

High-birefringence two-core fiber vector bending sensor

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Abstract: We propose and demonstrate a simple vector bending sensor based on polarization dependent supermodes interference in a high birefringence two-core photonic crystal fiber. The bending responses of both two polarizations depend on the bending direction.

OCIS codes: (060.2370) Fiber-optics sensors; (060.4005) Microstructured fibers; (060.2420) Fibers, polarization-maintaining

1. Introduction

The measurement of bending is significant in many fields such as aerospace, structure health monitoring, oil pipeline monitoring and so on. A great many of optical fiber bending sensors based on fiber gratings, interferometers and multicore fiber have been investigated extensively. For most optical fiber bending sensors, they can only measure the bending curvature and cannot predicate the bending direction. However in some fields, both the bending curvature and bending direction have to be detected simultaneously. Therefore, developing vector bending sensor which not only can measure the bending curvature but also can determine the bending direction is extreme important.

Several bending sensors based on circular asymmetrical structures were demonstrated as one-dimension directional bending sensors. They can measure the bending curvature and identify the bending direction simultaneously. Nevertheless, the one-dimensional sensors have a fatal drawback in that they are sensitive to the bending direction but cannot distinguish the specific bending angle. In order to have the ability to distinguish the bending angle, some vector bending sensors based on multicore fibers (MCFs) [1–4], fiber Bragg gratings (FBGs) [5] or long-period gratings (LPGs) were developed. Specialty optical fibers such as photonic crystal fibers (PCF) [6] and MCF offer new possibilities to develop bending sensors, but bending sensors based on MCFs with isolated cores require complex fabrication setups or interrogation systems, while those based on symmetric coupled-core MCFs cannot distinguish the bending orientation.

In this work, we report on a simple vector bending sensor based on a high-birefringence two-core photonic crystal fiber (TCF) consisting of two cores, see Fig 1. One of the cores is located at the center of the TCF which simplifies the splicing with a conventional single mode optical fiber (SMF), the other one is on the side. When a broadband light launches into the centered core and transmits for a few centimeters, the output spectrum is sinusoid-like due to the intermodal coupling of the supermodes guided by the two cores. For x-polarized input light, we find it has a maximum bending sensitivity of 409 pm/m⁻¹; for y-polarized input light, we find it has a maximum bending sensitivity of 358 pm/m⁻¹. And the sensitivity map for different bending angles looks like an “8” in polar coordinates.

2. Experiments

The TCF was fabricated at PRC of Hong Kong PolyU. The cross-section electron microscope images of the TCF are shown in fig. 1. One core is centered, while the other is off-center. Both cores are made noncircular by properly modifying the diameters of air-holes surrounding them. This introduces geometric modal birefringence to both cores of the TCF. The air hole pitch, diameter of small air hole, diameter of large air hole and outside diameter of the TCF are 2.2 μm, 1.28 μm, 2.55 μm and 150 μm, respectively. Fig 1(c) presents the experimental setup with the vector bending sensor based on TCF. Light from a broadband source in the window of 1550 nm is linearly polarized with a polarizer and injected into the suspended TCF with a length of 4 cm.

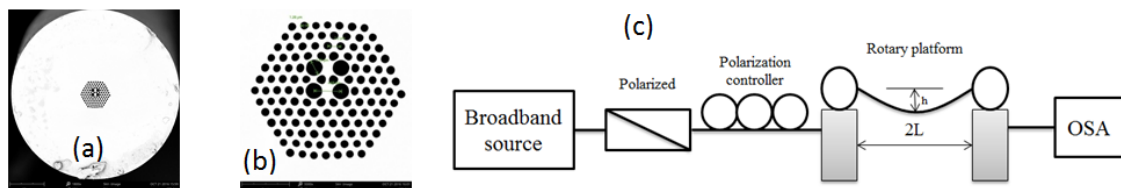


Fig.1. (a) Scanned electron microscope image of TCF cross-section; (b) the amplified image of TCF's core; (c) Schematic of experiment setup for bending measurement

For the bending test, a section of the suspended TCF ($2L = 400$ mm) in the middle was clamped between the rotary platforms. The curvature C is given by $C = 1/R = 2d / (h^2 + L^2)$, where h is the bending displacement at the

center of the PCF, L is the half distance between the edges of the two clamps, and r is the bending radius. Besides, the translation stage can adjust the bending curvature and bending direction simultaneous, thus the spectrum of different angles and different curvature are obtained.

