Electric field effect on the absorption coefficient of hemispherical quantum dots

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THEORETHICAL FRAMEWORK

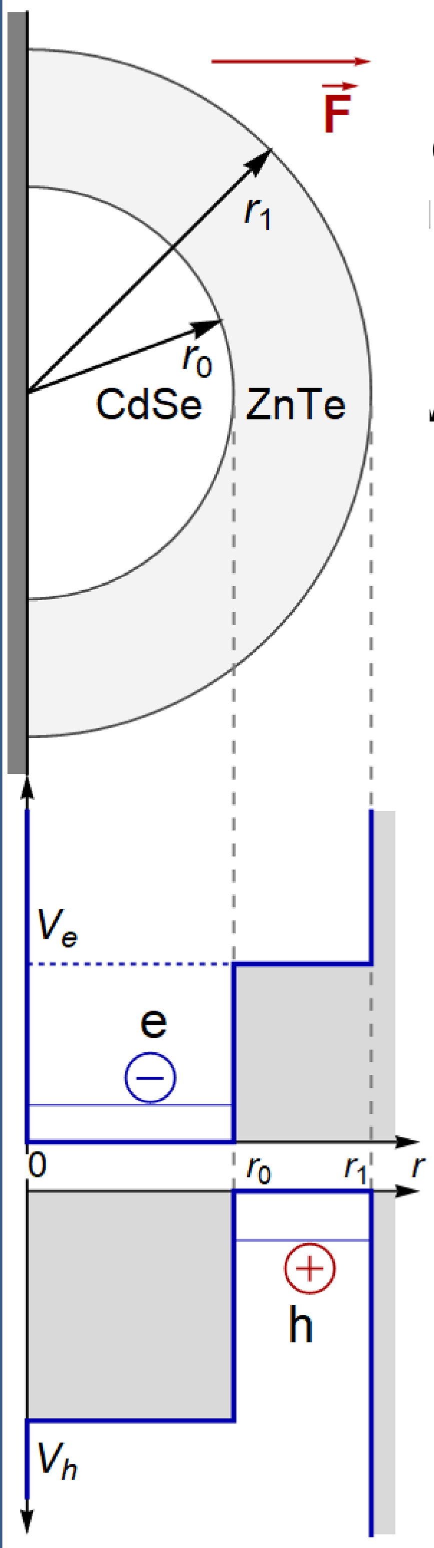

Fig.1. Geometrical and potential shemes of CdSe/ZnTe HQD

This study presents a simple model within the effective mass approximation to describe the effect of an external electric eld on the energy structure and wave functions of electrons and holes in type II hemispherical quantum dots. The case of a niform electric field perpendicular to the surface on which a hemispherical quantum dot is grown is considered.

The solutions of the Schrödinger equation were obtained by the matrix method on the orthogonal basis of the exact vave functions oof quasiparticles in this nanostructure without the influence of an electric field.

$$U_{e,h}(r,\theta) = U'_{e,h}(r) + U''(\theta), \quad (1) \qquad U''(\theta) = \begin{cases} 0, & 0<\theta\le\pi/2 \\ \infty, & \pi/2<\theta<\pi \end{cases} \quad (2) \qquad \mu_{e,h}(r) = \mu_0 \begin{cases} m_0^{e,h}, & r\le r_0 \\ m_1^{e,h}, & r_0<r\le r_1 \end{cases},$$

$$U'_e(r,\theta) = \begin{cases} 0, & r\le r_0, \\ V_e, & r_0<r\le r_1, \\ \infty, & r>r_1, \end{cases} \quad (3) \qquad U'_h(r,\theta) = \begin{cases} V_h, & r\le r_0, \\ 0, & r_0<r\le r_1, \\ \infty, & r>r_1, \end{cases} \quad (4)$$

$$H\psi^{e,h}_{jm}(\vec r) = \tilde E^{e,h}_{nl}\psi^{e,h}_{jm}(\vec r) \quad (5) \qquad H = \frac{p^2}{2\,\mu(r)} \pm eFr\cos\theta + U_{e,h}(r) \quad (6) \qquad \left|H^{e,h}_{nl,n'l'} - \tilde E^{e,h}_{jm}\delta_{n,n'}\delta_{l,l'}\right| = 0$$

$$\psi^{e,h}_{jm}(\vec r) = \sum_{n,l} c^{jm}_{nlm}\Phi^{e,h}_{nlm}(\vec r) \quad (7) \qquad \Phi^{e,h}_{nlm}(\vec r) = R^{e,h}_{nl}(r)Y_{lm}(\theta,\varphi) \qquad R^{e,h}_{nl}(r) = A\,j_l(k^{e,h}_n r) + B\,n_l(k^{e,h}_n r)$$

$$Y\left(\frac{\pi}{2},\varphi\right) = 0 \qquad k^{e,h}_n = \frac{1}{\hbar}\sqrt{2\mu_{e,h}(E^{e,h}_{nl} - V_{e,h})}$$

