Dual-core fiber interferometer for sensing applications

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Abstract: We introduce a novel dual-core fiber interferometer composed of a central core surrounded by an external ring core. Results shows that this fiber interferometer can be used to make cost effective devices for sensing applications.
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1. Introduction

In recent years, large numbers of optical fibers have been proposed as interferometer devices for optical sensing due to the large advantages that they present. The sensing fibers are commonly microstructured capable to intrinsically produce an interference pattern of the light when this is propagated down the fibers [1,2]. Alternatively, the fiber could be also modified via micromachining or via chemical process in order to achieve an adequate microstructure able to produce the desired interference pattern [3]. Special attention has been paid on single mode-multimode-single mode (SMS) fiber devices, these devices have been investigated using a great variety of multimode fibers (MMF) or photonic crystal fibers (PCF) [4,5]; however, some devices that uses multimode fibers MMF usually produce chaotic interference patterns that are sometimes difficult to control [4]. In contrast, PCF can produce a controlled interference pattern with sharp spectral feature but this involve challenging fabrication process, increasing the complexity and final cost of the fiber device [5]. In this paper, we introduce a novel dual-core fiber (DCF) for sensing applications. The fiber consists of two Ge-doped cores; a central core surrounded by an external ring core separated by a very tiny pure silica ring. The Ge-doped cores are embedded in a pure silica background that acts as the cladding of the fiber. Due to the fiber geometry and central core excitation we can only excite two modes, the LP_{01} and LP_{02}, Therefore, we are performing an investigation of supermode interference in the DCFs through numerical modeling and experiments in order to reach appropriated fiber design with sharp spectral features and high overall transmission.

2. Dual-Core Fiber Operation Principle

DCF is a strongly-coupled cores fiber that allows the interference of the supported modes while propagating along the DCF length producing modulated sharp transmission spectra, hence, the DCF was designed and fabricated with aim to study the inference effects produced in a SMS fiber device. A microscope image of the DCF is depicted in Fig. 1(top). The central core and the ring core diameters are both of 9.8 µm with refractive index of 1.4499, the separation of between cores is ~ 0. 35 µm given by a pure silica ring. The cores are embedded in pure silica background with cladding diameter of 128 µm. A short segment of DCF is spliced between two SMF sections giving rise to a simple SMS device as is shown in Fig. 1(bottom). The fiber supports two interfering modes, LP_{01} and LP_{02}, able to produce a sharp periodic transmission spectrum due to only two modes are interfering.

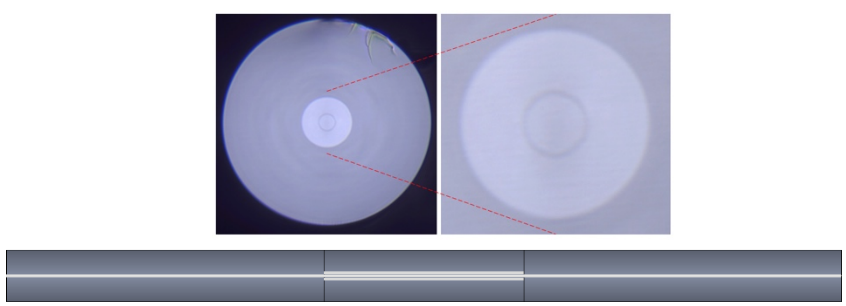

Fig. 1(top) Microscope image of the fabricated dual-core fiber. (bottom) Schematic design of the interferometric dual-core fiber SMS device.

Using this simple SMS configuration, when light is coupled from the SMF into the DCF cross-coupling between the central core and the surrounding core is produced along the DCF during the propagation to finally couple back into an output SMF. In the spectral domain, the interference among these two supported modes produces periodic modulation of the input light that strongly depends on the DCF length, cores refractive index and diameters, and also of the operating wavelength. Fig. 2 (left) illustrate the spectral response of a simulated SMS device composed of fourth centimeters (top) and two centimeters (bottom) of DCF with the afore mentioned fiber dimensions and refractive index values. The operating wavelength range goes from 1200 nm to 1400 nm demonstrating suitable fiber devices whose transmission spectrum with sharp features are attractive for applications in sensors.

