Optics & Laser Technology 82 (2016) 53–56

Contents lists available at ScienceDirect

Optics & Laser Technology

journal homepage: www.elsevier.com/locate/optlastec

Full length article

Asymmetrically infiltrated twin core photonic crystal fiber for dual-parameter sensing

Shuhui Liu [a,*], Zhe Wang [a], Maoxiang Hou [b], Jie Tian [a], Jujiang Xia [a]

[a] Laboratory of Optical Information Technology, Wuhan Institution of Technology, Wuhan 430205, China
[b] School of Physics, Huazhong University of Science and Technology, Wuhan 430074, China

ARTICLE INFO

Article history:
Received 7 December 2015
Accepted 16 February 2016
Available online 27 February 2016

Keywords:
Photonic crystal fiber
Fiber sensor
Simultaneous measurement

ABSTRACT

We demonstrate a fiber-optic dual parameter sensor based on a water filled Mach–Zehnder interferometer. Such a sensor is fabricated by asymmetrically infiltrating a twin core photonic crystal fiber with water, and splicing it between single mode fibers. Two sets of interference fringes which result from multi-mode interference are obtained by such a structure. By measuring the wavelength shift of the small fringe and the big envelop of the spectrum, strain and temperature can be determined simultaneously.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Optical fiber sensors have been drawing great attentions theses years due to their wide applications for various physical parameter sensing, such as strain, temperature and curvature. Fiber devices in the form of fiber Bragg gratings (FBGs) have been widely employed as sensing heads [1–4], which are compact and robust, however, since FBGs are sensitive to strain and temperature, independent measurement of each parameter is not possible. There has been considerable interest in developing dual parameter sensors these years [5–8], since the demands for multi-parameter measurements are growing, and cross sensitivity is a key issue for practical use of optical fiber sensors. Techniques based on the combination of two fiber elements [9–12], such as FBG Fabry–Perot Cavity [13], or FBG with a modal interferometer [14], have been proposed for simultaneously measurement of two parameters. Such sensors are usually integrated structures which are complicated to fabricate, and are also costing the compactness of the system. Sensors with single element and multiple mechanisms would be preferred for being capable of multi-parameter sensing and also being compact.

In this paper, we report a dual parameter fiber sensor based on the multiple modal interference of an asymmetrically infiltrated twin core PCF. The asymmetrically infiltration of air holes in the twin core fiber is realized by manual gluing at the fiber end face. Air holes by the side of one fiber core of the twin core PCF is blocked by glue while those by the other side are left open, where water can be filled into by capillary force [15]. The infiltrated twin core PCF is then spliced to single mode fibers to form a compact fiber interferometer. The asymmetric filling of water results in the multiple modal interference in the twin core fiber, which can be used for simultaneously sensing of strain and temperature with high temperature sensitivity.

2. Sensor fabrication and principle

The proposed structure is consists of a water filled twin core PCF splicing between two single mode fibers. The twin core PCF we used is produced by the Yangtze Optical Fiber and Cable Corporation, which has a holey cladding form by arrays of air holes, as can be seen in Fig. 1(a). The diameter of the air hole is 3 μm, and the holes' separation is 3.7 μm. The two solid cores locate symmetrically on two sides of the center point. To make the asymmetrically infiltrated PCF structure, the selectively infiltration method with manual gluing is employed [16]. First, the end face of the twin core fiber is partially sealed with glue by carefully dropping glue on the air holes by the side of one fiber core. After the glue cured, the end of the fiber is immersed into water, where those air holes that are left open can be filled with water by capillary force. As a result, the air holes around one fiber core (core A) are filled with water, while those around the other core (core B) are left open, as shown in Fig. 1(b).

After the twin core PCF is selectively infiltrated with water, the section of PCF is cleaved at both ends, and then spliced between single mode fibers. The splicing process is carried out with a Fujikura 80 s fusion splicer, the splicing parameter of which is optimized to minimize the air hole collapse at the splicing joints.

* Corresponding author.
E-mail address: lsh20060388@163.com (S. Liu).

http://dx.doi.org/10.1016/j.optlastec.2016.02.014
0030-3992/© 2016 Elsevier Ltd. All rights reserved.

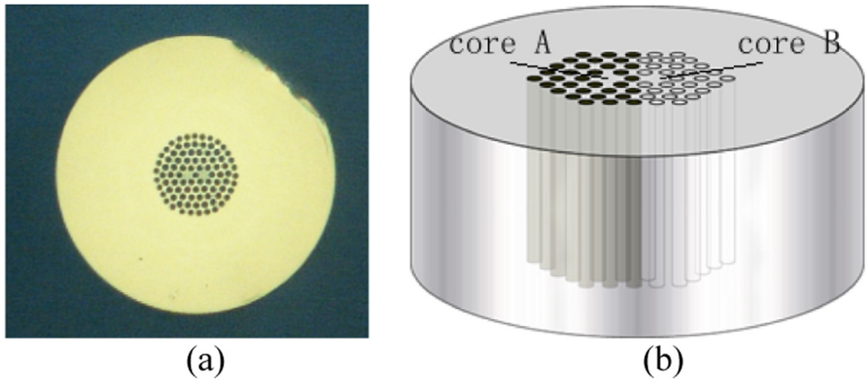

Fig.1. (a): The cross section view of the twin core PCF. (b): Schematic illustration of the asymmetrically infiltrated twin core PCF.

