Modelling confinement loss in practical small–core holey optical fibres

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Microstructured optical fibres (MOFs) are all-silica fibres that guide light by means of an arrangement of air-holes that run down the entire fibre length. In the kind of MOFs here considered, also named holey fibres (HFs), guidance arises from average-index effects: the holes form the cladding region around the solid core. The modes of such fibres are leaky because the core refractive index is the same as the index beyond the (finite) cladding region. HFs with a core diameter of the scale of an optical wavelength and large holes have been fabricated, resulting in the smallest effective area ever measured in a fibre at 1550 nm [1]. Such small effective areas make these fibres attractive for nonlinear applications. The cladding of a HF is usually comprised of hexagonally-packed rings of holes, and when the hole-to-hole spacing (Λ) is of the order of the wavelength, several rings of holes are required to reduce the confinement loss to a practical value. Fibre fabrication feasibility on the other hand constrains the number of rings that can be used. Therefore in order to optimise the design of this class of fibres, it is necessary to study the loss characteristics for small-core HFs.

To perform this study we applied the multipole method recently developed in Ref. [2]. This method considers MOFs with a finite cladding region of circular holes and performs full-vector modal calculations. This method yields the complex propagation constant, and thus the confinement losses can be calculated via the imaginary part. It uses polar coordinate systems centred in every hole, therefore no-false birefringence is introduced and the symmetry properties of the structure are preserved. The location of the circular holes is arbitrary, although they cannot overlap.

Fig. 1 shows a sample calculation of the modal characteristics of the 2-degenerate fundamental mode for a 3-ring structure with $\Lambda = 1.2\mu$m and holes of diameter $d = 1.08\mu$m. The calculated propagation constant is $n_{eff} = 1.2958442367 45 + 9.825 \times 10^{-9}i$, corresponding to a loss of 0.35 dB/m and an effective area of 2.36 μm^2 at 1550nm. This effective area is similar to the one reported in Ref. 1 ($\sim 2.8\mu$m^2) for a real HF. The confinement loss for small-core HFs as a function of the number and dimension of the holes and of the modal effective area will be presented and discussed.

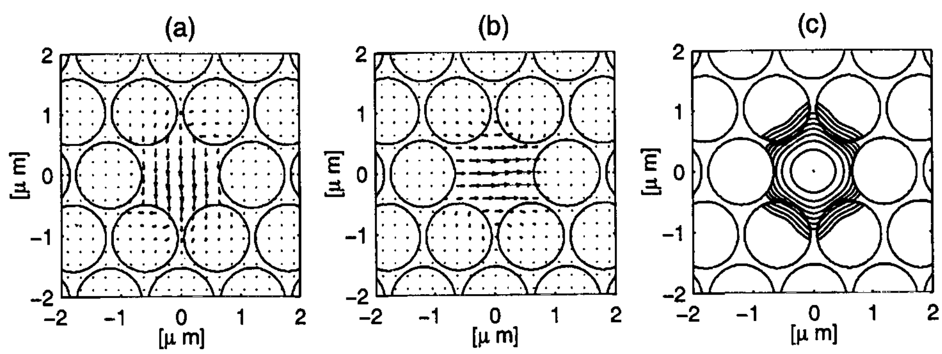

Fig. 1. Degenerate fundamental mode: (a) transverse electric and (b) magnetic fields; (c) Normalized poynting vector (contours spaced by 2 dB). See text for MOF structure details.

References

[1] P.Petropoulos, T.M. Monro, W.Belardi, K.Furusawa, J.H. Lee, and D.J. Richardson, "2R–regenerative all–optical switch based on a highly nonlinear holey fiber," *Opt. Lett.*, vol. 26, no. 16, pp. 1233–1235, Aug. 2001.

[2] T.P. White, R.C. McPhedran, C.M. de Sterke, and L.C. Botten, "Multipole method for efficient microstructured optical fiber calculations," in *Proc. CLEO*, Baltimore, 2001, OSA Technical Digest, paper JTuC6.