Sensing with coupled-core optical fiber Bragg gratings

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Abstract: Sensitive bending and vibration sensors based on a coupled-core optical fiber with Bragg gratings are proposed and demonstrated. The interrogation of such sensors is cost effective without comprising the sensors performance.

1. Introduction

Sensors based on fiber Bragg gratings (FBGs) are accepted and widely used in different fields and sectors. In a sensor based on FBGs, the position of the Bragg wavelength (λ_B) is monitored and correlated with the measurand [1]. To do so, among others interrogation methods, a broadband light source and a picometer-resolution spectrometer or a tunable laser and a suitable photodetector are necessary. Either of these interrogation systems are in general costly, which makes a sensor based on FBGs expensive.

To reduce the cost of the interrogation of FBG sensors, changes in the position of λ_B can be converted to intensity changes by means of edge filters, interferometers or similar wavelength-selective devices placed before a low-cost photodetector [2,3]. A drawback of these techniques is that the linear section and the useful wavelength range is limited. Therefore, only FBGs with certain Bragg wavelengths can be interrogated.

Here, we propose the use of a coupled-core optical fiber with Bragg gratings for cost-effective sensing. The reflection spectrum of such gratings is a narrow peak similar to that of FBGs inscribed in conventional optical fibers. We have observed that the intensity of the FBG peak changed when the coupled-core fiber was subjected to bending or vibrations. Such intensity changes can be easily monitored with a photodetector. The advantages of our sensors include fabrication of FBGs with standard procedures and simple interrogation that do not require wavelength filters to monitor intensity changes. We believe that the concepts and approaches reported here may expand the use of Bragg gratings in optical sensing and other applications.

2. Results and Discussion

The coupled-core fiber that was used in our experiments is shown in Fig. 1(a). The fiber has two identical cores; one of them is located in the geometrical center of the fiber and the other core is 15.5 µm from the central one. A segment of the twin-core fiber (TCF) was fusion spliced to a conventional single mode optical fiber (SMF). The central core of the TCF and the unique core of the SMF were axially aligned. In this manner, the excitation of the TCF was carried out with the fundamental SMF mode, see Fig. 1(b).

A Bragg grating was inscribed in the two cores of the TCF. To do so, the TCF was first hydrogenated and then the grating was inscribed in the cores with the same procedure that is used to inscribe Bragg gratings in a standard SMF. After the inscription of the FBG we investigated the potential of our device for sensing applications. The cores of the TCF were oriented in the y-direction, according to the coordinate system shown in Fig. 1(a), then, the TCF was bent in the –y direction. Some observed reflection spectra are shown in Fig. 1(c). It can be noted that the position of the peak does not change in wavelength but the height or intensity of the peak changes with the bending angle. The inset of Fig. 1(c) shows the calibration curve. In such a figure, R and DR means, respectively, peak reflection of the FBG and changes in R at a particular bending angle. Our preliminary results suggest a linear dependence of DR/R on the bending angle. Our results are different for those reported in [4] in which a dual core fiber was used.

It is important to notice that the fiber is non-symmetric, thus, when it is bent, the core outside the geometrical center of the fiber suffers more deformation than the central core. This means that the propagation constants of each core are different with the bending induced to the fiber. Therefore, the coupling between cores for a given length of TCF is bend-dependent. Since the relative light intensity reaching the two Bragg gratings changes with bending, the signal reflected and measured at the central core of the TCF is modulated with bending.

