Fabrication of Mach-Zehnder interferometers with conventional fiber optics in detection applications of micro-displacement and liquids.

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ABSTRACT

In this paper we shows the results obtained to fabricate and implement Mach-Zehnder interferometers of conventional fiber optic using Long Period Fiber Gratings (LPFG´s) which were developed by electric arc technique. We obtains this type of interferometer when we fabricated two LPFG's in series or in cascade with the same characteristics such as number of discharges and the same period, placing them in cascade separated by a distance which three times the length of the LPFG. The application which was given at interferometer fabricated was as a liquids sensor, volume sensor of liquids and micro-displacement sensor. The sensors of liquids and liquids volumes were placed in a container in which the interferometer is fixed so that results of measurements are only by incorporating each of the liquid and not by some external movement. The sensed fluids were: water, alcohol and solution (water with sugar). Final length of the interferometer is between 4 to 6 cm. We analyze the results obtained to when a section the Mach-Zehnder interferometer is displaced in of the order of microns. The variations observed in transmission spectra obtained from each of the sensors mentioned, show changes in the amplitude and the attenuation peak of the interferometer was displaced.

Keywords: Long Period Fiber Gratings (LPFG´s), Mach-Zehnder interferometer, Optic sensors, Interferometer all fiber optic.

1. INTRODUCTION

One of the important greatest discoveries in the field of fiber optics, was undoubtedly in 1978 made by K. O. Hill et al, launched intense Argon-ion laser radiation into a Germanium-doped fiber and observed that after several minutes an increase in the reflected light intensity occurred which grew until almost all the light was reflected by the fiber. This achievement, subsequently called "Hill gratings", was an outgrowth of research in the nonlinear properties of Germanium-doped silica fiber [1].

The fiber gratings are between the most popular devices extensively used in optical communications and optical fiber sensors. Within the optical communication networks, optical devices based in fiber fundamental performing operations as coupling and dispersion, selective filtering wavelength and optical switching. In the field of optical sensors, optical fiber sensors, with single benefits as immunity to electromagnetic interference, high sensitivity, corrosion resistance and a capacity to resist high temperatures, are very used for measuring different physical variables such as temperature, pressure, refractive index, and chemical parameters [2].

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Therefore, the LPFG´s consists of a periodic spatial variation (along the longitudinal axis of the fiber) in the refractive index of an optical fiber [2]. In this work using LPFG´s, which were fabricated using the electric arc technique using micro taper, in which changes the number and frequency of each discharge, this to modify the attenuation peak in terms of amplitude and depth.

Its important mention that has been fabricated Mach-Zehnder interferometer with two fattened fiber long period gratings in series in dispersion shifted fiber [3]. But on this occasion we use the micro-taper.

2. THEORETICAL DEVELOPMENT

The LPFG´s as the Bragg gratings consists of periodic modulation of the refractive index on the core of an optical fiber. Although in the LPFG, the periodic modulation is used to couple the light of the fundamental mode in the core of a single mode fiber with the modes of propagation in the coating in the same direction [2].

The LPFG's have a period typically in the range of 100µm to 1000µm (1mm). A LPFG introduces a coupling between the guided modes and cladding mode propagation. In fig. 1.1, shows the power transmission spectrum of LPFG's taped in a standard fiber. The wavelengths of the peaks shown in fig. 1.1 are defined as [2]:

$$\lambda^{m} = \left(n_{eff}^{01} - n_{eff}^{m}\right)\Lambda \qquad \text{Eq. (1.1)}$$

Where n_{eff}^{m} and n_{eff}^{01} represent the effective indices of the guided fundamental mode, the mode of the coating of order m coupled in the mode guided why the grid respectively, will then Λ is the period of the LPFG [1].

There are several techniques for fabricate LPFG's such as amplitude mask, laser UV, irradiation of CO_2 and electrical arc. Two methods have been used to fabricate LPFG's by electric arc discharge. The first creates micro-tapers introduced a small lateral displacement at one end of the fiber [2, 4].

Double LPFG's or pairs of gratings have a high resolution for measurements of the refractive index compared with LPFG's simple. The advantage of using a sensor with double LPFG's was based on the principle of operation, where the coupling of the modes of the core and cladding of the first LPFG is combined again with the second LPFG as to form interference fringes. The optical paths of the core and the cladding constitute the arms of a Mach-Zehnder interferometer (MZI) in the transmission mode configuration [5].

When several identical gratings are cascaded or series with a distance which is three times the length of the LPFG, the power transmission spectrum is exposed to have a series of peaks regularly spaced appropriately to obtain multi-channel filters. The depth of each peak can be controlled by adjusting the depth of the grate simple. The spacing between grids adjacent determines the spacing between the peaks. The thinness of the peaks can be increased by more gratings in cascade (fig. 1.1). This part made LPFG's in cascade using the same technique electrical arc by the method of micro-taper [2,3].

