Fiber sensors for optical training courses

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Abstract

Laboratory experiments for graduate optical disciplines of different engineering courses and training schools of short duration have been implemented and developed. The work has been focused on the development of general optical competences and its applications on innovative engineering solutions.

The polymeric optical fibres have emerged almost simultaneously with traditional optical glass fibres, in the 60s of last century and are usually produced in polymethylmethacrylate, rigid and transparent thermoplastic polymer. The sensors characterized in these experimental works use the changes in the attenuation value, on the coupling region between two polymeric optical fibers, due to external disturbances, related to the parameter to be measured. The obtained results was analysed and discussed and its impact that such projects can have on engineering education, namely on the students who attend summer courses or discipline of optics

and optoelectronics in graduate and postgraduate engineering physics courses.

Keywords: Polymeric fibers; optical signal; attenuation, optical losses.

Summary

The work developed had main focus for the development of general optical skills and its applications on innovative engineering solutions, and yet on the students who attend summer courses or discipline of optics and optoelectronics in graduate and postgraduate engineering physics courses.

Introduction

In the last years many optical sensors capable of monitoring the deflection and elongation of various elements, the distance between points of a structure, level and flow rate of liquid, relative humidity, electric current, pressure, temperature, refractive index and others have been proposed (Peters, 2010 & Birlo, 2007,2011). In spite of the polymeric optical fibers (POF's) data transmission over long distances being limited, it is possible to use sensors within a reasonable distance (tens of meters) from your interrogation system.

Therefore, it is possible to apply the technique of monitoring in numerous situations in which the use of electrical sensors can cause some problems, such as environments with high humidity, corrosive, flammable (Antunes *et al.*, 2007 & Leitão et al, 2011). In this sense, it is important the development and or optimization of optical sensors based on polymer optical fiber, in order to meet the needs of a demanding industry of construction and maintenance of infrastructure. These sensors have some advantages compared to conventional sensors such as being compact, lightweight, robust, and potentially with lower cost (Peters, 2010, Birlo, 2007, 2011 & Leitão *et al.*, 2011).

In relation to the electrical sensors, the optical sensors have considerable advantages because they are immune to electromagnetic fields, there is no risk of a short circuit (can be used safely in flammable environments), can be used in water environments.

The polymeric fibers are composed of two distinct regions, designated core (were optical signals propagate) surrounded by a region called the cladding (Antunes *et al.*, 2007). The optical signal is guided by total internal reflection, mostly inside the core.

The fibers can be classified into two categories, taking into account the propagation modes permitted for the optical signal, namely, the single-mode fibers and multimode fibers, (the single-mode fibers have a core of smaller diameter about 10 µm, while the diameter of the multimode fibers can go up to 2 mm).

Attenuation, α, can be defined as,

$$\alpha(dB) = 10 \times \log_{10} \frac{P_i}{P_0}$$

where, Pi and P0 are, respectively, the input and output power of the optical signal (Arrue *et al.*, 2007 & Ziemann, 2008). The polymeric optical fiber used throughout these experimental works presents a core diameter of 1 mm and typical attenuation 0,22 dB/m.

The main advantage of the polymeric fibre for glass fibers are ease of connection and handling, which results from its large diameter thereby enabling the use of connectors with low precision and low cost, and spectral window of operation of these fibers (the spectral region where attenuation is minimal) happens in the visible, resulting in a reduction in the cost of optoelectronic components used, particularly in optical sources and receivers (Antunes, 2007, Birlo 2007 & Leitão 2011).

The development of mini projects was implemented on the 3rd OPTICWISE Training School on Optical Wireless Communications which took place in University of Aveiro, in april 2014.

Experimental Systems

The attenuation in the coupling between the polymer optical fibers has a dependency to external disturbances applied.

The characterization process involves injecting an optical signal into a fiber subject to external disturbance; and the detection of this signal at the other end of the fiber, making it possible to quantify the attenuation resulting from the propagation. The linear position fiber sensor has as main objective, monitoring up to 15 mm through fibre light coupling losses (dB).

