InAs/AlSb structures for giant Rabi splitting of intersubband polaritons

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***Abstract*—The optical response of the intersubband excitation of multiple InAs/AlSb quantum wells embedded in a planar semiconductor microcavities has been studied through angle-dependant reflectance measurement. Strong coupling is demonstrated between the intersubband optical transition and the cavity photon. A giant vacuum-Rabi splitting (∼33 meV) was observed both at liquid Helium and room temperature for transition energies of 123 meV and 83 meV. The observed ratios are record-high values for any strongly-coupled systems, and demonstrates the huge potential of this material system for the achievement of the ultrastrong coupling regime predicted theoretically.**

RECENTLY, the interaction of intersubband transitions with the optical mode of a semiconductor microcavity has become the object of intense investigation. The cavity field and the electronic transition can be viewed as two oscillators, which interact strongly when they are brought into resonance and the coupling is larger than any dephasing time or lifetime. The coupled modes exhibit an anticrossing in energy with a separation $2\Omega_R$ termed "*vacuum-field Rabi splitting*", in analogy to the atomic physics phenomenon. Several interesting new applications based on these intersubband polaritons have been proposed, including tunable intersubband light emitting devices [1].

Intersubband polaritons were first observed in 2003 through angle-dependent reflectance measurements in GaAs/AlGaAs multiple quantum wells using a resonator based on total internal reflection. A clear mode splitting of several meV was detected up to room temperature [2], which represented about 5% of the intersubband transition energy. More recently, the quantum properties of the intersubband polariton were discussed by Ciuti and Bastard [3]. An ultrastrong coupling regime in which $2\Omega_R$ is a significant portion of the intersubband resonance ω_{12} is in principle achievable. In this regime, fascinating quantum electrodynamics effects are predicted, such as the emission of correlated photon pairs. The very large vacuum Rabi energy considered was however not explored experimentally.

The Rabi splitting Ω_R is a function of the oscillator strength f_{osc} and the number of quantum wells N_{QW}:

$$\Omega_R \sim \sqrt{f_{osc} N_{QW}}$$

Thus, the InAs/AlSb seems to be a good candidate to achieve the unprecedented ultra-strong coupling regime because of the small effective mass in InAs material, which provides larger oscillator strength. We present in this poster the experimental results we obtained on intersubband polaritons measured in two InAs/AlSb heterostructures showing large Rabi splitting. The intersubband transition energy is centered at 10 μm for one sample, and 15 μm for the other.

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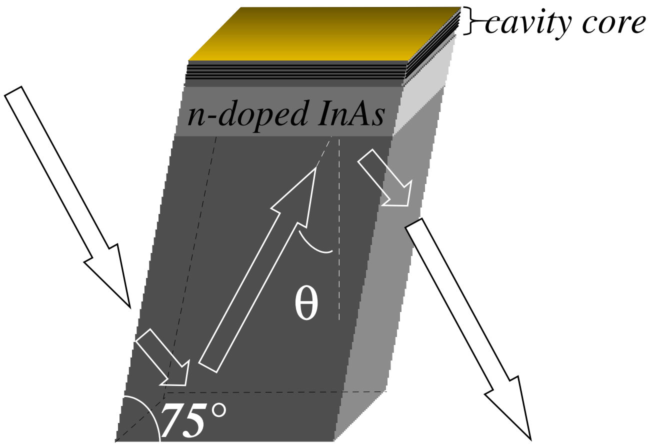

Fig. 1. Schematic view of the microcavity wedget at an angle of 75° with respect to the plane of the substrate. The large arrows represent the optical path in the substrate.

As shown in figure 1, the resonator implemented for these studies is a planar microcavity tuned for propagation at 75° incidence. It is formed by ten InAs quantum wells (13.7 nm and 18.6 nm) doped approximately at 5×10^{11} cm^{-2} separated by 10 nm wide AlSb barriers. This active region is sandwiched between a semiconductor-metal interface on top and a highly-doped low-index InAs cladding layer of about 1 μm thickness n-doped to 5×10^{18} cm^{-3}. These structures are grown by MBE on undoped InAs (001) substrates.

Angle-resolved TM reflectance measurements on the microcavity at liquid helium temperature are reported in fig. 2 for different internal incidence angle. To investigate the coupling between the cavity mode and the intersubband transition, the cavity resonnance is tuned across the intersubband one by varying the angle of incidence. The anticrossing behaviour of the absorption peaks reveals the polariton dispersion. One can note that these features are still clearly observable at room temperature. The relative Rabi splitting was observed to be about 33 meV for the 10 μm sample and 31 meV for the 15 μm one.

The resulting ratio of Rabi to intersubband transition energy

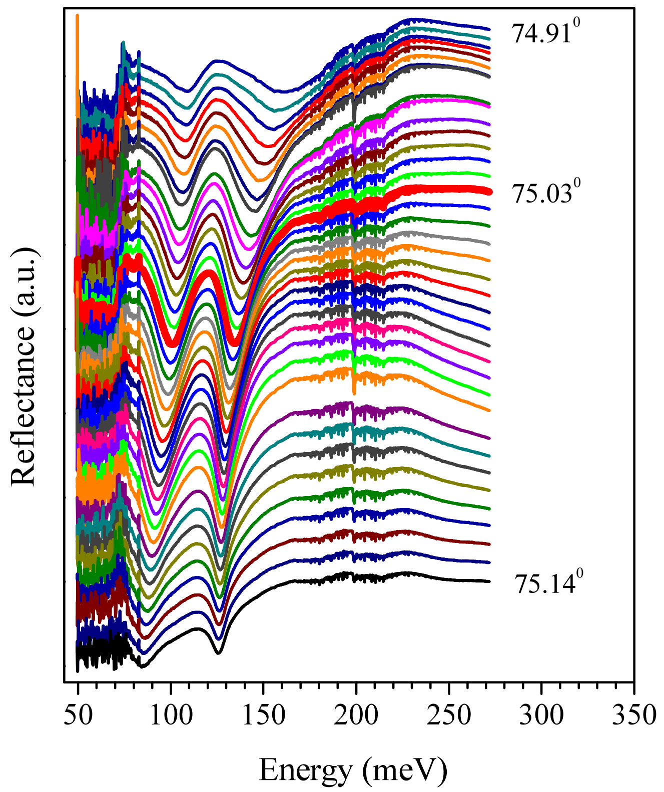

Fig. 2. Reflectance of the microcavity sample for different angles of incidence in TM polarization at 4K.

are record values (14% and 15%) for any strongly-coupled solid state systems [4]. This ratio can still be increased by choosing higher values of doping level inside the wells. This enhanced magnitude of the ratio should be of great interest for the achievement of the unprecesented *ultrastrong coupling* regime of light-matter interaction.

References

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