Fibre-optic interferometric pressure sensor based on droplet-shaped PDMS elastomer

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Introduction

A range of single-mode fibre-optic based on reflective Fabry-Perot (F-P) interferometer have been developed in the past two decades for the detection and measurement of various physical, chemical and biomedical parameters[1]. It is considered as the most convenient configuration as it is simply based on the optical cavity where beam interference occurs and is formed by two parallel mirrors.

In this work, we present a low pressure sensor based on white-light Fabry-Perot interferometer where poly-dimethylsiloxane (PDMS) elastomer is defined as the F-P optical cavity. An erbium-doped fibre amplifier (EDFA) has been used as low-coherent white-light source transmitted through a single-mode fibre (SMF-28). The light is coupled from a 50:50 four-port 3-dB coupler and is splitted in two ends. One of the outputs is connected to the sensing element (PDMS elastomer) while index-matching liquid has been used to eliminate the reflections from the extra end. Finally, an optical spectrum analyser (ANDO AQ-6310B) and a computer are connected in order to measure and analyse the reflected spectrum. The experimental set-up is illustrated in Figure 1 (a).

The sensing element of our system is based on PDMS elastomer due to ability to provide low young's modulus (~1.8 MPa). Furthermore, PDMS is optically clear, and is generally considered to be biocompatible, non-toxic and low-cost silicone [2]. The F-P cavity of the sensing probe is formed by two reflecting mirrors (M1, M2) separated at distance d, as shown in Figure 1 (b). The deformation of the elastomer induced by the pressure varies the cavity length. The cavity length d, corresponding to applied pressure can be determined by measuring the spectrum of reflection light of the sensor. Conversion of the cavity deformation to pressure [3], can finally provide the performance of the sensor system.

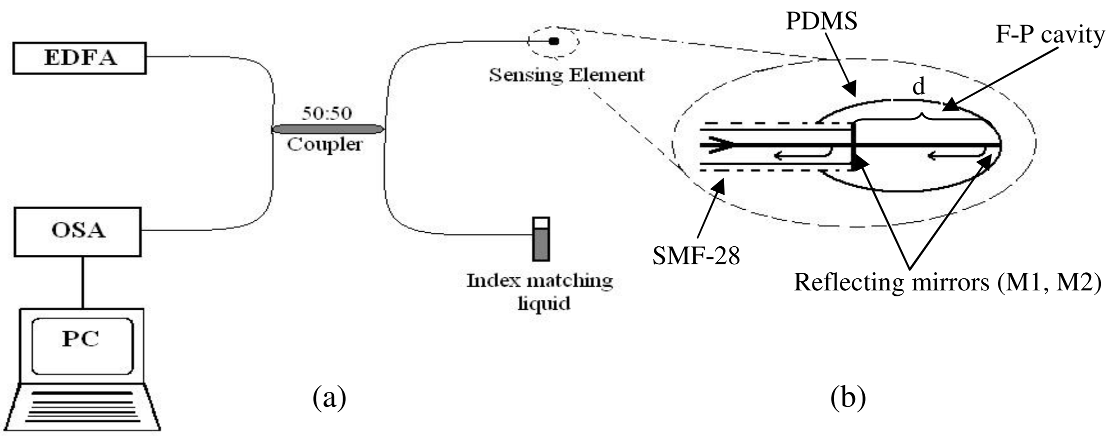


Figure 1: (a) Experimental configuration of the fibre-optic interferometric pressure sensor. (b) Droplet-shaped PDMS F-P cavity of distance d with two reflecting mirrors M1, M2.

