Optical Fiber Sensor for Pressure Based on Multimode Interference as Sensitive Element

V. I. Ruiz-Pérez[1], M. A. Basurto-Pensado[2], G. Urquiza-Beltrán[2], D. May-Arrioja[3], E. Gasca-Herrera[4], J. J. Sánchez Mondragón[1], P. LiKamWa[5].

[1]*Photonics and Optical Physics Laboratory, Optics Department, INAOE Puebla, México*
[2]*CIICAp, Universidad Autónoma del Estado de Morelos, Cuernavaca, México*
[3]*Departamento de Ingeniería Electrónica, UAM Reynosa Rodhe, Universidad Autónoma de Tamaulipas,* Reynosa, México
[4] *Facultad de Instrumentación Electrónica y Ciencias Atmosféricas, Universidad Veracruzana, Xalapa, Veracruz, México*
[5]*CREOL, The College of Optics and Photonics, University of Central Florida, Orlando, FL 32816-2700, USA*
Email: mbasurto@uaem.mx

Abstract. The experimental results of applications on a novel intrinsic fiber optic pressure sensor based on multimode interference are presented. The sensitive element consists in a SM–MM–SM (MMI) fiber structure embedded in a membrane.

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1. Introduction.

The theory of multimode interference (MMI) and self-image formation recently has been intensively employed in integrated waveguides [1, 2] has also been applied in all-fiber optic devices using a single-mode – multimode – single-mode (SMS) fiber structure[3, 4]. In this structure, an incident optical field emerging from de single-mode fiber (SMF) excites higher order modes which will propagate through the multimode fiber. The characteristics of the field at the output SMF will be defined by the MMI effect, which is a function of parameters such as the core and cladding refractive index, core diameter, and the length of the multimode section. Environmental effects can alter these parameters and therefore modify the response of the MMI device which can be used to sense or detect a particular parameter. The MMI effect has been successfully employed in important optical sensing applications [5, 6]. In this paper, we present the results of the application of MMI structures to develop a pressure sensor device. The principle used in our proposed device is based on bending of the MMI device, which will induce the gradual lost of higher order modes. Since the self-image is formed by the combination of all the modes, thus the transmitted intensity will be modulated due to bending of the optical fiber resulting from the applied pressure [7, 8].

2. Experimental set-up.

The sensitive element consists of a SMS fiber structure attached to a acrylic membrane using a V-groove. The membrane is peripherally clamped to an aluminum chamber. The length of the multimode fiber (MMF) was 14.25 mm which is optimized to obtain the first self-image at a wavelength of 1530 nm. We used a SMF-28 with a diameter of ~9 µm and refractive index of 1.4615, which is spliced to a *no-core* MMF with similar refractive index and a diameter of 125 µm. Another section of SMF-28 is used at the other end of the MMF section. The response of the sensors was interrogated using a tunable laser (HP Lightwave Measurement Systems Company) with a wavelength range from 1460 to 1580 nm. The setup is shown in Fig. 2

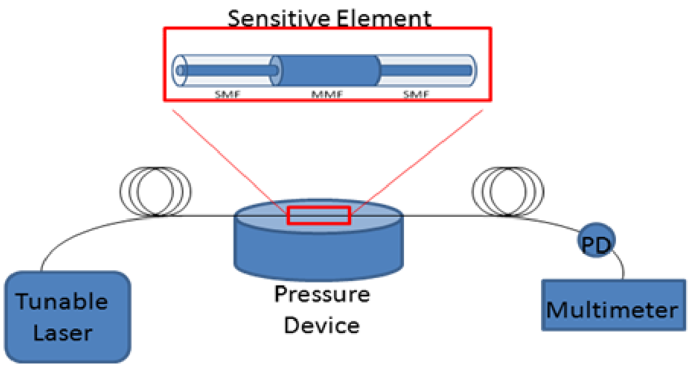

Fig. 1. Setup, laser, fiber and photo detector.

The fiber is held straight along the V-groove on the acrylic membrane (with 3 mm and 6 mm in thickness) with a channel depth of 0.5 mm, which is then covered with PDMS polymer to keep the fiber in place. One end of the MMI pressure sensor was connected to the tunable laser, while the other end was connected to a photo-detector and a digital multimeter (DMM 2000 Keithley) with 1 µV in resolution. The figure 2 show a picture of us device.

