

## **FIBRE BRAGG SENSOR INTERROGATOR BASED MACROBENDING**

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A low-cost all fibre interrogator system for fibre Bragg grating sensors is demonstrated. It is based on single-mode fibre macrobending. Due to the wavelength dependence of the bending loss, it is possible to discriminate the evolution of the peak wavelength of the sensor. The technique has been tested in a textile platform, which can be integrated in wearable devices. The methodology and the technical content have been exploited for physics teaching in engineering education. Some preliminary results will be presented and discussed.

Keywords: Macrobending, Optical fibre losses, Single mode fibre, Interrogator, fibre Bragg sensors

### **1 Introduction**

The teaching of optical fibre waveguides, fibre losses and Bragg sensors should be considered in the different courses of optics and optoelectronics of physical engineering degrees, at level of laboratory experiments or project works. In particular, it should be taken into account the methodology of problem/project based learning [1].

In fibre optic sensing and other applications, the measurement of spectral parameters of an unknown signal is a common practice including optical sensing devices based on fibre Bragg gratings (FBG). These sensors require an interrogation device in order to sense the wavelength change of reflected light [2, 3]. Since the interrogation systems of fibre Bragg sensors are quite expensive and with reasonable large dimensions, great efforts have been made in order to develop simple and inexpensive all fibre interrogator device based on wavelength dependent bending loss in fibre [2]. This study presents the preliminary results based on theoretical and experimental investigations of macrobend losses for standard single mode fibres.

The progress of fibre optic technology allows both sensing and signal transmission functions with advantages of small size, lightweight and flexibility. Those advantages have opened the possibility of embedding fibre optic sensing elements into various structures, which can be incorporated with minimal interference to the structure and monitoring the state of the material in real time [4, 5].

In many applications, with a compact size and lower fabrication cost, the interrogator system should be embedded in wearable devices and provide a measurement of the incoming wavelength. Incorporating fibre optic sensors and networks with lightweight and small dimensions into smart structures will provide numerous advantages in many intelligent systems such as biomedical systems for health monitoring, diagnostics and treatment and civil and automobile engineering and military systems [4, 5, 6, 7].

## 2 Fibre bending loss

In general, fibre losses will result from distortions of the fibre (macro-bending and micro-bending losses) and from the propagation of light (scattering and absorption losses).

As well known, macro-bending occurs when a single mode fibre is bent into a visible curvature, causing radiation losses. This attenuation is essential for the design of fibres employed in optical communications or optical systems based on macro-bending, including fibre Bragg gratings sensors [8, 9].

In a single mode fibre, the bend loss has two contributions: pure bend loss in the bent section and a transition loss. Transition loss occurs when there is alteration in curvature of the fibre axis, produced by the discrepancy of propagation mode between the bent and the straight sections [8, 10].

The simplest model considers the fibre with infinite cladding. Therefore, hypothetically the bending loss of a fibre with an infinite cladding will increase monotonically as the bending radius decreases. In fact, practical optical waveguide have finite claddings and one or two additional coating layers offering mechanical protection. Whispering-gallery modes are excited in the various layers, because of radiated field's reflection at the interface between the cladding layer and coating layers (some of it eventually returned to the core). As a result, the fibre exhibits considerably different loss characteristics to those predicted by the simple case of infinite cladding outside [2, 3, 8].

In the last decades, many authors have been developed different theoretical models for practical analysis of the bending loss in a single mode fibre.

## 3 Experimental setup and results

In order to investigate bending loss over the whole wavelength range, an experimental setup that consisted in a tunable laser and an optical spectrum analyser was implemented as shown in Figure 1. The experimental setup was based on experimental investigations reported by Wang [8]. The fibre used in the experiment is SMF28e with core, cladding and coating layer. The core and cladding radius are  $4.1 \mu\text{m}$  and  $62.5 \mu\text{m}$ , respectively.

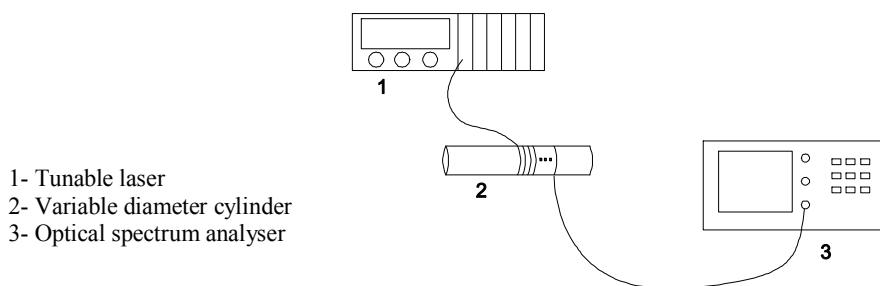


Fig1. Experimental setup for bending loss measurement

The bending loss was measured in the bending radius range of 8.5 mm to 12.5 mm, in increments of 0.5 mm. The wavelength range was from 1500 nm to 1600 nm.

Some comparisons between theoretical and experimental results were been carried out in this section. Matlab software was used in order to analyse theoretical results.

