3100

ELECTROMAGNETIC MODELLING IN OPTOELECTRONICS

Modelling of Microstructured Optical Fibres with the Finite Element Method

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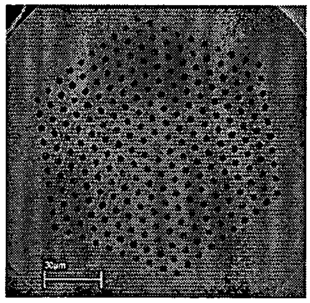

Fig. 1: Scanning Electron Micrograph of a silica-core MOF

Microstructured Optical Fibres (MOF) include a vast range of structures in which the light guidance is provided by geometrically arranged wavelength-sized holes running along the full length of the fibre. Applications of these fibres range from telecommunication uses as transmission or nonlinear devices, to more general purposes such as the delivery of high optical power, gas sensing, or the generation of supercontinuum light[1].
Being able to accurately model the complex transversal structure of MOF (an example is shown in Fig.1) allows us to gain an insight into some of the physical effects occurring and to design fibres with a specific optical behaviour targeted to the final application.
Amongst the several numerical methods available for the modal study of electromagnetic propagation in MOF[2], we have chosen to employ a full vector Finite Element Method (FEM) due to its superior calculation efficiency and adaptability to a different range of problems. Through the solution of the full vector Maxwell equations, our implementation makes it possible to visualise the different guided modes and to calculate their basic properties such as Group Velocity Dispersion (GVD) and nonlinear coefficient which are of fundamental importance to characterise the MOF guiding features in both linear and nonlinear regime. Moreover, since all guided modes in a MOF are inherently leaky due to the finite extent of the holey cladding, in order to evaluate their confinement loss, which may represent the principal form of loss, we include Anisotropic Perfectly Matched Layers (PML)[3] outside the computational domain.
Besides allowing us to study the more conventional silica-core index guiding MOF, our FEM model also enables us to study the behaviour of Photonic Bandgap Fibres (PBG) in which the light can be confined in an air core by a periodically arranged cladding of air holes in a pure silica structure. This periodical lattice can create a photonic bandgap preventing certain wavelengths from leaking out of the core. We applied our FEM model to study how the shape and dimensions of the holes affect the bandgap strength, bandwidth and central frequency, which are of paramount importance for the fabrication of such fibres.
Besides these (direct) studies of the optical properties of MOF, we are also actively engaged in solving of the (inverse) problem of determining the structure which possesses some desired properties. Since the multidimensional search space of feasible structures is vast and unknown and we need an optimisation tool as general as possible, we implemented a Genetic Algorithm (GA). As an example application we targeted the optimisation of highly nonlinear index-guiding silica MOF, where the dimensions of the circular air holes and their spacing were to be optimised in order to achieve an overall GVD as flat as possible in the wavelength range of interest. The GA proved to be an efficient inverse tool for this problem, allowing us to identify structures with remarkable dispersion flatness[4].
In conclusion we demonstrate how the FEM can be applied to a range of direct and inverse MOF simulation problems with excellent results in terms of efficiency and accuracy.

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1 P. Russell, "Photonic Crystal Fibers," Science, 299, 358-362, (2003).

2 T. M. Monro and D. J. Richardson, "Holey optical fibres: Fundamental properties and device applications," Comptes Rendus Physique, 4, 175-186, (2003).

3 K. Saitoh and M. Koshiba, "Full-vectorial finite element beam propagation method with perfectly matched layers for anisotropic optical waveguides," *Journal of Lightwave Technology*, **19**, 405-13, (2001).

4 F.Poletti, V.Finazzi, T.M.Monro, N.G.R.Broderick, D.J.Richardson, "Ultra-flattened dispersion holey fibers: genetic algorithm design and fabrication tolerances", CLEO/QELS 2005 Baltimore 22-27 May 2005 (accepted).