8 Inelastic Light Scattering in Microcavities

8.1 Introduction

A semiconductor microcavity is an optical resonator, where the mirrors consist of alternating layers of two different semiconductors with different refractive indices, e.g., GaAs and AlAs, which have thicknesses of a quarter wavelength each. The resonator itself is called *spacer*, and has a thickness of a few half wavelengths. The electric fields of the light waves, and hence the light–matter interaction can be modified significantly inside a microcavity. In the past decades, a number of sophisticated experiments have been reported that took advantage of the strongly enhanced electric field inside the spacer of a planar semiconductor microcavity. A prominent example is the enhanced exciton–photon coupling, resulting in an enlarged Rabi splitting, in planar microcavities containing *undoped* quantum wells [1]. Subsequently, a wealth of theoretical and experimental work on exciton polaritons in semiconductor microcavities, e.g., about the influence of a magnetic field [2], or coupling between different microcavities [3], followed.

Fainstein et al. [4] impressively demonstrated for the first time that the enhanced electric field inside a microcavity can also enhance optical–phonon Raman scattering by over 4 orders of magnitude. Even stronger enhancements could be reached by using the cavity polariton mode as a resonant intermediate state in the scattering process [5]. In all these investigations, excitonic or polaritonic effects caused by the interaction of photo–excited carriers in *undoped* structures with the photonic cavity mode were studied.

In this chapter, we will discuss the investigation of *electronic excitations* of a 2DES, embedded inside a planar semiconductor microcavity [6, 7]. It will be shown that the inelastic light scattering by electronic intersubband excitations can be enhanced by about three orders of magnitude under conditions of an optical double resonance [4], where the incoming photons as well as the inelastically scattered photons are in resonance with the cavity mode, compared to the single–resonance case, where only the laser photons are in resonance with the cavity mode. Moreover, since a high–quality cavity with a cavity–mode width smaller than the widths of the electronic excitations was used, it is possible to selectively enhance distinct parts of the excitations. These investigations may offer the opportunity to use the presented method in the future as some kind of a selective spectrometer to enhance

Christian Schüller: *Inelastic Light Scattering of Semiconductor Nanostructures*
STMP **219**, 161–168 (2006)
DOI 10.1007/3-540-36526-5_8

electronic elementary excitations. This would enable one to study, e.g., excitations in quantum–wire or quantum–dot structures containing only few electrons, which might be too weak for a direct observation.

8.2 2DES Inside a Semiconductor Microcavity

We will start by introducing the sample structure used by T. Kipp et al. [6, 7]. The MBE grown microcavity samples consist of a $Al_{0.2}Ga_{0.8}As$ λ cavity (spacer) with AlAs-$Al_{0.4}Ga_{0.6}As$ quarter–wave layers on both sides (24 on the top, and 33 on the bottom side), which act as distributed Bragg reflectors (DBR's). The finesse of the microcavities is between about 1200 and 2400. In the center of the spacer, there is a one–sided modulation–doped GaAs quantum well with 30 nm well width grown. A Si–doped layer is separated from the well by a 20 nm spacer. The sample structure is schematically shown in Fig. 8.1a. Figure 8.1b shows the calculated distribution of the electric field amplitudes inside the cavity. To allow for simultaneous transmission and Raman experiments, the GaAs substrate was completely removed from the back side of the sample. After the removal of the substrate, the only GaAs which was left in the sample was the 30 nm quantum well and an undoped 2 nm cap layer. By magneto–luminescence measurements, the carrier density inside the well could be determined to be 5.3×10^{11} cm^{-2}. The Raman experiments were performed using a tunable Ti:sapphire laser and a triple Raman spectrometer with liquid–nitrogen cooled CCD camera. The sample

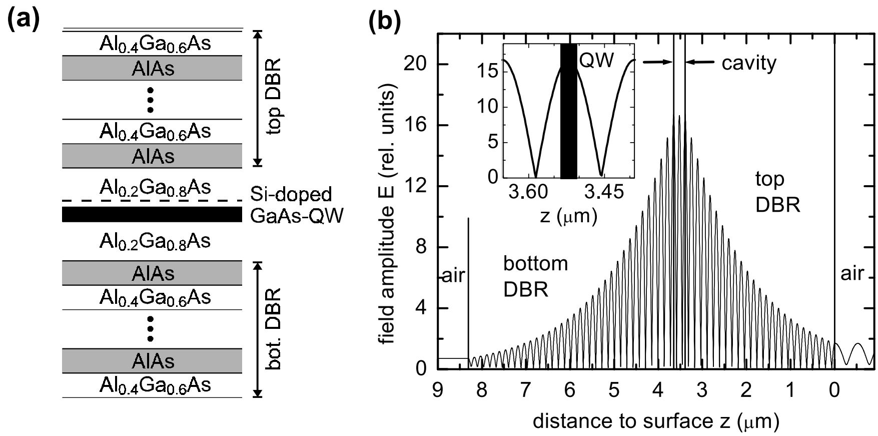

Fig. 8.1. (**a**) Layer sequence of a sample containing a modulation–doped single quantum well embedded inside a semiconductor microcavity. (**b**) Calculated electric–field amplitudes inside the microcavity sample. The inset shows a magnification of the field distribution inside the spacer. The position of the quantum well is marked by the vertical bar