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Generation of ultra violet signal from visible light using photonic crystal fiber: A realization of PCF based UV torch

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ABSTRACT

Though photonic crystal fiber has been exhibiting an exhilarating application since a couple decades, the current communication divulges an another noteworthy upshot vis-à-vis Ultra Violet (UV) signal from Visible light. The photonic crystal fiber is taken as square type silicon based photonic crystal, where nature, position and configuration are mainstay of this research work. The principle of investigation of present study is based on the distribution of electric field in the said suggested fiber in such way that emerging signal from such fiber lies with the range of UV signal. Finally the proposed device acts as fiber based torch light, which could be used for UV applications.

1. Introduction

Nevertheless photonic crystal fiber has been dealing with various type of devices over last two decades, ultraviolet torch is a new notion to envisage the application of photonic crystal fiber. Basically various type of UV applications is found in market, where applications relay on emerging signal from said device. It indicates that specific wavelengths are used for particular purposes. For example; wavelength of 13.5 nm is used for lithography, 30–200 nm is employed for photonization, 200–400 nm is applied for forensic analysis and drug detection. Further the wavelength of 300 nm–320 nm is used for medical therapy and others found in literature [1]. To realize the importance of the same, this paper attempts to solve the above said issues using silicon based photonics and more specifically using photonic crystal fiber. The proposed device for the same is shown in Fig. 1.

Fig. 1, bestows information to envisage the conversion of Ultraviolet signal from Visible to light, which is made through photonic crystal fiber whose cross-sectional view is discussed in next section. Moreover this figure also realises that the complete device signified as Laser torch. Here signals from visible source incident on photonic crystal fiber (PCF), the PCF is designed in such way that the output signal would lie with the range of ultraviolet signal. The whole components (visible source and PCF) can be considered as UV torch.

As far as organization of this manuscript is concerned section two deals with the concept of the structure along with operational principle of photonic crystal fiber to realize UV device, where result and outcomes of present work is disclosed in Section 3, finally conclusion is shown in Section 4.

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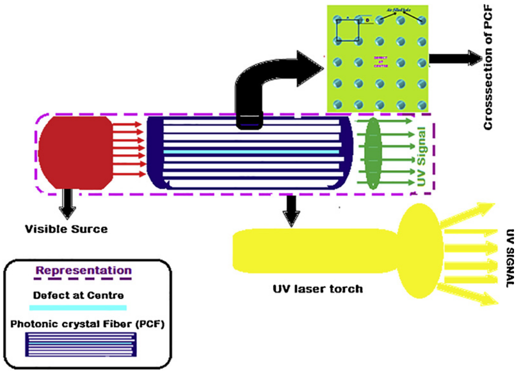

Fig. 1. Complete information to realise fiber based UV Laser torch.

2. Structure and principle of PCF

Although the present discussion focuses on the uses of photonic crystal fiber for UV application; let us disclose a brief notion about photonic crystal fiber. Photonic crystal fiber is pioneered by the research group of Philips S. J Russell in the 1990s which could be used for a great variety of possible application in the field of light wave and technology [2]. Particularly, this kind of fiber offers many degrees of freedom to design as well as a several sorts of properties which lead to a variety of applications in the field of science and technology. Though there is no special material required to design a photonic crystal fiber but the arrangement of very tiny and closely spaced air holes go through the entire length of the fiber is quite different from conventional fiber. Apart from this a variety of arrangement of air holes on different shape of background or substrate exhibits different properties of photonic crystal fiber. Beside this the principle of photonic crystal fiber is based on either photonic band gap or modified total internal reflection which is quite different from conventional optical fiber whose principle relays on total internal reflection.

Nonetheless several sorts of photonic crystal fiber have been designed for several applications, this paper chose a square type photonic crystal fiber to explore a new type of green photonic applications, which is shown in Fig. 2.

The above said figure is represented as a cross-sectional view of a square type photonic crystal fiber which consists of 5 × 5 air holes in regular manner in such way that a defect is made at the central region of the fiber where no etching of air holes. The structure of said fiber depends on dimension (lattice spacing of the structure (a), dimension of the air holes (D)), shape and size of the structure including the nature of both background or substrate and infiltrated materials. Though no experimental work have been divulged using similar type of square lattice photonic crystal fiber, a few works pertaining to the same have appeared in literature. For example reference [3] and [4] discusses the sensing application silicon based photonic crystal fiber, where reference [3] investigates the percentage of potassium chloride in their aqueous solution and concentration of intallipid is estimated in reference [4]. Also optical characteristics of similar type of structure are discussed in reference [5] to realise optical communication, where the dispersion properties were the backbone of this research. Apart from this a beam splitting application using silicon based microstructure optical fiber is made in reference [6]. Moreover recently different type of novel application has been seen in literature using square type optical fiber. For examples; reference [7–9] exhibit optical memory, optical demultiplexer and topological insulator respectively. Even though this paper uses similar type of structure but the present work explores new type of application with respect to optical element vis-à-vis green device. So keeping the view of the importance of the structure, we in this paper selected an apt structure parameter to envisage the emerging signal as UV range of the spectrum which leads to the realization of UV application. Further considering the principle of realization of emerging signal belongs to UV spectrum, the electric field distribution in the photonic crystal fiber which is the backbone of this research. As far as the dimension of proposed crystal fiber is concerned, it lies in the order of nanometer, where silicon is manipulated background material. The reason for choosing such nature, dimension and material is that the emerging signal from photonic crystal fiber shall divulge UV signal at this condition only.

