TENSOR OF ELECTRIC FIELD ENHANCEMENT IN THE VICINITY OF A METALLIC TRIANGULAR EQUILATERAL NANOPRISM

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Abstract

Among metal nanoparticles of various shapes, triangular nanoprisms attract much attention due to their unique optical properties. Thus, near the surface of such nanoparticles, there is a significant amplification of electric fields, which makes them ideal candidates for the manufacture of sensitive elements of optical sensors. However, information on the optical properties of prismatic nanoparticles is practically not presented in the scientific literature, so the corresponding studies are relevant.

Statement of the problem and results of calculations

We will consider a metal nanoparticle in the form of a triangular equilateral prism located in a medium with the permittivity ϵ_m (fig. 1). Due to the symmetry of the nanoparticle under study, the field enhancement is described by a second-rank diagonal tensor, the components of which have the form

$$\mathcal{G}_{\perp(\parallel)} = \frac{\epsilon_1^{\perp(\parallel)\,2} + \epsilon_2^{\perp(\parallel)\,2}}{\left|\mathcal{L}_{\perp(\parallel)}\left(\epsilon_1^{\perp(\parallel)} + \epsilon_m\right) + \epsilon_m\right|^2 + \left|\mathcal{L}_{\perp(\parallel)}\epsilon_2^{\perp(\parallel)}\right|^2}, \qquad (1)$$

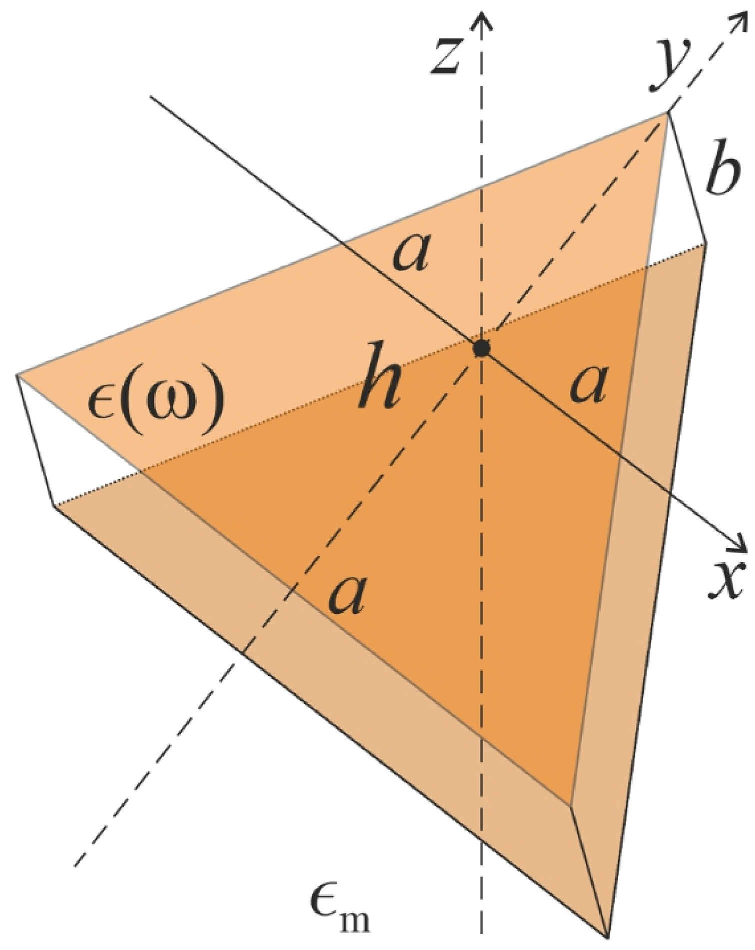
where the real and imaginary parts of the dielectric function, according to the Drude theory, are

$$\epsilon_1^{\perp(\parallel)} = \epsilon^{\infty} - \frac{\omega_p^2}{\omega^2 + \gamma_{\rm eff}^{\perp(\parallel)\,2}}, \qquad \epsilon_2^{\perp(\parallel)} = \frac{\omega_p^2 \gamma_{\rm eff}^{\perp(\parallel)}}{\omega\left(\omega^2 + \gamma_{\rm eff}^{\perp(\parallel)\,2}\right)}. \qquad (2)$$

In formulas (1) and (2), $\mathcal{L}_{\perp(\parallel)}$ and $\gamma_{\rm eff}^{\perp(\parallel)}$ are the depolarization factors and effective electron relaxation rates determined within the framework of the equivalent oblate spheroid approach as functions of the effective aspect ratio [1]; ϵ^{∞} and ω_p are the contribution of the crystal lattice to the dielectric function of the metal and the frequency of bulk plasmons, respectively.

