Electromagnetic Wave Guidance Mechanisms in Photonic Crystal Fibers

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Abstract

Photonic crystal fibers (PCFs) guide light through a solid or hollow core by employing various inherent optical properties of artificially created crystal like cladding, generally, which is a periodic arrangement of air holes in silica glass. Process of fabricating PCF is now a proven technology which is providing applications like super continuum generation, low loss ultra-short pulse propagation, lasing and sensing. A clear knowledge of wave propagation characteristics into PCFs is the fundamental requirement of designing various PCF based devices. The schematic diagram of a solid core (SC) and a hollow core (HC) PCF are shown in figure 1. Two types of light guidance mechanisms, namely index guidance and photonic band gap (PBG) guidance have been widely adopted during the last decade. Light is guided through a high refractive index core by total internal reflection (TIR) in a SC index guiding PCF and by Bragg's reflection in a HCPBG guiding PCF. Recently, possibility of another type of wave guidance employing a special point of the photonic band structure (PBS) of the cladding known as the Dirac point has been explored. Dirac point for a specially designed PC ensures isotropic linear dispersion relation between the bands crossing in the Brillouin zone (BZ). Light corresponding to Dirac frequency can be trapped in a PCF by creating appropriate defect core. The effective index of the fundamental space filling mode (nFSM) and PBS are calculated using the mode solver of COMSOL Multiphysics® to understand various light guidance mechanisms.
Use of COMSOL Multiphysics: Mode analysis and eigen frequency studies of electromagnetic waves, frequency domain (emw) of RF module are used to calculate nFSM and PBS respectively. The unit cell of the cladding and structure of the PCF cross section are drawn using geometry of model builder. Finally the effective index of the trapped core modes is calculated using mode analysis study.
Results: The magnetic field distribution of the fundamental space filling mode at 1300nm calculated using mode analysis is shown in Figure 2(a). Figure 2(b) shows the electric field distribution of the fundamental eigen mode of the crystal at BZ centre. The dispersion relations of 6 eigen modes with in plane wave vectors for a fixed out of plane wave vector is calculated to obtain the PBS which shown in Figure 3.The electric field distributions of the fundamental core guided mode of various PCFs are shown in Figure 4.The numerical value of nFSM, positions of PBG and Dirac point depend on PCF parameters like, d(diameter of the air hole), Λ (center to center distance between two consecutive air holes) and index contrast between base glass and air hole.
Conclusions: Propagation characteristics of PCF operating on different guidance mechanisms are studied and presented. Various operational parameters like dispersion, confinement loss of PCFs

are calculated using COMSOL mode analysis to estimate their performances. This study may be useful for designing various PCF based photonic devices for advanced applications.

Reference

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Figures used in the abstract

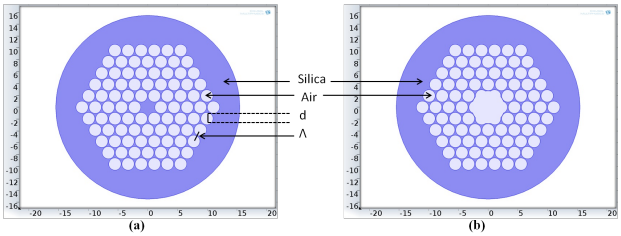

Figure 1: diagram of the cross section of (a) solid core and (b) hollow core PCF.

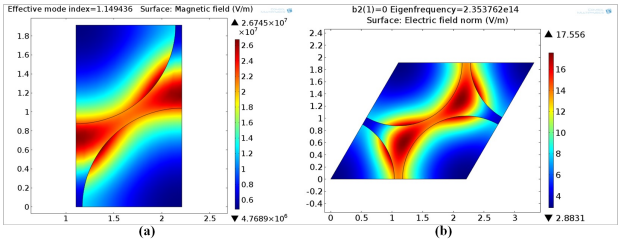

Figure 2: (a) The magnetic field distribution of the fundamental space filling mode and (b) The electric field distribution of the fundamental eigen mode.

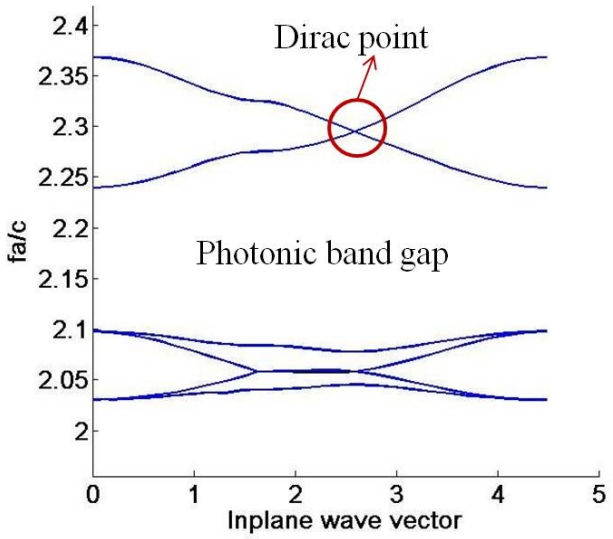

Figure 3: PBS as calculated using COMSOL for a fixed out of plane wave vector.

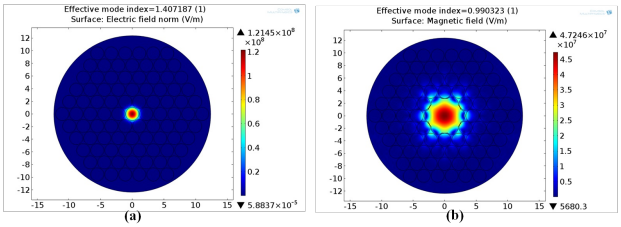

Figure 4: The electric field distributions of the fundamental core guided mode of (a) SCPCF and (b) HCPCF.