Ultrashort Pulse Generation in Tapered Photonic Crystal Fiber at 400 nm

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Abstract— In this paper, we design hexagonal and octagonal TPCFs wherein dispersion and nonlinearity vary exponentially at 400 nm wavelength according to the self-similar analysis. By exploiting these optical properties, we demonstrate the effective pulse compression schemes at 400 nm wavelength.

1. INTRODUCTION

The generation of ultrashort pulses at shorter wavelength near 450 nm is especially preferred in satellite sensors, ophthalmology in optical coherence tomography system, optical imaging,etc [1]. However, it is difficult to produce such a shortest pulse at near visible wavelength even from the best available laser sources. Of late, the generation of desired pulse width of ultrashort pulses is quite possible through pulse compression technique with the advent of photonic crystal fiber (PCF) where the anomalous dispersion can also be obtained at visible regime [2]. Achieving single mode and high dispersion near the visible wavelength turns out to be a challenging task in the generation of ultrashort pulses using PCF. In general, there are two proven ways to enhance the nonlinearity and dispersion values in PCFs. First, one can modify the design of PCF with large air hole size leading to high nonlinearity and large dispersion. However, this usually results in switching over to multimode propagation owing to larger values of air hole size. Second, the nonsilica technology such as SF6, TF10, CS2, nitrobenzene, and so on, enhances the nonlinearity and eventually requires relatively less input energy [3]. In general, the tapering is done by reducing the pitch and diameter. Fiber tapering provides a convenient way to reduce the mode-field diameter of fibers, thereby allowing for a better pulse compression [4]. We, thus, emphasize that the tapered PCFs (TPCFs) are very much suitable for effective pulse compression when compared to conventional PCFs. In this paper, we design hexagonal and octagonal TPCFs wherein group velocity dispersion (GVD) and nonlinearity vary exponentially at 400 nm wavelength in line with the self-similar analysis. By exploiting these optical properties, we demonstrate the effective pulse compression schemes at 400 nm wavelength.

2. DESIGN OF THE PROPOSED TPCF

The proposed geometric hexagonal and octagonal tapered structures consist of five rings of air holes. TPCFs can be designed by simultaneous reduction of their geometrical parameters, namely, air-hole diameter, d, and pitch, Λ. While tapering the PCF, we decrease the value of the pitch as per self-similar condition [5].

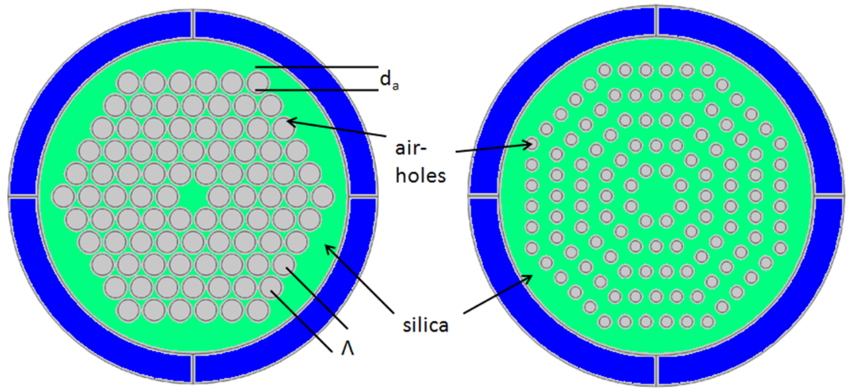
$$\Lambda(z) = \Lambda_0 \exp(-\sigma z), \tag{1}$$

where Λ is the pitch, if σ is the decay rate and z is the propagation distance.

The geometrical structures of the proposed hexagonal and octagonal TPCFs are shown in Fig. 1(a). Here pitch is kept at 7 µm.

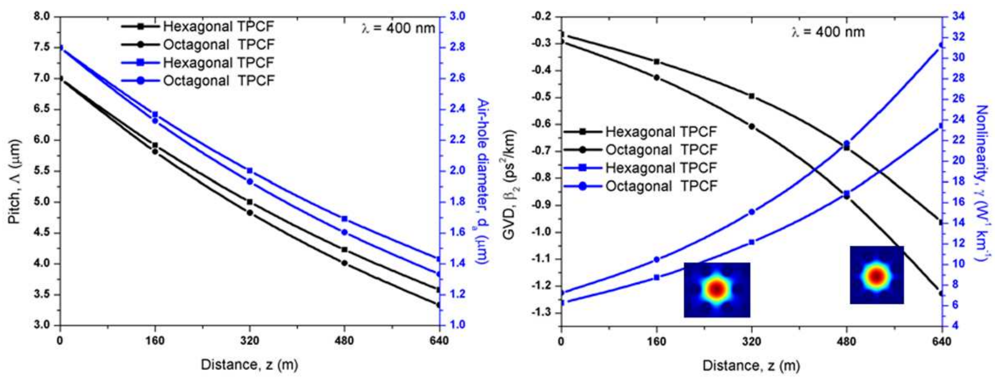
3. OPTICAL PROPERTIES

In this section, we describe an important linear effect called. It is known that the dispersion does depend on both operating wavelength and the physical parameters such as core diameter and pitch. The value of GVD is determined from the second derivative of the computed n_{eff}



