Charge-induced Autler-Townes doublet in coupled semiconductor quantum wells

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The absorption of a photon in a quantum structure is commonly illustrated as a transition between two electronic states. In systems such as atoms and molecules the energy of the photon corresponds to the energy separation between the two states. However, in solid state systems when a large number of particles is involved in the absorption process, many body effects induce a strong renormalization of the transition energy [1]. One such example are the electronic transitions in highly doped semiconductor quantum wells, which are the object of our investigation.

For electronic concentrations above 10^{18} cm^{-3}, the absorption resonances associated to transitions between conduction-band states in a quantum well are blue-shifted by the Coulomb interaction between the microscopic dipoles. The induced electronic excitation is now a collective mode, also called "intersubband plasmon". Furthermore, when several intersubband plasmons are involved in the interaction with light, they Coulomb-couple to each other. It has been recently demonstrated that in a quantum well with several occupied subbands [2] this coupling gives rise to a sharp optical resonance, at an energy completely different from that of the transitions. In other words, Coulomb interaction introduces a common phase among the individual dipoles of the system.

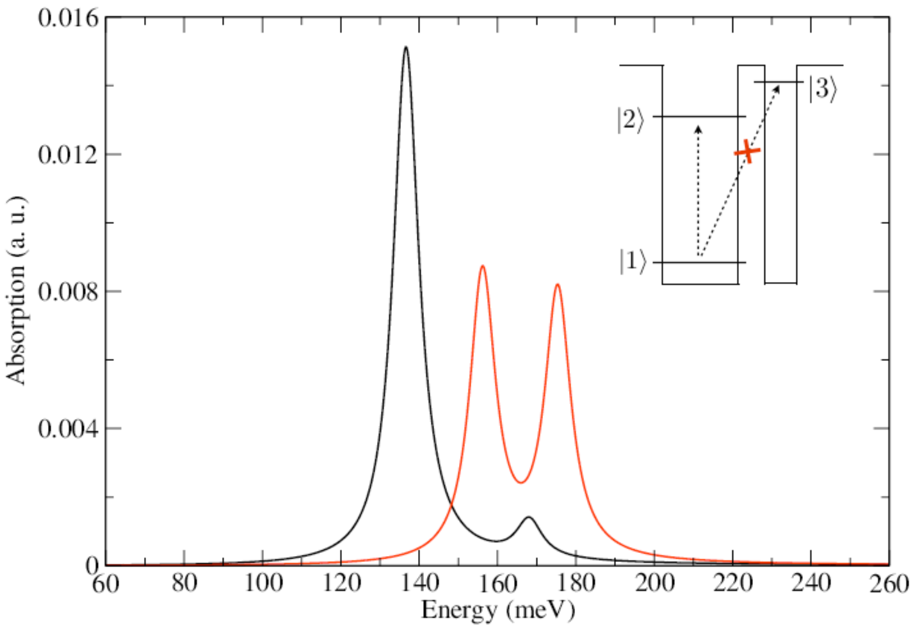

Fig. 1: Calculated absorption spectra for coupled quantum wells V-type structure in single particle picture (black line) and with the inclusion of Coulomb interaction (red line). Inset: Band structure, GaAs/Al_{45}GaAs, 80/**30**/22, Nv = 4.5 10^{18}cm^{-3}

In this work, we exploit Coulomb interaction to generate a laser-free Autler-Townes doublet [4]. Our system is based on two coupled quantum wells, as shown in the inset of Fig. 1. This configuration allows to obtain a V-type scheme where the 1-3 transition has very weak oscillator strength, as it can be seen from the single particle spectrum presented in Fig. 1 (black line).

We numerically calculate the optical response, taking into account dipole-dipole Coulomb interactions, using a generalization of the formalism described in [3]. The absorption resonances are calculated by diagonalizing the light-matter Hamiltonian in the dipole gauge.
Fig. 1 presents the calculated absorption spectrum (red line), where we can see the appearance of a doublet, induced by Coulomb interactions. In this three-level system, the macroscopic manifestation of the microscopic common phase of the electron oscillations is the activation of a transition that would be almost dark in single-particle picture.
This phenomenon is therefore analogous to the Autler-Townes effect [4], in which the external coupling field is replaced by the charge-induced coherence.

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