Multiparameter measurement using a double-Y-shaped suspended-core fiber in a fiber loop configuration

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ABSTRACT

In this work, an all-fiber loop mirror using a four-bridge silica fiber with a double-Y-shaped suspended-core is presented for the measurement of strain and torsion. The sensing head is formed by a section of the microstructured fiber with 90 mm in length. The fiber loop sensor allowed observing a distinct interference pattern as a result of the geometry of the core fiber. Different sensitivities to strain and torsion were obtained, namely, -5.11 pm/με and ±1.34 pm/degree.

Keywords: Interferometers, fiber optic sensors, multimode interference, microstructured fibers.

1. INTRODUCTION

Fiber Loop Mirrors (FLMs) are very attractive structures to be used in several applications such as wavelength filters for fiber lasers and also for specify optical sensors [1]–[3]. The mode operation of a FLM relies on two interfering waves counter-propagating through the same optical fiber, and which are exposed to the same environment. Usually, the FLM works in reflection. In the last two decades, FLMs made of highly birefringent fibers (HiBi-FLM) have been proposed and present several advantages, including input polarization independence and high extinction ratio.

Besides the gyroscope application, various kinds of sensors based on HiBi-FLMs have been developed [3], such as low and high temperature sensors [2],[4], strain sensors [5],[6], pressure sensors, liquid level sensors [7], biochemical sensors, UV detection [8] and multiparameter measurement [9]-[11]. For simultaneous measurement three solutions can be used. The first is based on a simple microstructured fiber [9] where the spectral response presents the interference generated by the group birefringence combined with interference multimodal. The second solution is to splice different types of HiBi birefringence fibers [10] in the fiber loop and the last solution is to combine the HiBi-FLM with other optical device [11].

In this work, a four-bridge silica fiber with a double-Y-shaped suspended-core fiber is used to generate two distinct interference effects. This novel fiber is illuminated inside of loop mirror and the spectral response present distinct response. The behavior of the sensing head was studied in terms of strain and torsion showing different sensitivities to the measured parameters.

2. EXPERIMENTAL RESULTS

In this approach it was used a broadband source (BBS) in the 1550 nm spectral range with a bandwidth of 100 nm, a typical fiber loop mirror and an optical spectrum analyzer (OSA) with 0.1 nm resolution. The experimental setup and detail of the sensing fiber implemented in the experiment is shown in Figure 1.

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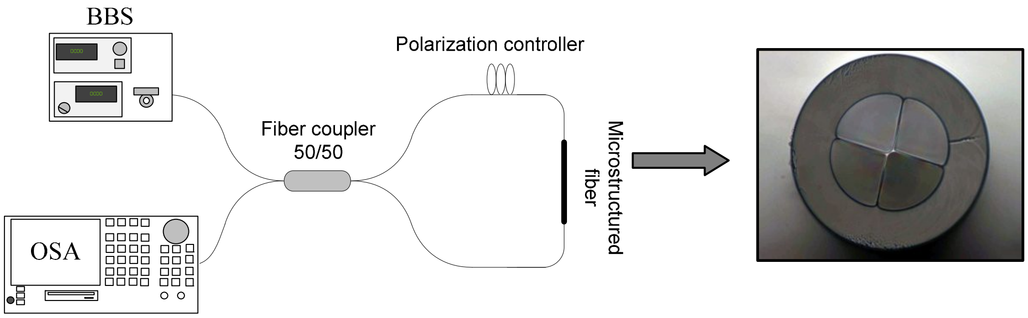

Figure 1. Schematic diagram of the sensing system and microscope image of the suspended-core fiber.

The fiber loop mirror was formed by a 3dB (2 × 2) optical coupler with low insertion loss, an optical polarization controller and a four-bridge silica fiber section with a double-Y-shaped suspended-core and 90 mm in length that was spliced in the two output ports. The new suspended-core fiber was designed and fabricated at XLIM laboratory (ref. SW-MOF); it is made of pure silica and it presents four central air holes and a suspended core with rectangular shape. The fiber has an outer diameter of 127.6 µm and a cavity diameter of 65 µm. The core is suspended by four bridges with a thickness of 0.8 µm each, and the core dimensions are 6.5 µm and 1.5 µm in length and thickness, respectively.

Figure 2 illustrates the spectral response obtained with the proposed fiber loop sensor structure. Due to the geometry of the fiber section, it presents high birefringence and intermodal interference simultaneously. The fringes arise from intermodal interference while the fringe modulation is the result of the birefringence effect. In this case, the beat length is ~3.9 nm and the fiber birefringence is $\sim 6.8\times10^{-3}$.