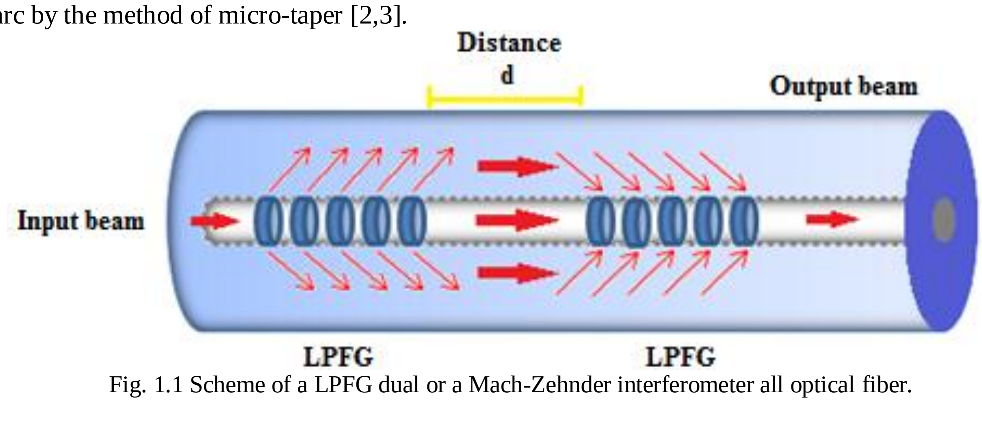

Fig. 1.1 Scheme of a LPFG dual or a Mach-Zehnder interferometer all optical fiber.

3. APPLICATIONS OF THE MACH-ZEHNDER INTERFEROMETER IN DIFFERENT SENSORS

The following schemes used and the results obtained using Mach-Zehnder interferometers fabricated.

3.1 Sensors of liquids and liquid volumes.

In fig. 1.2, shows the experimental scheme which is used for testing of both sensors: different liquids and liquid volumes. It is observed each of the component parts as a white light source (WLS), a container, fiber interferometer, the optical spectrum analyzer (OSA) and bare fiber adapters. The operation is as follows: after having fabricated the LPFG's are placed in the container and paste at both ends so that the fiber is fully seated, one end of the fiber is connected to a bare fiber adapter to the power white light and the other end is positioned at another adapter OSA obtaining the results in the power transmission spectra shown in fig. 1.3.

