CI short biography

Martijn de Sterke received the M.Eng degree in Applied Physics 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. He has been the Editor in Chief of the journal Optics Express since 2007.

Awards, honours, major international visits

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

Key areas of research contribution within the Centre

Martijn de Sterke contributes 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 a waveguide, nonlinear, periodic, or random.

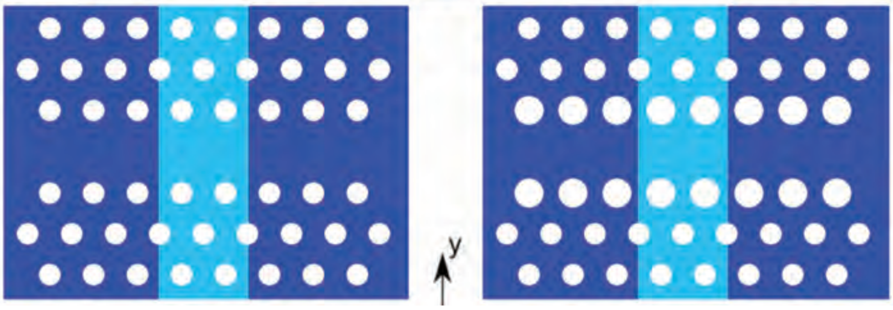
Researchers and students

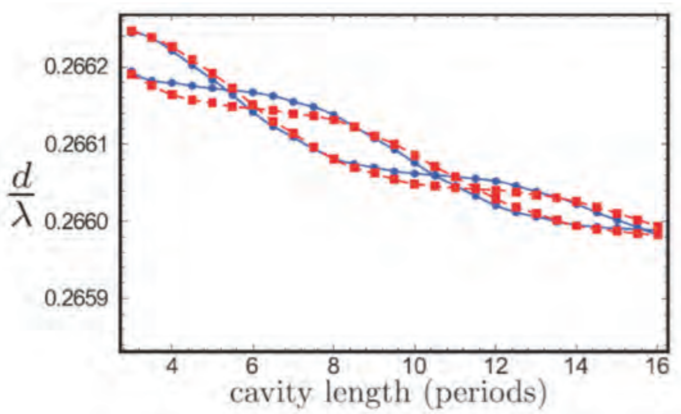
During 2009 I worked directly with Research Fellows Kokou Dossou and PhD students Neil Baker, Perry Chan, Irina Kabakova, Felix Lawrence, Sahand Mahmoodian, and with honours student Casey Handmer. I also work closely with Lindsay Botten, Ben Eggleton, Ross McPhedran, Chris Poulton, and Mike Steel, Andrey Sukhorukov and Snjezana Tomljenovic-Hanic.

Much of my research was carried in the context of the Flagship Projects, 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 the work not covered elsewhere in this report.

Cavities are often characterized by their Quality (Q)-factor, which indicates how long the cavity keeps oscillating once it has been excited. Since high-*Q* cavities oscillate for so long, and any energy in the cavity thus takes a long time to escape or dissipate, the energy density in these cavities is very high. This high energy density leads to a number of obvious applications, such as all-optical switching based on optical nonlinearities, and optical sensing. Optical cavities in Photonic Crystals (PCs) can have *Q* values as large as 10^6, which means that the light, once injected in the cavity, stays inside the cavity for well over hundred thousand optical periods.

