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Martijn de Sterke

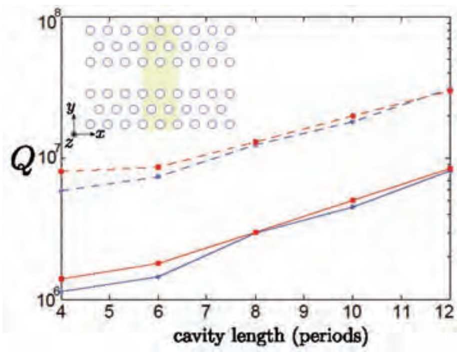
Martijn de Sterke received the MEng degree in Applied Physics from the University of Delft in the Netherlands, and his PhD in Optics from the University of Rochester in the USA. After postdoctoral work at The University of Toronto in Canada, he joined the School of Physics at the University of Sydney, 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. Martijn de Sterke was the 1999 winner of the Pawsey Medal of the Australian Academy of Sciences and has been a Fellow of the Optical Society of America since 2003.

Key Areas of Research Contribution and 2011 Achievements

One of the key applications of photonic crystals is that they can support cavities with very high Q-values, routinely larger than 10^6. This means that, once injected, the light rattles around in the cavity for over a million optical periods, which leads to very high field strengths. These high-Q cavities can be used in sensing or in experiments studying light-matter interaction. CUDOS has had a longstanding interest in these cavities, and has previous reported a number of novel designs, some of which are specifically suited for chalcogenide glasses.

One of the difficulties is calculating the Q-value of these cavities accurately, especially when it is high so that the energy loss is very small. Traditionally these are very subtle calculations, which can take days, even on a supercomputer. This is the reason why Professor de Sterke and his team have been working on an alternative semi-analytic approximate method of calculation. In this method, developed with PI John Sipe, they expand the field in terms of a limited number of states of the photonic crystal, and then find expressions for the expansion coefficients, from which the radiation loss, and hence the Q-value, can be determined.

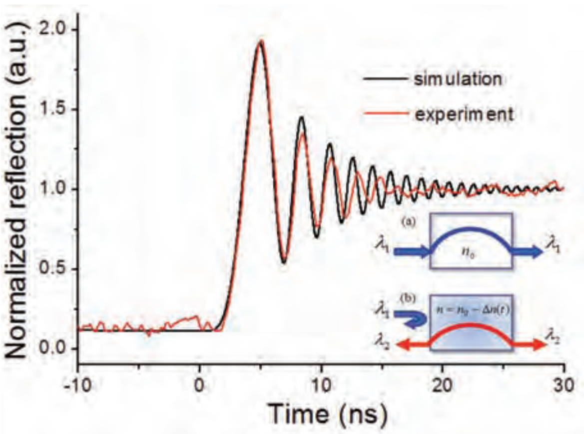
Results are summarised in the figure below.



These refer to the following photonic crystal cavity design (see inset): the research group starts with a photonic crystal waveguide, i.e., a photonic crystal with a line of holes missing. Then, using the photosensitivity of chalcogenide the refractive index of a strip of glass is slightly increased (yellow in the inset). The dashed lines in the main figure refer to an increase of $\Delta n=0.02$, while the solid lines refer to $\Delta n=0.04$. The figure shows Q versus the width of the strip with elevated refractive index. The agreement between their theory (red) and a full numerical calculation (blue) is excellent. This is especially so since the numerical calculation itself can easily be off by 25%. This means that, at least for these types of cavities, a full numerical calculation is no longer required as the semi-analytic method gives accurate results in a fraction of the time.

Professor de Sterke and the research team have studied experimentally and numerically how light which is caught in a cavity comprising a fibre grating with a localised defect behaves when it is subjected to a short and strong electrical pulse. This research was carried out in collaboration with colleagues Acreo AB and the Royal Institute of Technology in Stockholm, Sweden. The electrical pulse is applied through electrodes inside the fibre. This leads to a shock wave that compresses the fibre core and hence increases the core refractive index. The resonant frequency of the cavity shifts, and if the cavity contains light, then so does the frequency of this light. While frequency-shifting of light is usually a nonlinear process, this approach is not. Rather, the physical environment changes with time. This *adiabatic frequency* shift has been studied before, but only in photonic crystal cavities and then only for cases in which the shift is caused by an intense light pulse, rather than an electrical pulse.

A schematic of the experiment is shown in the inset of the figure below. Light is incident on the cavity at its resonant frequency, setting up a strong resonant field inside the cavity. The electrical pulse, via the shock wave, then causes the refractive index of the cavity to change. This has two consequences. First, the external source no longer resonates with the cavity and the incoming light is reflected. Secondly, the light which was inside the cavity leaks out at a rate which is given by the cavity's Q-factor. These two contributions have different frequencies, and since the adiabatic frequency shift is a coherent process, they beat with each other. This results in the oscillations in the total reflected signal, as shown in the figure below. Here the red trace is experiment and black is simulation. They clearly show excellent agreement. We developed a simple analytic model which fits both of these results well.



References

Irina V. Kabakova, Zhangwei Yu, David Halliwell, Pierre-Yves Fonjallaz, Oleksandr Tarasenko, C. Martijn de Sterke, and Walter Margulis, "Switching and dynamic wavelength conversion in a fiber grating cavity," 29, 155-160 (2012).