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($\rho_0 = (a+b)/2 << l$, where a and b are the major and minor semiaxes of the ellipse), and the eccentricity of the cross section $\varepsilon = \sqrt{1-(a/b)^2} << 1$. We will assume that the indicated 1D structure is located in a homogeneous isotropic dielectric medium with permeability ε_m, and its axis is oriented along the axis z of the cartesian coordinate system (Fig. 1).

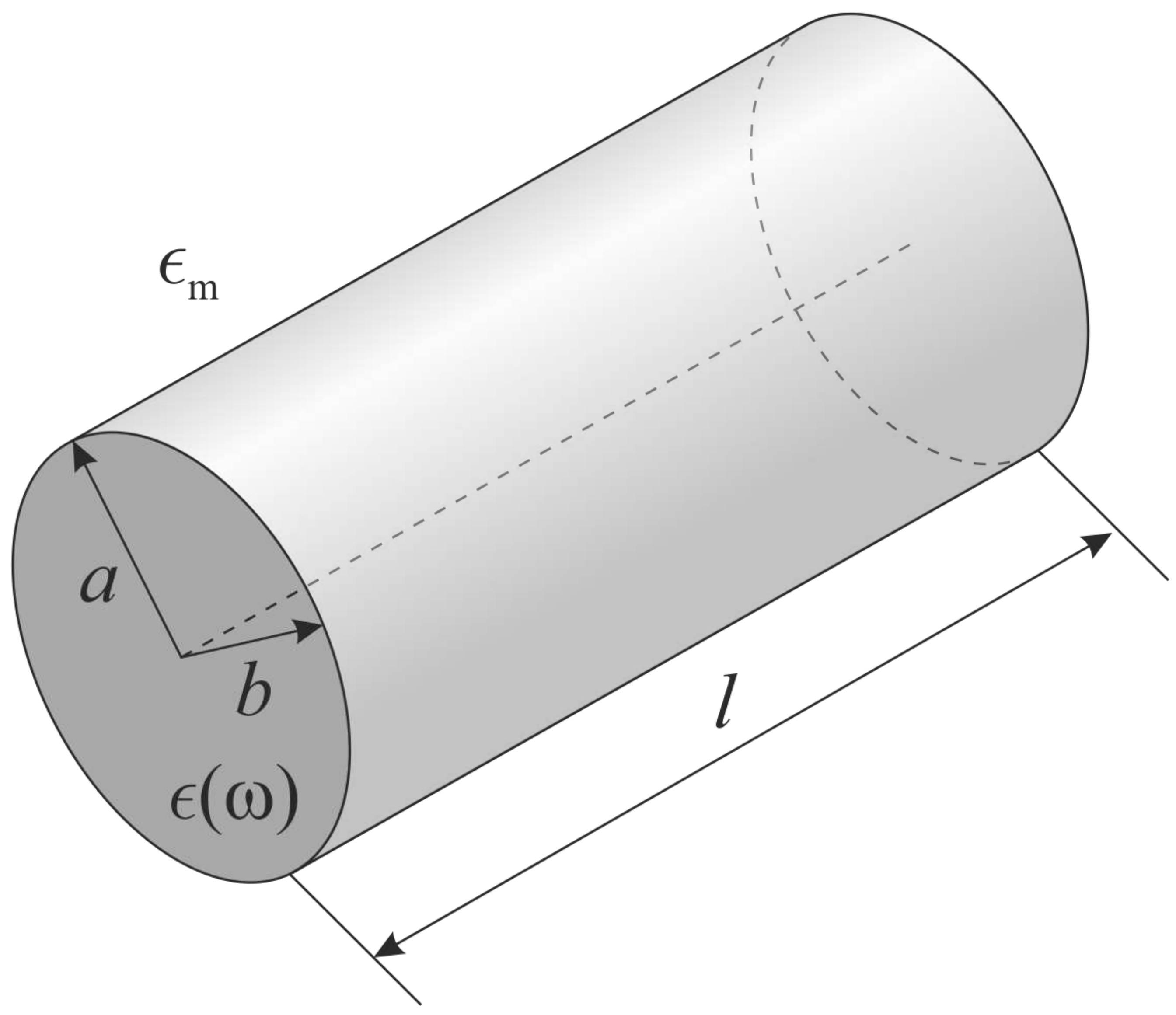

Fig.1 Geometry of the problem

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

$$\alpha_{ii} = V\frac{\varepsilon_{jj}(\omega)-\varepsilon_m}{\varepsilon_m + \mathcal{L}_j\left(\varepsilon_{jj}(\omega)-\varepsilon_m\right)} \tag{1}$$

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

$$\varepsilon_{jj}(\omega) = \varepsilon^{\infty} - \frac{\omega_p^2}{\omega\left(\omega + i\gamma_{jj}^{\text{eff}}\right)} \tag{2}$$

Here ε^{∞} is the contribution of the ionic core to the dielectric function of the metal; $\omega_p = \sqrt{e^2 n_e/\varepsilon_0 m^*}$ 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

