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Er-doped fiber based Mach-Zehnder interferometer for simultaneous strain and temperature measurement

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ABSTRACT

A novel mode interferometer for simultaneous strain and temperature measurement is proposed, which is based on Mach-Zehnder interferometer (MZI) realized by splicing a short section Er-Doped fiber (EDF) between two sections of single mode fibers (SMF) with core-offset technique. The structure is compact and easy to fabricate. A strain sensitivity of 0.0247 dB/με and a temperature sensitivity of 0.2225dB/℃are achieved experimentally.

Keywords: mode interferometer; Mach-Zehnder interferometer; Er-doped fiber; core-offset.

1. INTRODUCTION

Fiber mode interferometer has attracted much attention in recent years, for they are widely used in measurement of various parameters, for instance, temperature [1-3], strain [4-5], refractive index (RI) [6-9] and humidity [10-11]. Sometimes measurements of multi-parameters are needed, which leads to requirements of simultaneous measurement of different parameters (such as strain and temperature). Many approaches have been proposed for simultaneous strain and temperature measurement, which can be categorized as follow: two different types of fiber grating [12], fiber grating based sensor with a fiber grating Fabry-Perot cavity [13], connecting a photonic-crystal-fiber with a fiber Bragg grating (FBG) [14], a FBG and a thermochromic material [15], a tilted FBG [16] and a dual cladding modes fiber up-taper interferometer [17]. In most of the techniques mentioned above, more than one fiber devices are needed, which have a large footprint and complicate fabrications.

In this letter, we propose a novel sensor with compact structure and easy fabrication which is constructed by splicing a short section of EDF between two sections of SMFs with core-offset technique. The sensor can realize simultaneous strain and temperature measurement commendably. Our experiments demonstrate a strain sensitivity of 0.0247 dB/με, and a temperature sensitivity of 0.2225 dB/℃ respectively.

2. FABRICATION

A commercial optical splicer (Fujikura FSM-80S) and a fiber cleaver (CT-30) are utilized to make the SMF-EDF-SMF (SES) structure. And the fabrication process is only contains cleaving and splicing. Fig. 1 shows the schematic of the SES structure. The length of the Er-doped fiber is denoted as L which is equal to 1.5cm, as is to say, the length of the interferometer is 1.5cm. The core-offset is ~4μm which is well controlled by the splicer.

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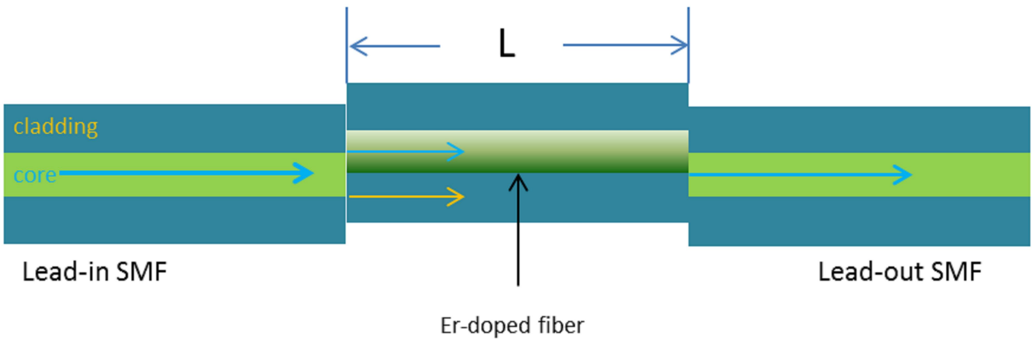

Fig. 1. Schematic diagram of the SES structure

3. EXPERIMENTAL RESULTS AND DISCUSSION

A C-band broadband source (BBS) is used as the light source, and an optical spectrum analyzer (OSA) with a resolution of 0.02 nm is used to monitor the transmission spectra of the SES structure, as is shown in Fig. 2. The spectrum of the SES structure is shown in Fig. 3, and we can find there are several maximums and minimums which could be used to monitor the strain and the temperature. With the interference pattern, a fast Fourier transform (FFT) is made to gain the spatial frequency, as is shown in Fig.4.

