Theoretical analysis of magnetoplasmonic interferometers for sensing

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Surface plasmon polaritons (SPP) are evanescent waves that propagate along a metal-dielectric interface. Its wavevector is defined as: $k = k_0\sqrt{\frac{\varepsilon_d \varepsilon_m}{\varepsilon_d + \varepsilon_m}}$, being k_0 the wavevector of light in vacuum, and ε_d and ε_m the dielectric constants of the dielectric and the metal respectively. SPP have the ability to confine the light beyond the diffraction limit, which makes them appropriate for miniaturized optical devices. Besides, due to the dependency of the SPP with the dielectric constants of the materials of the interface, they have been broadly applied for sensing techniques, being the prism-based Surface Plasmon Resonance (SPR) with propagating SPP one of the most popular ones [1]. On the other hand, interferometry is in general known as a very sensitive and reliable technique and plasmonic interferometry for sensing has been recently demonstrated, both theoretically and experimentally [2-4]. Nevertheless, a precise theoretical comparison with the traditional SPR has not been done. Following the path inspired by these results, in this work tilted slit-groove plasmonic interferometry [5] is being proposed as a promising sensing device, and it will be compared with SPR systems based on prism coupling.

Furthermore, it has also put forward that this plasmonic interferometric device can be magnetically modulated [6,7], and that this modulation presents quite a large dependence on ε_d [8]. This has encouraged us to also analyze its sensitivity with small variations in ε_d and its potential for sensing applications, and compare its performance with purely plasmonic interferometers.

In our particular set-up, the plasmonic interferometers are arranged in a tilted slit-groove geometry (Fig. 1). When the interferometers are illuminated with a p-polarized laser, the light collected at the other side of the slit consists of the interference between the light directly transmitted through the slit and a SPP excited in the groove and decoupled back to radiative light in the slit. When the refractive index of the dielectric present at the interface changes (Δn), the wavevector of the SPP will change ($\Delta^{\varepsilon}k$), and so will do the Intensity of the interference ($\Delta^{\varepsilon}I_p$). In fact, this change of the intensity $\Delta^{\varepsilon}I_p$ is proportional to the product $\Delta^{\varepsilon}k$ d, where d is the groove-slit distance. In a SPR system, on the other hand, the SPP wavevector change with Δn modifies the reflectivity (ΔR). By comparing ΔR with $\Delta^{\varepsilon}I_p$ under the same amount of Δn, our results show that the sensitivity of the plasmonic interferometric configuration can be higher than that of the SPR one for large enough d (see Fig. 2a).

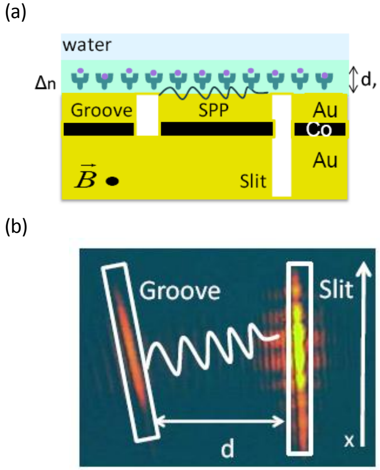

Figure 1: (a): Sketch of the proposed interferometer for sensing in transversal section. (b): Upper view of an actual interferometer.

On the other hand, the magnetoplasmonic devices are basically equal to the above plasmonic interferometer but with a magnetic field applied. Under application of an external oscillating magnetic field, the SPP wavevector is modified ($\Delta^{m}k$, that we are going to name k_m to simplify) therefore synchronously changing the interference intensity ($\Delta^{m}I_{mp}$). Moreover, under Δn, both k and k_m change in this magnetoplasmonic interferometer ($\Delta^{\varepsilon}k$, $\Delta^{\varepsilon}k_m$). As can be seen in Fig. 2b, the relative change induced by Δn is higher for km than for the SPP wavevector k. This suggests that the magnetoplasmonic interferometers are a promising alternative for SPP-based sensing.

References

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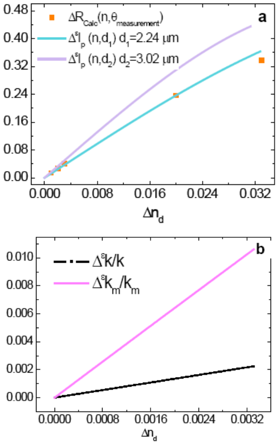

Figure 2: a) Comparison between the variation of the reflectivity in an SPR and the variation of the plasmonic intensity in a plasmonic interferometer as a function of the change of refractive index of the dielectric layer. Two different distances for the interferometers are shown. The calculations correspond to a wavelength of 633 nm. b) Comparison between the relative variation of the main parameters involved in a plasmonic and a magnetoplasmonic interferometer as a function of the change of refractive index n of the dielectric layer.