ENHANCEMENT OF LOCAL ELECTRIC FIELDS IN THE GAP BETWEEN THE METALLIC SUBSTRATE AND THE SCANNING MICROSCOPE PROBE

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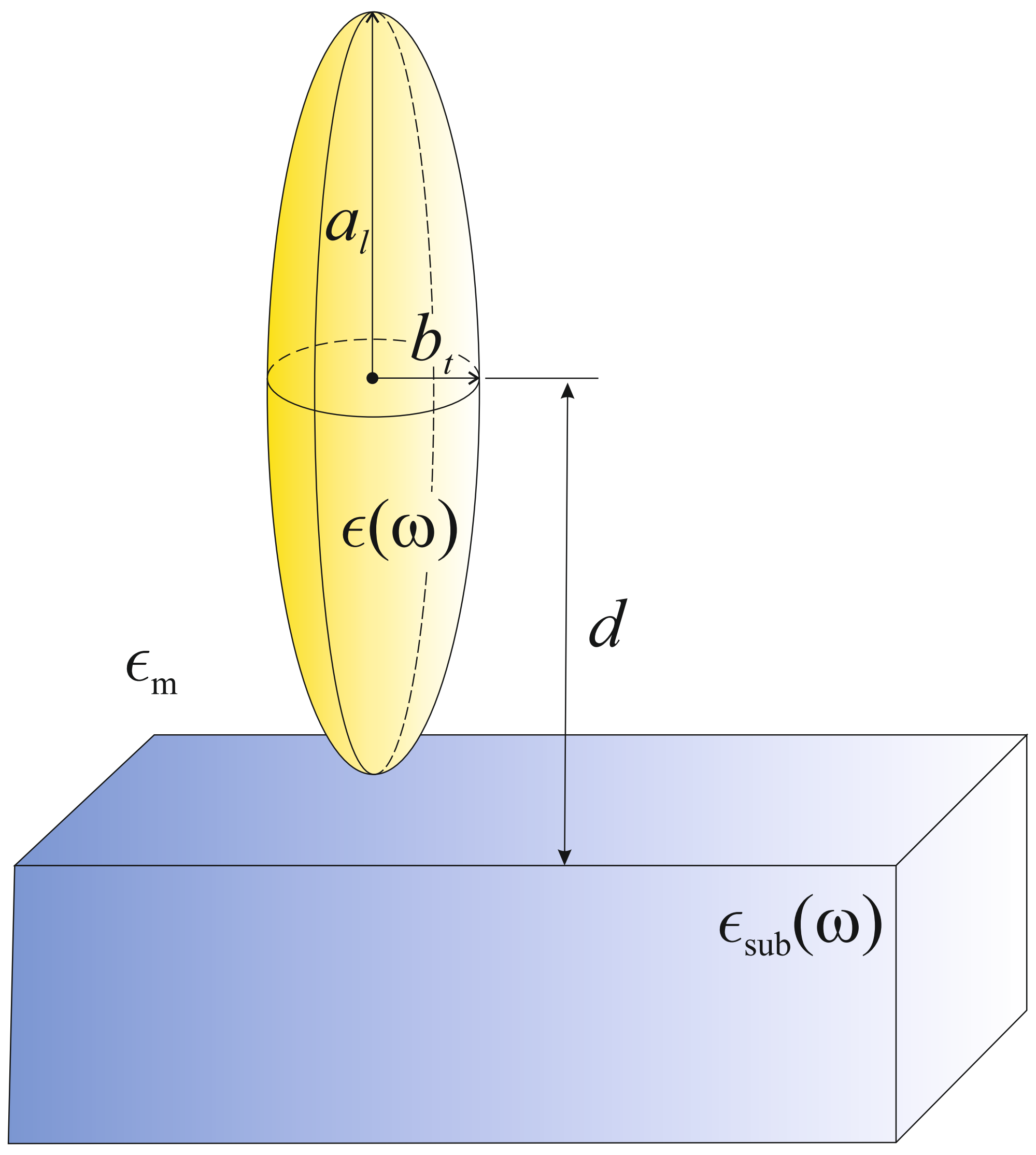
Abstract

The study of the optical resonance phenomena in a nanometer-scale “probe-substrate” gap is important for the applications such as surface-enhanced Raman scattering (SERS), surface fluorescence, adsorbed molecule spectroscopy, and near-field microscopy [1]. In the case when the probe and substrate materials are metals, the picture of the resonance phenomena in the small gap is quite complex. This is due to the fact that the permittivity of metal in the optical frequency range is negative, and the optical resonances (plasmons) are excited in the gap, providing the significant enhancement of the local electric field. Thus, the probe and the substrate, which support the localized resonances in the gap, behave like an open resonator. In this case, the controlling parameters that determine the spectral characteristics are geometry and dimensions of the probe, as well as the width of the gap. It should be pointed out that the scientific literature contains a very limited number of the studies of the optical phenomena in the nanometer gap between the metallic nanostructures, which are restricted by certain probe geometries, and therefore such studies are relevant.