(a) (b)

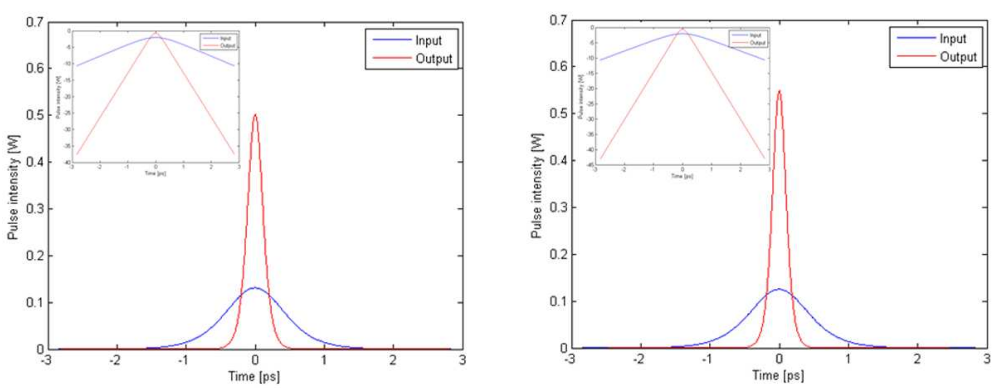
Figure 1: Geometrical structure of (a) hexagonal and (b) octagonal TPCFs when $\Lambda = 7\,\mu$m.



(a) (b)

Figure 2: (a) Pitch and air-hole diameter with respect to distance at 400 nm wavelength and (b) variations of GVD and nonlinearity for the proposed hexagonal and octagonal TPCF at 400 nm wavelength.

using finite element method [6]. It is clear that the proposed tapered PCFs exhibit anomalous dispersion varying exponentially based on self similar condition at 400 nm wavelength. To compute the effective nonlinearity, we first calculate the effective area, A_{eff}. From the numerical results, we find that the effective area decreases and hence the effective nonlinearity increases exponentially as shown in Fig. 2(b).



(a) (b)

Figure 3: The calculated output pulse profiles through self-similar analysis of the proposed (a) hexagonal and (b) octagonal TPCFs at 400 nm wavelength with their log plots.

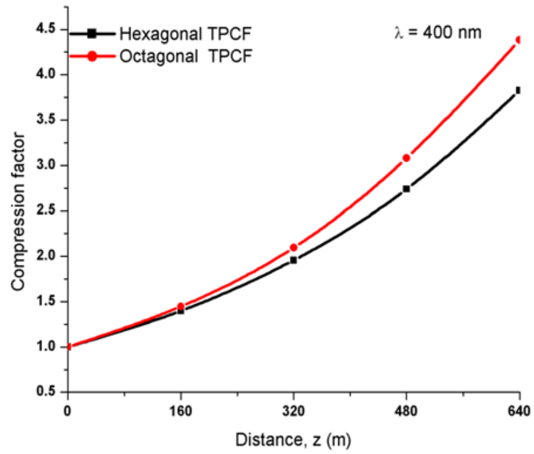


Figure 4: Compression factor of self similar pulse compression for tapered PCF at 400 nm.

4. SELF SIMILAR PULSE COMPRESSION

Self-similar pulses are preferred since the linear chirp facilitates efficient pulse compression. A self-similar analysis has been utilized to study linearly chirped pulses in optical fiber and fiber amplifiers. It is obvious that length of the TPCF is a significant factor for a compact self similar pulse compressor [7]. We choose the fiber length in such a way that it is always lesser than the chirp length in order to ensure that the chirp does not contribute to the spectrum of the compressed pulses. The calculated output pulse profiles through self-similar analysis of the proposed (a) hexagonal and (b) octagonal TPCFs at 400 nm wavelength are shown in Fig. 3.

Note that the initial full width at half-maximum (FWHM) intensity of the pulse is $1.76T_0$. Here FWHM is kept as 1 ps. It is obvious that length of the TPCF is a significant factor for a compact self similar pulse compressor [8]. We choose the fiber length in such a way that it is always lesser than the chirp length in order to ensure that the chirp does not contribute to the spectrum of the compressed pulses.

5. CONCLUSION

We have been able to generate the self-similar ultrashort pulses at 400 nm wavelength using both hexagonal and octagonal tapered photonic crystal fibers. We strongly envisage that the proposed TPCFs at 400 nm wavelength would find useful in satellite sensors, ophthalmology, optical imaging, etc..

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