the waveguides diffracts into many other waveguides, but surprisingly returns completely to the initial waveguide at an integer number of periods. This is illustrated in Fig 1, in which the light travels in the vertical direction, and which shows the measured (left) and calculated (right) intensity versus propagation distance in such an array.

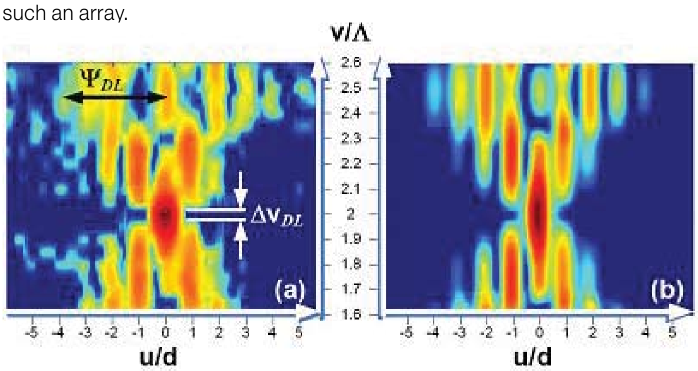


Fig 1.

In other work we developed a framework and convenient starting point for the linear analysis of linear photonic crystal-based filters. Though we applied this formalism to the folded directional coupler and to the side-coupled directional coupler, it is very general and can be applied to a variety of geometries. The method is based on the understanding that the various components of device can be described by complex reflection and transmission coefficients. If these reflection and transmission coefficients are strapped together appropriately, then an accurate, semi-analytic description of the device is found, providing key insight and also simplifying calculations considerably. Figure 2 shows the calculated electric field inside a folded-directional coupler, one of the devices we have targeted. The field's frequency was chosen to be on resonance, so that the transmission is almost perfect.

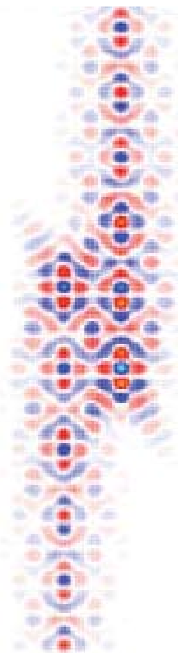


Fig 2.

While many photonic crystal applications rely on the strong reflectivity associated with a photonic bandgap, many others, such as the super-prism and super-collimation, do not require strong reflection and operate at frequencies between gaps. For these applications reflections are in fact a nuisance and need to be reduced as much as possible. In general, interface reflections are most easily calculated using the concept of impedance, but it is not clear how to find the impedance of a photonic crystal. It is a difficult problem because the field propagates in the photonic crystal as Bloch functions, while traversing an interface is most easily described using plane waves. The fact that a photonic crystal can in general support more than a single Bloch function means that the impedance is represented by a matrix. We showed that an absolute impedance does not exist, but that another more fundamental quantity corresponding to the square root of the impedance can be found, the value of which we calculate with respect to air.

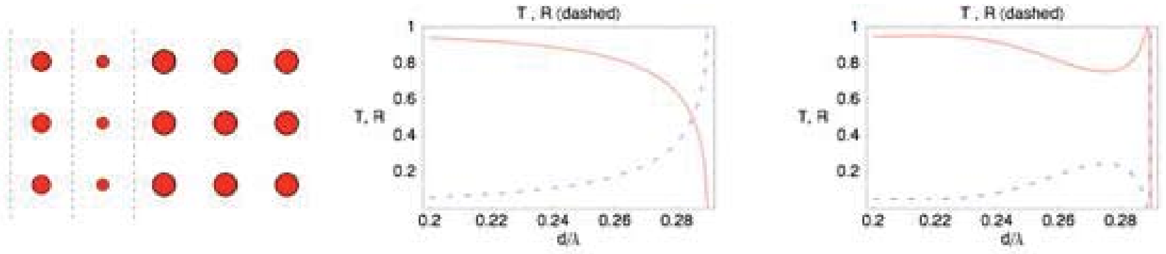


Fig 3.

Though it is satisfying to be able to define an impedance-like quantity, it is only really useful if it used for something that cannot be done otherwise, or is otherwise very difficult. In fact, we used it to design a two-layer photonic crystal anti-reflection coating utilizing the techniques developed in thin-film optics. The result is shown in Fig 3. The left figure shows a schematic of the geometry. The reflectivity and transmissivity versus normalized wavelength without the coating is shown in the middle figure. After designing the coating, by choosing the radii of the inclusions in the layers appropriately, the reflectivity at one frequency can be eliminated.

