The plasmons in a metal nanocylinder with an elliptical cross-section

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Let us consider a metal nanowire with a length l with an elliptical cross section, the effective radius of which is ρ_0 ($\rho_0 = (a+b)/2 \ll l$, where a and b are the major and minor semiaxes of the ellipse), and the eccentricity of the cross section $\varepsilon = \sqrt{1 - (a/b)^2} \ll 1$. We will assume that the indicated $1D$ structure is located in a homogeneous isotropic dielectric medium with permeability ι_m, and its axis is oriented along the axis z of the cartesian coordinate system (Fig. 1).
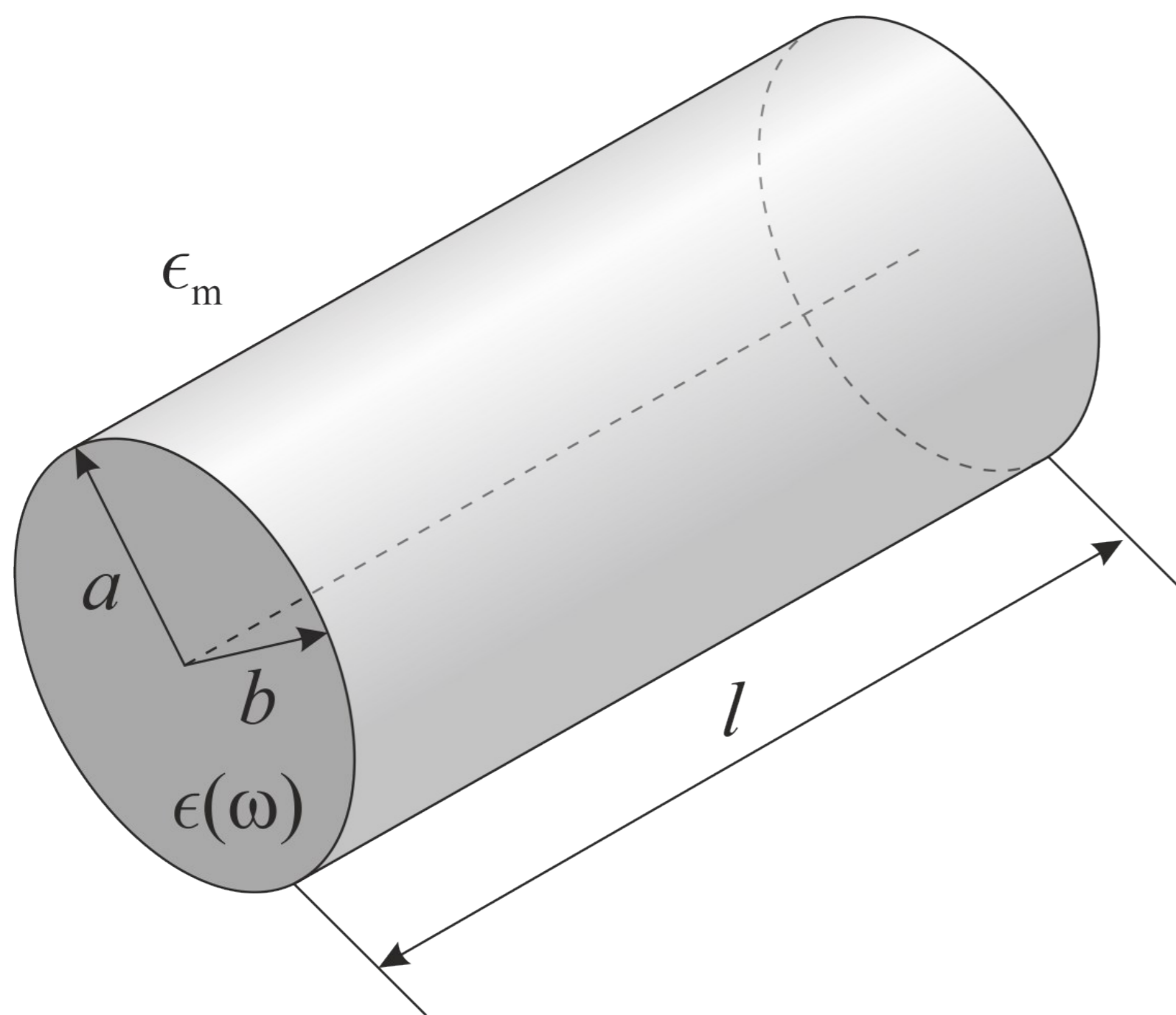

Fig.1 Geometry of the problem

In general, the diagonal components of the polarizability tensor are determined by the expression

$$\alpha_{ii} = V \frac{\tau_{jj}(\omega) - \tau_m}{\tau_m + L_j\left(\tau_{jj}(\omega) - \tau_m\right)} \qquad (1)$$

Where $V = \pi abl$ is the volume of an ellipsoidal nanoparticle; L_j - depolarize-ation factors ($j = x, y, z$); $\iota_{jj}(\omega)$ - dielectric tensor of the nanoparticle material

$$\tau_{jj}(\omega) = \tau^\infty - \frac{\omega_p^2}{\omega\left(\omega + i\,\gamma_{jj}^{\text{eff}}\right)} \qquad (2)$$

Here ι^∞ is the contribution of the ionic core to the dielectric function of the metal; $\omega_p = \sqrt{e^2 n_e / \iota_0 m^*}$ is the frequency of bulk plasmons, e, n_e and m^* are the charge, concentration and effective mass of an electron ($n_e^{-1} = 4\pi r_s^3/3$, r_s is the average distance between conduction electrons), and the diagonal components of the effective relaxation rate tensor are determined as

