Excitation of surface plasmon polaritons by inhomogeneities of the surface of a plasmonic material

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Illumination of metal surfaces with regular and irregular microscopic inhomogeneities of relief leads not only to excitation of local plasmon resonances in such inhomogeneities, but also to interaction of these structures by means of surface plasmon-polariton (SPP) waves [1]. This interaction can lead to the formation of new modes with other spectral and spatial properties and, of course, to significant changes in the optical properties of surfaces. However, prediction and analysis of these properties are hampered by the complexity of analytical solution of the problem of SPP excitation by surface objects of arbitrary configuration. This problem can be solved analytically in the dipole approximation for small plasmonic nanoparticles on a metallic substrate illuminated by a plane wave using the formalism of the dyadic Green's function [2,3]. This method gives good agreement with full-wave numerical simulations, but it is rather cumbersome and requires the calculation of Sommerfeld integrals.

We present an alternative approach using the Lorentz reciprocity theorem and orthogonality of modes, similar to the method used in waveguide theory [4]. The problem is solved analytically for "point" nanoantennas in both 2D and 3D geometries, when SPPs are excited by an infinitely long cylindrical wire or a plasmonic sphere, and in the simplest case of a nanostructured surface with a sinusoidally perturbed boundary. In all cases, the obtained analytical solutions are compared with the results of numerical simulations. The results of such comparison demonstrate almost perfect agreement of analytical and numerical solutions for "point" nanoantennas with radius of curvature less than $\lambda/10$. In the case of a sinusoidally perturbed boundary, the analytical solution correctly predicts the optimal corrugation height (x_{opt}), which provides the maximum SPP excitation efficiency. At the same time, analytical and numerical values of the SPP amplitude agree when the corrugation height x turns out to be $x \ll x_{opt}$ or $x \gg x_{opt}$; at $x = x_{opt}$ their mismatch does not exceed 25%. The limitations of the analytical model leading to such mismatches are discussed. We believe that the presented approach can be useful for modeling various phenomena related to SPP excitation.

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