Figure 1

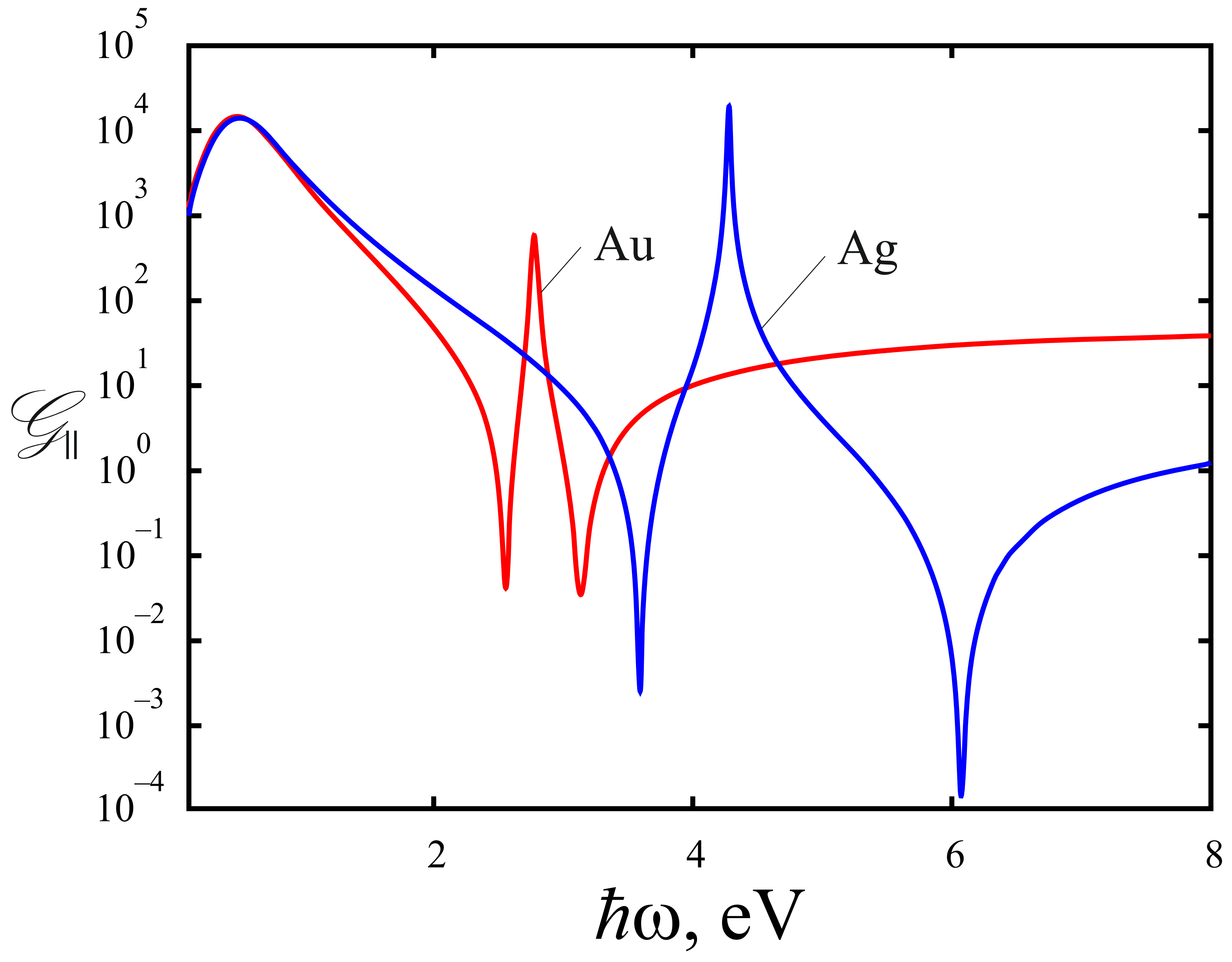


The geometry of the problem

Statement of the problem

This paper investigates resonance phenomena in the nanometer-scale gap between the axisymmetric metallic probe and the metallic substrate (Fig. 1). The consideration is performed in the quasi-static approximation, since the characteristic dimensions (gap width and probe thickness) are significantly less than the wavelength.

