THE EFFECT OF SPATIAL DISPERSION ON OPTICAL PHENOMENA IN SPHERICAL METALLIC NANOPARTICLES

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Abstract

In the last two decades, the hybrid nanostructures of the type "metallic nanoparticle – semiconductor quantum dot" have attracted the attention of many researchers due to the manifestation of unique optical effects in such structures, for example, exciton-plasmon Coulomb interaction. The study of the optical properties of such nanostructures relies on the consideration of the spatial dispersion (nonlocality) of the dielectric function of the metallic nanoparticle.

Statement of the problem and results of calculations

The relation for the nonlocal dielectric function has the form [1]

$$\epsilon_{\mathrm{NL}}(\omega)=\left[\frac{1}{\epsilon_{\mathrm{D}}(\omega)}+3\left(\frac{\omega_p R}{\beta u}\right)^2 I_{3/2}(u) K_{3/2}(u)\right]^{-1} \quad (1)$$

where $u = R\sqrt{\omega_p^2 - \omega\,(\omega\ + \mathrm{i}\gamma_{\mathrm{eff}})/\beta}$; $\beta = \sqrt{3/5 v_{\mathrm{F}}}$, v_{F} is Fermi electron velocity, R is the radius of nanoparticle; ω_p is plasma frequency; Drude (local) dielectric function

$$\epsilon_{\mathrm{D}}(\omega)=\epsilon^{\infty}-\frac{\omega_p^2}{\omega(\omega+\mathrm{i}\gamma_{\mathrm{eff}})} \quad (2)$$

ϵ^{∞} is is the contribution of the crystal lattice into the dielectric function; is effective relaxation rate, in which bulk and surface relaxation and the radiation damping make an additive contribution.

The calculations for the frequency dependencies of the real and imaginary parts of nonlocal dielectric function have been performed for silver nanoparticle with the radius R = 10 nm (Fig. 1). The results of the calculations indicate that $R\ e\ \epsilon_{\mathrm{NL}}(\omega)$ is alternating function, while $\mathrm{Im}\,\epsilon_{\mathrm{NL}}(\omega) > 0$ in the frequency range, which is under the consideration. In this respect the behavior of the function $\mathrm{Re(Im)}\epsilon_{\mathrm{NL}}(\omega)$ is similar to the behavior of the function $\mathrm{Re(Im)}\epsilon_{\mathrm{D}}(\omega)$. At the same time, in the optical frequency range (under $\hbar\omega \geq 1.56$) $\mathrm{Re(Im)}\epsilon_{\mathrm{NL}}(\omega) \approx \mathrm{Re(Im)}\epsilon_{\mathrm{D}}(\omega)$.

However, and are significantly different in the infrared frequency range, and the differences between $\mathrm{Im}\,\epsilon_{\mathrm{NL}}(\omega)$ and $\mathrm{Im}\,\epsilon_{\mathrm{D}}(\omega)$ are essential only in the interval $0.7\ \mathrm{eV} < \hbar\omega < 1.5\ \mathrm{eV}$.

