Modeling of photonic crystal fibers

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Photonic crystal [1, 2] have been widely studied in the last few years. It turns out that one of the most interesting practical applications of photonic crystals could be the fabrication of a new kind of optical fiber: the photonic crystal (pc) fiber. This kind of fiber is made of a lattice of air holes in a silica fiber. Recent experimental works have demonstrated the feasibility of making such fibers using the traditional two steps process: fabrication of a fiber preform from silica rods and tubes then drawing of this using a high temperature furnace in a tower setup [3]. Waveguidance in these structures has been shown [4] and very interesting properties have been predicted, for instance the possibility of making single mode fibers at any wavelength or the ability of some of these fibers to concentrate the light power inside the holes.

The plane wave methods are considered as the standard methods for modeling the propagation of light in such structures. These methods provide the location of band gaps but, since they use approximations like super cell representation, they are unable to compute some of the most important features of an optical fiber like radiation losses. The aim of the communication is to describe a rigorous electromagnetic theory of photonic crystal fibers which can predict nearly all the performances of these structures, especially dispersion properties. Our theory fully takes into account the finite size of the crystal in the fiber cross-section. Moreover it can deal with pc fibers surrounded by a cladding. The work has been undertaken in collaboration with the group of R. C. McPhedran and L.C. Botten in the School of Physics of the University of Sydney.

Our theory is inspired by the method developed in our laboratory in the frame of photonic crystals theory [5]. Closely linked theories have been developed almost at the same time and independently by other research groups, in particular in Australia [6]. The first step of the method is to elaborate a theory of electromagnetic scattering on a pc fiber in conical (off-plane) mounting. As in [5], this theory is based on the use of the scattering matrices of the air holes located in silica and on the translation properties of Fourier-Bessel functions. In addition, the notion of generalized scattering matrix is employed for including the influence of the cladding. The solution leads to the inversion of a linear system of equations. The second step of the method is to find homogeneous solutions of this scattering problem. It leads to the search for poles of the determinant of the scattering matrix associated to the whole fiber.

References

[1] E. Yablonovitch. Inhibited spontaneous emission in solid state physics and electronics. *Phys. Rev. Let.*, 58, 1987.

[2] S. John. Strong localization of photons in certain disordered dielectric superlattices. *Phys. Rev. Let.*, 58:2486–2489, 1987.

[3] A. Bjarklev. *Optical fiber amplifiers: design system and applications*. Artech House, 1993.

[4] J.C. Knight, J. Broeng, T.A. Birks, and P. St. Russell. Photonic Band Gap Guidance in Optical Fibers. *Science*, 282:1476–1478, november 1998.

[5] D. Felbacq, G. Tayeb, and D. Maystre. Scattering by a random set of parallel cylinders. *J. Opt. Soc. Am. A*, 9:2526–2538, 1994.

[6] S. K. Chin, N. A. Nicorovici, and R. C. McPhedran. Green's function and lattice sums for electromagnetic scattering by a square array of perfectly conducting cylinders. *Phys. Rev. E*, 49:4590–4602, 1994.