This sensor consists of two metal parts, where one of the parts slides through a slot in the other. As displayed on Figure 1, two polymer optical fibers are glued to the sensor, one on each side, in the groove aligned along of the two parts. As show, one can see a schematic diagram of linear position fiber sensor. One of these fibers is connected to a LED (light emitting) and the other fiber connected to a photodiode (receptor).

In order to be able control the existing offset between the optical fibers, a micrometer was used. And to optimize the laboratory tests, LED should be used for the blue (430 nm) light since it has the greatest optical power.

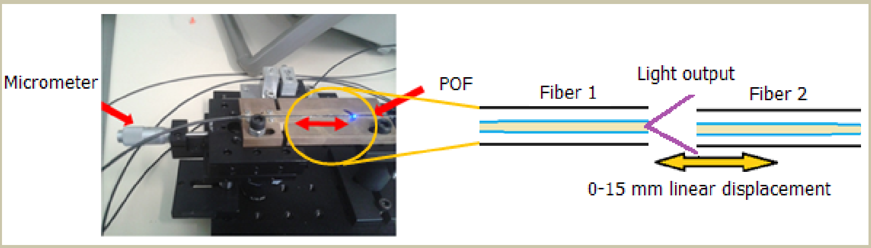

Fig. 1. Experimental Systems and schematic diagram of linear position fiber sensor.

The experimental systems used for linear position fibre sensor was: 2x1 m plastic optical fibre, 1 blue LED (model IF E92A, Industrial Fiber Optics), 1 Photodetector (IFD91, Industrial Fiber Optics), 1 Single Axis Translation Stage (Accuracy: 0,01 mm), 1 Oscilloscope (HEWLETT PACKARD 54600A) or Data acquisition board (NI USB6008) associated with Software Labview ®, and 1 Power Supply (12 V). The polymer optical fiber used in both mini projects has a core diameter of 1 mm, numerical aperture 0,47 and typical attenuation 0,22 dB/m (Avago Technologies - HFBR-RUS100Z).

The angular position fiber sensor has as main objective, monitoring up to 50º through fibre light coupling losses (dB). The angular displacement has an effect over the light waves that travel from the horizontal fiber to the angularly misaligned one, causing optical losses. These losses depend on the wavelength of electromagnetic radiation that travels in the fiber, since every wavelength has its own propagation mode. The sensor is based on light coupling losses, due to rotation of two fibers aligned in the same horizontal plane. When the angular movement varies up to 50 , there will be some optical loss due to the intrinsic divergence of the beam. The angular gap between fibers is manually controlled with a rotary positioning stage, as shown in Figure 2.

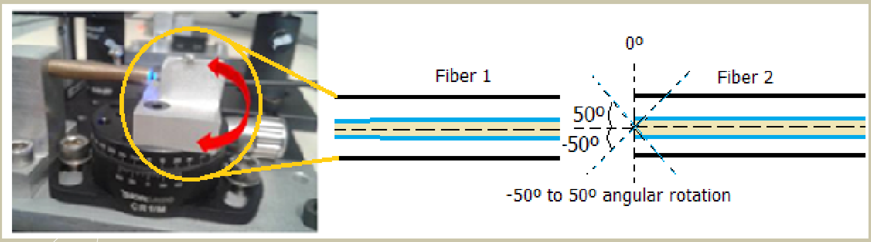

Fig. 2. Experimental system of angular position fiber sensor.

The experimental systems used for angular position fiber sensor was: 1 blue LED (model IF E92A, Industrial Fiber Optics), 1 Photodetector (IFD91, Industrial Fiber Optics), 1 Rotary positioning stage (Range: 50 Accuracy: 0,1), 1 Oscilloscope (HEWLETT PACKARD 54600A) or 1 Multimeter, and 1 Power Supply (12 V).

Experimental Results

The results presented here reflect the results of mini projects developed by the student on the 3rd OPTICWISE Training School on Optical Wireless Communications. Here groups of three students for a limited period of time performed the mini projects and swirled with each other to perform all the works. The results will show the linear and angular displacement. All projects were implemented within the set time, once they have managed in a short time carry out and realize these mini projects.

In Figure 3a the curve of the normalized voltage with the displacement and in Figure 3b, the curve of the optical losses due to the distance between the two fibers obtained experimentally is shown.

The measurements were performed with a step of 0,5 mm for a total of 15 mm between the optical fibers.

