Polarization dependent gold-coated multicore fiber interferometer for refractometry

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Abstract

A single supermode interferometer fabricated with a segment of a seven-core fiber fusion-spliced to a standard single-mode fiber has the capability of monitoring temperature and refractive index simultaneously. In this work, we study the effect of a thin metal film deposited on the end face of the multicore fiber on the interferometer. We demonstrate that for a ~10 nm-thick gold layer on the multicore facet, the interferometer shows an important polarization dependency, which thereby influences the refractometric sensitivity.

Introduction

An optical fiber sensor that can measure refractive index requires easy fabrication and reproducible response for real-world applications. There are several kinds of optical fiber sensors that are capable of monitoring refractive index, for example, tilted Bragg gratings [1,2], Fabry-Perot interferometers [3] and multicore fiber (MCF) interferometers [4]. Among all the aforementioned optical sensors, a supermode interferometer which is composed of a centimeter-long segment of MCF spliced to a single mode fiber (SMF) is popped up with its advantages of dual-parameter (temperature and surrounding refractive index (SRI)) sensing, controllable supermodes and reproducibility. The capability of supermode MCF interferometer in sensing temperature and refractive index simultaneously has been experimentally and analytically investigated in [5-7].

In this work, we investigate the effect of a 10 nm-thick gold layer on the MCF's facet on the performance of the interferometer. We show that unlike the bare MCF interferometer, the interference amplitude sensitivity to SRI is polarization dependent with a maximum sensitivity of ~7.8 a.u./RIU. This effect provides a possibility of further surface modification to enhance the refractometric sensitivity. Furthermore, it has a potential in biosensing by functionalizing the facet of MCF.

MCF interferometer and statement of the work

A sketch of the cross section of the multicore fiber used to fabricate the interferometer is shown in Fig. 1(a). The interferometer is assembled with the multicore fiber fused spliced to a conventional single mode fiber (SMF). The MCF is cleaved at a length L= 3.7 cm and the cleaved end facet of the multicore fiber is coated with a 10 nm-thick gold layer using a sputtering chamber from Leica (shown in Fig. (b)). Fig. 1(c) shows the interrogation set-up of the sensor, which is composed of a supercontinuum laser source from NKT, an optical polarizer set at the input of a circulator and an optical spectrum analyzer (OSA) connected to the output of a circulator. The OSA collects the reflected optical signal from the MCF interferometer. To study the polarization effect on the device, we changed the input polarization of the light within 180° by a step of 30°. The reflection spectra of the sensor were recorded and analyzed. Fig. 1(d) shows the microscope image of the gold-coated MCF facet.

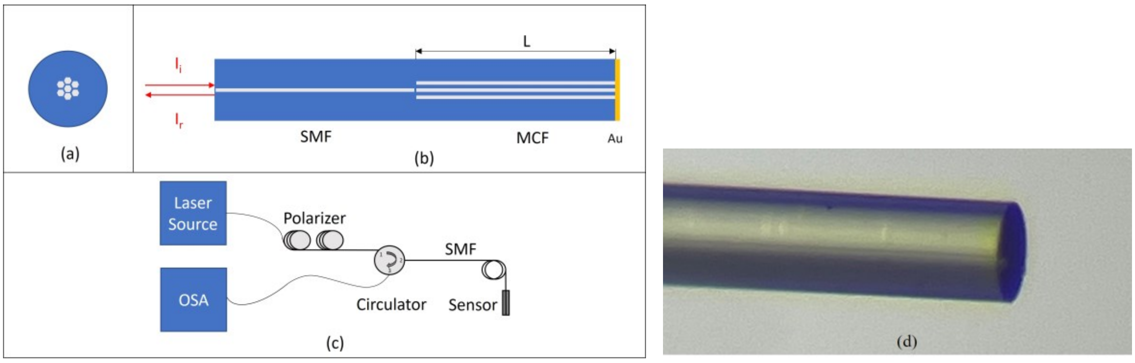


Fig. 1. (a) Cross-section of the multicore fiber. (b) Consistence of MCF interferometer. (c) Set-up of the refractometric experiment. (d) Microscopic image of 10nm gold-coated MCF facet

For each input polarization, the MCF interferometer is immersed into different LiCl solutions with RI ranging from 1.3333 to 1.3600. The evolution of the reflection spectra (amplitude of the peaks and their respective wavelength shift) were analyzed.

