LARGE POLARONS IN SEMICONDUCTOR NANOSTRUCTURES

J.T. Devreese[1,2]

[1]TVFS, Departement Fysica, Universiteit Antwerpen,
Universiteitsplein, 1, B-2610, Antwerpen, Belgium,
[2]Department of Semiconductor Physics, TU Eindhoven,
NL-5600 MB Eindhoven, The Netherlands

Abstract. I present an overview is presented of the fundamentals of large-polaron physics, which provide the basis of the analysis of polaron effects in semiconductor nanostructures. The emphasis is on the polaron optical absorption. As illustrative examples, I consider polaron effects in quantum wells (the polaron binding energy and effective mass; many-electron effects and cyclotron resonance) and polaron effects in semiconductor quantum dots (the optical absorption and the effects of non-adiabaticity).

Key words: large polaron, nanostructures, quantum wells, quantum dots.

The fabrication of systems of reduced dimension and dimensionality has given rise to the study of polarons in quantum wells, heterojunctions, quantum dots etc. Here I consider the example of a polaronic exciton in a quantum dot. In sufficiently small quantum dots the exciton-phonon states are no longer factorizable by an adiabatic product Ansatz (contrary to the bulk case), so that a non-adiabatic treatment is needed [1]. As shown in Ref. [1] in subsequent work, the non-adiabaticity of the exciton-phonon systems can lead to a strong enhancement of the phonon-assisted transition probabilities (as compared to the probabilities obtained adiabatically). The "non-adiabatic" phonon optical spectra can differ considerably from a Franck-Condon progression, even for the relatively small values of the electron-phonon coupling constant that is characteristic for semiconductor nanostructures. While, for some quantum dots, the adiabatic approximation predicts negligibly low intensities of the one- and two-phonon sidebands, the non-adiabatic theory allows for a quantitative interpretation of the experimentally observed high intensity of the phonon sidebands in the photoluminescence spectra of those quantum dots, in agreement with experiment. The non-adiabatic effects predicted in Ref. [1] have been confirmed experimentally (see, e. g., Refs. [2 to 5]).

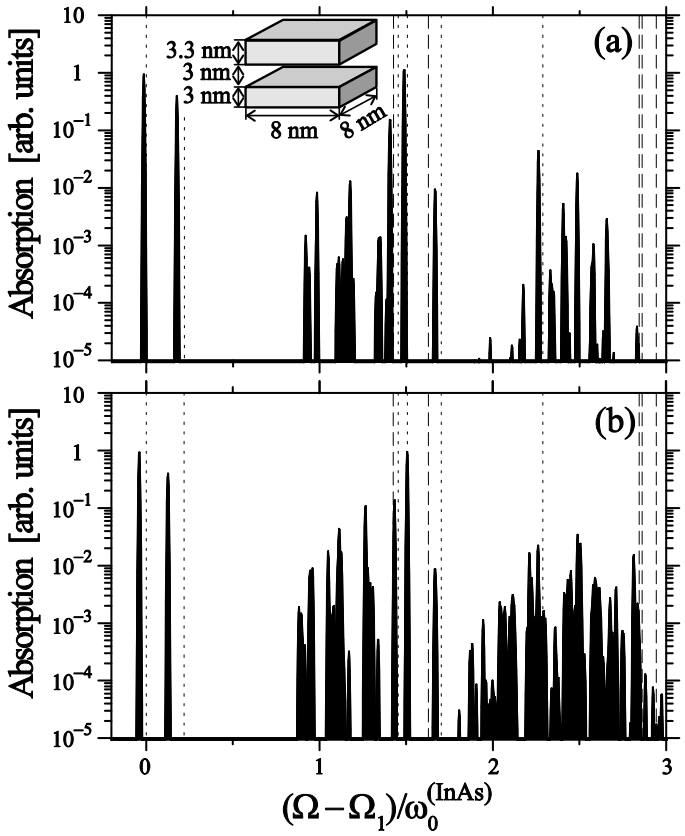

Fig. 1. Absorption spectra, calculated with theadiabatic approximation [panel (a)] and with the non-adiabatic approach [panel (b)] for two stacked quantum dots of different height. Optically active and non-active energy levels of a bare exciton are shown as dotted and dashed lines, respectively. Ω_1 is the transition frequency for the lowest state of a bare exciton. (From [6].)

The optical-absorption spectra reveal the role of the non-adiabaticity of the exciton-phonon systems in certain types of quantum dots. The polaron shift of the absorption peak, which reflects the zero-phonon transition to the lowest one-exciton state, is considerably larger in the non-adiabatic approach of Ref. [6] than in the adiabatic approximation. Another consequence of the non-adiabaticity effects is a redistribution of oscillator strengths among the transitions to different states. In particular, the intensities of the phonon sidebands are significantly enhanced as compared to those given by the adiabatic approximation. Moreover, in the optical absorption spectra found within the non-adiabatic approach, there appear phonon satellites related to dark bare-exciton states. This results in a rich structure of the absorption spectrum of the exciton-phonon system [6 to 8], as illustrated in Fig. 1.

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