PHOTONIC CRYSTAL FIBRE: THE BASICS

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Photonic crystal fibers (PCFs) guide light by "corralling" it within a periodic array of microscopic hollow channels (or "holes") that run along the entire fiber length [1]. Standard "step-index" optical fibers guide light by total internal reflection, which operates only if the core has a higher refractive index than the encircling cladding. The small index difference available in standard fibres (of order 1%) means that there is little scope for radical re-design – because conventional fibres have to operate within the straitjacket of total internal reflection. Appropriately designed, the photonic crystal fibre cladding can form a full two-dimensional bandgap for close to glancing incidence, and thus prevent the escape of light from a hollow core. It is thus possible to avoid the restrictions of total internal reflection, and trap light in a hollow fiber core surrounded by glass. (The refractive index of the core is actually almost immaterial – photonic band gap guidance is a property of the cladding and provided the core is large enough to support a resonant state, guidance will occur.) The closest prior design, suggested by Yeh & Yariv in 1976, was a cylindrical Bragg waveguide in which rings of high and low refractive index are arranged around a central core [2]. This has proved very difficult to make, and despite some good recent progress, it still remains of mainly of scientific interest [3]. PCF can in fact also support guidance by total internal reflection, in which case the core must have a higher refractive index than the average index of the holey cladding [4].

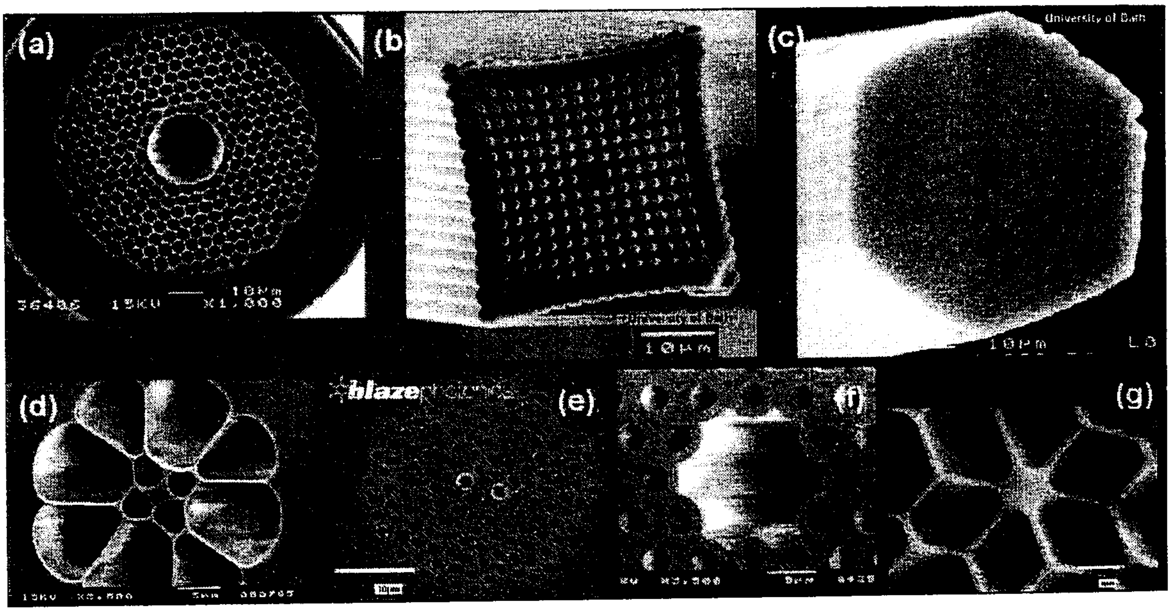

Figure 1: Scanning electron micrographs of several different PCFs & year when made: (a) state-of-the-art hollow core (www.blazephotonics.com, 2004); (b) square-lattice solid core (1998); (c) endlessly single-mode (hole spacing 2.3 μm, 1995); (d) extruded from Schott SF6 glass (~2 μm core, 2002); (e) highly birefringent (www.blazephotonics.com, 2003); (f) hollow core (~13 μm core, 1999); (g) highly nonlinear with dispersion zero at 560 nm (800 nm core, 2000).

Both types of guidance have unique properties, allowing light to be controlled and transformed with unprecedented freedom. Among the highlights are ultra-low loss hollow core PCF (1.7 dB/km at 1550 nm) [5,6], dispersion-engineered solid-core PCFs with very high nonlinear figures of merit [7-9]; PCFs with zero dispersion wavelengths in the visible [10,11]; ultra-large mode area PCFs [12], fibres that support only one transverse spatial mode at all wavelengths [13]; and polarisation-maintaining PCFs with record-breaking levels of birefringence and 100 times better thermal stability than standard PM fibres [14].

Largely through their ability to overcome the limitations of conventional fiber optics – for example by permitting low-loss guidance of light in a hollow core – PCFs are proving to have a multitude of important technological and scientific applications spanning many disciplines. The result has been a renaissance of interest in optical fibers and their uses. These examples illustrate how the PCF concept has ushered in a new and more versatile era of fibre optics, with a multitude of different applications spanning many areas of science.

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