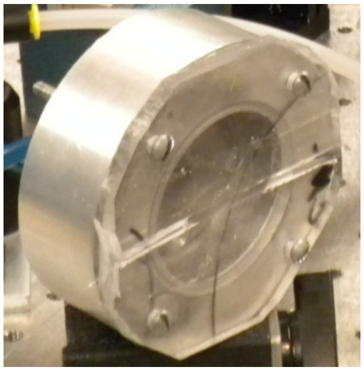

Fig. 2. Device with membrane acrylic of 3mm.

3. Experimental results.

The MMI sensor spectral response as pressure is applied was recorded and plotted as shown in Fig. 3. This figure shows that the intensity decreases as the pressure is increased which is consistent with the results in references [7, 8]. In our tests, the acrylic membrane with 6 mm in thickness was broken around 160 psi, which limited our maximum pressure range to 140 psi.

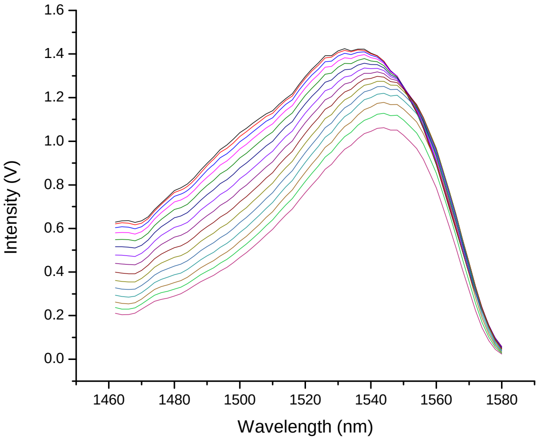

Fig. 3. Spectral response in function of increase of pressure.

By tracking the intensity changes at a particular wavelength, in this case a wavelength of 1510 nm, we can observe consistent intensity changes as shown in Fig. 4. After three different measurements we obtain very high repeatability with our proposed optical pressure sensor.

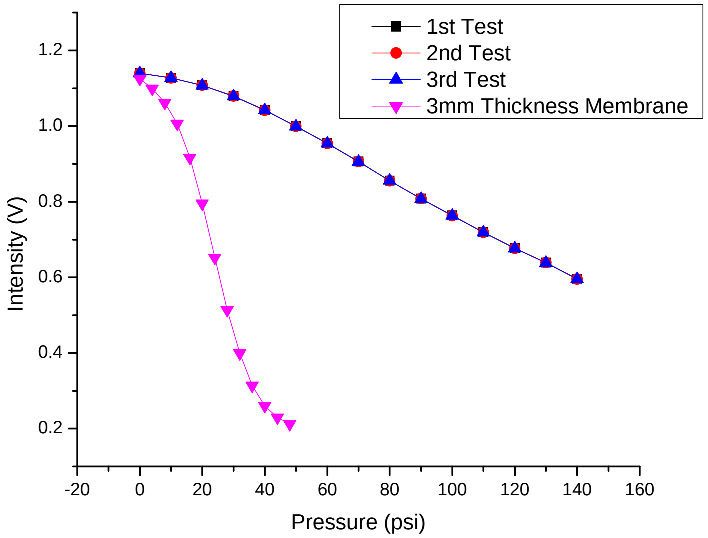

Fig. 4. Repeatability of tests, with a 3mm membrane.

It is also possible to increase the sensitivity of our pressure sensor using a thinner membrane in order to detect a smaller dynamic pressure range. In this case we used a membrane with a thickness of 3 mm. We can notice that although the range is reduced we gain a higher sensitivity which can be easily adjusted by just changing the membrane thickness. We should also emphasize that due to the wavelength dependence of the MMI devices, the sensor has the potential for multiplexing by simply changing the length of the MMF.

4. Conclusions.

Is this paper, a novel intrinsic fiber optic pressure sensor with a SMS fiber structure as the sensing element has been proposed and experimentally demonstrated. We took advantage of the MMI effects in order to detect pressure by detecting intensity variations on the MMI response. Such intensity changes can be controlled at will by modifying the membrane thickness, which allows us to easily modify the sensing range and sensitivity. We should highlight the high repeatability of the sensor as well as other important advantage such as, greater strength, durability and low cost of our fiber optic pressure sensor. The process of fabrications is very simple and inexpensive instruments are required.

5. References.

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