Pressure Response

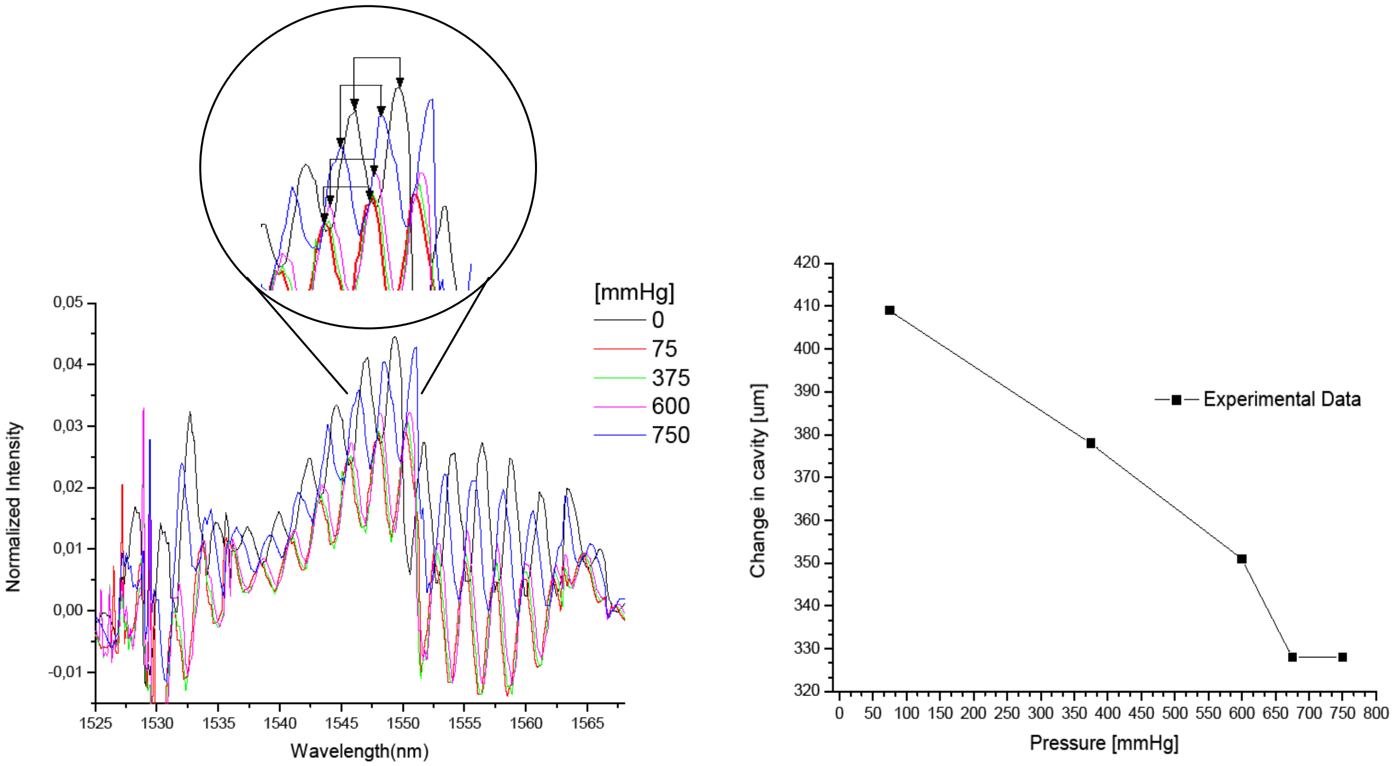
Based on the mechanical properties of the PDMS, the sensor characterization can be based on the reflection spectrum and the pressure response of the developed system (Figure 2). The deformation of the PDMS sensor head induced by the pressure varies the cavity length. The cavity length *d* corresponding to applied pressure is determined by measuring the spectrum of the reflection light of the sensor. The cavity length *d* can be obtained by using

$$d = \frac{\lambda_1 \lambda_2}{2n(\lambda_2 - \lambda_1)}$$

where *n* represents the refractive index of the material of the sensor cavity, $\lambda 1$ and $\lambda 2$ represent adjacent peaks in the reflection spectrum.

Measurements were made up to 750 mmHg (1 bar) . Fig. 2a clearly demonstrates the shifting of the white light fringes of the reflection spectrum due to the applied pressure. This pressure sensing technique in which Fabry-Perot interferometry is applied to measure pressure-induced elastomer deflection, relies upon a precise cavity length measurement being a reliable indicator of the pressure difference across the cavity formed.

From the slope of the curve in Fig. 2b the response of the current sensor head (change in cavity length per pressure) is 125nm/mmHg.



(a) (b)

Figure 2: (a) Reflection Spectrum of the developed PDMS-based sensor for different applied pressures. Shifting of the adjacent peaks of the reflection spectrum due to cavity length, d, variation. b) Pressure response graph of the sensor.

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