



OPTICAL RESPONSE OF METALLIC NANOTUBE WITH THE VARIABLE THICKNESS



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Abstract

The cylindrical metallic nanoshells (nanotubes) attract the attention of the researchers due to their tunable sensory properties for the optical measurements. Currently, the process of exciting the surface plasmon resonances in the metallic nanotubes of the constant thickness is well studied [1]. In particular, it is established that the plasmonic hybridization of the inner and outer surfaces and changes in the shell thickness regulate the position of the surface plasmon resonance peaks. The violation of the symmetry in the metal-dielectric cylindrical nanostructures due to the displacement of the dielectric core leads to the significant complication in the behavior of the plasmonic modes. It should be pointed out that these issues remain poorly studied, and therefore their study is relevant.

Statement of the problem

Let us consider the interaction of light with the metal-dielectric non-coaxial cylindrical nanostructure located in the dielectric medium (Fig. 1). We consider this interaction in the quasi-static approximation, since the characteristic dimensions of the system are significantly less than the wavelength of light. This approach allows us to analytically determine the frequency dependence of the transverse polarizability of the composite cylindrical nanostructure, which is under the consideration

$$\alpha_{@}(\omega) = 1 - 2\epsilon_m \left\{ -\beta_c(\epsilon_s - \epsilon_m)(\epsilon_s - \epsilon_c) + (\epsilon_s + \epsilon_m) \times \left[\epsilon_c + \epsilon_s - \frac{2\beta_c^2 \delta_c (\epsilon_s - \epsilon_c)(\epsilon_s - \epsilon_m)(\epsilon_s + \epsilon_c)}{(\epsilon_s + \epsilon_m)(\epsilon_s + \epsilon_c) - \beta_c^2 (\epsilon_s - \epsilon_c)(\epsilon_s - \epsilon_m)} \right] \right\}^{-1} \times \left\{ -\beta_c(\epsilon_s - \epsilon_c) + \epsilon_s + \epsilon_c - \frac{2\beta_c^2 \delta_c (\epsilon_s - \epsilon_c)(\epsilon_s - \epsilon_m)(\epsilon_s + \epsilon_c)}{(\epsilon_s + \epsilon_m)(\epsilon_s + \epsilon_c) - \beta_c^2 (\epsilon_s - \epsilon_c)(\epsilon_s - \epsilon_m)} \right\}, \quad (1)$$

where $\beta_c = a^2/b^2$, $\delta_c = d^2/b^2$, and ϵ_c , ϵ_s and ϵ_m are the dielectric permittivities of the materials of the core, shell, and surrounding medium.

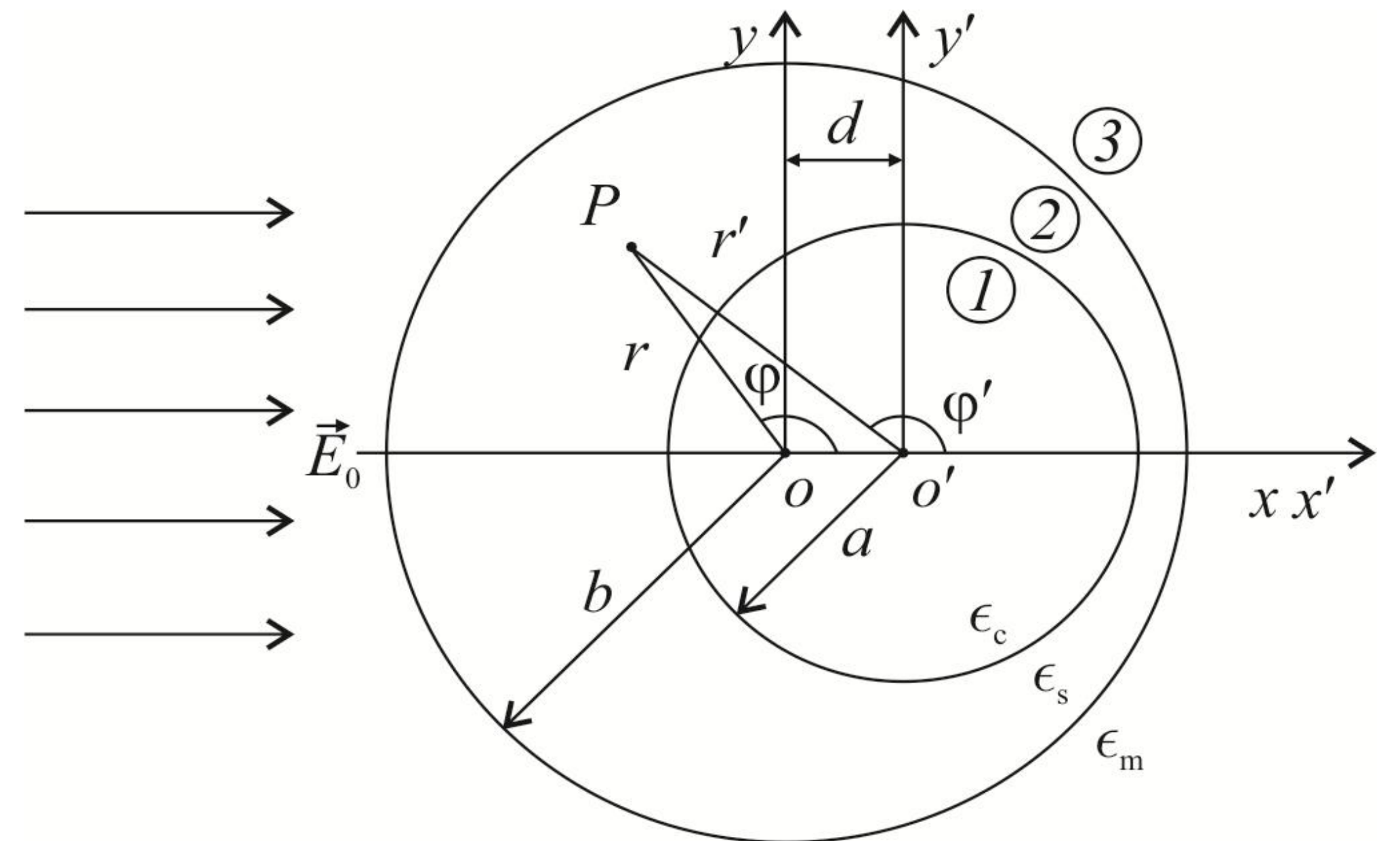


Figure 1. Geometry of the problem

In turn, the analysis of the obtained expression for the polarizability allows us to obtain the size dependencies of the surface plasmon resonance frequencies and the invisibility frequencies. These dependencies in the dissipation-free approximation are obtained from the conditions of zero denominator and numerator of the expression for the polarizability. However, unlike the metallic nanotube of the constant thickness, which has two frequencies of the invisibility and two frequencies of the surface plasmon resonance, the nanostructure, which is under the study, has four frequencies of the invisibility and four frequencies of the surface plasmon resonance due to the non-coaxiality of this nanostructure.

Results of calculations and conclusions

The results of the calculations show that if the splitting of the surface plasmon resonance frequencies is noticeable, then the splitting of the invisibility frequencies is insignificant. This behavior of the invisibility frequencies, which is close to the degeneracy, is due to the fact that they are practically independent of the distance between the axes of the inner cylinder and the entire metal-dielectric nanostructure.

References

- [1]. A. V. Korotun, Y. V. Karandas, Phys. Met. Metallogr. 123, 7 (2022).