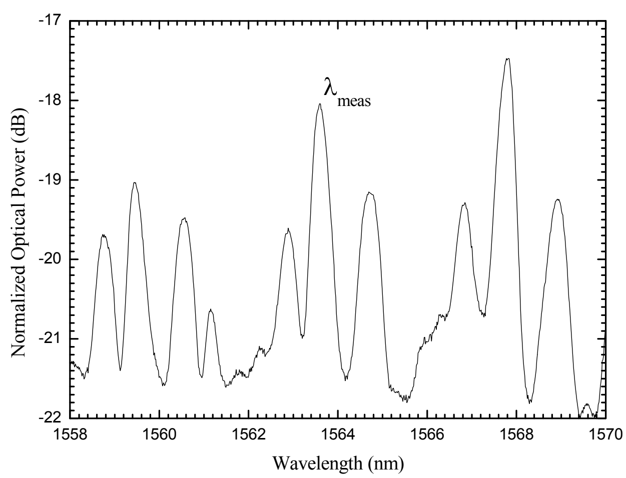

Figure 2. Optical spectrum of the fiber loop sensor.

The fiber loop sensor structure was characterized in terms of strain. The new suspended-core fiber was fixed at two points 480 mm apart, and submitted to specific strain values (at room temperature) by using a translation stage (via successive 10 µm-displacements). Figure 3 presents the obtained result. The peak wavelength (λ_{meas}) shows a linear response to strain variations, with a slope sensitivity of -5.11 pm/µε. When compared with others structure this structure presents more sensitivity.

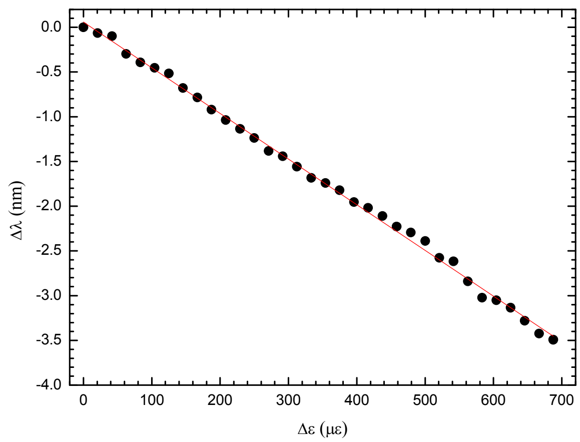

Figure 3. Wavelength shift as a function of strain change for the proposed fiber loop sensor.

The fiber loop sensor was also characterized in terms of torsion (at room temperature). The sensing fiber was placed between two twist stages with a length separation of 250 mm. The torsion was only performed in one of the twist stages, while the other was kept fixed. Figure 4 shows the wavelength response of the sensing head when submitted to different twist angles. The result presents two linear regions associated with the torsion ranges [-90°, 0°] and [0°, 90°]. The slopes correspond to a twist angle sensitivity of approximately ±1.34 pm/degree. When compared with conventional torsion fiber sensors, this structure changes with the wavelength variation.

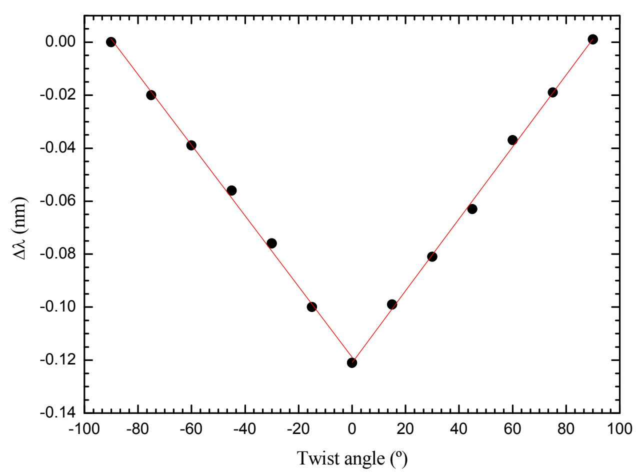

Figure 4. Wavelength shift as a function of twist angle for the proposed fiber loop sensor.

3. CONCLUSIONS

In conclusion, an all-fiber loop mirror using a four-bridge silica fiber with a double-Y-shaped suspended-core for multiparameter measurement was reported. The geometry of the fiber allowed obtaining an interference pattern caused by intermodal interference and birefringence simultaneously. The sensing head presented different sensitivities to strain and torsion, -5.11 pm/με and ±1.34 pm/degree, respectively. This configuration may be optimized by decreasing the length of the suspended core fiber, in order to increase the birefringence effect. Therefore, it could be possible to take advantage of different polarization states and consequently the possibility of obtaining distinct sensitivities to the measured parameters and make use the matrix method for simultaneous measurement of strain and torsion.

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