Light-matter coupling in semiconductor microcavities: excitons, exciton-polaritons and two-dimensional electron gas.

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The research on light-matter interaction touches the nature of the most fundamental physical processes. Our work was stimulated by recent discoveries on exciton-polariton quantum fluid that show many spectacular phenomena (Bose-Einstein condensation [1], superfluidity [2] and strong correlations in microstructured cavities [3]).

In this work we investigate properties of light –matter interaction in two-dimensional semiconductor microcavities. Inside a microcavity, in a maximum of the electromagnetic field, we place a single (SQW) or multiple (MQW) quantum wells. We study interactions of photons with excitons created in SQW or MQW, also in the presence of a two-dimensional electron gas (2DEG).

The semiconductor microcavities were grown by the molecular beam epitaxy and consist of GaInAs SQW or MQW sandwiched between GaAs/AlAs distributed Bragg reflectors (DBRs). In same heterostructures for high concentration of 2DEG the QW barriers were Si doped. To fully determine properties of the heterostructures we constructed special experimental setup where the angular emission of polaritons was investigated by optical microscopy methods at liquid-helium temperature and magnetic field up to 5T. The observed polariton dispersion (energy – wavevector dependence) provides us the information about the strength of the light-matter coupling. Based on a two-level system model [4] we determine the interaction energy in our structures.

In undoped cavities we observe different regimes of the light-matter coupling with the strength increasing from weak to strong. At the weak coupling, the observed phenomena can be explained by the Purcell effect; at the strong coupling exciton-polaritons are formed with a characteristic avoided crossing of the exciton and photon dispersion. We investigated many samples with different exciton and photon linewidth. We observed that the strength of the coupling strongly increases when the emission linewidth of the coupled oscillators (exciton and photon) are of the same order. In the samples with very high cavity finesses no coupling was observed if the exciton line was one order of magnitude broader than the cavity photon mode. The strong coupling regime was reached when the photon cavity was on purpose broadened to match the exciton linewidth.

We discuss also the possibility of a strong coupling in a much complex case when the excitons are perturbed by the presence of a 2DEG. We expect that the excitons from the Fermi edge would strongly couple to the photon field in the cavity. In this work we demonstrate the Purcell effect on 2DEG placed in a microcavity. When the magnetic field is applied, the 2DEG emission splits into Landau-levels and strongly narrows at higher fields.

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