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THz waves propagation through photonic crystal fiber

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Abstract:

Low-loss terahertz (THz) wave guiding based on hollow core-photonic crystal fiber is demonstrated. The fiber proposed adapted for high THz frequency transmission, reached 3THz frequency. The fiber is designed for low transmission, confinement and material losses. Finite element method was used to analysis the transmission of fiber. The air holes of the fiber beside the two cores inside the middle of the fiber were supported for efficient confinement. The presented fiber has many applications for range THz radiation.

Introduction:

A few years back, photonic crystal fiber (PCF) has been design and fabricated to apply new properties rather than conventional optical fiber. PCFs are obtained an unusual guiding, dispersion and low attenuation properties [1]. Two types of these fibers are most common used in optical fiber technology (solid or hollow) core PCF. In both, the fiber consists of a core surrounded by a periodic structure of air holes running in all fiber, these holes are allow the light for confinement inside the core [2]. Solid core PCFs are used modify total internal reflection (MTIR) to apply guiding theory while photonic Band gap theory is used in hollow core PCF. These fibers offer high design flexibility compared with conventional optical fiber, by changing the air-hole dimensions or disposition, it's possible to find new optical guiding properties [3].

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In this paper, we analyze novel hollow core photonic crystal fiber for Terahertz (THz) transmission, THz waves have attracted more attention due to THz frequency region has a number of important potential applications in the medical, imaging fields, photoconductive antenna, optical rectification and optical parametric oscillation [4-6]. Previous works are discussed different types of THz waveguides theoretically and experimentally, including dielectric metal-coated tubes [7], metallic wires [8], Bragg fibers [9], and all-dielectric sub-wavelength polymer fibers [10]. there is a disadvantage for the sub-wavelength fibers and metallic wires that most of the field propagates outside the waveguide core, thus resulting in strong coupling to the environment. Photonic crystal fibers (PCFs) with solid cores have also been demonstrated. Nevertheless, absorption losses in the solid-core PCFs are too high [11]. Also, field mode confinement inside the core region of fiber is still challenge for THz waves. This will increase the loss for THz transmission. In this work, we present a design and analysis of hollow core PCF with high confinement efficiency and low leakage loss for transmission of THz radiation. The proposed fiber is comprised of hollow core with a triangular air-hole lattice array. The cross section of the fiber proposed has shown in figure 1. The geometric parameters of the fiber are described as: the diameter of the air hole, d. the refractive index of the air n_1, the refractive index of silica n_2.

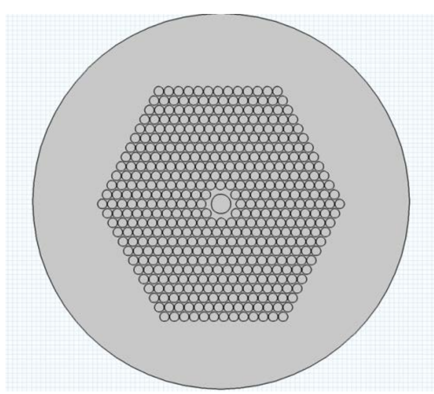


Fig. 1. Cross-section of the hollow core PCF with silica background material.

Finite element method (FEM) was to analyze the terahertz transmission fiber. The center diameter of the core was 3.25µm and the outer was 5.63µm, while the hole to hole center was 0.15µm and the diameter of the hole was 0.27µm.

The fiber is adaptive for 3 THz with low loss transmission as shown in figure 2.a. The ratio of the air-hole area to the cross-section area of the core is responsible for dispersion effects. For a fixed (air-holes area) value, the effective index decreases in fixed wavelength range. Also figure 2.b describes the Arc length of the fiber. The absorption loss of the fundamental mode is very important in our work. Particularly, the ratio of the modal absorption loss to the bulk material loss of a core material can be calculated using perturbation theory expression [12]:

$$f = \frac{\alpha_{\text{mode}}}{\alpha_{\text{mat}}} = \frac{Re(n_{\text{mat}}) \int_{\text{mat}} |E|^2 \, dA}{Re\left(\hat{z} \cdot \int_{\text{total}} dA \, E \times H^*\right)} \quad (1)$$

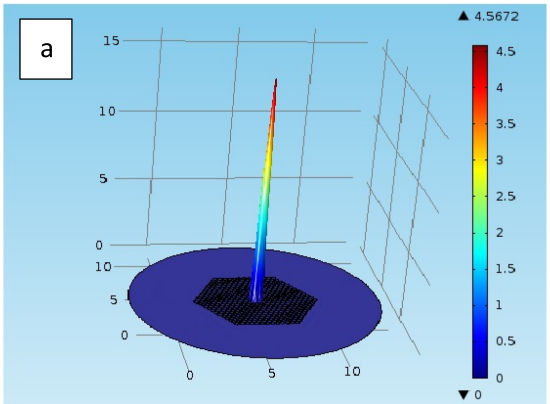
Where α_{mat} is the bulk absorption losses of the core material (air has no loss). While *E*, *H* are the modal electric and magnetic fields. The modal propagation constant b is defined as $2\pi n_{eff}/\lambda$ and A_{eff} is the modal effective area defined as:

$$A_{\text{eff}} = \left[\int I(r) r dr\right]^2 \Big/ \left[\int I^2(r) r dr\right] \quad (2)$$

Where $I(r) = |Et|^2$ is the transverse electric field intensity distribution in the fiber cross-section.

Conclusion:

Novel hollow core-PCF is design for high range terahertz transmission was demonstrated, finite element method (comsol multiphysics) was used for theoretical analysis. The frequency of the transmission of the fiber reached 3 Thz with low confinement loss. This fiber is good candidate for new optical communication system.



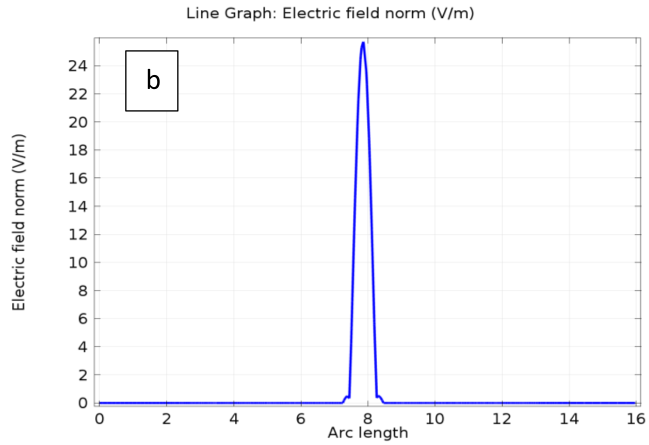


Fig. 2: (a): Fundamental component of the electric field at 2.87THz transmission in hollow core PCF, (b): electric field distribution with Arc length.

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