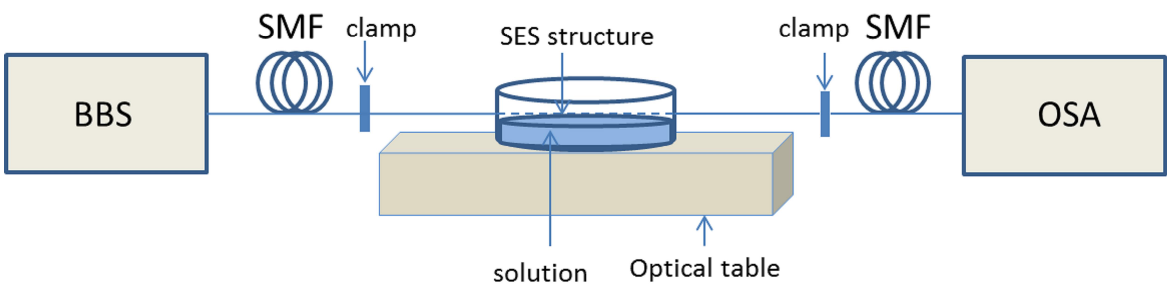

Fig. 2. Schematic configuration of the experimental setup

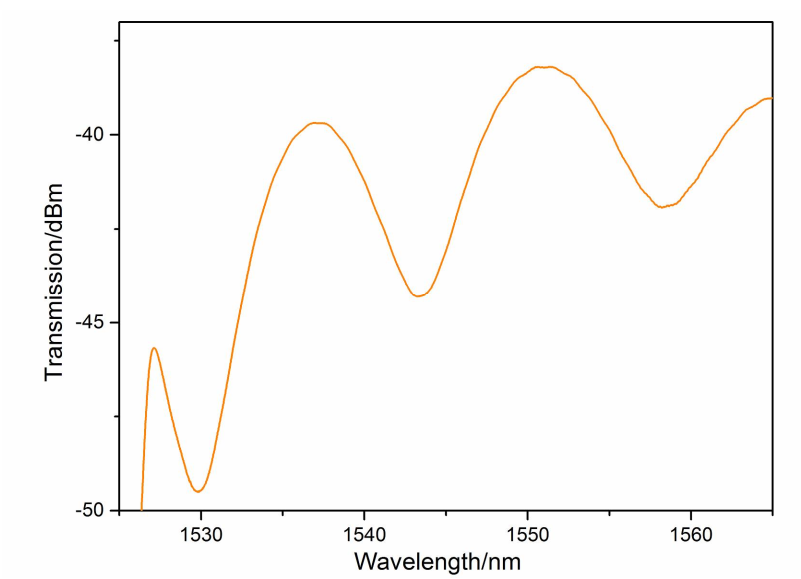

Fig. 3. Transmission spectrum of the SES structure

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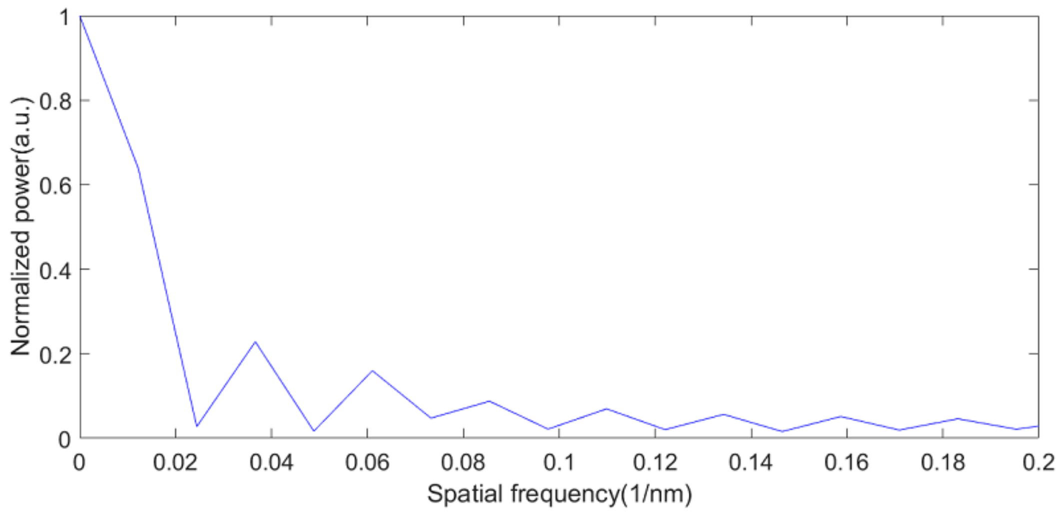

