Surface plasmon photonics on nanostructured metal surfaces

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We investigate theoretically and numerically the interaction of light with vacuum-metal surfaces supporting surface plasmon-polaritons (SPP). The rich phenomenology associated with such interaction is explored in two specially relevant configurations.

On the one hand, the scattering of SPP by nano-defects on an otherwise planar metal interface is studied. Such configuration provides much insight into the recently proposed Nano-Optics of SPP [1], (single or arrays of) defects thereby playing the role of devices such as couplers, mirrors, beam-splitters, interferometers, etc. In particular, we have theoretically investigated the dynamics of the scattering of SPP pulses by one-dimensional defects through a rigorous calculation (spectral FT decomposition, k-space integral equations based on surface impedance boundary conditions [2, 3]) of the time dependence of the reflected and transmitted SPP, of the near-field, and of the angular distribution of scattered light. SPP resonances occurring at deep grooves are probed with SPP pulses, the resonant scattering being unequivocally manifested both by the exponential tails of the scattered SPP and light pulses and by delay times [3]. In addition, the opening of a SPP band gap has been investigated in the case of arrays of subwavelength defects [4, 5], with special emphasis on the exact evaluation of the spectral dependence of the energy balance of all scattering channels for finite arrays. Thus we are able to optimize the array parameters in order to minimize radiative losses and maximize SPP reflection, leading to highly efficient SPP Nano-mirrors [4].

On the other hand, light scattering from disordered, nanostructured metal surfaces is studied. The roughness-induced excitation of SPP leads to large fluctuations of the surface electromagnetic (EM) field, with huge intensities at so-called hot spots. Such electric field enhancements are crucial to the EM mechanism of surface-enhanced Raman scattering (SERS), and to a large extent responsible for the phenomenon of SERS single-molecule detection [6]. We have carried out extensive numerical calculations, based on the exact Green's theorem integral equation formulation [7], characterizing the EM field enhancements in connection with SERS [8], for randomly rough surfaces exhibiting (nanostructured) self-affine fractality and Gaussian correlation. In addition, the physical mechanism underlying the appearance of such localized SPP was investigated [9]. Very recently, we have developed a model for the EM mechanism in SERS within the above mentioned formalism, that fully accounts for the enhancement of the Raman-shifted signal emitted by Langmuir-Blodgett films or single molecules. This enhancement is typically assumed to be equal to that of the near-field intensity at the pump frequency (which indeed drives the molecular vibrational modes).

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