RESULTS AND DISCUSSION

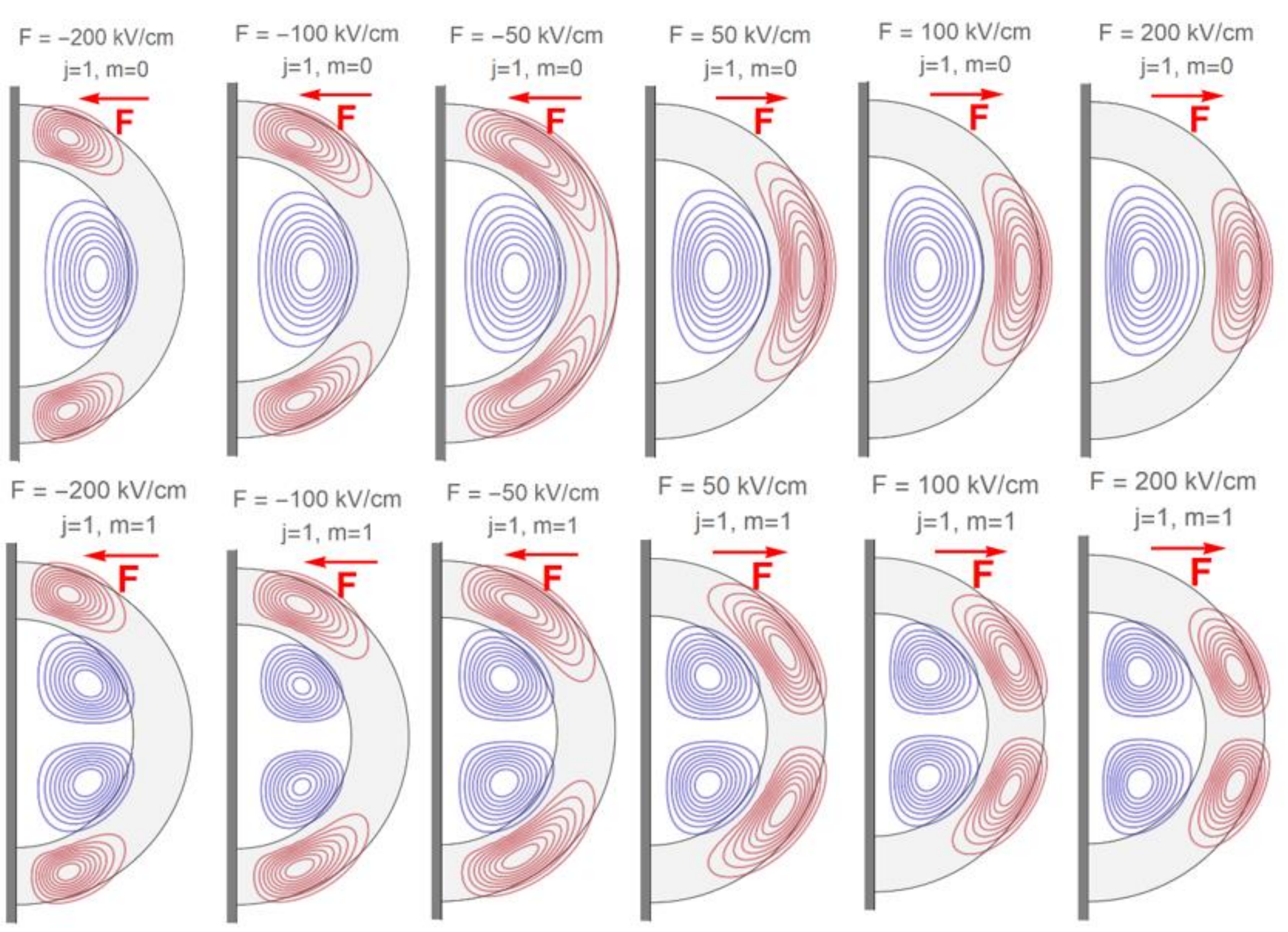

Fig. 2 Evolution of the density of the electron and hole distribution in the two lowest quantum states depending on the intensity of the electric field.

