



# ENHANCEMENT OF LOCAL ELECTRIC FIELDS IN THE GAP BETWEEN THE METALLIC SUBSTRATE AND THE SCANNING MICROSCOPE PROBE



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## Abstract

The study of the interaction between light and matter in the semiconductor nanostructures attracts the attention of the researchers for the use in optoelectronics. In order to optimize this interaction, it is proposed to create the quantum dots in the neighborhood of the metallic nanoparticles of different geometries and, accordingly, to obtain the hybrid “metal-semiconductor” nanostructures. An interesting effect observed in the hybrid systems, which are under the consideration, is the excitation of excitons and the presence of various modes of plasmon-exciton interaction. It should be pointed out that the optical properties of the hybrid system “spherical metallic nanoparticle – semiconductor quantum dot” are fairly well described in the scientific literature. For example, in [1], light absorption in such a hybrid system was studied and the factors, which influence the spectral position of the absorption coefficient maxima were established. At the same time, the optical properties of the considered nanosystems with metallic nanoparticles of non-spherical geometry have been poorly studied, so such problems are relevant.

## Statement of the problem

We investigate the hybrid system, which consists of the prolate spheroidal metallic nanoparticle and the semiconductor quantum dot located on its axis. It should be pointed out that the optical properties of the spheroidal nanoparticle can be described within the framework of the quasi-static approximation (since the characteristic sizes of the system are significantly less than the wavelength). In this case, the semiconductor quantum dot is considered to be two-level system, and the spatial dispersion of the permittivity is taken into account for the nanoparticles. In addition, the paper investigates the influence of the electron relaxation processes in the nanoparticles on the absorption of light by the hybrid system.

The relationships for the frequency dependence of the absorption coefficient of the considered hybrid system have the form:

## References

[1]. R. Korolkov, O. Berezhnyi, and A. Korotun, Proc. 2025 IEEE 15th Intern. Conf. NAP 2025, UBMP041 (September, 07-12, 2025).

$$\eta(\omega) = \frac{2\omega}{c\sqrt{\epsilon_{\text{eff},s}}} \text{Im}\{\sqrt{1 + \text{Re}\chi_{QD} + i\text{Im}\chi_{QD}}\}, \quad (1)$$

where

$$\epsilon_{\text{eff},s} = \frac{2\epsilon_m + \epsilon_{QD}}{3\epsilon_m},$$

Here,  $\epsilon_m$  and  $\epsilon_{QD}$  are the permittivities of the surrounding medium and the material of the quantum dot;  $\chi_{QD}$  is the susceptibility of the quantum dot, which is ultimately determined by its parameters and the longitudinal component of the nonlocal dielectric tensor of the material of the prolate spheroidal nanoparticle:

$$\epsilon_{NL}^{\parallel}(\omega) = \left[ \frac{1}{\epsilon_D^{\parallel}(\omega)} + \frac{3}{\epsilon^{\infty}} \left( \frac{\omega_p a_l}{\beta u_{\parallel}} \right)^2 I_{\frac{3}{2}}(u_{\parallel}) K_{\frac{3}{2}}(u_{\parallel}) \right]^{-1} \quad (2)$$

In formula (2)

$$u_{\parallel} = \frac{a_l}{\beta} \sqrt{\frac{\omega_p^2}{\epsilon^{\infty}} - \omega(\omega + i\gamma_{\text{eff}}^{\parallel})} \quad (3)$$

$I_{\nu}(x)$  and  $K_{\nu}(x)$  are the Infeld and Macdonald functions;

$\beta = \sqrt{\frac{3}{5}} v_F$ ,  $v_F$  - is the Fermi velocity;  $a_l$  - is the semi-major axis of the prolate spheroid;  $\omega_p$  - is the plasma frequency;  $\gamma_{\text{eff}}^{\parallel}$  - is the longitudinal component of the effective relaxation rate;  $\epsilon^{\infty}$  - is the contribution of the crystal lattice to the dielectric permittivity of the nanoparticle material; and  $\epsilon_D^{\parallel}(\omega)$  - is the longitudinal component of the Drude dielectric tensor.

## Results of calculations and conclusions

The results of the calculations indicate the presence of the sharp maxima of the susceptibilities of the spheroidal metallic nanoparticles and semiconductor quantum dots, as well as the sharp maxima of the the absorption coefficient of the hybrid nanosystem. It is shown that in the system, which is under the consideration, it is necessary to take into account the relaxation processes that determine the width of the resonance peaks observed in the experiment.