Figures 2, 3 shows measured and theoretical bending losses for different bending radius under two wavelengths, 1500 nm and 1600 nm, respectively.

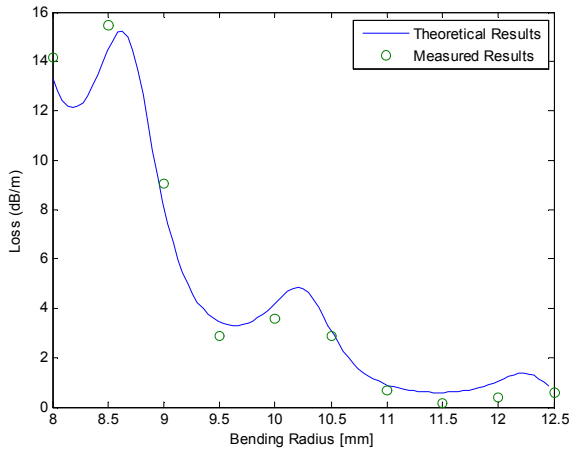


Fig. 2: Bending losses measurements at wavelength 1600 nm

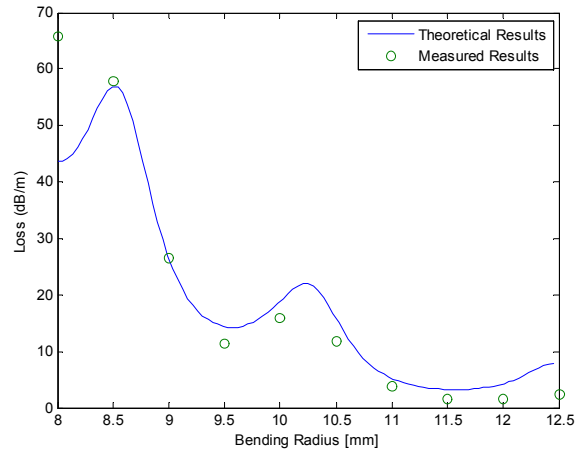


Fig. 3: Bending losses measurements at wavelength 1500 nm

Theoretical calculations of the above bending losses are based on the proposed model by Renner [11]. As can be seen, bending loss doesn't strictly increase with bending radius decreasing when compared with the simplest model, which considers a fibre with an infinite cladding. The presence of the coating layer(s) on fibre, generate the reflection of the radiated field at the interface between the cladding layer and the coating layer, producing a whispering-gallery mode in a bent fibre. The so called whispering-gallery cause considerably effects on bend loss characteristics [2, 3, 8]. The implemented theoretical model can predict bending losses with a good agreement with experimental results.

Figure 4 demonstrates bending losses for bending radius 10, 10.5, 11 and 11.5 mm with a bending length of 8 turns.

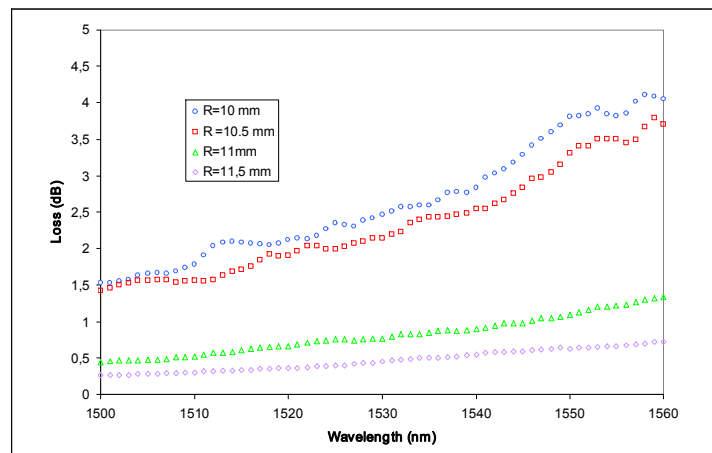


Fig.4: Measured bending loss of bending smf-28e

These results demonstrate that measured bending loss linearly depends with wavelength. Thus, this macrobending single-mode fibre filter is appropriated for wavelength measurement. However, this research work is an initial study and will be further developed in order to obtain better and improved results.

## 4 Conclusion

The implementation of a fibre Bragg interrogator based on macrobending has been successfully explored as a project for the laboratory work of the course on optoelectronics of the physical engineering degree. In particular, it has stimulated creative and critical thought, adoption of holistic approaches and leadership skills [1].

The aim of this research work was the development of a simple and inexpensive interrogator system based on macrobending effects. It has been shown that it can be employed in fibre Bragg gratings optical sensing systems for wavelength measurement, using its dependence on bending loss of an optical fibre. The experimental results have demonstrated that the smf-28e optical fibre is an adequate macrobending fibre filter for wavelength measurement.

The small dimensions of this optical device enable the possibility of textile integration. The integration of fibre optic sensors in textiles will be tested and analysed in the near future, in the perspective of a low cost device. It will be explored as a final project.

## 5 Acknowledgements

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