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# Realization of photonic topological insulator using photonic crystal fiber at visible regime: A new application of silicon photonics

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ABSTRACT

Simulation upshot of photonic crystal fiber (PCF) is lucidly divulged in this research to envisage photonic topological insulator which depicts as a new application of silicon photonics. The notion and proposition of present work manipulates with plane wave expansion method to realize the photonic current at surface of PCF rather than core region. Finally the current proposal asserts that photonic crystal fiber with apt structure and parameter can be a good candidate for photonic topological insulator application.



## 1. Introduction

The term 'topology' is not new pertaining to the geometrical mathematics. However it is a great academic interest with respect to physics and technology owing to its efficient applications in various fields. Layman definition says " topology" is the branch of geometry concerned with those properties of a geometrical figure that remains unchanged even when the figure is deformed by bending, stretching and twisting etc. Similarly physics says topological insulator is material whose inner behaves as insulator (no flow of current) where outer acts as conducting surface. As far as research on topological insulator is concerned, it is not confined with the radio or microwave frequency only but it penetrates through infrared range and visible ranges. Though many works related to optical structure deals with topological geometry, this communication manipulates with photonic crystal optical fiber to realize photonic topological insulator at visible frequencies. Making a brief analysis of literature review on topological insulator, in reference [1] authors discuss the recent progress of topological insulator for realising time reversal invariant topological insulator, where reference [2] explains the photonic bandgap structure of topological insulator using dielectric materials. Also multiple experimental observation of discrete transmission peak in photonic topological insulator is cleared in this reference. Similarly in reference [3], microwave photonic topological insulator is reconfigured using both 3D finite element method and Hamiltonian model. Again photonic topological insulator with broken time reversal symmetry is mentioned in reference [4]. Apart from this, reference [5] and [6] discloses a new type of topological insulator based on nanometer holograms and nanoplasomic particle respectively. Though above cited references tells about the recent research pertaining to photonic topological insulator, the present work tries to disclose

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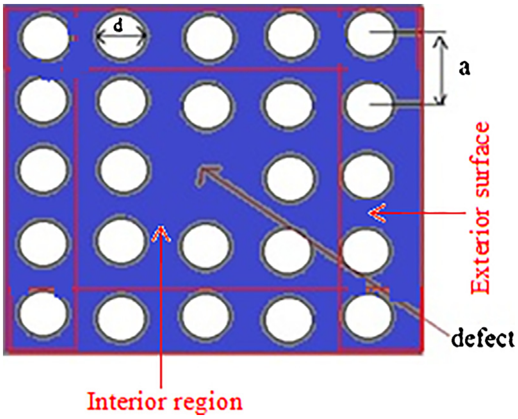


**Fig. 1.** Cross-sectional view of microstructure optical fiber.

photonic topological insulator application using silicon based photonic crystal fiber (PCF). Silicon is a collegial material and apposite for both electronics and photonic research. Further realising the silicon based photonics, recently certain works related to photonics have been established using one, two and three dimensional structure for sensing [7–14] and communication [15–28] purposes.

## 2. Designed structure

Though the later part of previous section explores different structures and techniques to understand topological insulator and several applications using silicon photonic structure, the current work describes current flows at the surface of photonic crystal fiber at visible regime (400 nm − 750 nm).The proposed photonic crystal fiber is simple and made up silicon as background material such that 5 × 5 air holes with defect at centre are itched on the substrate. The designed PCF structure is envisaged in Fig. 1;

In this case signals with wavelength ranges of 400 nm to 750 nm manipulates with propsed photonic fiber such that the dimension of the above square lattice is taken of $50 \times 50\,\mu m^2$ with 8 μm and 10 μm of diameter (d) of air holes and lattice spacing (a) respectively. The reason for choosing above parameters and materials is that the photonic current are realised at the surface only for all visible wavelengths. Moreover no seepage (inner part of the MSOF) of signal is found in above said structures.

## 3. Results and discussion

For comprehending photonic current at surface rather core region of structure 1, plane wave expansion technique is employed to make simulation for electric field distribution through the aforementioned photonic crystal fiber [29]. Though simulation is done for all wavelengths of visible regime, output result corresponding to the wavelengths of 400 nm and 750 nm are shown in Fig. 2(a) and (b) respectively.

In Fig. 2, x any y (μm) is represented as length and breadth of fibe and electric field (V/μm) is taken along vertical axis. An interesting result is revealed from above figures. For example the transmitted signals (field distribution) are only coming out from the surface air hole of optical fiber. But the peak intensities of the electric filed distribution are differed from different wavelengths. Apart from this, it is also realised that no field distribution is accomplished with the internal part of the optical fiber. So silicon microstructure optical fiber can be a suitable candidate for topological insulator. Aside above two wavelengths (400 nm and 750 nm), the present photonic crystal fiber manipulates with other entire wavelengths (410 nm, 420 nm, . . .. . .. . .., 730 nm,740 nm). During the manipulation and simulation in all cases, it is found that photonic current exhibits at surfaces of PCF and moreover no current flows at core regions. The physics of above said beautiful result lies with the silicon as background materials pertaining to different refractive indices of silicon at different wavelengths which is drawn from the reference [30]. For example; the refractive index of silicon at the wavelength 450 nm (4.68) is not same at 470 nm (4.49). Therefore different refractive index of silicon background materials gives rise to dissimilar electric field distribution at different wavelengths. However position and configuration of the structure including lattice spacing and diameter of air holes remains invariant with respect to all wavelengths of visible regime.

## 4. Conclusion

A new application of silicon photonic crystal fiber is exhibited in this work at visible wavelengths. A beautiful variation of photonic current is found at the surface of photonic crystal fiber rather than core region. Physics of the work confirms that nature, position and configuration of proposed photonic structure paly vital role for flowing of photonic current at