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Using a mobile smartphone as a low cost optical sensor.

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Abstract
This work proposes a smartphone-based optical sensor for measuring temperature, displacement, and refractive index. The multimode fiber is connected to the smartphone using a 3D-printed adaptor, so the light intensity modulations resulting from different transducers are correlated to the assessed variable.

Key words:
Optical fiber sensor, smartphone, measurement of physical variables.

Introduction

The aim of this research is to develop a low-cost optical sensor to measure physical variables such as displacement, temperature, and refractive index, to be used in educational, scientific, and consumer applications. The measurement setup, Image 1(a), is comprised of a Samsung S9+ smartphone (Snapdragon 845 2.8 GHz, 6 GB RAM, 12 MP Camera resolution) with an Android 9.0 system application capable of measuring the optical signals and convert them into intensity data, Image 2.(b) and (c). Multimode optical fibers work as the probe and waveguide, coupling the light from the LED source to the phone camera by means of a 3D-printed case (Ultimaker 2+ Extended, PETG material), Image 2.(a).

Results and Discussion

The system was tested as displacement, chemical, and temperature sensor, as shown in Image 1(a).

Displacement Sensor: A 3D-printed deformer with Λ = 10 mm periodicity is used as a microbending displacement transducer. The applied mechanical stimulus causes the coupling between the core propagating modes and the radiation modes, causing the attenuation of light intensity shown in Image 1(b), which is suitable for measuring pressures, displacement, and vibration [1].

Chemical Sensor: Sucrose-water solutions were measured using a multimode fiber coupler (1x2, 20:80) connected to the smartphone. The LED launches light into the 20% arm, the 80% arm is connected to the camera, and the third arm is immersed in the sample. Part of the light is reflected in the liquid-silica interface due the refractive indices difference, which allows, according to the Fresnel equation, a relation between the light intensity and the index of the solution [2]. The application could be calibrated to determine the concentration of solutions. The results of the experiments is verified in Image 1.(c).

Temperature Sensor: the sensor was fabricated by removing the acrylate buffer of a multimode fiber section and applying in this region a curvature of approximately 30 mm. The probe was placed on a flat surface and then heated with a hot air blower. The temperature modulates the refractive index of the surrounding medium, which influences the propagating evanescent field [3]. The temperature of the fiber was verified type K thermocouple, yielding the results shown in Image 1.(d).

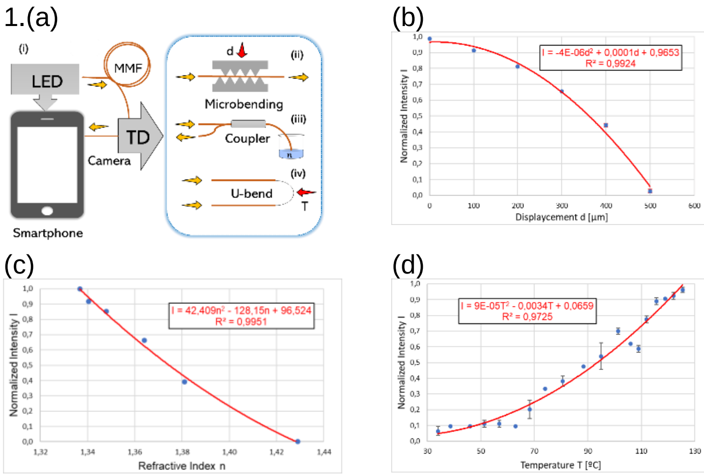

Image 1.(a).(i): Schematic of the optical sensor experiments. MMF: Multimode fiber, TD: transducer. **(ii)**: Transducer for Displacement, d. **(iii)**: Transducer for refraction index, n. **(iv)**: Transducer for temperature, T. **(b)**: Normalized intensity as a function of displacement. The red curve is a 2nd degree regression. **(c)**: Normalized intensity as a function of the refractive index. The red curve is a 2nd degree regression. **(d)**: Normalized intensity as a function of temperature. The red curve is a 2nd degree regression.

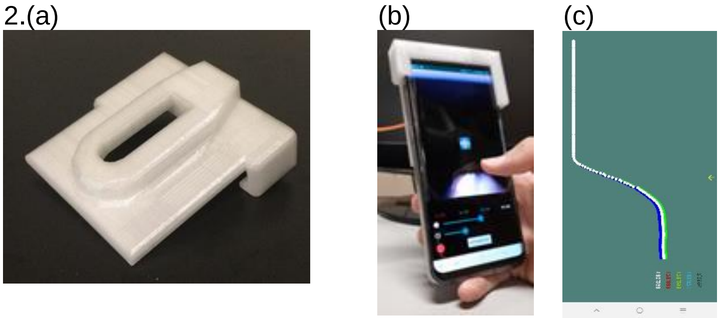

Image 2.(a): 3D-printed case with dimensions 76 x 86 x 13 [mm]. **(b)**: data acquisition interface for monitoring the fiber output intensity. **(c)**: measurement viewer for tracking the intensity variation as a function of the time.

Conclusions

A kit to transform the mobile phone into a versatile optical sensor based on a 3D-printed case and multimode fiber was demonstrated. The sensor is capable of measuring various physical quantities. In the next steps, the work will focus on developing sensors to be used in laboratories, classes, industries, and healthcare environments.

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