Experimental results

Firstly, we checked the refractometric characteristic of a bare MCF supermode interferometer. The evolution of the interference pattern as a function of RI change is shown in Fig. 2(a).

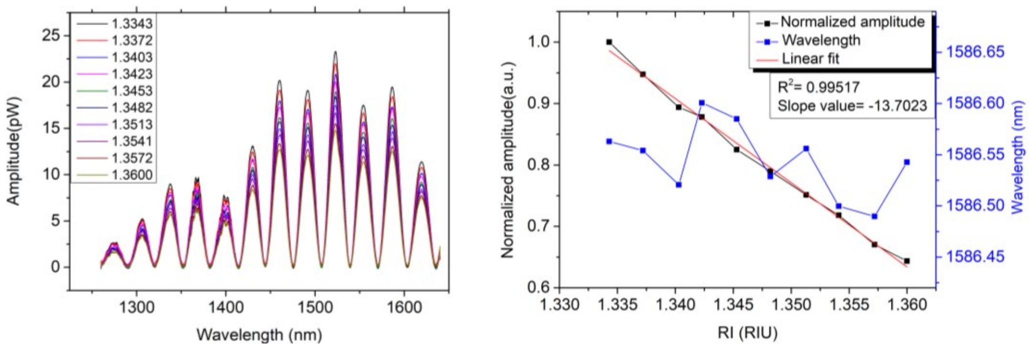
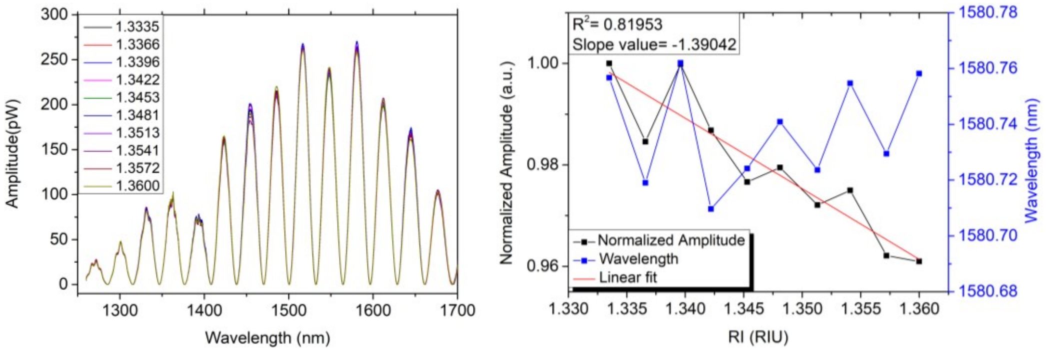


Fig. 2. Reflection spectra of a bare MCF with unpolarized light. (a) Evolution of the interference spectra as a function of RI change. (b) Normalized amplitude and wavelength shift of peak at 1586nm.

