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# Realisation of optical demux vis-a-vis 850/1310/1550 nm using photonic crystal fiber

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ABSTRACT

Simple optical demultiplexer is realised in this paper using photonic crystal fiber (PCF), where photonic crystal fiber acts as filter, that controls the permission or forbidden of input signal through it, which is the basic principle of operation of PCF based demux. Plane wave expansion method is employed in the present research to compute the electric field at out put end to envisage the above said operation at three communication windows. Finally, the present work divulges that aside nature and properties of material of PCF, the configuration of fiber including lattice spacing and diameter of air holes plays vital role to understand the filtering as well as DEMUX application.



## 1. Introduction

Photonic crystal fiber (PCF) is a new technical area in optical science and technology because of its novel kind of feature and robust applications. From theoretical point of view, it has several advantages over conventional optical fiber with respect to design, feasibility, compatibility and efficiency. However the work on the same is sluggish due to unavailability fabrication techniques pertaining to current research scenario. As far as literature review on photonic crystal structure is concerned, it is born in the year 1993–1994, after publishing two milestone paper on photonic crystal structure [1]. Since then different applications related to sensing communication, networking and computing have been found using photonic crystal fiber. Keeping the importance of photonic crystal fiber, this paper tries to design an optical demux using the same where PCF delivers filtering applications. As far as demux work is concerned, many paper deals with similar kind of applications. For example in reference [2], authors employed diffraction grating experiment to WDM system at the wavelength 800 nm only. Similarly reference [3] uses multi-layered a-SiC-H hetero-structure for showing wavelength division multiplexer. Also a conventional optical fiber is employed in Refs. [4,5] to design optical demultiplexer. Again add-drop using polymer waveguide is designed in reference [6], where 4 channel optical demux is developed using silicon nitride in reference [6]. Recently similar types of works have been disclosed by G. Palai et al. using one, two and three dimensional photonic crystal structure. For example, in reference [7,8] author discusses optical MUX/DEMUX applications using polymer and silicon based one dimensional photonic crystal structure where in reference [9] similar work is carried out using silicon based two dimensional photonic crystals [10]. Again, optical MUX/DEMUX has been shown in reference [11] using silicon based 3D photonic crystal structure. In all above cases, the principle of operation of work relay on the photonic band-gap analysis of photonic crystal structure. Though the present research discloses similar application but the method and structure is quite

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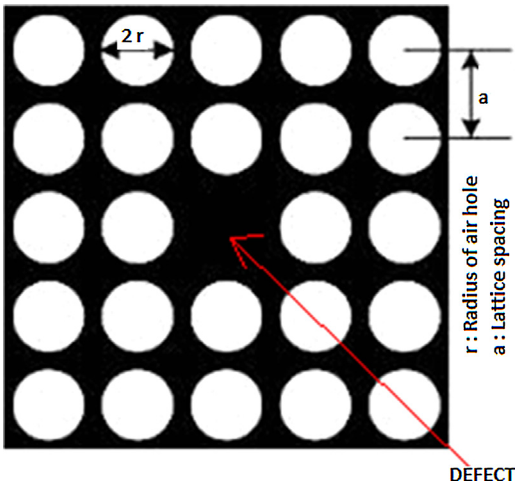


**Fig. 1.** Cross-sectional view of squre type photonic crystal structure with defect at centre.

different as compared to existing one. For example it deals with photonic crystal fiber and principle of operation is based on the electric field distribution inside the photonic crystal fiber.

This paper is organised in following manner; Section 2 explains the proposed structure of optical DEMUX including principle of operation, where simulation result and discussion is made in Section 3. Finally conclusion is made in Section 4.

## 2. Structure and operation

In this research, optical demux is combination of filter and optical circulators where filter is realised photonic crystal fiber, which is a heart of present work. Before going to discuss the complete demux structure, let us focus on PCF, which is shown in Fig. 1.