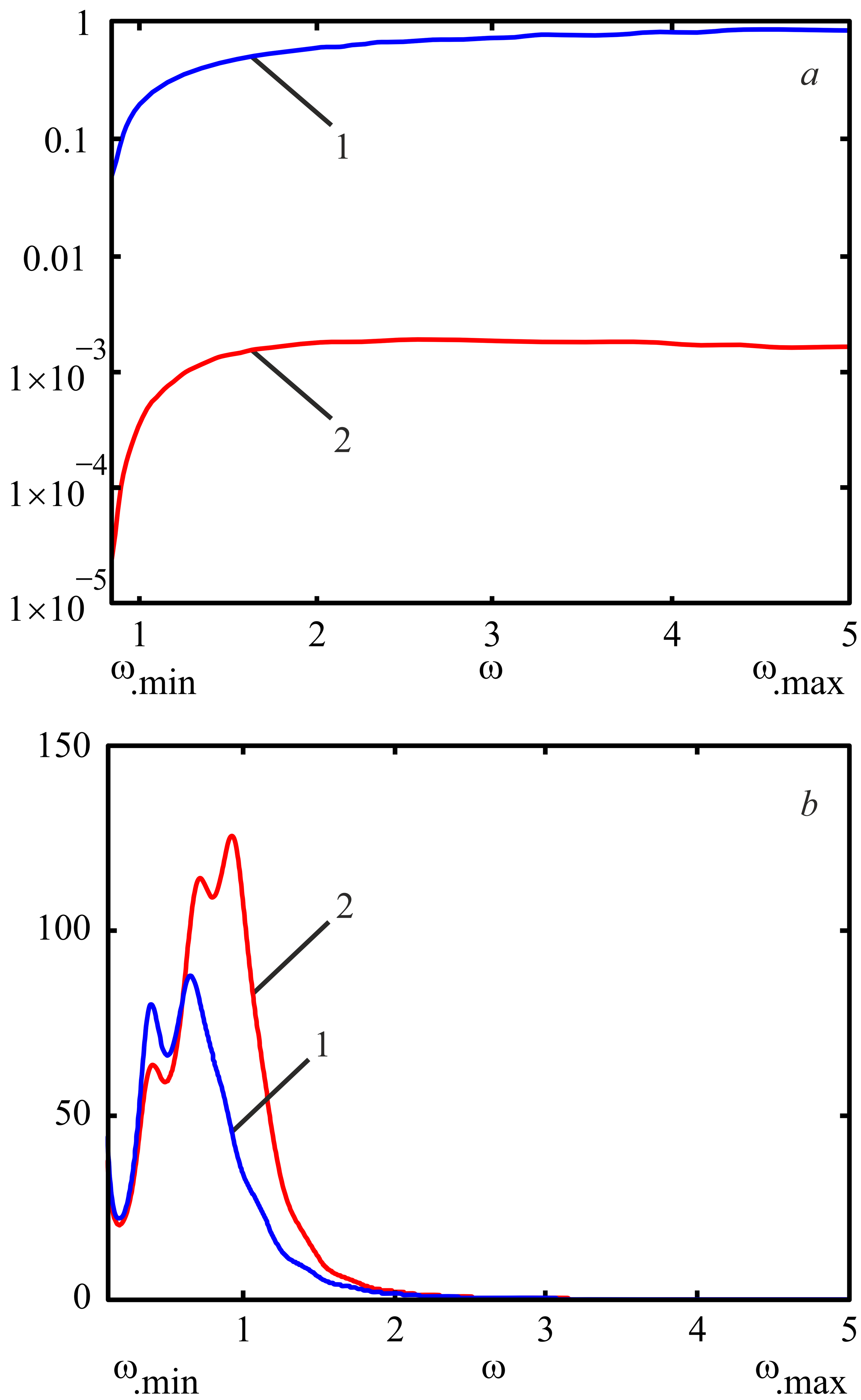

Figure 1. Frequency dependence of the real (*a*) and imaginary (*b*) parts of the Drude and nonlocal dielectric functions of Ag nanoparticles with radius R = 10 nm in air.

Conclusions

It has been established that the real and imaginary parts of the local and nonlocal dielectric functions differ significantly in the infrared region of the spectrum. In particular, if $\mathrm{Im}\,\epsilon_{\mathrm{NL}} > \mathrm{Im}\,\epsilon_{\mathrm{D}}$ at $\hbar\omega > 1.56\,\mathrm{eV}$, then $\mathrm{Re}\,\epsilon_{\mathrm{NL}} > \mathrm{Re}\,\epsilon_{\mathrm{D}}$ at $\hbar\omega < 1.0\ \mathrm{eV}$, while for $1.0\ \mathrm{eV} < \hbar\omega < 1.56\ \mathrm{eV}$, the opposite is observed $\mathrm{Re}\,\epsilon_{\mathrm{NL}} < \mathrm{Re}\,\epsilon_{\mathrm{D}}$.

References

[1] V. V. Datsyuk. Nonlocal effects in the optical properties of metal nanoparticles. Ukr. J. Phys., 56 (2011) 122.