Fig. 4. Spatial frequency spectrum of the SES structure

3.1 Strain experiment

The strain experiments are carried out on an optical table with a micro-displacement platform mounted on it. The range of the strain is controlled from 0 με to 94.118 με with a step of 23.529 με. With the increase of the strain, the intensities of the spectra have an obvious shift, as is shown in Fig. 5. And Fig. 6 shows that the strain sensitivity of dip1 and dip2 are 0.0247 dB/με and 0.0068 dB/με with linear R-squares of 0.9938 and 0.9928 respectively.

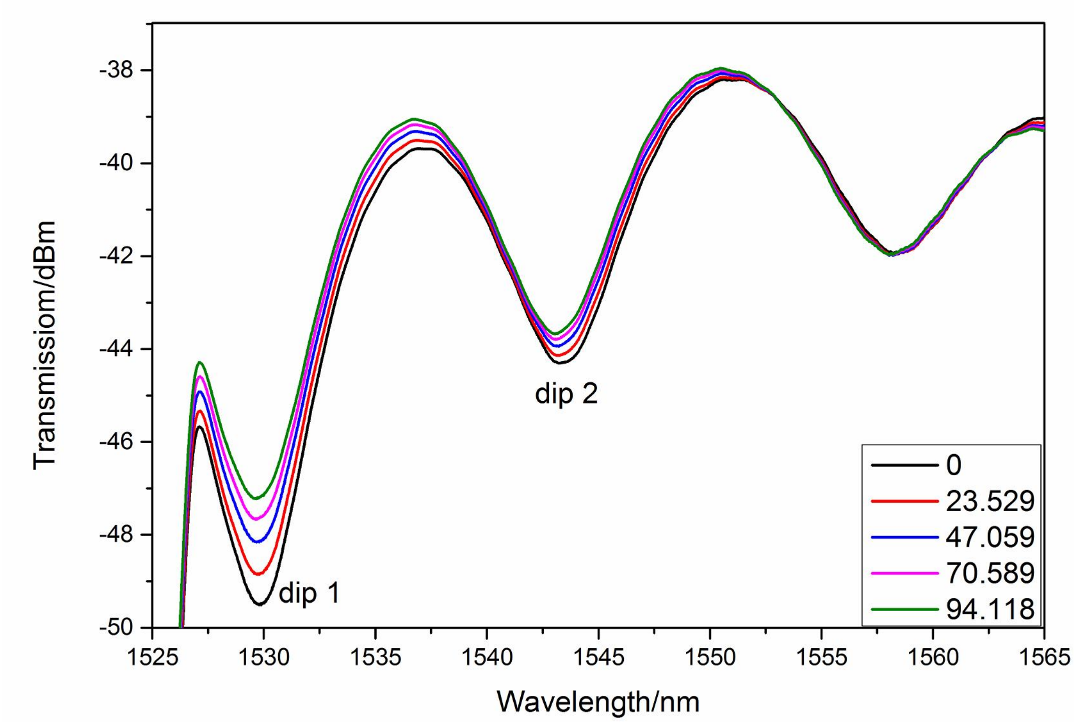

Fig. 5. The spectra of SES structure under different strain

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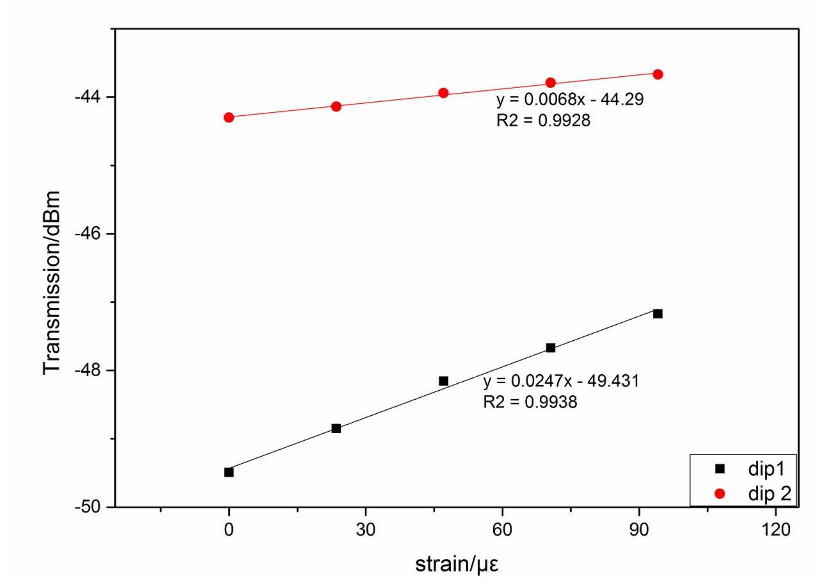

Fig. 6. Strain variation against intensity

3.2 Temperature experiment

The temperature experiments are conducted in a thermostat. The temperature range is controlled from 29.6 ℃ to 38.4 ℃. With the increase of the temperature, the intensities of the spectral have an obvious shift, as is shown in Fig. 7. And Fig. 8 shows that the temperature sensitivity of dip1 and dip2 are 0.223 dB/℃ and 0.074 dB/℃ with linear R-squares of 0.9901 and 0.9902 respectively.

