Optik 147 (2017) 334–342

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

Dispersion compensating photonic crystal fiber using double-hole assisted core for high and uniform birefringence

Yong Soo Lee[a], Chung Ghiu Lee[b], Soeun Kim[a,*]

[a] Integrated Optics Laboratory, Advanced Photonics Research Institute, GIST, Gwangju 61006, South Korea
[b] Department of Electronic Engineering, Chosun University, Gwanju 61452, South Korea

ARTICLE INFO

Article history:
Received 29 June 2017
Received in revised form 22 August 2017
Accepted 22 August 2017

OCIS codes:
(060.23309) Fiber optics communications
(060.2420) Fibers, polarization-maintaining
(060.5295) Photonic crystal fibers

Keywords:
Photonic crystal fiber
Polarization maintaining fiber
Dispersion compensating fiber

ABSTRACT

A novel photonic crystal fiber design is presented. The design provides broadband high and uniform birefringence, large negative dispersion and low confinement loss. The fiber is based on double-hole assisted core in the conventional square lattice cladding. For the proposed PCF, high and uniform birefringence of 7.5×10^{-3}, the negative dispersion of -150 ps/(nm km) and an extremely low confinement loss can be obtained over E+S+C+L+U (1380 ∼ 1780 nm) wavelength bands.

1. Introduction

Over the past decade, photonic crystal fibers (PCFs) have been intensively studied to overcome the limitation of conventional step index optical fibers due to their outstanding optical properties such as endless single mode, unique dispersion properties, high birefringence and new nonlinear effects [1–4]. High level of birefringence in optical fiber is often required to preserve two orthogonal linear polarization states over long length of fiber in recent coherent optical communications and optical sensing applications [5,6]. Fortunately, high birefringence in PCFs can be easily realized due to the large refractive index contrast between core and cladding compared to the conventional optical fiber. In addition, chromatic dispersion control is important for practical applications in optical fiber communication, dispersion compensation and nonlinear optics. Broadband negative dispersion in optical fiber is necessary to compensate chromatic dispersion over wide range of wavelength division multiplexed communication systems [7]. However, simultaneous control of light polarization and dispersion is not easy because there is a tradeoff between high birefringence and large negative dispersion with low confinement loss in conventional PCF [8]. The large refractive index contrast between core and cladding in PCF can be obtained by arranging large air holes in the cladding which contributes to increase the modal birefringence and to obtain low confinement loss but results in excessively large chromatic dispersion. Therefore, the accumulated chromatic dispersion should be compensated by dispersion compensating device such as dispersion compensator or dispersion compensating fiber (DCF). However, it makes the systems complex. The future development of compact and low cost optical communication system aims at a

* Corresponding author.
E-mail address: sekim@gist.ac.kr (S. Kim).

http://dx.doi.org/10.1016/j.ijleo.2017.08.121

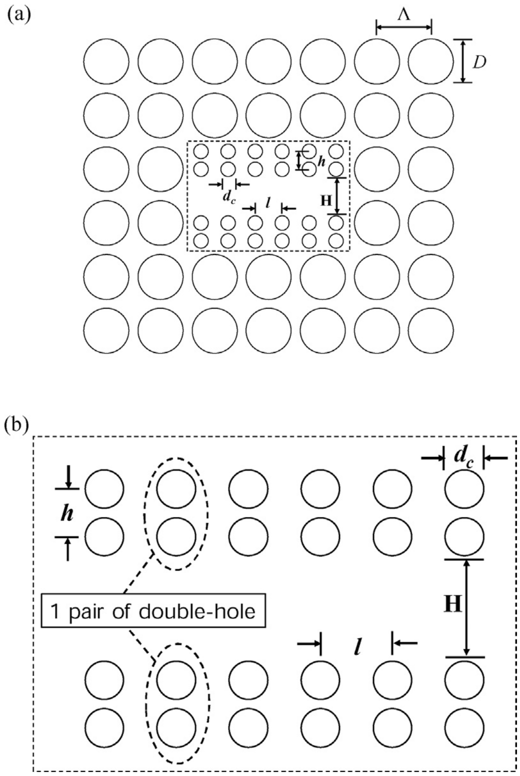

Fig. 1. (a) Cross section of the proposed PCF with 6 pairs of double-hole defect core (b) Enlarged schematic diagram of 6 pairs double-hole assisted core.

single simple device to perform the multiple functions. For many applications, it is required to design PCFs that exhibit high birefringence, dispersion compensation and low confinement loss over broad optical communication bands at the same time. In prior HB PCFs, birefringence increases monochromatically with increasing wavelength [9–11]. For the first time to the best knowledge of the authors, we investigated the uniform properties of modal birefringence and discussed the needs [12]. The PCF with high and uniform birefringence finds various applications in polarimetric sensory systems [13,14]. However, it is difficult to control various optical properties in a PCF over the wide wavelength range at the same time. Recently, various PCF designs with high birefringence and dispersion compensating property simultaneously have been proposed to control optical properties simultaneously [15–17]. Negative dispersion and high birefringence with the order of 10^{-2} based on a modified rectangular lattice cladding in a PCF was reported [15]. The design of equiangular spiral PCF exhibits high birefringence of 0.028 at the wavelength of 1550 nm and negative flattened dispersion of −393 ps/(nm·km) in the wavelength range 1350 nm to 1650 nm [16]. The double-line defect core PCF exhibits high birefringence of 0.0192 and negative dispersion of −425 ps/(nm·km) at the wavelength of 1550 nm [17].

In this work, we propose a PCF design that simultaneously exhibits uniform and high birefringence, negative dispersion and low confinement loss covering E, S, C, L and U bands based on 6 pairs of double-hole assisted core in the conventional square lattice cladding. Compared with the previous work of double-line defect core PCF with high birefringence and negative dispersion at 1550 nm in [17], the proposed double-hole assisted core PCF has some unique features of wide-band uniform and high birefringence, negative dispersion and low confinement loss over wide wavelength range of 400 nm at the same time. To the best of our knowledge, this study is the first to achieve the uniformity of birefringence as well as high birefringence and negative dispersion over such a wide wavelength range. Pure silica is the only used material, and its refractive index is obtained from the Sellmeier equation [21]. The effects of double-hole assisted core for the proposed PCF on the modal birefringence, chromatic dispersion and confinement loss have been investigated compared to the single-hole assisted core PCF. It is numerically demonstrated that the proposed 6 pairs of double-hole defect core PCF has the crucial property of uniform and high birefringence, large negative dispersion and low confinement loss covering E, S, C, L and U bands (1380 ∼ 1780 nm) simultaneously.

2. Design algorithm and mode analysis

Fig. 1 shows the geometry for the proposed double-hole assisted rectangular core PCF. Basically it has a square lattice cladding of diameter D and a lattice constant Λ. The rectangular core of the proposed PCF is supported by defect composed of 6 pairs of double-hole with air hole diameter (d_c) and distance between two small holes (h). The spacing between double-