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

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

where

$$\operatorname{Re}\varepsilon\left(\omega_k^{sp}\right) = -\frac{1-\mathcal{L}_k}{\mathcal{L}_k}\varepsilon_m = -\left(\frac{b}{a}\right)^{\delta_k}\varepsilon_m \tag{4}$$

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

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

$$\left(\omega_k^{sp}\right)^2 + \left(\gamma^{\text{bulk}} + \frac{\mathscr{K}_{pp}}{\left(\omega_k^{sp}\right)^2}\right)^2 = \frac{\omega_p^2}{\varepsilon^{\infty} + \left(1-\delta_k\frac{\varepsilon^2}{2}\right)\varepsilon_m} \tag{6}$$

where

$$\mathscr{K}_{pp} = \frac{9}{64}\omega_p^2\frac{v_F}{a}\left(\frac{\pi}{2}+\frac{a_p}{l}\right)\left[\frac{3}{\varepsilon_m+1} + \frac{\pi V}{\sqrt{\varepsilon_m\left(\varepsilon^{\infty}+2\varepsilon_m\right)}}\left(\frac{\omega_p}{c}\right)^3\right] \tag{7}$$

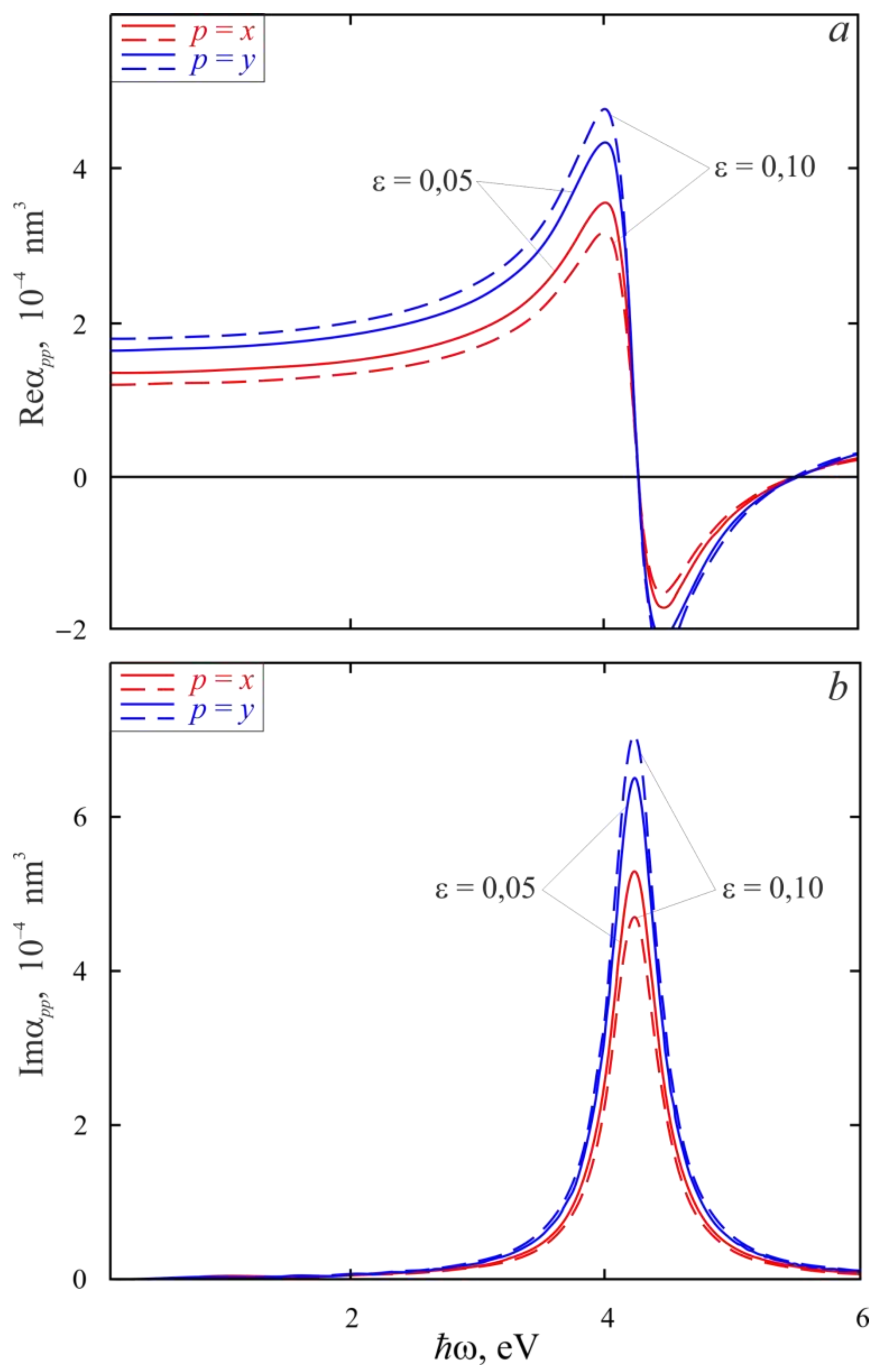

Fig. 2. Frequency dependences of the real (a) and imaginary (b) parts of the polarizability tensor components of Ag nanocylinders with different eccentricity values.