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Dispersion Flattened Decagonal Photonic Crystal Fiber

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Abstract
Ultra-flattened dispersion of 0 ± 0.80 ps/(nm-km) within a 370 nm band and low confinement loss 0.1 dB/km is obtained from a decagonal photonic crystal fiber. This fiber has a modest number of design parameter.

Key words: *decagonal photonic crystal fiber (PCF), chromatic dispersion, effective area (A_{eff}), confinement loss*

1. Introduction

In photonic crystal fibers (PCFs) [1], control of chromatic dispersion is crucial for practical applications to optical fiber communication systems, dispersion compensation and nonlinear optics [2].

Various index guiding hexagonal PCFs (H-PCFs) with remarkable dispersion and leakage properties [3] have been reported to date including PCFs with two defected rings, PCF designs with uniform optimized air-holes, PCFs with several different air-hole diameters, and PCFs with a defected air-hole in the core [4]. In almost all instances, either many rings layer, or many design parameters, or submicron adjustments are required; efforts continue to locate a simple PCF structure. As a part of the ongoing effort to locate a novel PCF structure, we propose a decagonal PCF (D-PCF) having a modest number of design parameters.

In this paper, it is numerically shown that a three-ring D-PCF can operate a single mode in the entire telecommunication windows with ultra-flattened chromatic dispersion and very low confinement losses. D-PCF with such novel properties as wideband single-mode operation with ultra-flattened chromatic dispersion and low confinement losses may pave the way for different potential applications in optical communication systems and nonlinear optics.

2. D-PCF structure

Fig.1 shows air-hole geometry of the D-PCF. For the purpose of simplicity only two rings are shown. Pitch, Λ is the spacing between air-hole centers on the adjacent rings and the spacing between air-hole centers on the same ring is Λ_1. Λ_1 is related to Λ by the relation $\Lambda_1 \approx 0.618\Lambda$. Therefore, the maximum diameter of an air hole may have a value of 0.3075Λ. The D-PCF is constructed by repeating a unit isosceles triangular lattice with vertex angle of 36^0 around the silica core. The core diameter is 2a, where 'a' equals Λ-d/2. The air-holes with diameter d are located at each corner of the isosceles triangle resulting lower refractive index due to higher air-filling fraction (*AFF*) around the core compared to an H-PCF. Using the definition of *AFF* [5] it can easily be shown that the air-hole radius of a D-PCF can be around 18% smaller than that of the H-PCF for a same AFF and pitch values. Fig.2 is the proposed D-PCF structure with three rings of which the first ring is defected (hereinafter known as defected D-PCF). The air-holes on the first ring have a diameter d_1 and d is the air-hole diameter on the other rings. The core diameter is 2a, where 'a' equals Λ-d_1/2.

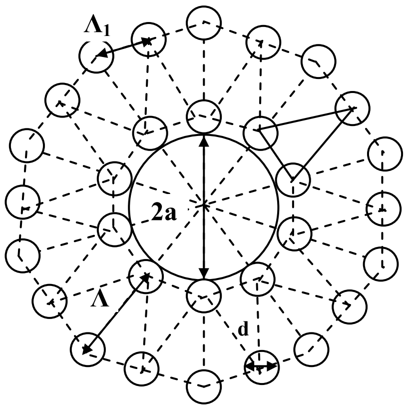

Fig.1 Geometry of a D-PCF with isosceles triangular lattices

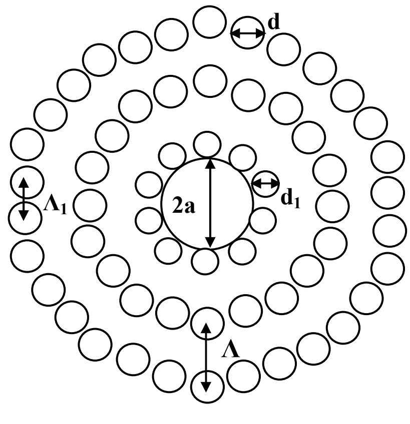

Fig. 2 Geometry of the defected D-PCF with one defected ring

3. Simulation results

The finite difference method (FDM) [6] with anisotropic perfectly matched boundary layers (PML) is used to calculate the chromatic dispersion and confinement loss.

Once the modal effective indices n_{eff} is obtained by solving an eigenvalue problem drawn from Maxwell equations using the FDM, the chromatic dispersion parameter $D(\lambda)$, confinement parameter Lc and effective area A_{eff} can be given by the equations [4].