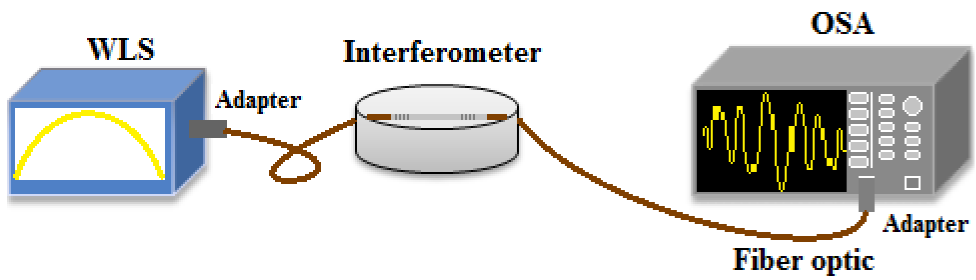

Fig. 1.2 Experimental setup Mach-Zehnder interferometer in a straight position

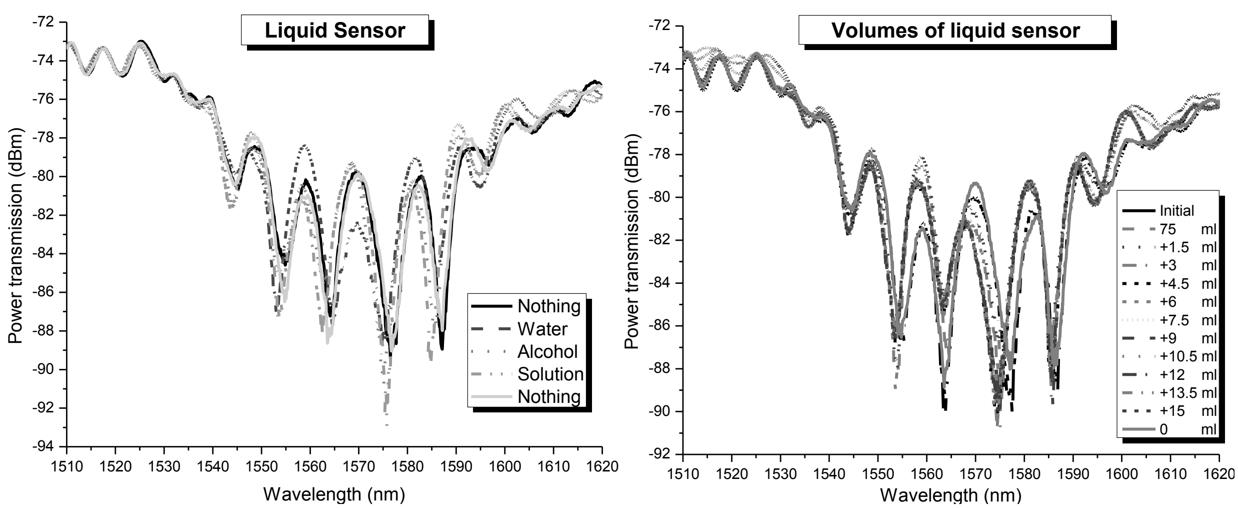

Fig. 1.3 Power transmission spectra of a liquid sensor (left) and water volume sensor (right) with a Mach-Zehnder interferometer fabricated.

3.2 Micro-displacement sensor.

The sensors of micro-displacements we used to detect small changes of displacement, were used to measure displacements in structures in seismic detection and others parameters. It is clearly seen in fig. 1.4, that the interferometer is connected to the source of white light through a bare fiber adapters, is then fixed to the positioner linear motor so that it performs the curvatures of the interferometer section, through the PC to which this connected; finally, the other end of fiber is connected to OSA connect by mean of an bare fiber adapter and is observed the sensor power transmission spectra produced in the fig. 1.5.

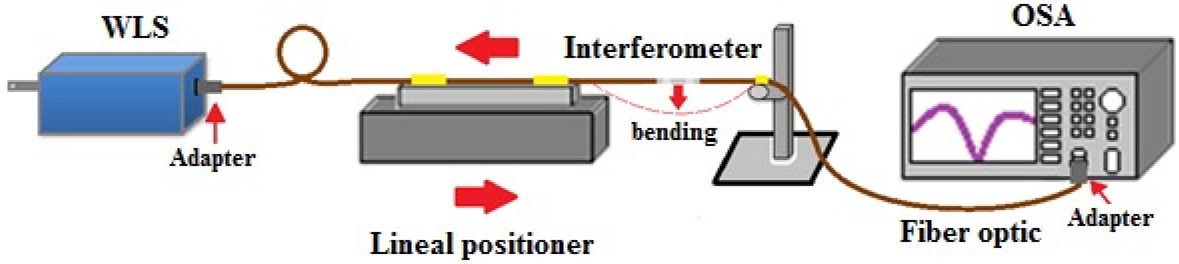

Fig. 1.4 Experimental setup for sensor micro-displacements and thus to obtain its power transmission spectra.

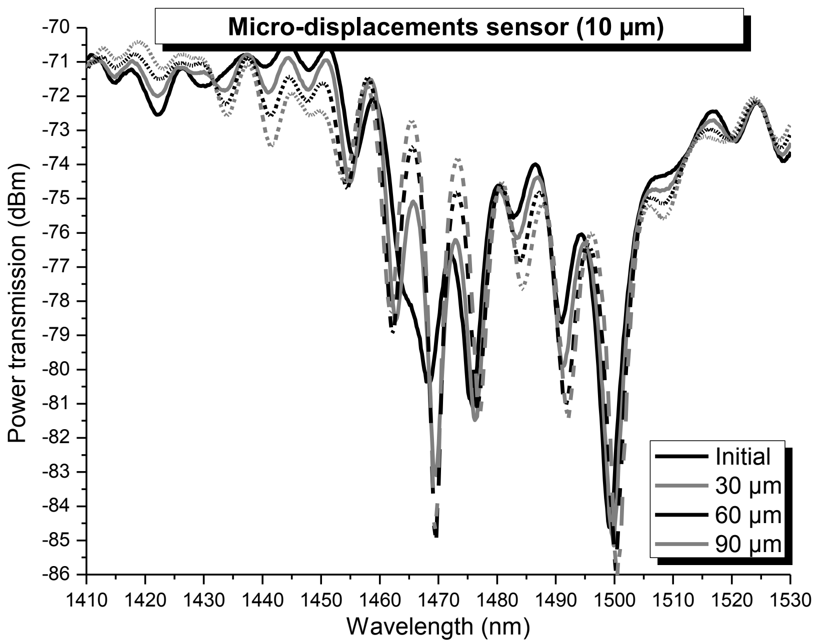

Fig. 1.5 Power transmission spectra of micro-displacements sensor with a Mach-Zehnder interferometer with micro-displacements of 100μm.