The expression for the frequencies of transverse surface plasmon resonances is obtained from the conditions

$$\gamma_{jj}^{\text{eff}} = \gamma^{\text{bulk}} + \gamma_{jj}^{\text{surf}} + \gamma_{jj}^{\text{rad}} \qquad (3)$$

where

$$\text{Re}\,\tau\left(\omega_k^{sp}\right) = -\frac{1 - L_k}{L_k}\tau_m = -\left(\frac{b}{a}\right)^{\delta_k}\tau_m \qquad (4)$$

$$\delta_k = \begin{cases} 1, & k = x; \\ -1, & k = y, \end{cases} \qquad \left(\frac{b}{a}\right)^{\delta_k} = 1 - \delta_k \frac{\varepsilon^2}{2} \qquad (5)$$

Thus, the frequencies of transverse surface plasmon resonances are determined by solving the equation

$$\left(\omega_k^{sp}\right)^2 + \left(\gamma^{\text{bulk}} + \frac{K_{pp}}{\left(\omega_k^{sp}\right)^2}\right)^2 = \frac{\omega_p^2}{\tau^\infty + \left(1 - \delta_k \frac{\varepsilon^2}{2}\right)\tau_m} \qquad (6)$$

where

$$K_{pp} = \frac{9}{64}\omega_p^2 \frac{v_F}{a}\left(\frac{\pi}{2} + \frac{a_p}{l}\right)\left[\frac{3}{\tau_m + 1} + \frac{\pi V}{\sqrt{\tau_m\left(\tau^\infty + 2\tau_m\right)}}\left(\frac{\omega_p}{c}\right)^3\right] \qquad (7)$$
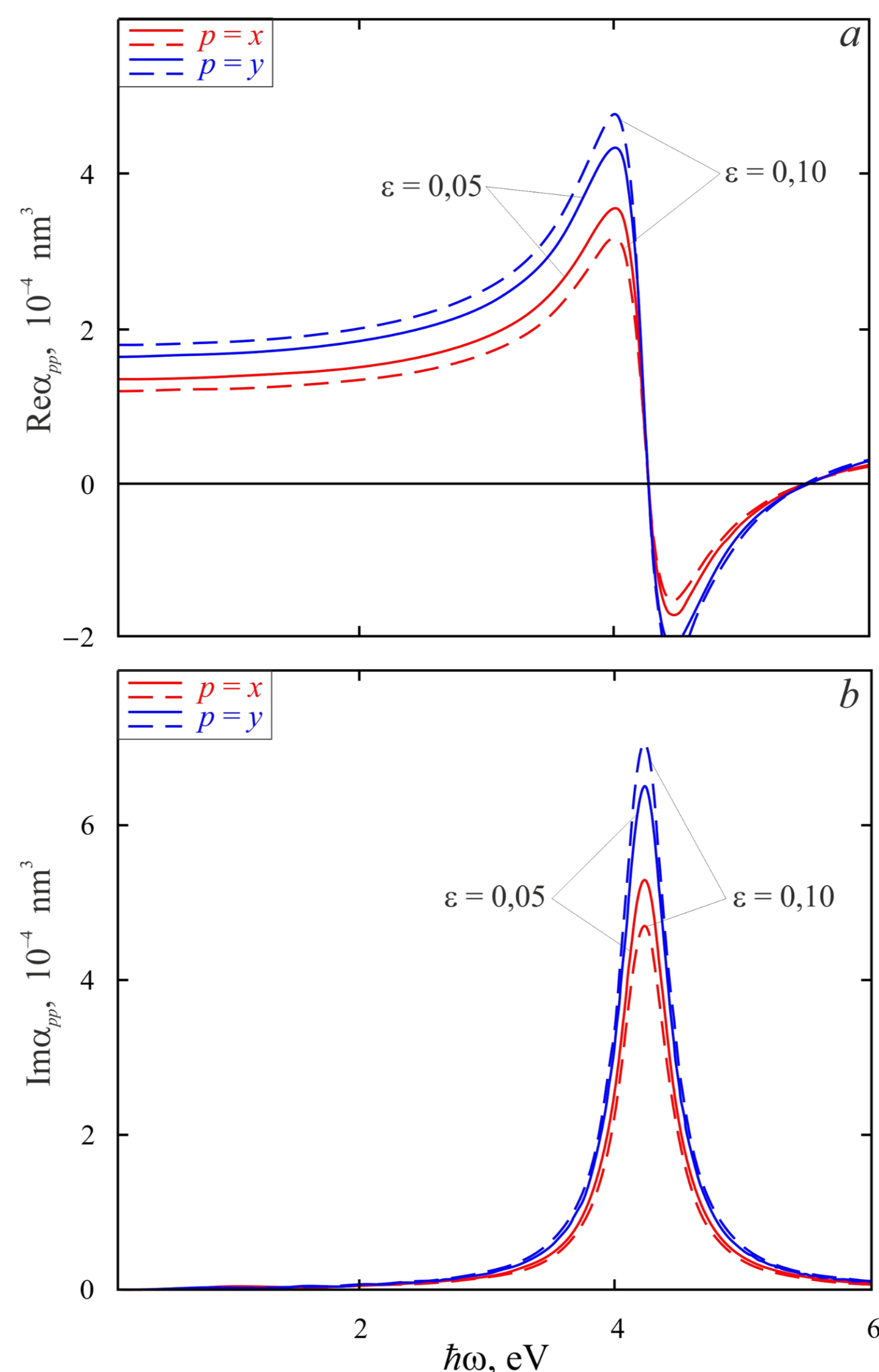

Fig. 2. Frequency dependences of the real (a) and imaginary (b) parts of the polarizability tensor components of Ag nanocylinders with different eccentricity values.