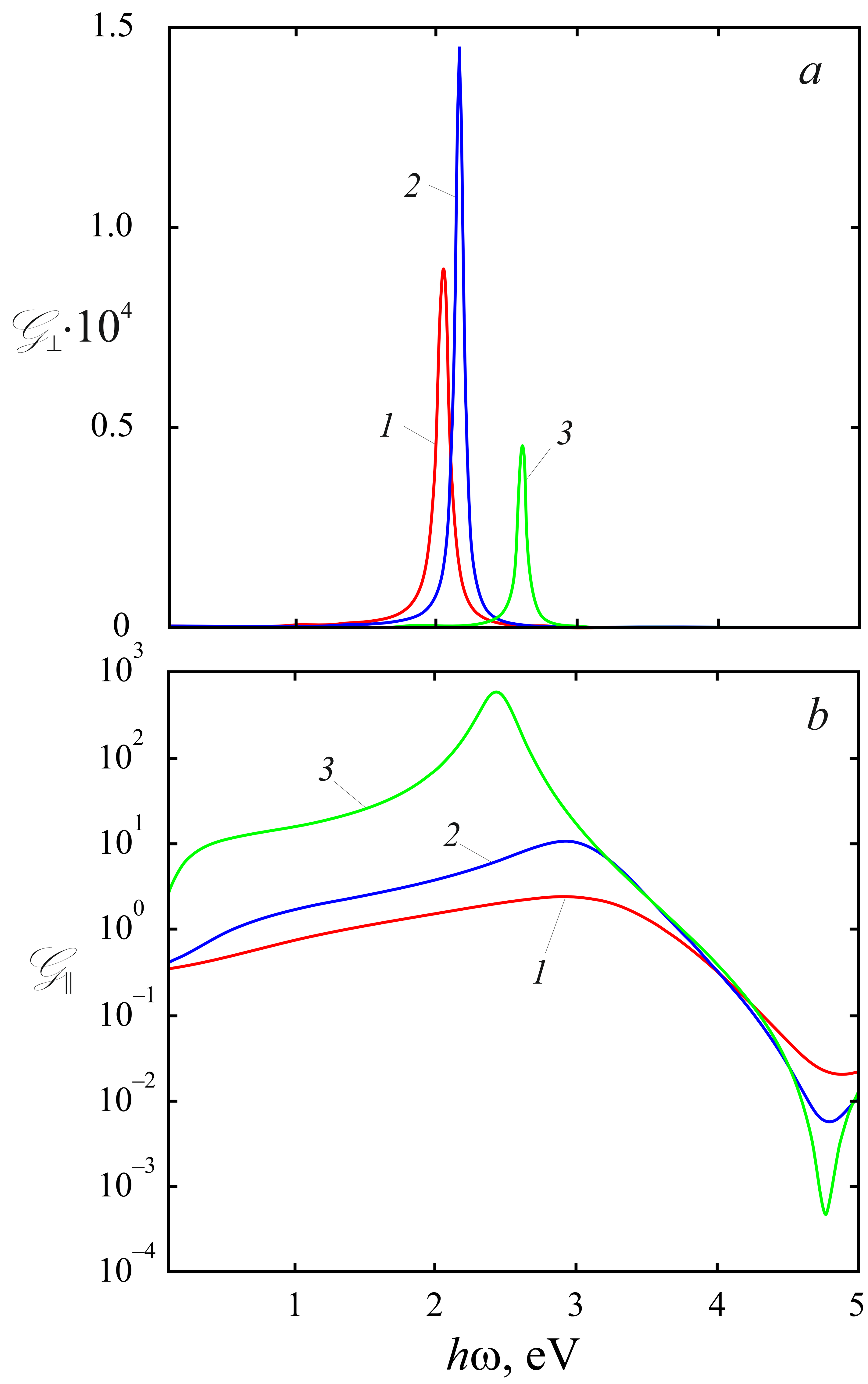
Calculations of the dependences $\mathcal{G}_{\perp}(\omega)$ and $\mathcal{G}_{\parallel}(\omega)$ were carried out for silver nanoprisms located in Teflon (fig. 2). It was found that the maxima of the frequency dependence curves experience a "blue" shift with an increase in the aspect ratio, accompanied by a decrease in the magnitude of the maximum $\mathcal{G}_{\parallel}(\omega)$. It should be noted that the "blue" shift is more significant for the longitudinal component of the electric field enhancement tensor.

Figure 1



Geometry of the problem

Figure 2



Frequency distributions of the transverse (*a*) and later (*b*) components of the field enhancement tensor of composite nanoparticles of different geometries in teflon: *1* – oblateness of spheroids (b_l = 80 nm, a_l = 20 nm); *2* – disk (*D* = 80 nm, *H* = 20 nm); *3* – prism (*L* = 80 nm, *H* = 20 nm)

Conclusions

Thus, it is shown that the field enhancement tensor component corresponding to the larger size of the prismatic nanoparticle is significantly smaller than the component corresponding to the smaller size ($\mathcal{G}_{\parallel} < \mathcal{G}_{\perp}$). In turn, the spectral width of the maxima $\mathcal{G}_{\perp}$ is significantly smaller than for $\mathcal{G}_{\parallel}$.

References

[1] N. I. Pavlyshche, A. V. Korotun, V. P. Kurbatsky. Optical properties of assemblies of disc-shaped metallic nanoparticles. Low Temp. Phys. 51 (2025), 127-132.