3. Results and discussion

When bending was applied to the TCF, the output spectra for two polarizations were recorded and the spectral wavelength shifts were tracked. As an example, the results for 0° direction bending were given in fig. 2.

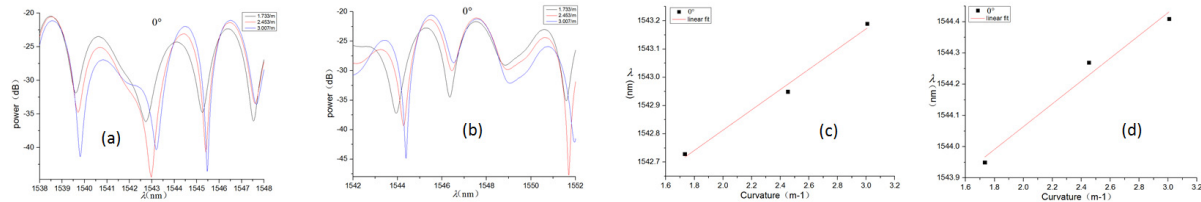


Fig. 2. (a) and (b) Spectral shifts at 0° direction bending for x- and y-polarizations, respectively; (c) and (d) Dip wavelength as a function of applied curvature at 0° direction bending for x- and y-polarizations, respectively.

By rotating the fiber and repeating the bending measurements, we achieve the bending sensitivity map of the sensor for both two polarizations at $0^\circ \sim 360^\circ$ directions, and the results are plotted in fig. 3. We find that at 0° direction both polarizations achieve largest positive sensitivities, while at 180° direction both polarizations achieve largest minus sensitivities. What's more, for each direction the two polarizations show different bending sensitivity. This allows us to determine the bending direction by using these two sensitivity information.

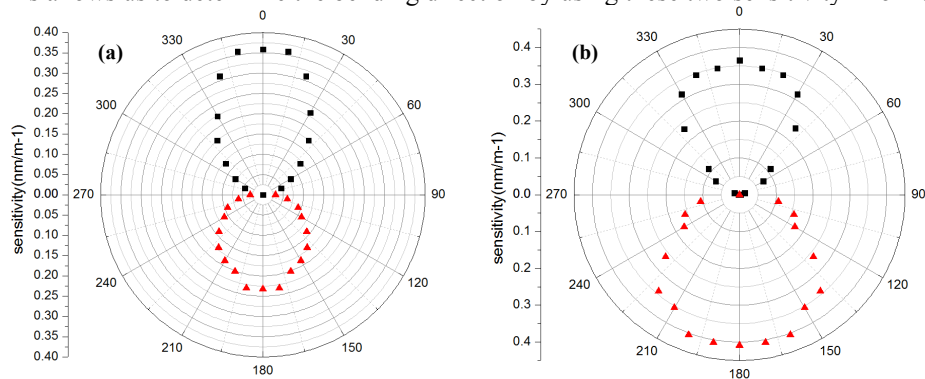


Fig. 3. (a) and (b) The sensitivity map in polar coordinate for x- and y-polarizations, respectively.

4. Conclusion

We have proposed and demonstrated a vector bending sensor based on polarization dependent supermodes interference in a high-birefringence two-core photonic crystal fiber. For each bending direction, the output spectra of two polarizations have different responses, allowing the bending direction to be determined.

Acknowledgement

This work was supported in part by the Guangdong Provincial Natural Science Funds for Distinguished Young Scholars (2014A030306040), the Guangdong Provincial Special Support Program for Young Top Talents in Scientific and Technological Innovation (2016TQ03X124), the Guangzhou Pearl River New Star of Science and Technology (201806010197), the National Natural Science Foundation of China (61575083), and Guangdong Natural Science Foundation (2014A030313364).

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