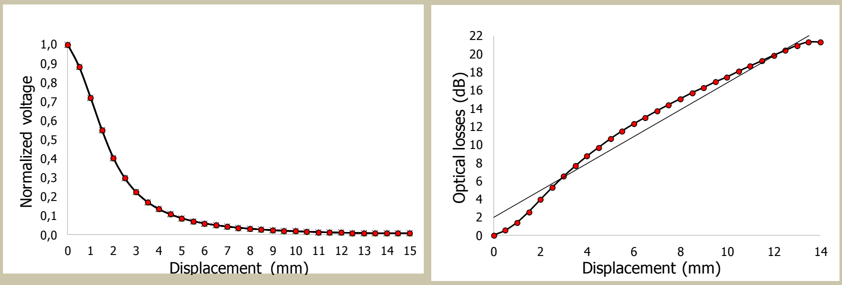

Fig. 3. (a- Normalized voltage with the longitudinal displacement; b- Optical losses versus the longitudinal displacement).

Based on Figure 3a, it is possible to check that the sensitivity of the sensor depends on the distance, and is more sensitive in the area 0,5-3 mm. From the start 3 mm losses vary with the least distance between two fibers. With respect to the sensitivity can be yet assess which of 0-3 mm, there is a sensitivity in the reading the displacement of 2,16 db/mm whereas the 3-14 mm, the sensitivity decreases to 1,34 dB/mm, hence it is possible to better visualize the distribution of normalized voltage.

Regarding Figure 3b, while the distance between the fibers is small (less than 2 mm) losses are minimal since most of the optical signal provided by the emitting fiber is still in the direction of the receiving fibre acceptance cone.

With reference to figure 3, can be pointed out that the correlation factor was higher than 0,96.

Then in Figure 4a displays the curve of the normalized voltage with displacement and in Figure 4b the curve of the optical loss due to the angular distance separating the two fibers obtained experimentally. The measurements were performed with an interval of 5° to 50° in total for each side.

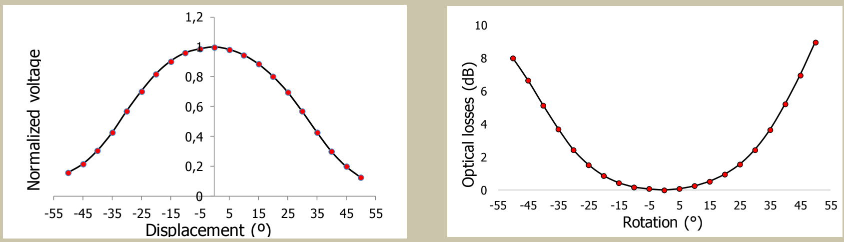

Fig. 4. (a- Normalized voltage with the angular displacement; b- Optical losses versus rotation of the angular displacement).

From the results shown in Figure 4, the sensitivity of the measurement of the optical loss can be analyzed from -50° to 50°. It can also be seen that there is a greater sensitivity in the detection of optical losses between 25° and 50° and between -25° and -50°. Data analysis was gauged that from 0° to 25° and 0° to -25°, there is a sensitivity of 0,062 dB/° and 0,061 dB/° respectively, while the 25° to 50° and from -25º to -50º sensitivity increases to 0,297 dB/° and 0,259 dB/° respectively.

As expected, there is an almost symmetry between positive and negative rotation.

Conclusions

This work may be considered an added value to engineering education, providing an important training on plastic optical fibre technology, and promoting working group skills. The execution of these mini projects on training courses received positive feedback from students. At the end of the laboratory work, these students left some written comments like “the experiments were very interactive”, “were accessibly executable”, and “the development of this work was an enriching experience”.

The interaction of students with these types of sensors allows them to get a sense of how the monitoring of structural health, ie the effect resulting from the application of forces to a structure, either internal forces (weight of the structure) or external forces (earthquakes, wind, bumps with structure) can be made. The implementation of these mini projects is expected to assist the laboratory work of students of Physical Eng. MSc, in the discipline of Optoelectronics. The contact of the students with this kind of work, will allow them gain some experience and skills in the area of sensors, which can turn out to be a real asset in these professional carrier.

Acknowledgement

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