Fig. 1 represent top view of square type photonic crystal fiber, which has silicon as background material and consists of $5 \times 5$ air holes on substrate in such way that defect is made at middle section that is clearly visible in this Fig. 1. The reason for choosing silicon material as background is that no absorption is found with the same [12]. So the proposed fiber deals with transmitted and reflected signal only rather than absorption. As far as allowed and disallowed of signal is concerned, with rely on lattice spacing of the structure and radius of the air holes. For example PCF has different lattice spacing and radius of air holes allows or disallows different signals (850 nm, 1310 nm and 1550 nm). Further moving to operational principle of optical demux, let us focus on the schematic diagram of the same, which shown in Fig. 2.

The Fig. 2 is not new pertaining to similar type of applications. However the components of above demux are different. i.e. it deals with a new kind of structure for demux applications. Basically above structure implies that it depends on optical circulators and photonic crystal fiber (OF-1, OF-2 and OF-3). Since this paper focuses on photonic crystal fiber rather than the circulator we looked away the optical circulator in this paper. Moreover photonic crystal fiber is being concerned for further analysis. Here the signals of 1st, 2nd and 3rd of optical communication windows (850 nm, 1310 nm and 1550 nm) is allowed to incident on optical circulator-1, then it turns to PCF-1. Here PCF-1 is designed in such way that it allows the signal of 850 nm and reflects 1310 nm and 1550 nm. Further the disallowed wavelength (1310 nm and 1550 nm) comes back to OPTCIR-1 then it bends to OPTCIR-2 and subsequently reaches at photonic crystal fiber-2. It is designed in such way that it allows 1310 nm and rejects 1550 nm. Using similar principle signals of 1550 nm would be propagated through photonic optical fiber 3 (PCF-3).The design of photonic crystal fiber-1,2 and 3 depends on lattice spacing and radius of air holes, which is discussed in next section.

## 3. Result and discussion

From previous section it is envisaged that, all three photonic crystal fiber acts as filter for transmitting 850 nm, 1310 nm and 1550 nm signal in Fig. 2 respectively. Such filtering application can't be realised through simulation studies, which is made by using plane wave expansion method [1]. Plane wave expansion method is a powerful technique to make a simulation pertaining to simple structure, which is described in this work. Aside this, the conformation of allowed and disallowed of signal is made through electric field distribution at output ends of the purposed photonic crystal fiber. The understanding of same permission or forbidden is found from simulating diagram Fig. 2(a)–(c) for allowing the 850 nm, 1310 nm and 1550 nm respectively. The above figures, represented as 3D diagrams for showing length (m), width(w) and electric field (E) along X, Y and Z-axis respectively. A lot of peaks of electric field have been found in the above said graphs. But we are interested for searching peak electric field corresponding to wavelength 850 nm, 1310 nm and 1550 nm only using simple equation