The SMF+TCF with gratings was subjected to low frequency vibrations. In these experiments, the FBG was illuminated with an SLED centered at 1550 nm. The reflected intensity was monitored with a photodetector

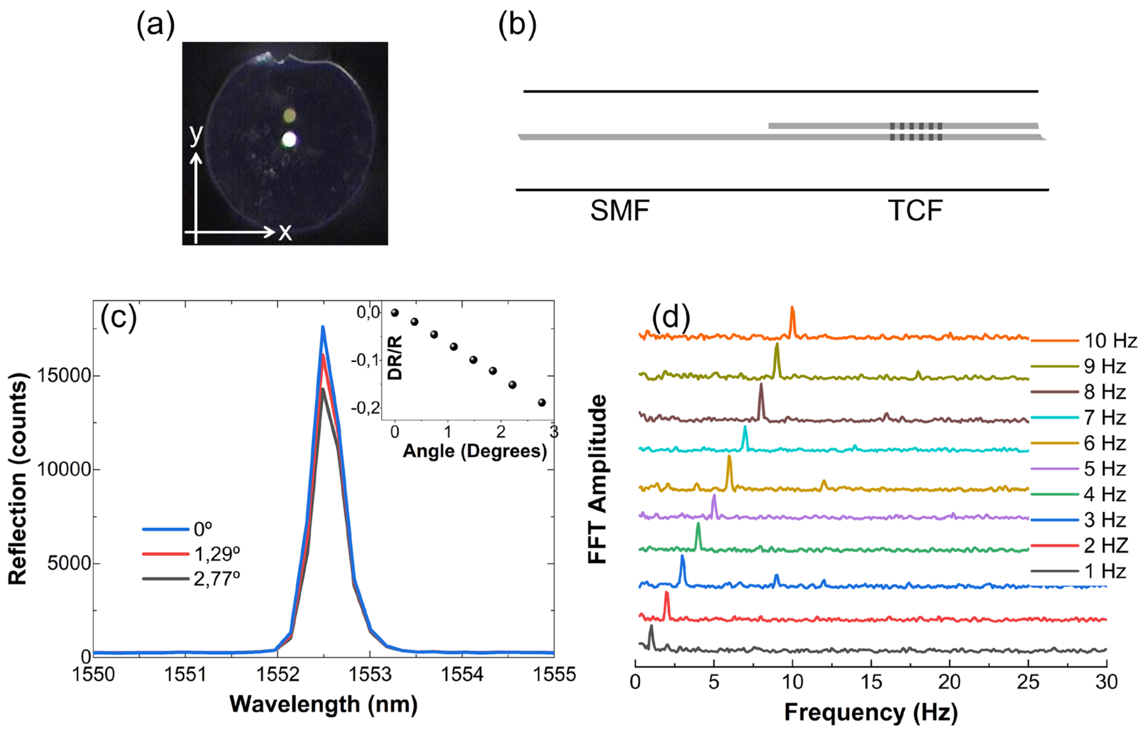

Fig. 1. (a) Cross section of the TCF. (b) Schematic of the SMF+TCF with an FBG. (c) Reflection spectra of the sensor when it was subjected to bending in the –y direction, the inset graph shows the calibration. (d) Vibrations measured with the TCF with FBGs. The optical power as a function of time was monitored from which the FFT were calculated.

connected to a miniature oscilloscope (PICO technology) connected to a computer via a USB cable. The software of such an oscilloscope allowed us to calculate the fast Fourier transform (FFT) of the intensity versus time signal. The observed FFTs at different frequencies are shown in Fig. 1(d). A dominant peak at the frequency at which the TCF was oscillating is clear. The effect of temperature on our devices is being investigated as well as the sensing of other parameters. In all these applications, the peak intensity is monitored with a single photodetector. The results of such investigation will be presented at the conference.

3. Conclusions

In this work, we have proposed and demonstrated the use of a twin-core fiber with Bragg gratings for the development of different cost-effective sensors. The cores of the optical fiber are close enough to allow optical interaction between them. We have found that the peak reflection of a Bragg grating changes when the twin-core is subjected to bending or vibrations.

The main advantage of the sensors here proposed is their simple interrogation, which may entail only a low-power SLED and a low-cost photodetector. No additional wavelength filters are necessary to convert the changes of the grating into intensity ones.

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4. References

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