Transformation of surface plasmon polaritons at surface structures.

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A surface plasmon polariton is an electromagnetic mode that propagates in a wave-like fashion along the planar interface between a dielectric and a metal, with an amplitude that decays exponentially rapidly with increasing distance from the interface into both the vacuum and the metal. The scattering of a surface plasmon polariton as it propagates across spatially localized surface defects leads not only to a reflected surface plasmon polariton but also to radiation of electromagnetic waves into the vacuum above the metal surface on which the surface plasmon polariton propagates. When a surface plasmon polariton propagating along a metal surface impinges at oblique incidence on an extended linear surface defect such as a linear groove or a ridge on an otherwise planar surface, the translational invariance along the surface structure imposes a conservation law on the tangential components of the wave vectors of all waves excited by the interaction of the surface plasmon polariton with the structure, namely the reflected and transmitted surface plasmon polaritons as well as the radiated bulk waves. This is Snell's law for surface plasmon polaritons. When the surface defect is formed from a different material, e. g. a dielectric film, so that in the region of the defect the surface plasmon polariton has a different wavenumber, the surface polariton is refracted at the boundary of the defect.

In the present work we consider the transformation of surface plasmon polaritons at one- and two-dimensional surface structures that are ruled on a planar metal surface or formed by a film on a planar metal surface. In particular we are interested in the case where the boundary between the clean metal surface and the film is a parabola, for which the surface profile function is given by $\zeta(x_1, x_2) = d\theta(x_1 - ax_2^2)\theta(x_1)$, where $\theta(z)$ is the Heaviside unit step function, and d is the thickness of the film, and the case where the film has an elliptic shape for which $\zeta(x_1, x_2) = d\theta(1 - (x_1/a)^2 - (x_2/b)^2)$. The refraction of surface polaritons at the boundary of such structures on a metal surface leads to a focusing of the transmitted surface waves.

We use a rigorous numerical approach to solve the problem of scattering of surface plasmon polaritons by one-dimensional surface structures. In the case of two-dimensional surface structures we derive the reduced Rayleigh equations for a vacuum/film/metal system with two two-dimensional rough interfaces and solve them numerically.