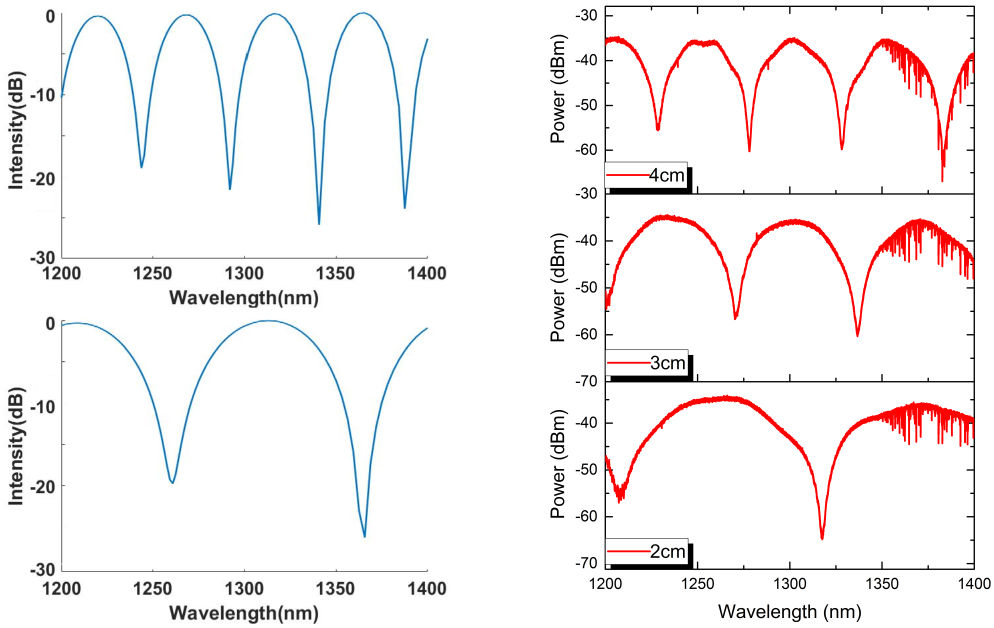

Fig. 2(left) Simulated transmission spectra of the SMS device at two different DCF lengths. (right) Experimental transmission spectra of the SMS device at DCF lengths of 4cm, 3cm and 2cm.

Fig. 2(right) depicts the acquired spectral response of the fabricated SMS device composed of approximately 4cm, 3cm, and 2cm of DCF with fringe visibility of approximately 30 dB at wavelength range going from 1200 nm to 1400 nm. For these measurements, we used a supercontinuum source (NKT Photonics SuperK Compact) as the broad band light source and a Yokogawa Optical Spectrum Analyzer to interrogate the sensor behavior. Based on Fig. 2 we can conclude that the longer is the DFC length, greater is the number of notches produced by the device, this results in two great advantages; first, by using short length of DCF, for instance only 1cm, we have the possibility for multiplexing several SMS sensors in a single chain that can be potentially applied in distributed systems such as oil and gas exploration lines. The second advantage can be its application as comb filter by using the adequate length of DCF, typically about one meter, is possible to produce a large number of peaks in a narrow wavelength range. In this case, the DCF length can be chosen according to the desired peak to peak separation of the comb filter.

3. Conclusions

We have introduced a dual-core fiber interferometer than can be applied for the fabrication SMS devices adequate for the detection of many physical parameters, such as, bending, high temperature, vibration, etc., just to mention a few. Based on the sharp spectral features of the DCF, it is possible to fabricate compact, stable, accurate, high sensitive, and reproducible fiber devices. Furthermore, this kind of SMS devices can be implemented as multiplexed sensor arrays suitable to hazard or extreme environments operation.

4. References

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