Fig.3 shows chromatic dispersion properties of the proposed defected D-PCF shown in Fig. 2. Optimizing the parameters ultra-flattened chromatic dispersion of 0 ± 0.80 ps/(nm-km) is obtained (solid line) for three-rings, $d_1 = 0.60$ µm, d = 1.15 µm and Λ=2.35 µm. Fig. 4 shows the confinement loss and effective area of the same fiber for the said optimum parameters. It is seen that the confinement loss is as low as a 0.1 dB/km within the flat-dispersion wavelength band. The effective area corresponding to λ = 1.55 µm is about 10.0 µm^2. Fig. 5 shows the fundamental mode field distribution of the D-PCF at λ = 1.55 µm. The parameters are set at $d_1 = 0.60$ µm, d = 1.15 µm and Λ = 2.35 µm. It is confirmed that the fiber can operates as a single mode fiber as the confinement loss for second order modes at shorter wavelength is found to be more than a 200 dB/m.

Therefore, it can be concluded that the proposed defected D-PCF may be a suitable candidate for the optical communication systems because of their ultra-flattened dispersion and very low confinement losses.

4. Conclusion

Decagonal PCF for ultra-flattened chromatic dispersion has been reported for single mode operation within a 370 nm band with a low confinement loss 0.1dB/km. It was observed that there are two apparent advantages of this PCF. First, it can assume higher refractive index difference between the cladding and the core thereby reducing the confinement loss, and second, design parameters are reasonably a modest number.

References

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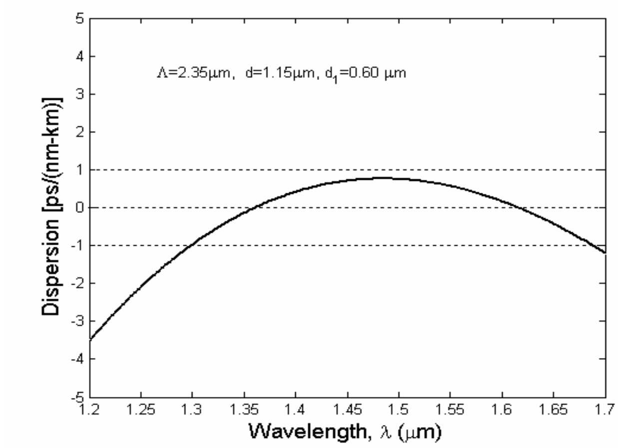

Fig. 3 Wavelength dependence of chromatic dispersion properties of the defected D-PCF with four-rings, $d_1 = 0.60$µm, d = 1.15µm and Λ=2.35µm.

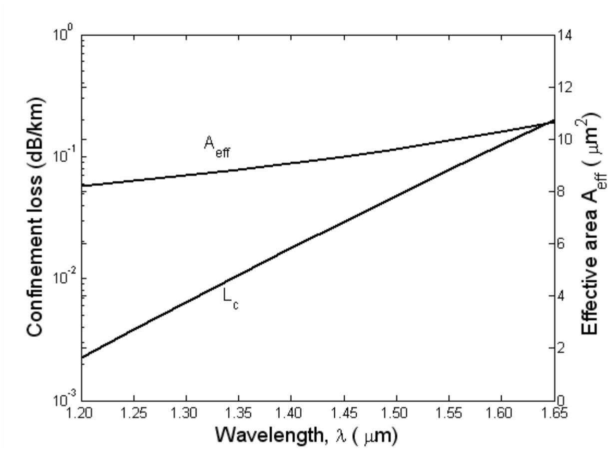

Fig. 4 Confinement loss (solid line) and effective area (dash-dot line) of the defected D-PCF with four rings, $d_1 = 0.60$µm, d = 1.15µm and Λ=2.35µm.

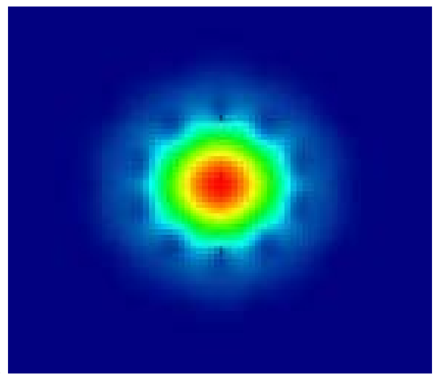

Fig. 5 Fundamental mode field distribution of the defected D-PCF at 1.55µm wavelength with four rings, $d_1 = 0.59$µm, d = 1.15µm and Λ = 2.35µm.