High-Q cavities are important in a number of different areas, for example in sensing, laser physics, and in experiments probing quantum electrodynamics. We have an on-going research project in high-Q cavities in photonic crystal slabs. This year we introduced a novel design for such cavities, which is formed by depositing a polymer strip on top of a photonic crystal slab (see Fig. 4) such that the average refractive index in the region underneath the strip is somewhat higher than the refractive index elsewhere in the slab. This leads to slightly different band structures in the two regions. A multilayer design like this can lead to cavities with a Q as high as about one million [3]. This paper was selected for a Focus Issue on “Physics and Applications of Microresonators” in Optics Express. This project benefitted from a travel grant from the Australian Research Network for Advanced materials (ARNAM) for Dr Snjezana Tomljenovic-Hanic, which allowed her to visit Prof Noda’s group at Kyoto University in Japan.

[1] R. Iyer, M.M. Dignam, J. Wan, C.M. de Sterke, J.S. Aitchison, “Exact dynamic localization in curved AlGaAs optical waveguide arrays,” Optics Express 15, 3212-3223 (2007).

[2] Gah-Yi Vahn, T.P. White, M.J. Steel, and C.M. de Sterke, K. Dossou and L.C. Botten, “Modeling light propagation in photonic crystal devices: Simplification of the Bloch mode scattering matrix method,” J. Appl. Phys. 102, 043103:1-7 (2007).

[3] S. Tomljenovic-Hanic, C.M. de Sterke, M.J. Steel, B.J. Eggleton, Y. Tanaka and S. Noda, “High-Q cavities in multilayer photonic crystal slab,” Optics Express 15, 17248-17253 (2007).

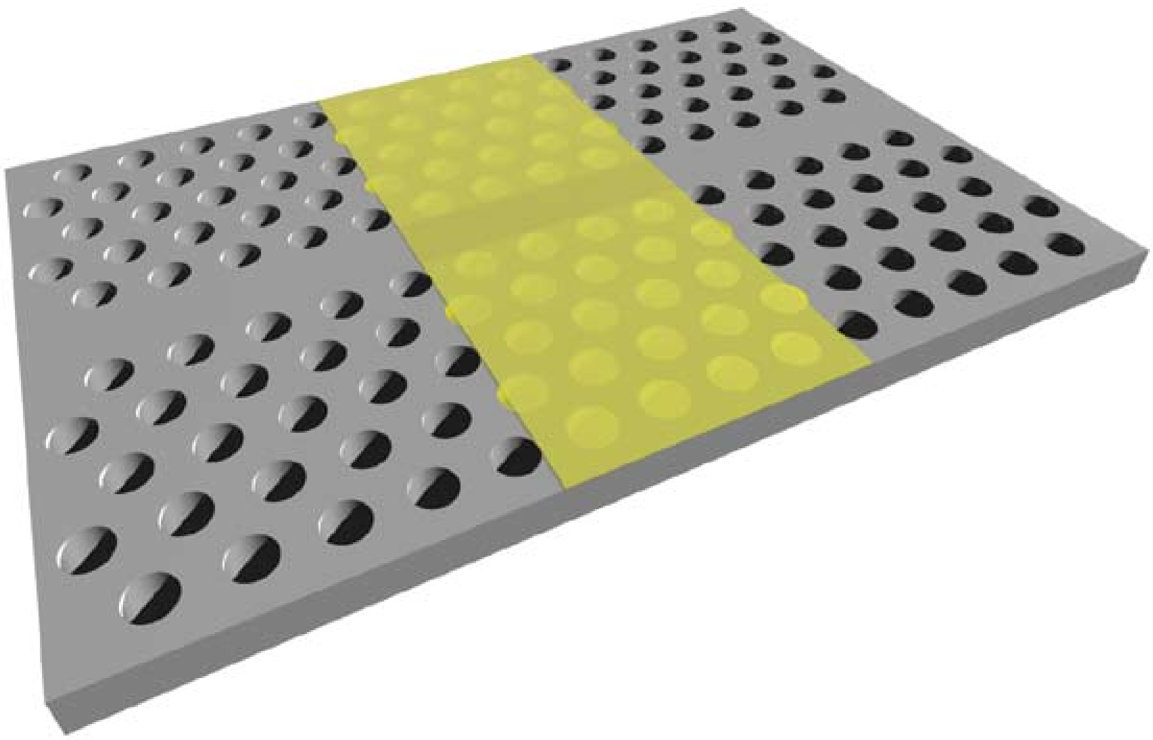


Fig 4.