ARROW guiding silicon photonic crystal fibres

N. Healy[1], *J. R. Sparks*[2], *R. R. He*[2], *P. J. A. Sazio*[1], *J. V. Badding*[2], *and A. C. Peacock*[1]

1. Optoelectronics Research Centre, University of Southampton, SO17 1BJ, UK

2. Department of Chemistry and Materials Research Institute, Pennsylvania State University, 16802 PA, USA

In this paper we describe a new class of silicon photonic crystal fibre (SiPCF) that brings together two powerful optical technologies, the photonic crystal fibre (PCF) and the semiconductor optical fibre. The PCF is now a well established fibre paradigm that has proven to be a very versatile waveguide and has found applications in nonlinear optics, fibre lasers, and sensors. The versatility of the PCF is due to its microstructured cladding which enables complex manipulation of the waveguide's characteristics, and also allows for enhanced light interaction with materials that are infiltrated into the cladding voids. The most typical form of semiconductor optical fibre has a fused silica cladding and guides light in the high refractive index semiconductor core. Although semiconductor optical fibres are a nascent technology, practical applications, such as nonlinear pulse shaping and all optical modulation, have begun to emerge in the last couple of years. However, material losses are currently preventing this fibre type from becoming a major disruptive technology and, with this in mind, we present the first steps to decouple the functionality of the semiconductor from its material losses. We achieve this by filling the holes of a modified total internal reflection guiding silica PCF with hydrogenated amorphous silicon (a-Si:H) inclusions. We will show that the resulting SiPCF guides light in the low loss core via the antiresonant reflecting optical waveguiding (ARROW) mechanism.

A high-pressure microfluidic chemical deposition technique, as described in [1], was used to fabricate two SiPCFs. The PCF template had a cladding hole diameter of d = 1.17 μm and a triangular lattice with a pitch of Λ = 2.15 μm. For the first fibre (ARROW) all of the holes were filled with a-Si:H, Fig. 1(a), whilst the second fibre (hybrid) was fabricated using a selective filling technique to exclude the inner ring of holes from the deposition, Fig. 1(b). Theoretical studies have shown that selectively filling in this manner can reduce the fibre's confinement loss [2] and also that the fibre's guidance mechanism is altered to become a hybrid of modified total internal reflection and ARROW. Full vector finite element analytical modelling was used to determine the waveguidance characteristics of both fibres and the simulated and measured transmission spectra of the ARROW and hybrid fibres can be seen in Figs. 1(c) and (d), respectively. For the ARROW fibre, it is clear that the mode is confined to the core, inset Fig. 1(c), and that the characteristic transmission bands expected from an ARROW fibre are observed. The lowest measured loss, 31 dB/cm, is in reasonable agreement with the lowest predicted confinement loss, 25 dB/cm, indicating that this is the dominant loss mechanism. In comparison, the band structure seen in the transmission spectrum of the hybrid fibre clearly shows that it has retained some of its ARROW guiding characteristics. However, the measured transmission loss of ~ 4 dB/cm at 1310 nm is almost three orders of magnitude lower than that of the ARROW fibre and an order of magnitude lower than that for a step index a-Si:H optical fibre [1]. We will also present the group velocity dispersion characteristics of both fibres which will serve to contrast their differing guidance mechanisms.

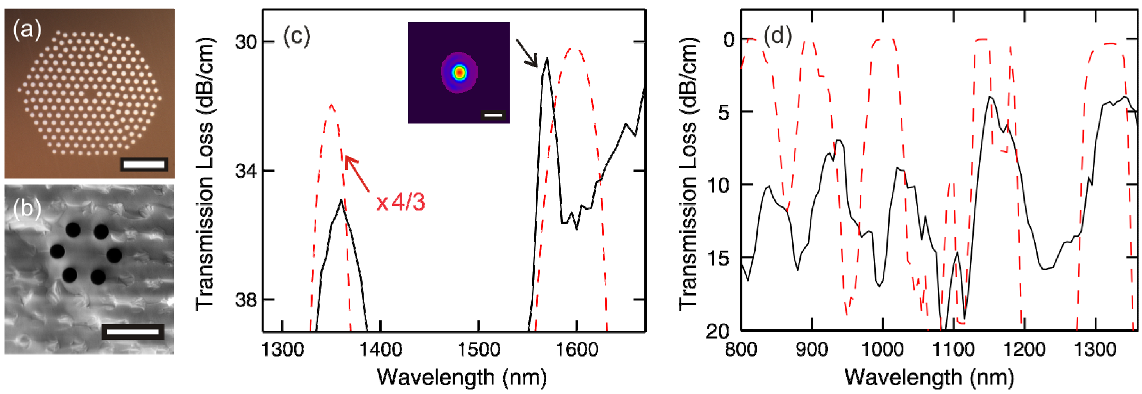

Fig. 1 SiPCF: (a) micrograph of the ARROW fibre, scale bar 10 μm. (b) SEM image of the hybrid fibre, scale bar 4 μm. (c) Transmission spectrum of the ARROW fibre, both simulated (red dashed factored by 4/3 to simplify the figure), and measured (black solid), inset mode profile at 1570 nm. (d) Transmission spectrum of the hybrid fibre, both simulated (red dashed), and measured (black solid).

References

[1] L. Lagonigro, N. Healy, J. R. Sparks, N. F. Baril, P. J. A. Sazio, J. V. Badding, and A. C. Peacock, "Low loss silicon fibers for photonics applications, " Appl. Phys. Lett. **96**, 041105 (2010).

[2] Chin-ping Yu and Jia-hong Liou, "Selectively liquid filled photonic crystal fibers for optical devices," Opt. Express **17**, 8729-8734 (2009).