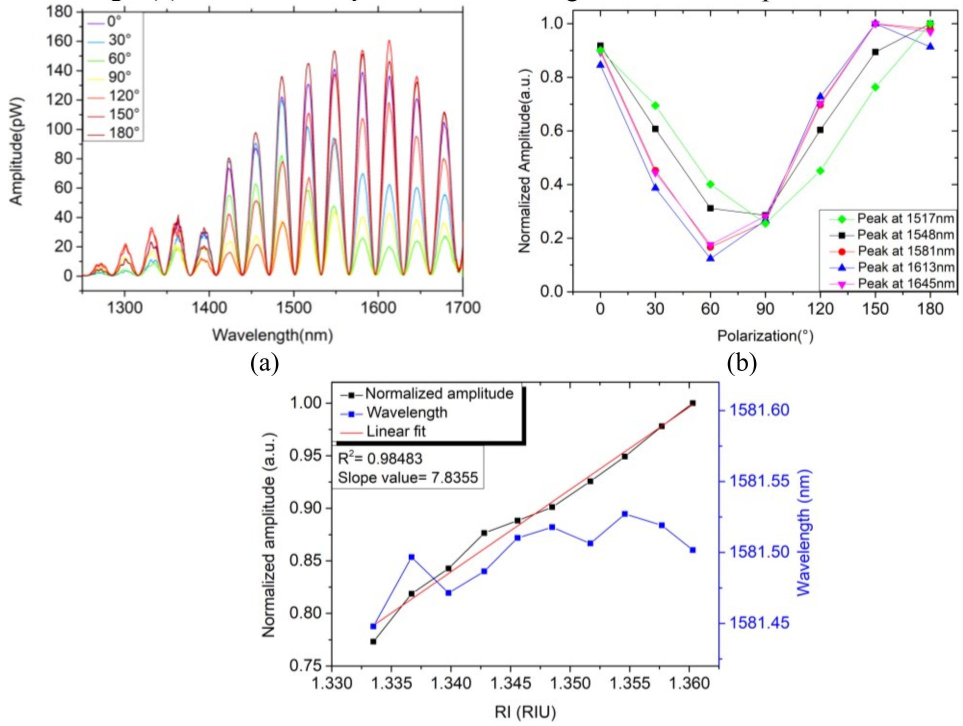
We considered the spectral range from 1460 nm to 1600 nm because the interference pattern shows good contrast and SNR ratio. We first analyzed all the peaks in terms of wavelength and amplitude changes versus SRI modification. Since, all the peaks show the same behavior, in the following, we focus and show only the evolution of one peak around 1586 nm as a function of SRI. The wavelength shift of this peak and the normalized amplitude (peak amplitude divided by the initial value) evolution as a function of the RI change are shown in Fig. 2(b). The linear fit in terms of amplitude versus RI indicates that the refractometric sensitivity of the peak is ~13.7 a.u./RIU. Besides, the wavelength of the peak is unchanged when the RI increases.

After studying the bare MCF in terms of RI sensing, we fabricated a sample with a 10 nm gold layer deposited on the MCF facet to evaluate its performances for RI measurements. Fig. 3(a) shows the evolution of the interference spectra of MCF versus RI change. When the RI of the solution increases from 1.3335 to 1.3600, the peak around 1580 nm shows a slight decrease in normalized amplitude but no wavelength evolution. The linear fit of the normalized amplitude (as shown in Fig. 3(b)) indicated that the refractometric sensitivity of the peak is relatively weak, about ~1.39 a.u./RIU.



(a) (b)

Fig. 3. Spectra of a 10 nm gold-coated MCF with unpolarized light. (a) Interference spectra as a function of RI change. (b) Normalized amplitude and wavelength evolution of a peak versus RI change.



(c)

Fig. 4. Results with a 10nm gold-coated MCF with polarized light. (a) Interference spectra observed at different polarizations. (b) Peaks evolution as a function of polarization state. (c) Normalized amplitude and wavelength evolution of an interference maximum versus RI change.

To investigate the refractometric properties of the MCF interferometer under different polarization angles of light, we measured the spectral response to RI changes each 30° of linearly polarized light up to 180°. Fig. 4 shows the experimental results of 10 nm gold-coated MCF to RI changes using polarized light. It is known that when polarized light propagates through an interface, its polarization state will change. At a flat surface, a greater proportion of the intensity component is polarized parallel to a surface (s-polarized) and is reflected compared with the component polarized perpendicular to that (p-polarized) [8]. So, when the reflected light reaches minimum amplitude, the polarization of the light will be left p-polarization. From Fig. 4(a), one can see that the interference spectra show strongly polarization dependency. Fig. 4(b) shows the evolution of 5 interference peaks as a function of polarization. When the polarization of the input light is around 90° (as indicated by the yellow curve), the amplitude of all interference patterns reaches minimum. The evolution of the peak located at 1581 nm as a function of RI change is shown in Fig. 4(c), with a sensitivity of ~7.8 a.u./RIU. Here again, the wavelength position of the peak is unchanged with RI increases.

Conclusions

The spectral characteristics of an MCF interferometer have been investigated to show the interesting perspectives of gold-coated MCF for refractive index sensing. The experimental results show that the bare MCF interferometer is sensitive to the surrounding environment. When the MCF facet is coated with a 10 nm-thick gold layer, the interferometer showed a strong polarization dependency. We observed a sensitivity to SRI only for polarized light with higher sensitivity under p-polarization. The observed behavior may be a result of plasma excitation in the thin gold layer by the polarized supermodes in the multicore fiber. Although, this requires further investigations. In any case, our results suggest the possibility for bio-sensing with a MCF interferometer if the gold layer is properly functionalized for binding a biological recognition element.

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