SURFACE PLASMON PHOTONICS ON NANOSTRUCTURED METAL SURFACES

V.Giannini, J. A. Sánchez-Gil, J. V. García-Ramos.
Instituto de Estructura de la Materia, Consejo Superior de Investigaciones Científicas
Serrano 121, E-28006 Madrid, SPAIN
vingenzino@iem.cfmac.csic.es

E. R. Méndez
División de Física Aplicada, CICESE Ensenada, B.C. 22800, MÉXICO Irvine.
emendez@cicese.mx
A. A. Maradudin
Dept. of Physics and Astronomy, University of California CA 92692, USA.
aamaradu@uci.edu

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, 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 [1]. In this work, we present a theoretical model for the classical el ectroelectromagnetic radiation from a molecular layer on a nanostructured metal surface. This model can it turn be employed to calculate the electromagnetic contribution to surface enhanced Raman scattering. The calculation of the scattered electromagnetic field is based on the exact Green's theorem integral equation formulation. With this model we are able to calculate the surface field, near field, and far field at the Raman-shifted frequency, separately of the electromagnetic field at pump frequency. A rigorous calculation of the scattered electromagnetic field has been carried out for random metal surfaces with similar properties to those exhibited by nanostructured metal substrates used in SERS. Numerical results are presented for single realizations, along with mean values of the SERS enhancement factor averaged over an ensemble of realizations [2].

On the other 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 [3], (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 [4,5]) 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 [5]. In addition, the opening of a SPP band gap has been investigated in the case of arrays of subwavelength defects [6,7], 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 [6].

We acknowledge financial support from Dirección General de Investigación, Ministerio de Educación y Ciencia (grants BFM2003-0427 and FIS2004-0108) and Comunidad de Madrid (grant GR/MAT/0425/2004 and MICROSERES).

References:

[1] S. Nie and S. R. Emory, Science **275**, 1102 (1997).

[2] V. Giannini, J. A. Sánchez-Gil and J. V. García-Ramos, E. Méndez, *preprint*.

[3] W. L. Barnes, A. Dereux, and T. W. Ebbesen, Nature **424**, 824 (2003).

[4] J. A. Sánchez-Gil and A. A. Maradudin, Phys. Rev. *B* **60**, 8359 (1999).

[5] J. A. Sánchez-Gil and A. A. Maradudin, Opt. Lett. **28**, 2255 (2003); Opt. Express **12**, 883(2004).

[6] J. A. Sánchez-Gil and A. A. Maradudin, Appl. Phys. Lett. **86**, 251106 (2005).

[7] J. Gómez Rivas, M. Kuttge, P. Haring Bolivar, H. Kurz, and J. A. Sánchez-Gil, Phys. Rev. Lett. **93**, 256804 (2004); Appl. Phys. Lett. (in press).

[8] J. A. Sánchez-Gil, J. V. García-Ramos, and E. R. Méndez, Phys. Rev. B **62**, 10515 (2000).

[9] J. A. Sánchez-Gil and J. V. García-Ramos, Chem. Phys. Lett. **367**, 361 (2003).