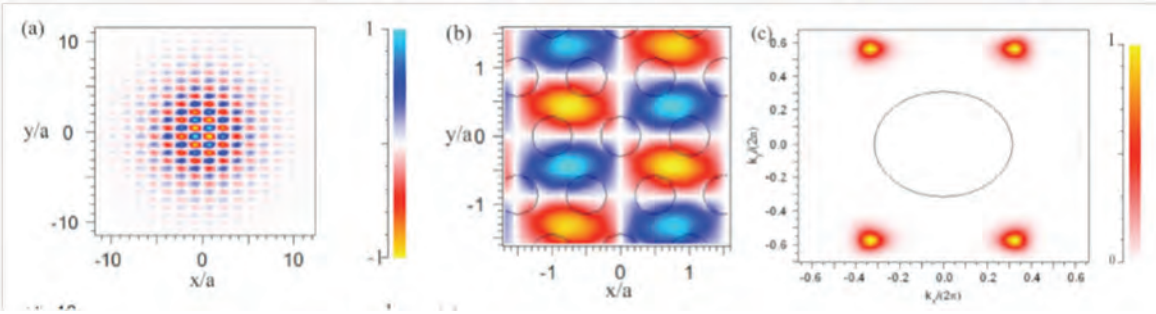
The standard cavity in a PC is shown schematically in the left figure below. It consists of a PC waveguide (a PC with a row of holes removed) in which the properties in a region perpendicular to the waveguide have been altered (indicated by the light colour), for example by changing the hole size, the refractive index or the period parallel to the waveguide. In a collaboration between CUDOS researchers at the University of Sydney, UTS, ANU and colleagues at Danish Technical University, we investigated a variation on this design [1]: we considered the modes of cavities such as in the centre figure, in which the row of holes closest to the waveguide have been changed. When designed correctly this has the effect of changing the properties of the modes propagating in the waveguide, and thus the properties of the modes in the cavity, which, specifically, now come in pairs, both of which have a high quality factor *Q*. In the particular case in which the light region in the figures has abrupt edges, the frequencies of these modes oscillate around each other as a function of the cavity length (see right figure below). Using a perturbation theory we established this general behavior and we also obtained good qualitative





agreement and intuitive insight. For example, when the edges of the light region are graded then the model frequencies never intersect as the cavity length is altered. Cavities with two high-*Q* modes which are spectrally separated by a predictable, and easily designed, frequency may have applications in quantum optics.

This year we reported on the design of a novel type of high-*Q* PC-based cavity [2]. In contrast to the cavities discussed above, this type of cavity is formed by starting out with a uniform PC



slab and then raising or lowering the refractive index in a small, circularly shaped region. Changing the refractive index in the chalcogenide glass, which is used extensively in our experimental program, can be achieved by irradiating the glass with light with a wavelength of 633 nm. The left figure above shows results for a cavity with a radius of 6 lattice constants. Shown is the major electric field component versus position of a mode of such a cavity. The middle figure shows details of the field structure, showing that some of the field is in the holes, which makes the cavity suited for sensing applications. The right figure shows the Fourier transform of the electric field. The fact that almost all of the field has frequency components which are outside the central circle (the "light cone") indicates that the field is well confined to the slab by total internal reflection, contributing to the high Q factor. Such cavities are particularly promising since they combine this high Q with substantial electric field in the air holes, which makes them particularly promising for optical sensor applications.

Although standard optical fibers have core of high refractive index, surrounded by a cladding of low refractive index, in a novel type of fiber the light is confined to the core by a periodic array of inclusions of high refractive index in the cladding. Traditionally these inclusions are circular strands of high-index glass. Such fibers, however, transmit light over a relatively narrow bandwidth. In a collaboration between CUDOS student Tom Grujic, CUDOS researchers Boris Kuhlmey and Martijn de Sterke, and colleagues Alex Argyros (University of Sydney) and Stéphane Coen (University of Auckland), we showed theoretically that fibers in which the inclusions are ring-shaped, rather than circular, should have a substantially larger bandwidth, in some case up to an octave. Using the polymer fibre draw facilities at the University of Sydney we verified this claim experimentally. The figure on the left below shows an electron micrograph of the fiber. The background medium is polymethylmethacrylate (n=1.4898), whereas the rings are made of polycarbonate (n=1.5802) with an air core. The transmission spectrum of such a fibre is shown in the figure below on the right. It has high transmission over a wide wavelength range, but is interrupted by two narrow low-transmission features. Our analysis shows that these are associated with imperfections in fabricated fiber. Quite generally, therefore, the experimental results confirm our theoretical predictions. This demonstration shows that fibers of this type can have substantial bandwidths, opening the way for novel applications which require such bandwidths, for example supercontinuum generation. This work was highlighted in the February 2011 issue of *Nature Photonics.* [ref]

References

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