Experimental models for SPR setup optimization

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***Abstract*—This paper reports the testing of three setup configurations for characterizing optical sensors based on Surface Plasmon Resonance (SPR). The aim was to observe if different sources of light and setup arrangements have influence over the plasmonic effect present at the interface of a liquid sample and gold-coated optical fiber.**

***Keywords*—Surface Plasmon Resonance, Plastic Optical Fibers, Fluorescent Optical Fibers, sensors.**

I. INTRODUCTION

Surface Plasmon Resonance is a phenomenon that appears at the separation between a metal and a dielectric when an optical excitation is induced in the surface plasmon polaritons. These polaritons can be defined as electromagnetic waves, coupled with free electrons from a metal, propagating on the separation surface.

For SPR analysis, p-polarized light has the main contribution in forming the surface plasmon wave. The resonance condition appears when the propagation constant and energy of the incident light and that of the resultant evanescent wave are the same. The result is a decrease in intensity of the reflected light.

II. EXPERIMENTAL SECTION

A. *Background*

There are several existing configurations for SPR generation and they depend on the result of interrogation, such as variation of the incidence angle or variation of resonance wavelength. In configurations that use spectral interrogation, the resonance wavelength is determined with reference to the refractive index of the sensing layer. The particular wavelength where a strong absorption of light takes place as a result of transfer of energy and the output signal demonstrates a sharp dip is known as resonance wavelength(λ_{res}).

Initial analysis was based on Kretschmann configuration method where the metal thin film is directly deposited on a prism, but in modern optical systems for low cost implementation the prism can be replaced with an optical fiber.

In the measurements performed for this paper were used 2 approaches: D-shaped plastic optical fiber and fluorescent optical fiber. Both types of fiber were coated with a 60nm gold layer in order to obtain SPR optical sensors.

D-shaped POF is obtained by polishing a plastic optical fiber with 5 µm polishing paper in order to remove the cladding and part of the core. The gold layer will be then sputtered on the exposed core.

Fluorescent optical fibers are optical fibers which emit light as a response to an incident phenomenon. Operation depends on the doping dyes, which determine specific fluorescence and optical characteristics. In this case, the gold layer is deposited around a segment of the fiber.

B. *Experimental Setup*

To obtain SPR characterization curves, the setup presented in *Figure 1* must be used. On this basic setup, I tried different sensor configurations and different light sources to find the best scenario for SPR analysis.

The procedure is to apply few drops of analyte on the gold layer and then acquire the spectrum. The spectra are then processed in Matlab, with reference to the air spectrum, acquired prior to analyte measurements. In this case, I used 5 water-glycerin solutions with refractive index ranging from 1.332 to 1.381 as analyte.

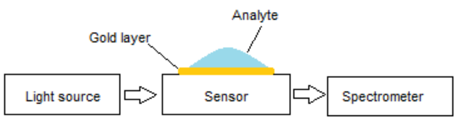

Figure 1. Experimental Setup schematic

III. RESULTS AND DISCUSSION

A. *Fluorescent fiber sensor and green light source*

First sensor used was one made of a fluorescent optical fiber and the light source was a green laser. After spectral interrogation there is observed a dip in the spectrum, around 926 nm. For all the substances analyzed there is present resonance, but the shift is too small to obtain an SPR sensor with a good sensitivity.

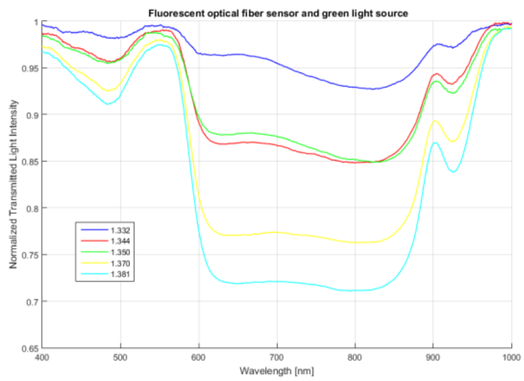

Figure 2. SPR response in case A

Table 1. Refractive index-resonance wavelength correspondence for case A

n *(refractive index)*	1.332	1.344	1.350	1.370	1.381
λ_{res} [nm]	925.9	926.2	926.4	926.7	928

B. *D-shaped POF sensor and halogen light source*

Second analysis was performed on a D-shaped POF sensor. As a light source, this time, was used a halogen lamp. In this case we can observe 2 dips in the spectra. Around 650nm in present a stronger SPR response.

