Transformation optics for plasmonics

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In this talk I will present the concept of Transformation Optics (TO) as applied to Plasmonics, a new strategy to control the flow of surface plasmon polaritons (SPPs) at metal-dielectric interfaces. It is based on the application of the concept of TO, a theoretical framework proposed as a general technique to design complex electromagnetic (EM) media with unusual properties [1,2]. TO provides us with expressions for the dielectric permittivit ε, and the magnetic permeability, μ, that need to be implemented in order to obtain a medium with a desired functionality. This recent proposal has brought a novel way of controlling the flows of photons in any desired way. It is a very general technique that has yield many different optical devices and diverse functionalities.

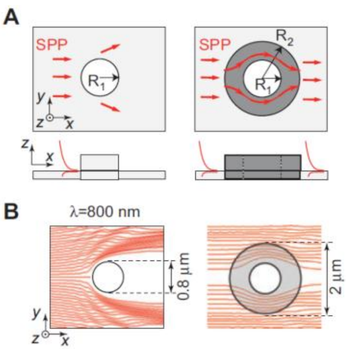

Figure 1: 3D cylindrical cloak for SPPs propagating along an airgold interface. (A) Sketch of the top and side views of the geometry. Left: scattering by a metallic cylinder. Right: the cloak is placed around the cylinder. (B) Power fl ow from 3D simulations. Left: a SPP experiences high scattering losses when it encounters the bare cylinder. Right: the cloak guides the SPP wave suppressing the scattering losses.

Recently [3], we have developed a general methodology for the design of Transformation-Optical devices for SPPs (see Fig. 1). We have shown that TO can also be used to effciently mould the flow of SPPs at metal-dielectric interfaces. Importantly, we have demonstrated that a simplified version of the TO recipes in which the optical parameters (ε and μ) are implemented only in the dielectric side of the interface leads to quasi-perfect functionalities [3,4].

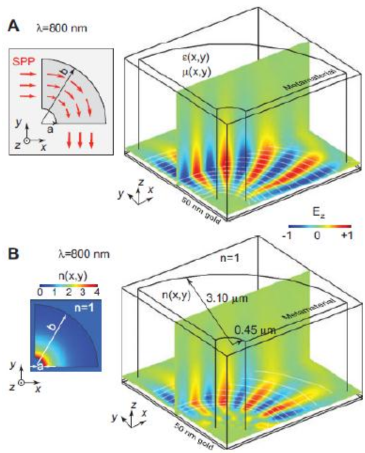

Figure 2: Simulation results for a SPP right-angle bend at = 800 nm. The curvature radius of the bend is ρ = 2 μm and the SPP has a Gaussian profi le of width Δ = 2.65 μm. (A) Anisotropic transformation medium. The propagation direction of a SPP is rotated by 90° by means of a metamaterial with anisotropic ε and μ. Inset: geometry layout in a top view. (B) Isotropic transformation medium. The SPP bend is characterized by the isotropic transformation medium n (x, y) shown in the inset panel. In both (A) and (B) the color scale plots the z component of the electric field of the SPP and the white lines correspond to power flow stream lines.

Additionally, we have shown that, thanks to the quasi two-dimensional character of SPPs and its inherent polarization, the application of conformal and quasi-conformal mapping techniques allows the design of plasmonic devices in which only the refractive index of the dielectric side needs to be engineered [5]. This leads to realistic models of plasmonic devices which can be fabricated with just isotropic dielectric materials (see Figs. 2 and 3) and, moreover, present a broadband response.

We study in detail several examples of plasmonic devices such as cloaks, bends, lenses and shifters. By means of numerical simulations, we quantify their efficiency as a function of the wavelength.

References

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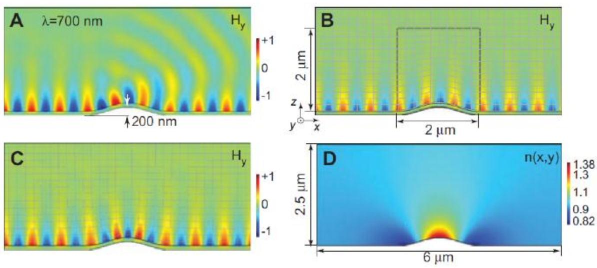

Figure 3: The scattering from a bump on a metal surface can be suppressed by means of a ground-plane cloak. (A) A SPP at 700 nm is scattered when it encounters a cos2 -shaped bump 200 nm high and 2 µm long in an air-gold interface. The SPP propagates in the x direction and the geometry is invariant in the y direction. (B) Scattering losses are suppressed when an anisotropic cloak (2 µm × 2 µm) is placed on top of the bump. The grid lines correspond to the coordinate map of the transfinite transformation used to derive the EM parameters of the cloak.