Surface plasmon polaritons in linear chains of metallic nanoparticles

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Waveguiding properties of linear 1D arrays of metal nanoparticles have recently attracted considerable attention. For applications in nanophotonics, integrated optical circuits, etc., the dispersive properties of surface plasmon polaritons (SPPs) in such waveguides are of primary importance and have been studied extensively in chains of spherical nanoparticles [1, 2]. The effects of nonsphericity, although have been noted [3], received little attention. In the recent paper [4], we have demonstrated that using nanoparticles of nonspherical shape provides additional tunability and can lead to dramatic improvement of the waveguide quality, in particular, in a significant increase of the operating bandwidth.

The strong dependence of the dispersive properties of SPPs on the nanoparticle aspect ratio is illustrated in the figure. For sufficiently small aspect ratios, a gap appears either in the middle of the first Brillouin zone of the lattice (longitudinal polarization) or on its edge (transverse polarization). No propagating SPPs with Bloch wave numbers in the gaps exist. At the band gap edge the dispersion curve acquires very large positive or negative slopes. It is even possible to achieve superluminal group velocities in both cases, which is not in contradiction with fundamental laws of physics. Our theoretical predictions account for retardation effects and are confirmed by frequency domain simulations of pulse dynamics in chains of finite length.

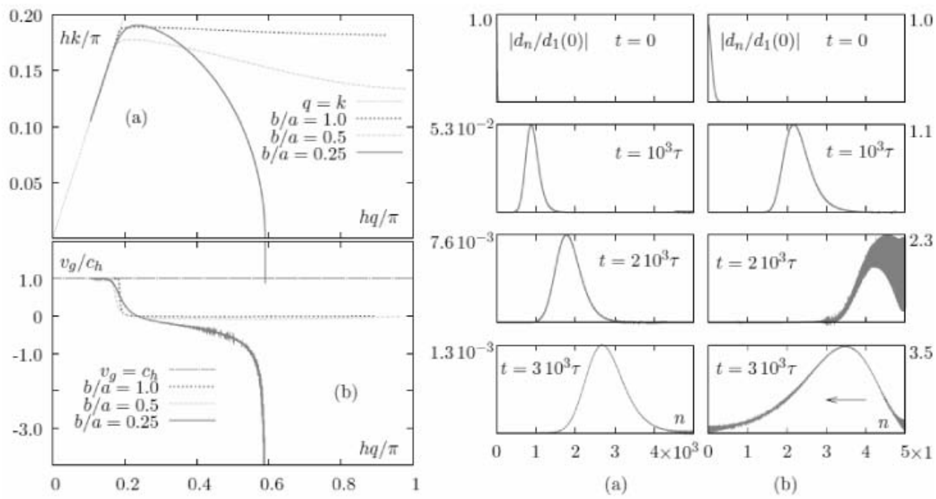

Fig.1. Left panel: Dispersion curves (a) and group velocities (b) for SPPs with transverse polarizations in chains made of oblate spheroids whose axis of symmetry is parallel to the chain; b and a are the smaller and the larger semiaxes and $h = 4b$ is the chain period. Right panel: Envelopes of longitudinally polarized wave packets in a chain of 5000 oblate spheroids with the aspect ratio $b/a = 0.25$. Time is measured in units of $\tau = h/c_h$, where c_h is the speed of light in the host medium. Column (a): the central frequency of the pulse is $\omega_0 = 0.25\omega_p$, where ω_p is the plasma frequency and the group velocity of the pulse is $v_g = 0.88c_h$. Column (b): $\omega_0 = 0.1\omega_p$, $v_g = 2.17c_h$.

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