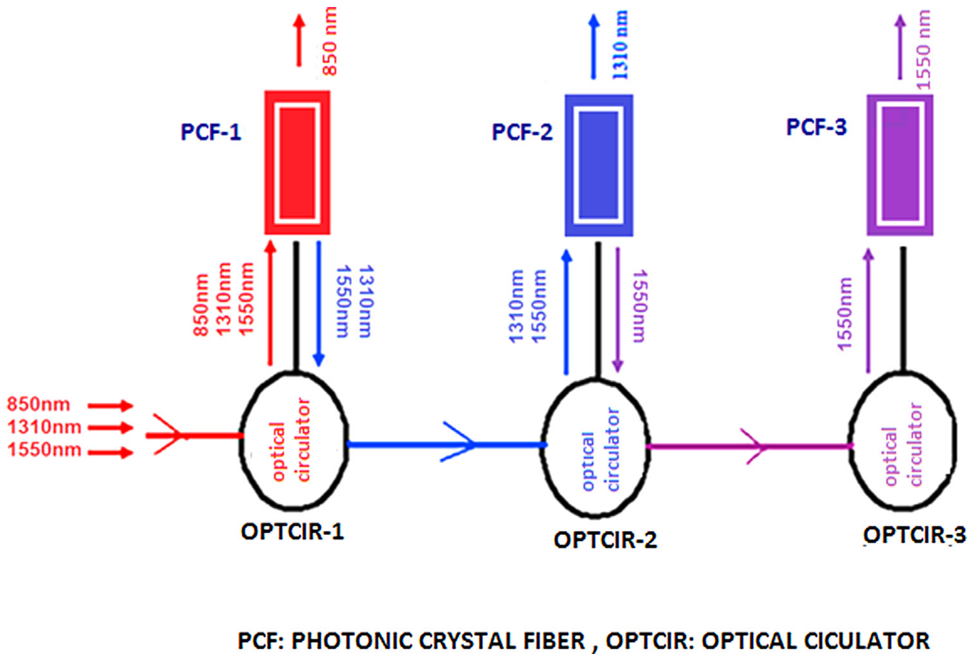


**Fig. 2.** Schematic diagram of PCF based optical demux.

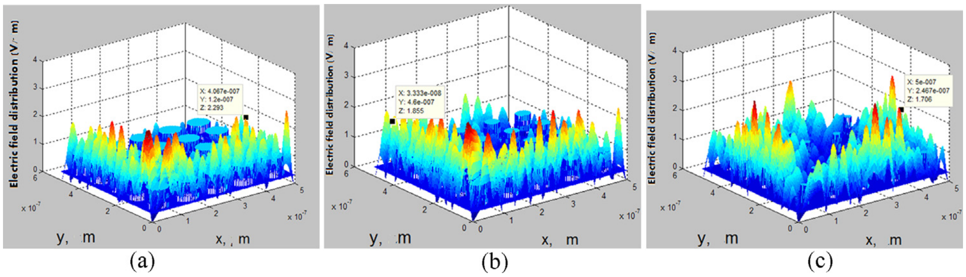


**Fig. 3.** (a) Electric field intensity of wavelength 850 nm (r = 35 nm and a = 100 nm). (b) Electric field intensity of wavelength 1310 nm (r = 22 nm and a = 1 nm). (c) Electric field intensity of wavelength 1550 nm(r = 12 nm and a = 100 nm).

$\boldsymbol{\lambda} = \frac{2hc}{\epsilon_0 E^2}$ ; (where h,c,$\varepsilon_0$ and E are represented as plank's constant, velocity of light in free space, permittivity of free space and peak electric field respectively). Using above said analysis, the peak electric field (2.293 V/m, 1.855 V/m and 1706 V/m) is shown in Fig. 3(a)–(c) corresponding to the lattice space and radius (100 nm, 35 nm), (100 nm, 22 nm) and (100 nm, 12 nm) respectively.

The reason for choosing such lattice spacing and radius is that the propagation of signal of 1st, 2nd and 3rd windows is found at above said parameters only. Again, as far as reflected signal is concerned, though it is not directly envisaged from above said simulate figures, but it is understand that other signals are reflected because no signal is absorbed by above said silicon structure. To sum up, it is revealed that the photonic crystal fiber with silicon as background material having lattice spacing of 100 nm and radius of air holes 35 nm allows the signal 850 nm and forbidden to 1310 nm and 1550 nm. Similarly lattice spacing of 100 nm and radius of air holes of 22 nm allows 1310 nm and reflects to 1550 nm. Further lattice spacing of 100 nm and radius of air holes of 12 nm allows 1550 nm only.

## 4. Conclusion

Optical DEMUX using photonic crystal fiber pertaining to the wavelengths of 850 nm, 1310 nm and 1550 nm is envisaged in this work. Simulation result using plane wave expansion method for finding electric field distribution divulges that aside background materials, the configuration of fiber structure including lattice spacing and radius of air hole plays vital to accomplish filtering application which will be an important components of optical demultiplexer. Finally it is inferred that silicon based photonic crystal fiber with apposite combination of lattice spacing and radius of air holes can be a good candidate for filtering and subsequently for demux application.

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