Magnetoplasmonic Interferometers and Applications

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Surface plasmons polaritons (SPP) are evanescent waves that propagate along a dielectric-metal interface. They can be confined in subwavelength metal structures, i.e. below the diffraction limit, which leads to many possible applications, including miniaturized optical devices. Within that context, the development of active plasmonics is important to achieve nanophotonic devices with advanced functionalities. This requires a system where the plasmon properties can be manipulated using an external agent. Among the different control agents considered so far, the magnetic field seems a promising candidate, since it is able to modify the dispersion relation of SPP at reasonable magnetic field strengths, and with a high switching speed. This modulation comes from the non-diagonal elements of the dielectric tensor, ε_{ij}, appearing when the magnetic field is turned on. For noble metals, the ones typically used in plasmonics, these elements are proportional to the applied magnetic field but, unfortunately, very small at field values reasonable for developing applications. On the other hand, ferromagnetic metals have sizeable ε_{ij} values at small magnetic fields (proportional to their magnetization), but are optically too absorbent. A smart system to develop magnetic field tunable plasmonic devices is the use of multilayers of noble and ferromagnetic metals.
That is the framework of the present work, where we analyze the magnetic field induced SPP wavevector modulation (Δk) in Au/Co/Au films as a function of the wavelength and its possible application as a sensor.
The experimental analysis of the SPP wavevector modulation has been performed via magnetoplasmonic interferometers. These micro-interferometers are formed by a tilted slit-groove pair. 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. Under application of an external oscillating magnetic field, both the real and imaginary part of the SPP wavevector are modified therefore changing the interference intensity synchronously with the applied magnetic field. The analysis of the interference allows us to determine the values of the magnetic modulation of the wavevector (Δk).
We have carried out a spectral analysis of the modulation, which can be useful to optimize the magnetoplasmonic interferometers performance. It will be shown how, for Au/Co/Au multilayers and in general for noble/ferromagnetic/noble metal systems, Δk decreases as the wavelength increases, contrary to the behavior of the magnetooptical constants (ε_{ij}), which is a counter-intuitive result. This implies that in these systems the plasmonic properties are the dominant ones, and a simple correlation between the magnetic modulation Δk and the SPP dispersion relation has been obtained. Considering both the modulation and the propagation distance, we have determined the optimal spectral range for application.
Moreover, an analytical obtained expression for Δk shows that this magnitude is proportional to $(\varepsilon_d)^2$, with ε_d the permittivity of the dielectric covering the metallic layer. This has interesting implications concerning magnetoplasmonic systems applications. On the one hand, the performance of the systems as modulators can be improved by covering the interferometers by thin layers of dielectrics with higher ε_d. On the other hand, the strong dependence of Δk with ε_d suggests that this magnitude could have sensing capabilities, which has also been studied.