Multimode Fiber Specklegram Twist Sensor

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Abstract: A twist sensor based on the analysis of multimode fiber speckle patterns is proposed. The fiber specklegrams are recorded and assessed for correlation change under different conditions. A preliminary resolution of 2.5 mrad has been obtained.

OCIS codes: (060.2310) Fiber optics; (060.2370) Fiber optics sensors; (030.6140) Speckle

1. Introduction

Due to its compact structure, excellent flexibility, and resistance to environment electro-magnetic interference, optical fiber twist sensors play an important role in the applications of aircraft and construction engineering. Existing optical fiber twist sensors are usually based on the variation of wavelength, such as long period fiber gratings [1,2], fiber Bragg gratings [3,4], titled FBGs [5,6], photonic crystal fiber [7,8], fiber interferometers [9,10], and so on. Most of them can provide high sensitivity, yet some need a complex process or sophisticated operations. Moreover, for all of them it is necessary to apply complicated external system setup.

Herein, we propose a simple method to measure the twist angle. We record the specklegrams produced by a multimode fiber coupled with a coherent laser source. Due to the mode coupling, light propagation inside the multimode fiber can be treated approximately as light being scattered by a complex medium, such as a tape, ground glass, and a piece of biological tissue. Recently, it has been shown that seemingly random speckles generated by coherence light in or through scattering samples are actually deterministic within the sample correlation time [11-14]. Due to the complexity of scattering, tiny variation of the scattering medium can be conveyed and amplified in the transmitted field [15]. In this work, we propose to only use a digital camera to record the different specklegrams induced by varying the twist angle of the multimode fiber. Then we study the correlation of every specklegram to assess the ability of the proposed sensor. The results indicate a sensitivity linearity of 0.9927 and an angle resolution of 2.5 mrad.

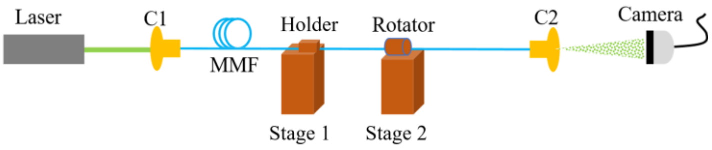

Fig.1 Experimental setup. C1 and C2: fiber collimators; MMF: multimode fiber.

2. Experiment and results

The proposed system is experimentally shown in Fig.1.The wavelength of a continuous laser at 532nm (EXLSR-532-300-CDRH, Spectra-Physics) is used as the light source. We use a collimator to couple light into a multimode fiber (FG050LGA, Thorlabs; the length is 1m). The fiber is mechanically fixed by a holder on Stage 1, and is twisted by a rotator on Stage 2. The distance between the two stages is 10.35 cm. The output light pattern from the fiber are recorded by an image sensor (PCO.edge 5.5, PCO, Germany). The light pattern distribute randomly as typical speckles, as shown in Fig.2.

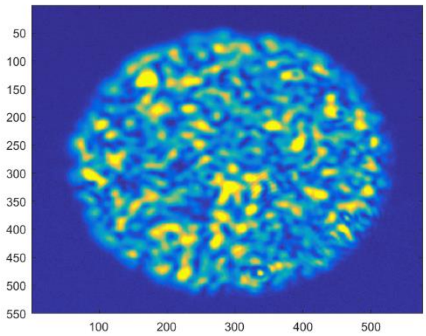

Fig.2 A typical specklegram from the multimode fiber

In experiment, we use a fiber holder to fix the fiber, a rotator to twist the fiber, and the camera to record every speckle and its change. Then we compute the correlation coefficient of each individual specklegram with the first one, as shown in Fig.3 (a). From the result, we calculate the linearity between the correlation and the twist angle to be 0.99287, and the sensor sensitivity is 0.178/(mrad/m). In contrast, we also use a photodiode (PDA36A-EC Thorlabs) to measure the intensity of the output for every change, as shown in Fig.3 (b). From the figure, the relationship between the intensity and twist angle is hard to interpret. In order to figure out the minimum measurable angle (or resolution) of our sensor, we also carry out the stability test in conventional environment for 30 mins, with results shown in Fig.3 (c). The maximal fluctuation is 0.0045 (the minimal correlation is 0.9955). Considering the sensitivity, the measurement resolution is 2.5 mrad (considering the twist length of the proposed sensor is 10.35 cm).

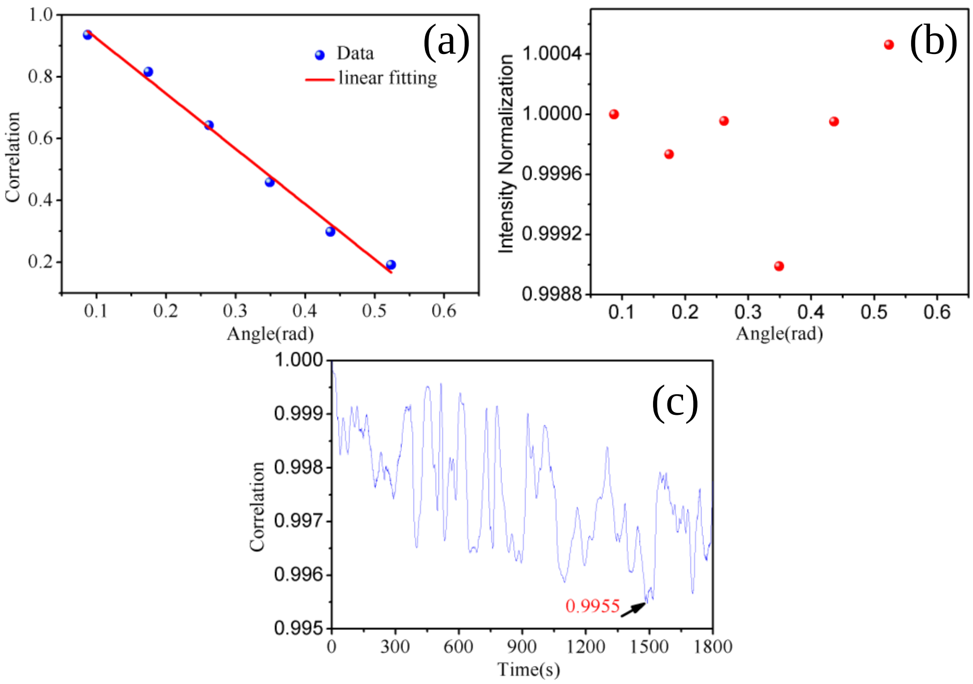

Fig.3(a) The relationship between the specklegram correlation and the twist angle; (b) The relationship between the overall specklegram intensity and the twist angle; (c) Stability of the specklegram correlation.

3. Conclusion

In this work, we propose a novel yet straightforward twist sensor based on the multimode fiber specklegram correlation. We use a camera to record the specklegram output from the multimode fibers and compute the correlation coefficient of specklegrams with different twist angles. The preliminary results show a good linearity between the correlation change and the twist angle, and the angle resolution of the sensor is 2.5 mrad Further optimization of the new method is under investigation, and this new strategy can potentially benefit widely to the optical sensor community.

4. Acknowledgement

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5. Reference

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