Figure 2

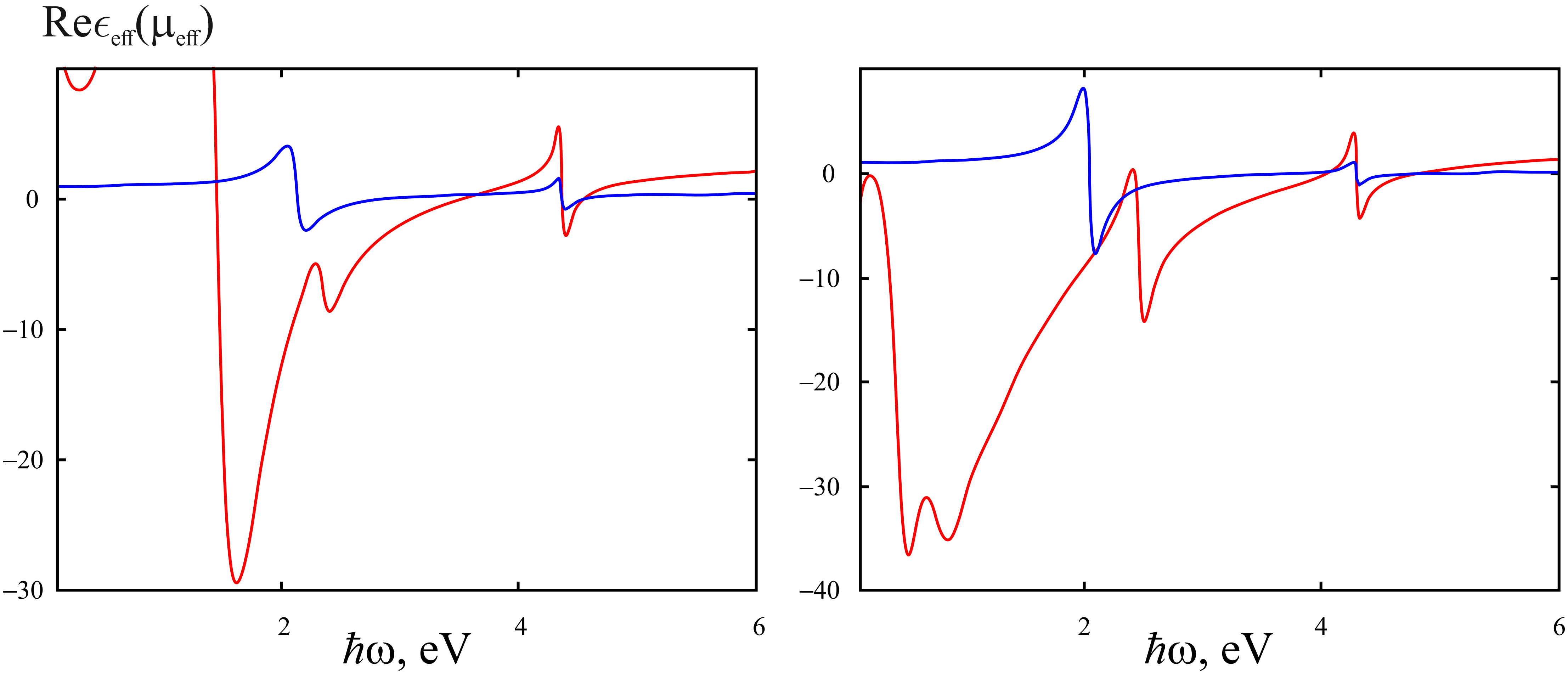


Frequency dependence of the longitudinal enhancement of prolate spheroids
($b_t = 20$ nm, $a_l = 60$nm, $d = 70$ nm)

Results of calculations and conclusions.

The calculation results (Fig. 2) indicate that the dipole resonance mode dominates in the weak and moderate interaction regimes within the prolate spheroidal probe–substrate system, which are most frequently implemented in experiments. At the same time, the relative spectral position max$\mathcal{G}_\parallel$ for probes and substrates of different metals is the same as that of the longitudinal plasmon resonances of isolated prolate spheroidal nanoparticles.

1. B.-Y. Jiang, L. M. Zhang, A. H. Castro Neto, D. N. Basov, M. M. Fogler, J. Appl. Phys. 119, 054305 (2016).


$\mathrm{Re}\,\epsilon_{\mathrm{eff}}(\mu_{\mathrm{eff}})$
0
−10
−20
−30
2
4
6
$\hbar\omega$, eV
0
−10
−20
−30
−40
2
4
6
$\hbar\omega$, eV