3.4 Micro-displacements sensor with an angle.

The scheme of fig. 1.6 is similar to fig. 1.4, the difference is the interferometer is to be placed at an angle that will vary depending on bond values of *a*. The interferometer is connected to the white light source (WLS), through a bare fiber adapter is also attached to the linear positioner which serves to give the curvatures to the interferometer; we can observe the power transmission spectrum in the OSA and changes the value than for different measurements at different angles. The power transmission spectrum is shown in fig. 1.7 as well as a table indicates the values of *a*, *b* and its corresponding angle.

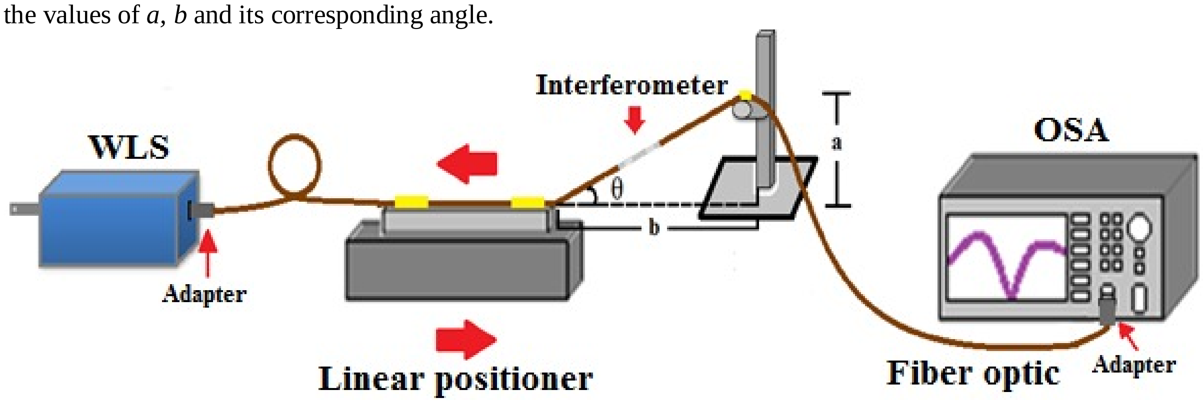

Fig. 1.6 Experimental setup for a micro-displacements sensor with an angle, the distance *b* is fixed, the parameters that varies are *a* and *θ*.

Parameters	Value
b	41.7 cm
a	20.5 cm
θ	26.179°

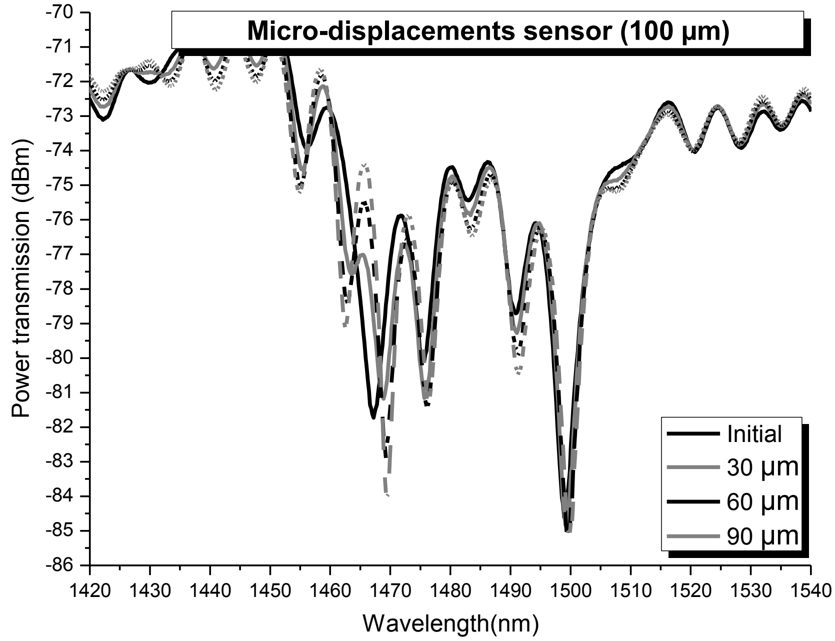

Fig. 1.7 Power transmission spectra of micro-displacement sensor with bending of 100μm, from 0 to 1mm; with an angle of 26.179°.

4. CONCLUSIONS

We did the comparison with other configurations of Mach-Zehnder interferometer can observe that this configuration (all fiber) are easier to fabricate, implement and less expensive in comparison to the configuration that uses couplers which uses mirrors, as the latter is very hard to build the correct alignment to obtain a good result.

Obtained changes in the transmittance spectrum of the interferometer may be more sensible because the greater number of peak intensity attenuation of the output will be increased to only have single peak attenuation as in LPFG's. Proposes a refractive index sensor which are observed due to variations in wavelength and power for the sensor of liquid, only that it may be necessary to amplify the input signal to the output of the interferometer can be analyzed with an optical power meter and so did not use the OSA.

5. ACKNOWLEDGEMENT

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