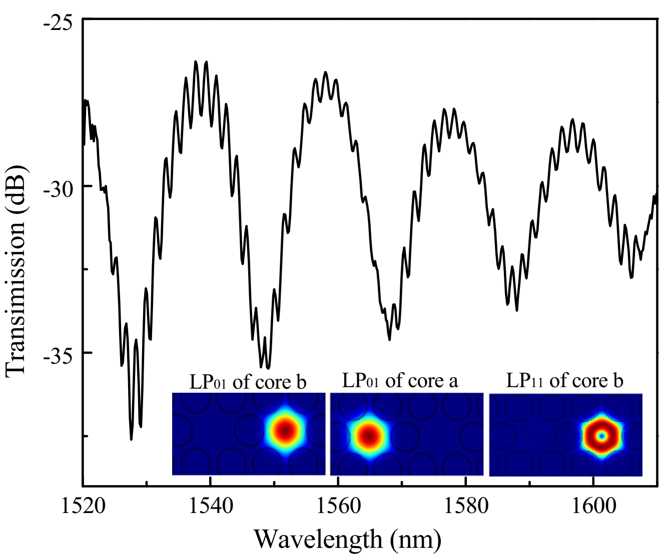

Fig. 2. Transmission spectrum of the sensor (insets: mode profile of the LP01 mode of core A and core B, and of the LP11 mode of core B).

The transmission spectrum of the sensor is collected by a broadband source (ALS-1550-20) and an optical spectrum analyzer (Yokogawa 6370B). Fig. 2 shows the transmission spectrum of a device with the length of the twin core fiber being about 7.7 cm. The spectrum contains two sets of interference fringe as can be seen from Fig. 2, which results from the multiple modal interferences in the asymmetrically infiltrated twin core fiber. The periods of the inference fringe are 20 nm for the big envelop and 1.3 nm for the small fringe, respectively. The periods of the interference fringe in Fig.2 predict that the index difference (Δn) of the interference modes to be 8×10^{-4} for the big envelop and 1.2×10^{-2} for the small fringe. We analyzed the modes guided in the infiltrated twin core PCF with the finite element method (COMSOL software), to find out which modes are involved in the interferences. The effective indices of the fundamental mode and higher order modes in the fiber cores of the PCF were calculated, and the index difference of LP01 mode in of core A and core B is 1.2×10^{-3} (close to the experimental predicted value 8×10^{-4}), and the index difference of LP01 and LP11 mode of core B is 1.6×10^{-2} (close to 1.2×10^{-2}), which indicates that these two set of interference correspond to the big envelop and the small fringe in the spectrum, respectively. The mode profile of the LP01 mode of core A and core B, and LP11 mode of core B are shown in the inset of Fig. 2.

3. Experiment and discussion

When the sensor is subjected to certain physical parameter variations, like change of temperature or strain, the effective index of the interference mode will be influenced, leading to the changing of phase difference. The interference pattern will shift in such cases, which can be observed from the spectrum.

The temperature sensitivity of the sensor is investigated by employing a heating treatment on the sensing head with a tube furnace. Temperature applied on the sensor is increased from 25 °C to 50 °C with an increment of 5 °C, while the spectrum is recorded for each increment. Fig. 3(a) shows the spectrum shift as temperature rises. Gauss fit is made to the spectrum, so that the wavelength shifts of the big spectrum envelop can be distinguished. One transmission dip (marked as Dip A) in the big envelop is monitored to measure its temperature sensitivity. Meanwhile, a dip in the small fringe is also traced (Dip B) to see the temperature response of the small fringe. As can be seen from Fig. 3(a), dip A in the big envelop experiences a red-shift for about 12 nm when temperature is increased from 25 °C to 50 °C, while dip B in the small fringe shifts about 0.2 nm towards longer wavelength.

Fig. 3(b) shows the temperature response of the big spectrum envelop and the small fringe, from which we can see that Dip A in the big spectrum envelop exhibits a high sensitivity of 1.23 nm/°C, while that of Dip B is only 0.024 nm/°C. The reason that the big envelop has a much higher sensitivity than the small fringe is that it results from the interference between the fundamental modes of two cores. One of the fiber cores is surrounded by water-filled air holes (core A), while the other one is not (core B). When temperature rises, the effective refractive index of the fundamental mode in the core A changes much more than that in core B due to the high thermal-optic coefficient of water, leading to a large variation in the index difference between the two fundamental modes.

The strain response of the sensor is investigated by applying tensile strain on the fiber. The applied strain is increased from 0 to 2000 $\mu\varepsilon$, and the transmission dips in the big envelop and small fringe shifts to shorter wavelength, as can be seen from Fig. 4(a).

The big envelop and the small fringe exhibit linear response against strain, and achieve a sensitivity of -1.93 pm/$\mu\varepsilon$ and -1.59 pm/$\mu\varepsilon$, respectively, as can be seen from Fig. 4(b). The infiltration of water does not improve much on strain sensitivity since the applied strain hardly affects the water in the air holes.

The observed difference in sensitivity allows the possibility of using the sensor for simultaneous measurement of temperature and strain. The dual parameter measurement matrix of the sensor can be expressed as:

Download English Version:

https://daneshyari.com/en/article/733368

Download Persian Version:

https://daneshyari.com/article/733368

Daneshyari.com