Wannier–Mott Excitons in Semiconductors with a Superlattice

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Abstract

The presentation demonstrates the strong effect of motion of the Wannier–Mott exciton as a whole in semiconductors with superlattice (SL) on the exciton binding energy and wave function. We show significant dependence on the exciton center of mass quasi-momentum, Q, of the resonance integral that controls the relative motion of an electron and a hole inside the exciton. The closer the resonance integrals of the electron and hole in the SL, the greater this dependence is. Consequently, both the binding energy of the exciton and its wave function in a semiconductor with SL strongly depend on Q.

At $Q = 0$, the wave function of relative electron and hole motion into the exciton is localized on some number of quantum wells and the localization length is proportional to the inverse value of the resonance integral. At Q value at the Brillouin zone boundary, the resonance integral is close to zero and we deal with the exciton consisting of an electron and a hole in the same quantum well (N = 0) and with spatially indirect excitons with an electron and a hole separated by one (N = 1), two (N = 2), etc. barriers. The larger the N, the lower the binding energy is. At N = 0, the exciton binding energy is close to energy of 2D exciton. There arises the pronounced Q- dependence of the overlap integrals of electron and hole wave functions. This yields Q-dependence of the optical transition rate.

We present analysis of the continuous approximation applicability. We show the similarity of such approximation with the problem of donors in semiconductors with anisotropic effective mass with the important difference that the mass components might strongly depend on Q.

We give a brief consideration of the exciton peculiarities in 2D and 3D Quantum Dot based SL.