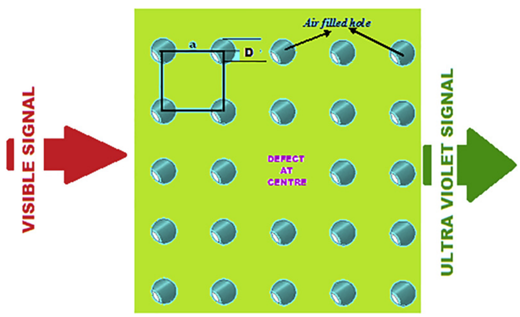

Fig. 2. Cross-sectional view of square type photonic crystal fiber.

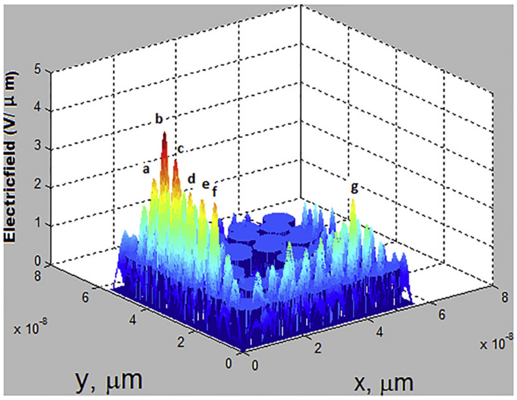

Fig. 3. Elecricfield distribution in photonic crystal fiber.

3. Result and discussion

Even though the previous section discloses the range of structure parameter, the present section shall divulge such parameters in explicitly for analysing an output upshot to understand UV signal. To comprehend the same, different values of both lattice spacing and diameter of air holes have been chosen in such way that the emerging signal from photonic crystal fiber should be the range of UV spectrum with respect to input signal (visible). Keeping in hand the above said objective, we picked up a several dissimilar combination of lattice spacing of structure with diameter of air holes, however it is realised that the UV spectrum application is observed with respect to a few suitable combination of same. Again concentrating on apt combination of lattice spacing and diameter of the same, we affirm that the combination, (8 nm, 4 nm), (5 nm, 4 nm), (7 nm, 5.6 nm), (6 nm, 4.8 nm), (10 nm, 8 nm) and (11 nm, 8 nm) of (a, d) is found as apt to realize the same. Though the simulation has been carried for aforementioned combination, the result for (11 nm, 8 nm) is shown in Fig. 3.

The above diagram is represented as 3 dimensional simulation output, which is simulated with the help of plane wave expansion [10] where length, breath in μm and electric field in volt/μm is taken along x, y and z axis respectively. Moreover Fig. 3, shows a peak electric field emerging from photonic crystal fiber. The same electric field is indicated with a,b,c,d,e,f and g, whose values are 3.131, 4.484,3.864,3.174,3.148,3.270 and 2.88 respectively. Then we use simple mathematical expression as $\lambda = \frac{2hc}{E^2}$ where h, c and E are represented as planks constant, velocity of light in vacuum and peak electric field respectively. Using above said principle, the wavelength of signal emerging from the waveguide is found to be 25 nm, 12 nm, 17 nm, 26 nm, 27 nm, 24 nm and 30 nm respectively corresponding to peak values of a, b, c, d, e, f and g. Apart from this it is observed that all the signals coming out from photonic crystal fiber pertaining to the lattice spacing of 11 nm and diameter of air holes of 8 nm is belonged to UV spectrum. Using similar type of principle, different type of wavelength can also be seen using different combination of lattice spacing and diameter of proposed photonic structure. The diagram corresponding to the same is not divulged here, but the Table 1 bestows complete information to understand the same. The column 1, 2, 3, 4, 5 and 6 shows different wavelength (λ) emerging from said photonic crystal fiber corresponding to the combination of (8 nm, 4 nm), (5 nm, 4 nm), (7 nm, 5.6 nm), (6 nm, 4.8 nm), (10 nm, 8 nm) and (11 nm, 8 nm) of lattice spacing and diameter respectively. From above information, different values of wavelengths have been observed and almost all wavelengths are belong to UV spectrum aside signals (813 nm and 831 nm of combination (6 nm, 4.8 nm). Because of all signals belong to UV range, various types of UV applications such as photonisation, manufacturing of photonic integrated circuit, optical

Table 1
Complete information of output upshot emerging from proposed photonic crystal fibre.

λ (nm) for a = 8 nm and D = 4 nm	λ (nm) for a = 5 nm and D = 4 nm	λ (nm) for a = 7 nm and D = 5.6 nm	λ (nm) for a = 6 nm and D = 4.8 nm	λ (nm) for a = 10 nm and D = 8 nm	λ (nm) for a = 11 nm and D = 8 nm
33	120	138	144	30	25
35	66	122	81	13	12
44	88	88	75	21	17
42	118	60	120	33	26
68	90	95	97	30	27
45	155	80	65	36	24
45	125	118	70		30
468		104	138		
56		150	813		
70		109	831		
468		215			
468		429			
		326			

sensing, and disinfection drugs detects, medical imaging of cells, light therapy in medium etc. can be carrying out using the proposed photonic crystal fiber.

4. Conclusion

Silicon based photonic crystal fiber is employed in this research to divulge UV spectrum application with the help of plane wave expansion technique. The output of simulation outcomes discloses that a variety of ultraviolet spectrum application can be realised with respect to (8 nm, 4 nm), (5 nm, 4 nm), (7 nm, 5.6 nm), (6 nm, 4.8 nm), (10 nm, 8 nm) and (11 nm, 8 nm) of (a, d) respectively. Finally it is concluded that the proposed photonic crystal fiber with appropriate structure parameters would be a good candidate for green photonic applications.

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