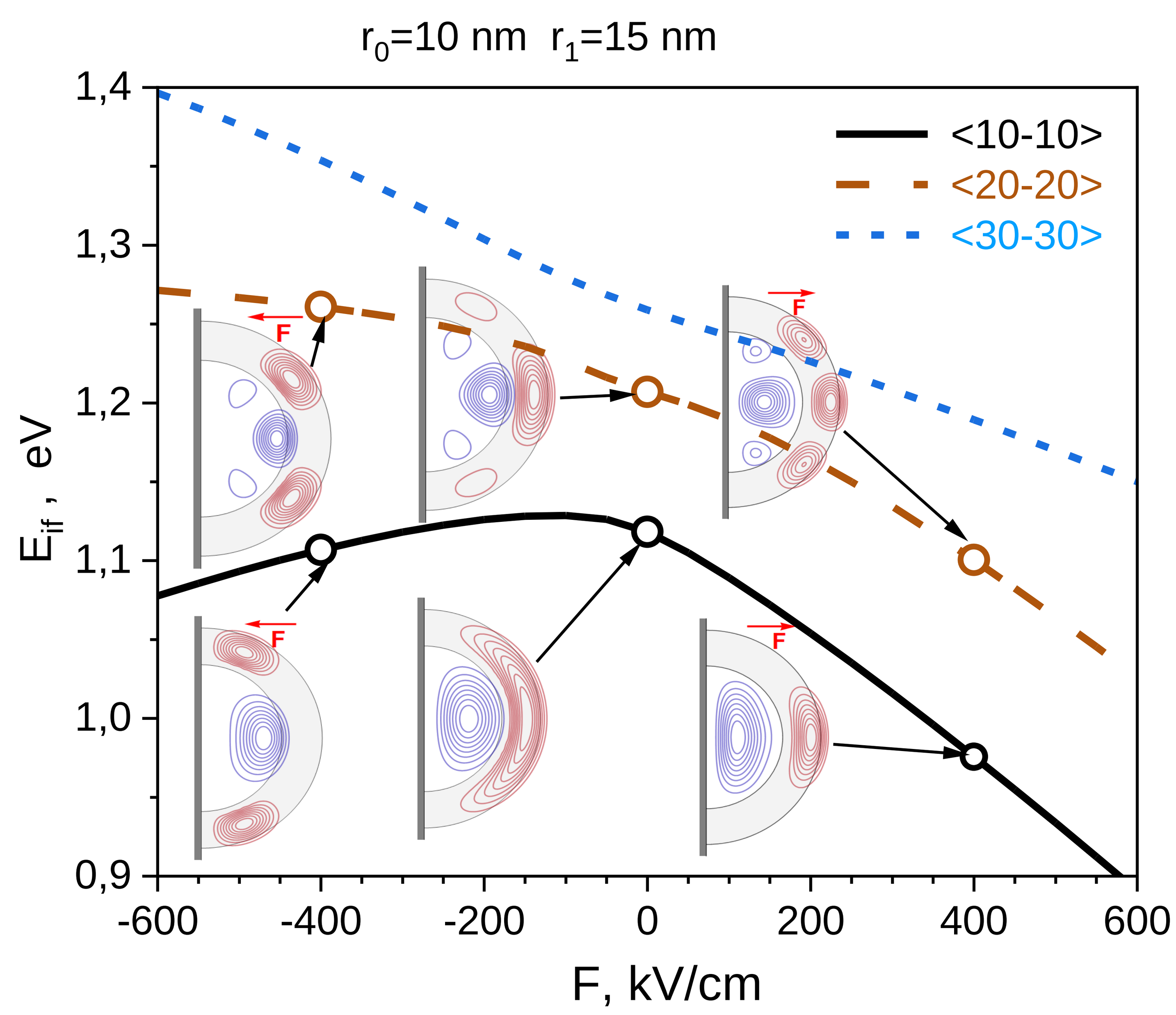

Fig.3 Dependence of the energy of the interband quantum transition on the electric field strength

CONCLUSIONS

1. It is shown that the ground state of a quasiparticle localized in outer shell of a spherical nanosystem (an electron in a ZnTe/CdSe nanosystemand a hole in the CdSe/ZnTe nanosystem) with increasing magnetic field inductionis successively formed by the lowest energy states with |m|=0, 1, 2...(Aaronov-Bohm effect)

2. When the intensity of the magnetic field increases, the energy of the quantum transitionbetween the electron and hole ground states increases

3. The overlap of wave functions decreases as the size of the core of the nanosystem increases,and when the magnetic field increases, it has a non-monotonic dependence: slowly at firstdecreases, and then sharply increases

REFERENCES

1. Jiao S., Shen Q., Mora-Seró I., Wang J., Pan Z., Zhao K., Kuga Y., Zhong X., Bisquert J. Band engineering in core/shell ZnTe/cdse for photovoltage and efficiency enhancement in exciplex quantum dot sensitized solar cells. ACS Nano, 9(1), 908–915 (2015).

2. Wu, S., Song, Y., Han, S., Yang, Y., Guo, F., & Li, S. Chinese Physics B, 2021, 30, 053201.

3. Mohammadi, S. A., Khordad, R., & Rezaei, G. Physica E: Low-Dimensional Systems and Nanostructures, 2016, 76, 203–208.

4. Kostić, R., & Stojanović, D. Electric field effect on the nonlinear and linear intersubband absorption spectra in CdTe/ZnTe spherical quantum dot. Journal of Nanophotonics, 6(1), 061606–1 (2012).