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Realization of fiber optic displacement sensors

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ABSTRACT

Fiber optic sensors are very promising because of their inherent advantages such as very small size, hard environment tolerance and impact of electromagnetic fields. In this paper three different types of Intensity Fiber Optic Displacement Sensors (I-FODS) are presented. Three configurations of I-FODS were realized in two varieties. In the first one, the cleaved multimode optical fibers (MMF) were used to collect reflected light, while in the second variety the MMF ended with ball lenses were chosen. To ensure an accurate alignment of optical fibers in the sensor head the MTP C9730 optical fiber ferrules were used. In this paper the influence of distribution of transmitting and detecting optical fibers on sensitivity and linear range of operation of developed I-FODS were investigated. We have shown, that I-FODS with ball lenses receive average 10.5% more reflected power in comparison to the cleaved optical fibers and they increase linearity range of I-FODS by 33%. In this paper, an analysis of each type of the realized sensor and detailed discussion are given.

1. Introduction

Fiber optic sensors offer a number of advantages, such as increased sensitivity compared to existing techniques and geometric versatility, which permits configuration into arbitrary shapes. Fiber optic sensors are dielectric devices and they are widely used in high voltage, high temperature or hazardous environments [1–6]. Low weight, high resolution and small dimensions make fiber optic sensors ideal for monitoring small cracks in constructions or machines [7] or even nanometer displacements in Micro- and Electro-Mechanical Systems (MEMS) [8]. Also in medicine fiber optics sensors are very popular. This group of fibre optic biosensors is often used as probes or as a sensing element in clinical and pharmaceutical applications [9,10]. Biosensors based on optical fibers can excite the target molecules and also capture the emitted light from the targets. Small dimensions of fiber optics biosensors enable scientists to measure biological species such as cells, DNA, or proteins [11]. Probe heads miniaturized to a few microns enable physicians to arrive at places inside the human body [12].

The light intensity is the simplest solution for most of the optical fiber sensors. In measurement method using intensity modulation, input and receiving light reflected from the tested surface are compared. Among different types of optical fibers, multimode optical fibers (MMF) are preferable to be used in optical sensors. Large numerical aperture (NA), 50 μm core radius and easy coupling with active elements, several dozen times smaller attenuation in comparison to plastic optical fibers are advantages over other optical fibers. A modern fiber optic sensor should be characterized by a wide operating range, acceptable linearity, low cost and as simple construction as possible. Furthermore, optical fiber used in intensity modulation sensors must enable precise positioning [13,14]. However, the use of light intensity introduces some problems in measurement processes because the light intensity is also sensible to other variables. Therefore a sensor with high sensitivity characterized by high slope and wide linear range of operation is very desired in various applications, especially in displacement monitoring.

Reflective Intensity Modulated Fiber Optic Sensors (RIM-FOS) were firstly described in 1966 in US Patents No. 3273447 by Frank and one year later in US Patent No. 3327584 by Kissinger. Applying optical fibers for detection of small displacement has become very attractive since then because sensing is totally touchless and it provides high accuracy measurements. These features are very desired e.g. in monitoring of movable parts of Micro-Electro-Mechanical-Systems (MEMS) [15,16]. Moreover, such sensors based on a knife edge obstruction have high signal to noise ratio (SNR) and they can be used to the dynamic and static measurement of a tuning fork oscillator [17]. I-FODS can be also used as a temperature sensor [18] or biosensor [19]. Despite a great number of I-FODS applications, their measurement range is still limited and the output linearity is not so satisfied, therefore I-FODS are still being developed and improved [20–22].

In this paper three different configurations of I-FODS are described, in which the influence of distribution of transmitting and detecting optical fibers on sensitivity and linear range of operation of the I-FODS were investigated. Moreover, all configurations were realized in two varieties. In the first variety all optical fibers were cleaved, while in the

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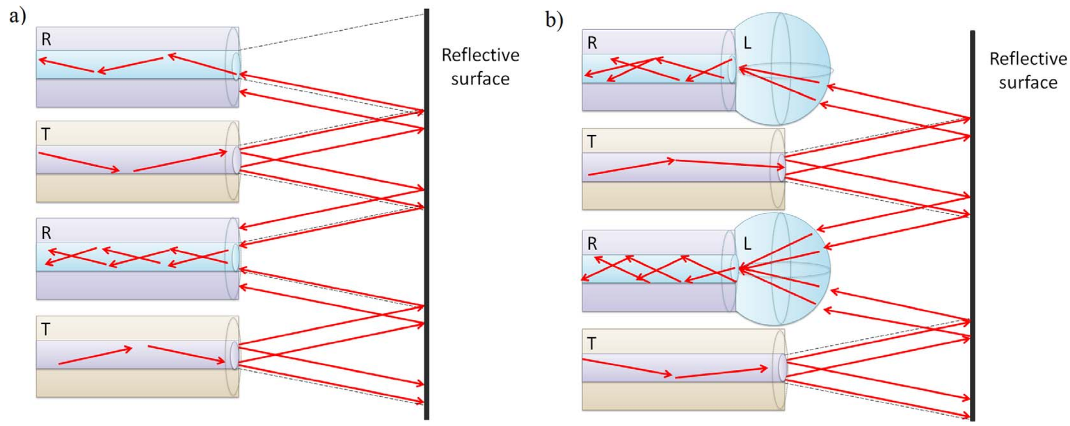

Fig. 1. The idea of mulit-fiber optic displacement sensor: (a) with cleaved fibers, (b) with BLOF.

