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QUANTUM STATISTICAL PROPERTIES OF EXCITON POLARITONS IN MICROCAVITIES

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Although semiconductor electrons and holes are fermions, the exciton – an electron and a hole bounded by the Coulombic potential – behaves approximately as a boson at low exciton density. When the exciton couples to a photon (exciton-polariton), the composite particle is also bosonic. It is well known that the bosonic nature of a particle leads directly to quantum statistical effects such as Bose-Einstein condensation and stimulated emission.

The purpose of this experiment is to realize final state stimulation of exciton-polaritons in a microcavity quantum well sample. We can expect to achieve final state stimulation via a scattering process involving lower and upper polaritons. The scattering process starts with two nearly exciton-like lower polaritons created at large, and opposite, in-plane momenta, and results in an upper and lower polariton created, both at zero in-plane momentum (in order to satisfy conservation of momentum and energy). From the rate equations of this scattering process, we expect that the final state upper polariton intensity should exhibit a quadratic dependence on the pump which initially created the two exciton-like lower polaritons. Furthermore, the upper polariton intensity should scale linearly with an additional probe beam, which serves to stimulate population at the lower polariton at zero in-plane momentum.

In the pump-probe experiment, we use monochromatic, single-mode lasers for the pump and probe beams. The pump laser is incident on the sample at an angle of 51° from the normal direction, and the probe laser is incident on the sample in the normal direction. The large angle of the pump is sufficient to create exciton-like lower polaritons with large in-plane momenta, as described above.

In the upper polariton luminescence, we observe an upper polariton population that is enhanced by both the pump and probe. The fact that this population has some linewidth means that the process is not four-wave mixing, since in that case, we would expect to see a very narrow linewidth (defined by the pump and probe beams), rather than the full linewidth of the polariton. The measured constancy of the center wavelength of the upper polariton throughout this experiment indicates that the polariton has not collapsed (we have not exceeded the Mott density). We have measured the reflectivity simultaneously with the emission, and because the normal mode coupling does not collapse, it confirms that we are in the linear regime. Furthermore, we observe a resonance behavior of the upper polariton intensity as a function of pump wavelength, centered on the exciton wavelength, that is consistent with exciton-exciton scattering.

We observe a quadratic dependence of the intensity of the luminescence of the upper polariton state, as a function of pump power, at a fixed probe power. In the low power limit, we observe a background level of spontaneous scattering. The dependence of upper polariton intensity versus pump power asymptotically approaches slope 2, which is what we would expect in the case of stimulated scattering. Furthermore, we observe a linear dependence of the fitted quadratic component of the UP intensity as a function of probe power.

These measurements are consistent with predictions from the rate equations for stimulated scattering of exciton-polaritons.