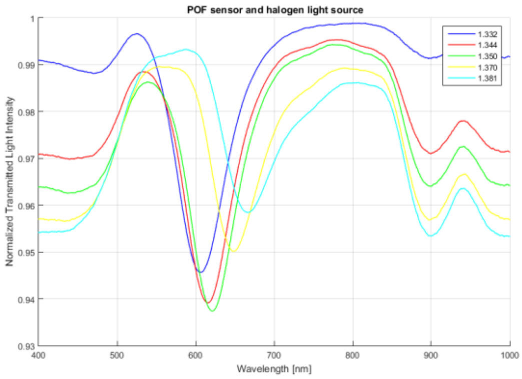

Figure 3. SPR response in case B

Table 2. Refractive index-resonant wavelength correspondence for case B

n *(refractive index)*	1.332	1.344	1.350	1.370	1.381
λ_{res} [nm]	604.8	614.2	622.5	650.4	666.8

C. *POF sensor, green light and fluorescent fiber*

For the third case I tried a combination of previous two. The light source was the green laser but between it and the POF sensor I placed a green fluorescent optical fiber for attenuation purposes and to modify the spectrum of the incident light. Even if the aim was optimization of the setup, because of integrating more elements there is present more noise on the curves and SPR is barely visible around 540nm. The setup needs to be improved by using the attenuation element and taking care about the good alignment between laser source and optical fiber. If the alignment elements are not appropriate, due to the coherence of the laser light, the efficiency of the coupling light is low and the SNR (signal to noise ratio increases).

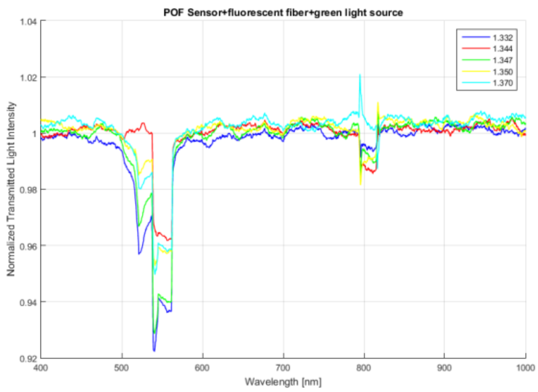

Figure 4. SPR Response in case C

Table 3. Refractive index-resonant wavelength correspondence for case C

n *(refractive index)*	1.332	1.344	1.350	1.370	1.381
λ_{res} [nm]	540	551	542.2	543.6	541.7

D. *Sensitivity of the sensors*

The sensitivity (Sn) can be defined by calculating the shift in resonance wavelength per unit change in refractive index (nm/RIU). If the refractive index n_s is altered by δn_s, the resonance wavelength shifts by $\delta\lambda_{res}$. In Figure 5 is presented the variation of the λ_{res}, with reference to the one in water, as a function of refractive index.

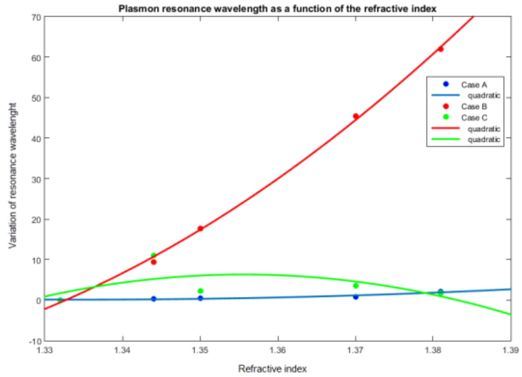

Figure 5. Plasmon resonance wavelength as a function of the refractive index

Table 4. Sensitivity values

Case	A	B	C
Sensitivity[nm/RIU]	37.659	1299.7	-26.155

Sensitivity can be measured as the slope of the linear fitting. It is easy to see that in case B the slope has the best value, the other two being very small values and even negative.

IV. Conclusions

Three possible configurations of experimental setup for SPR characterization were implemented and tested. The aim was to find the best solution, both in terms of cost and performance for such optical setup.

After performed measurements, it can be observed that the second setup, the one with POF sensor and broad spectrum light was the best solution for the proposed problem. In this case SPR effect is strong enough, and the shift in resonant wavelength is visible. This result is the proof that surface plasmon resonance is easier to detect on plastic optical fiber and with a wide spectrum light source.

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