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Square Photonic Crystal Fiber (SPCF) with Flattened Chromatic Dispersion and High Nonlinearity

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Abstract
An index-guiding SPCF for ultra-flattened dispersion of 0 ± 0.7 ps/(nm.km) and low confinement loss 10^{-4} dB/m in a wide wavelength range is presented. The nonlinear coefficient is 27 $[\text{Wkm}]^{-1}$ at 1.55 µm.
Key words: fiber design, photonic crystal fiber (PCF), chromatic dispersion, nonlinearity, confinement loss.

1. Introduction

Index-guiding photonic crystal fibers (PCFs) are a new class of optical fibers in which the solid pure silica core region is surrounded by a cladding region that contains air-holes running down their length [1]. It is possible to design various novel PCFs required in many applications such as optical communication systems [2], nonlinear optics [3], and ultra-broad supercontinuum generation [4].

It has been known that in index-guiding PCFs, since the periodicity in the cladding region is not essential to confine the guiding light into the core region, it is possible to control both the dispersion and dispersion slope in wide wavelength range by varying the cladding structure, air-hole diameter of each air-hole ring and the hole-to-hole spacing. Using a triangular and square PCF with a small core and large air-hole diameter, various flattened-dispersion PCFs with tight mode confinement and nonlinearity have been reported [3, 5, 6]. To the limit of our knowledge, without significantly increasing the number of the control parameters, this type of highly nonlinear dispersion flattened square PCFs (HNDF-SPCF) at 1.55 µm wavelength range has not been reported yet.

In this paper we propose and numerically characterize a simple structure of index-guiding HNDF-SPCF with flattened dispersion characteristics, low confinement loss and small effective area. It is shown through numerical results that the simple HNDF-SPCFs are obtained with 0 ± 0.7 ps/(nm.km) flattened-dispersion and less than 10^{-4} dB/m confinement loss in the wavelength range of 1.2 µm to 1.7 µm. It also exhibits large nonlinear coefficient of about 27 $[\text{Wkm}]^{-1}$ at 1.55 µm, which is found to be better than that of the reported triangular PCFs [4].

2. Proposed Design and Simulation Method

Fig. 1 shows the schematic cross-section of the proposed SPCF with two rings, which is composed of circular air-holes in the cladding arranged in a square array. Where Λ is the center-to-center spacing between the air-holes and d is the air-hole diameter, d/Λ is the normalized diameters of the air-holes in the cladding and $2a = 2\Lambda - d$ is the core diameter. Fig. 2 shows the proposed HNDF-SPCF, with the air-hole diameters in the first ring are varied and the rest of the air-hole diameters remained same. In the first air-hole ring, two different types of air-hole diameter are used. In this study, the finite difference method (FDM) [7] with anisotropic perfectly matched layers (PMLs) is used to analyze the various properties of HNDF-SPCFs. To demonstrate the proposed design, the chromatic dispersion $D(\lambda)$, confinement loss L_c, effective area A_{eff}, and nonlinear coefficient γ are analyzed based on [7-9].

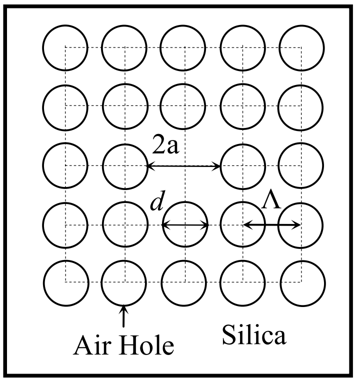


Fig. 1 Schematic cross-section of the conventional SPCF with two air-hole rings.

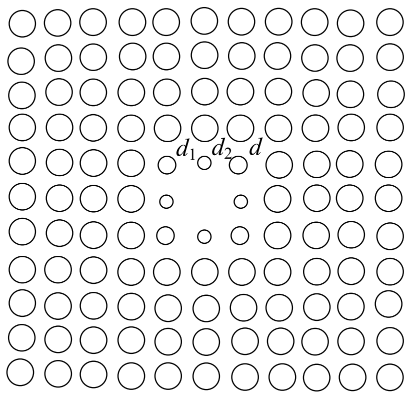
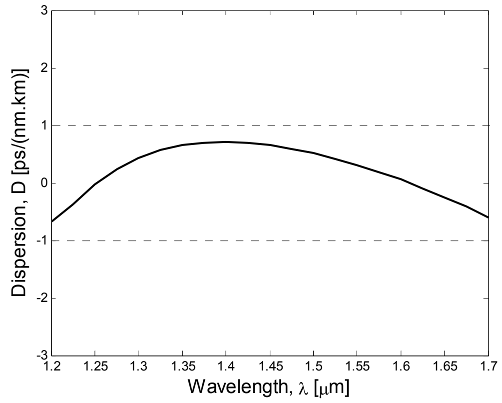


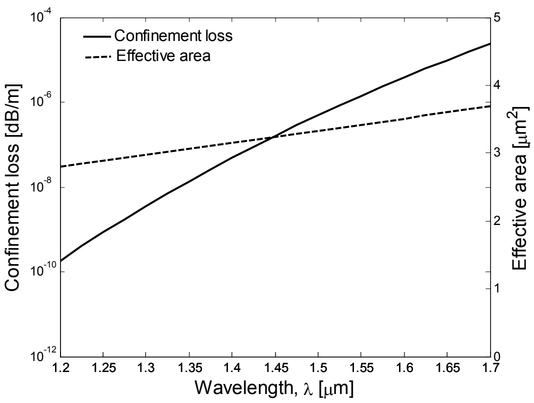
Fig. 2 Index-guiding HNDF-SPCFs with five rings.

3. Simulation Results and Discussion

Fig. 3 shows the chromatic dispersion, the confinement loss, and the effective area as a function of wavelength for the HNDF-SPCF in Fig. 2 at Λ = 1.0 μm. The flattened chromatic dispersion is 0 ± 0.7 ps/(nm.km) and confinement loss is less than 10^{-4} dB/m in a wavelength range of 1.2 μm to 1.7 μm. The effective area is 3.42 μm^2 and the nonlinear coefficient is about 27 $[Wkm]^{-1}$ at 1.55 μm wavelength.



(a)



(b)

Fig. 3 (a) Chromatic dispersion curve, (b) confinement loss and effective area as a function of wavelength for HNDF-SPCF with five air-hole rings in Fig. 2, where Λ = 1.0 μm, d_1/Λ = 0.32, d_2/Λ = 0.6 and d/Λ = 0.94.

4. Conclusions

A simple structure of index-guiding HNDF-SPCF with ultra-fattened dispersion, low confinement loss, small effective area and large nonlinear coefficient is investigated in this research. The numerical results revealed that it is possible to get flattened chromatic dispersion of 0 ± 0.7 ps/(nm.km) and the confinement loss is less than 10^{-4} dB/m in a wavelength range of 1.2 μm to 1.7 μm. In this case, flattened dispersion wavelength bandwidth is 500 nm. It means that our proposed fiber can be used in S, C, and L bands for controlling chromatic dispersion. Besides the nonlinear coefficient is about 27 $[Wkm]^{-1}$ at 1.55 μm wavelength. For these properties the proposed index-guiding HNDF-SPCFs may be suitable for applications such as, broadband optical communication systems, broadband supercontinuum generation, nonlinear optical loop mirror, etc.,.

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