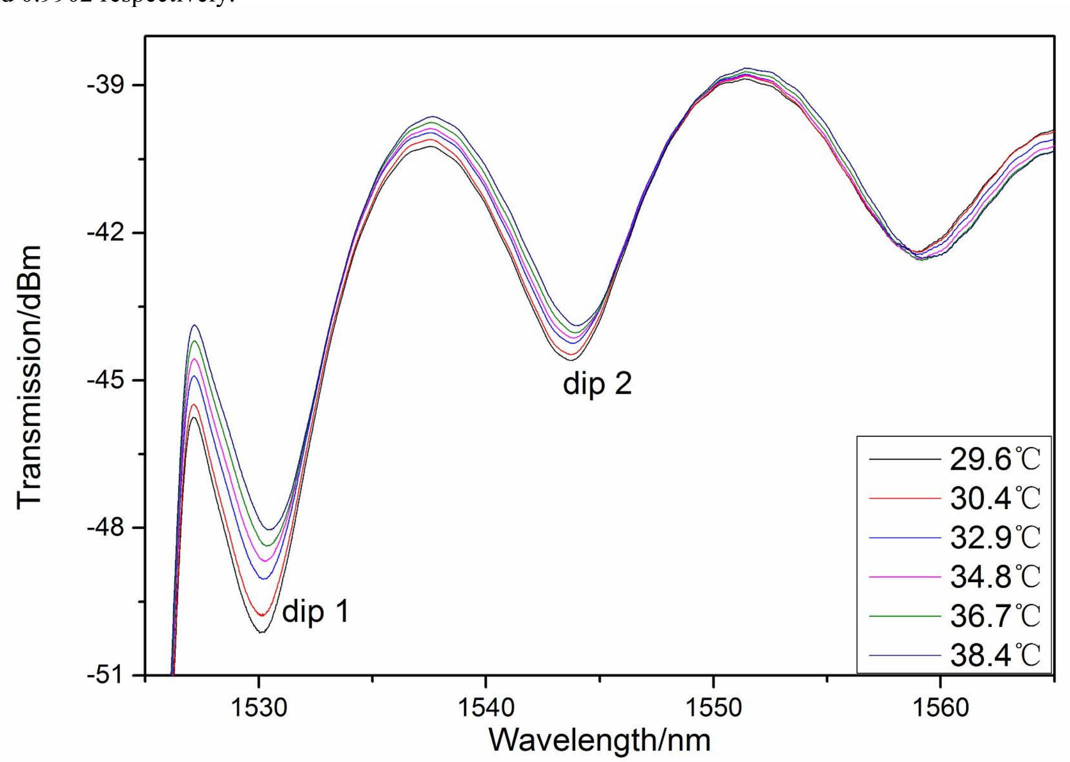

Fig. 7. The spectra of SES structure under different temperature

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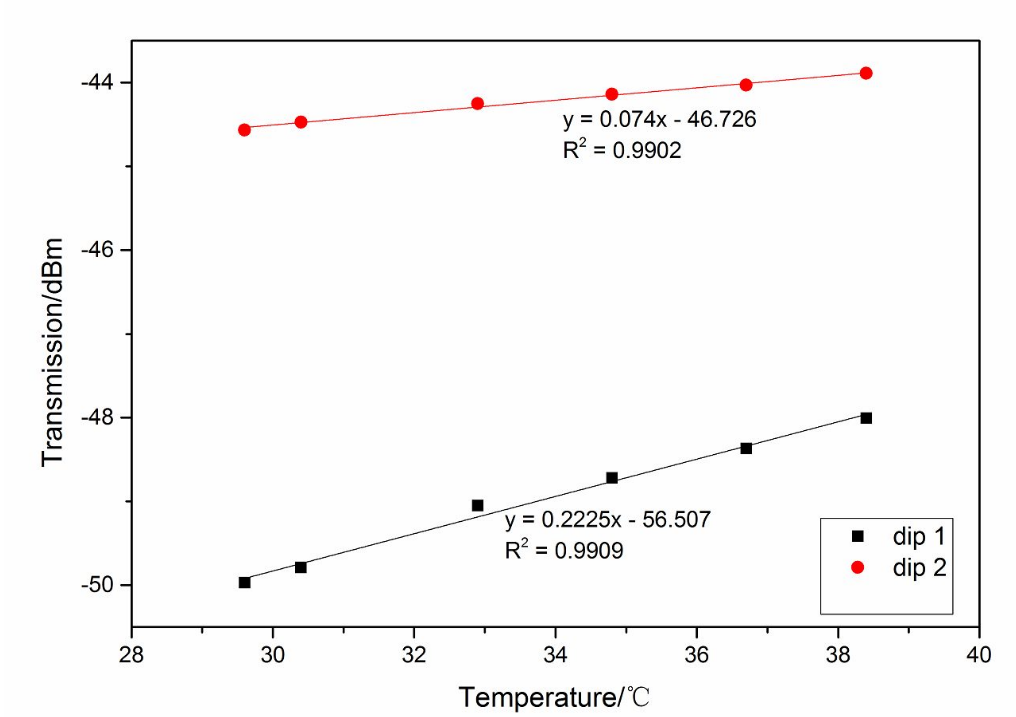

Fig. 8. Temperature variation against intensity

Based on the above experimental results, the strain and temperature measurement matrix of the SES structure can be given by

$$\begin{bmatrix} \Delta IN_1 \\ \Delta IN_2 \end{bmatrix} = \begin{bmatrix} 0.024 & 0.223 \\ 0.0068 & 0.074 \end{bmatrix} \begin{bmatrix} \varepsilon \\ \Delta T \end{bmatrix}, \tag{1}$$

According to (1), the strain and temperature measurement resolution can be described by

$$\begin{bmatrix} \delta(\varepsilon) \\ \delta(\Delta T) \end{bmatrix} = \frac{1}{|-0.0002596|} \begin{bmatrix} |0.074| & |0.223| \\ |0.0068| & |0.024| \end{bmatrix} \begin{bmatrix} \delta(\Delta IN_1) \\ \delta(\Delta IN_2) \end{bmatrix}. \tag{2}$$

4. CONCLUSION

In conclusion, a novel mode interferometer for simultaneous strain and temperature measurement is proposed, which is based on MZI realized by splicing a short section EDF between two sections of SMFs and making core-offset at the splicing points. The proposed sensor can realize simultaneous strain and temperature measurement. Compared with the sensors which are proposed before and utilized for simultaneously monitoring of stain and temperature, the SES structure has the advantages of compact structure and easy fabrication, which make it has a great potential in commercialization.

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