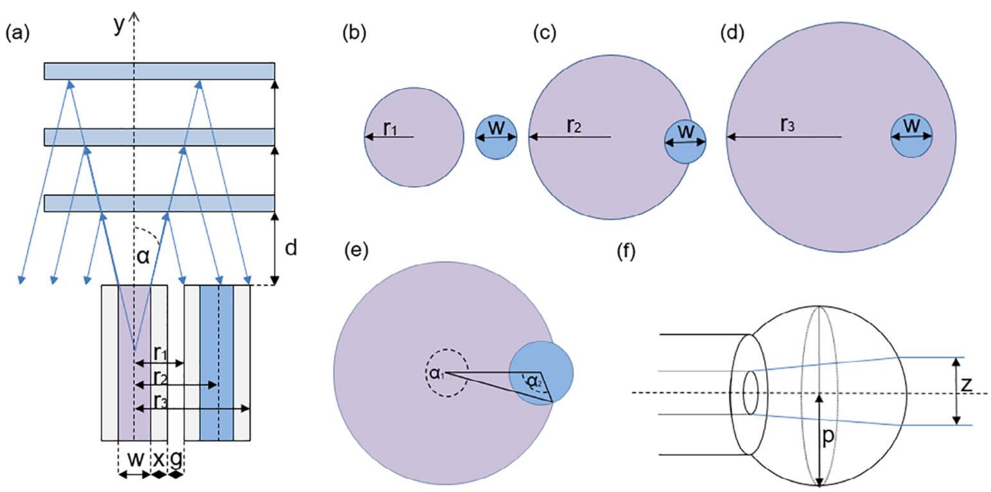

Fig. 2. (a) I-FODS theoretical model and (b)–(d) receiving optical fiber illumination dependence on distance d, (e) definitions of α_1 and α_2 angles, (f) the construction of ball lens.

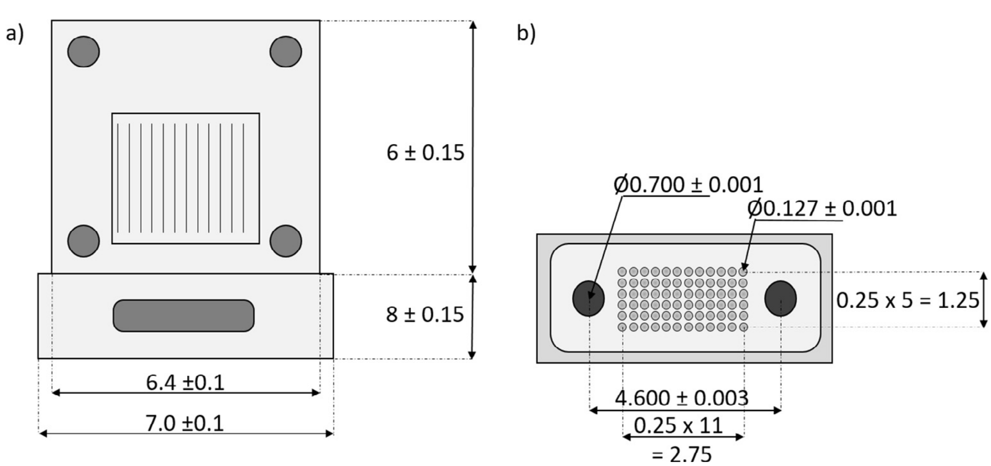

Fig. 3. MTP C9730 optical fiber ferrule (dimensions are given in [mm]): (a) top view (b) front view.

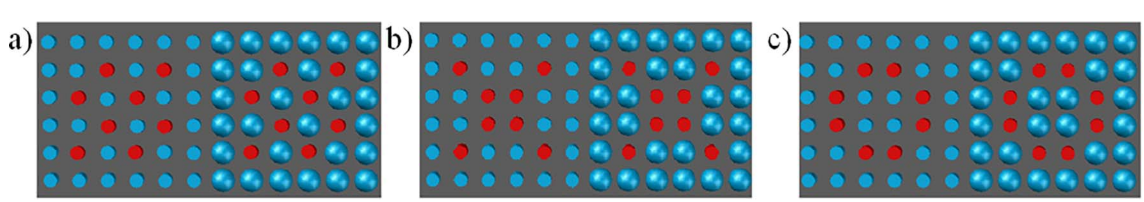

Fig. 4. The distribution of transmitting and receiving optical fibers in head of sensor: (a) Conf. 1, (b) Conf. 2 and (c) Conf. 3.