Polarization dynamics of microcavity polaritons: Three excitation regimes

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We present a study of angle-, time-, and polarization-resolved emission from a II-VI semiconductor microcavity as a function of excitation power. The measurements were performed at 5 K. The emission was excited by a circularly polarized beam from a 2 ps pulsed Ti:Al_2O_3 laser and detected and time-resolved with a synchroscan streak camera with overall time resolution of 10 ps.

Three excitation power regimes have to be distinguished: (i) a linear regime, where the emission intensity depends linearly on excitation power; (ii) a non-linear regime, where the bosonic character of polaritons leads to final state stimulation, which in turn results in a superlinear dependence of emission intensity on excitation power; and (iii) a saturation regime, where the exciton transition is bleached and the strong coupling between excitons and photons is lost.

The dispersion curves of the lower- and upper-polariton branches are obtained from the emission energies at different angles with respect to the normal of the structure. Here, we concentrate on the behavior of the lower polariton branch at negative detunings. This transition exhibits a doublet structure, which is clearly resolved in the nonlinear regime, where the emission lines become narrower, while in the linear and saturation regimes the broadening of the lines hinders their separation.
We define the polarization as $P = \frac{I^+ - I^-}{I^+ + I^-}$, where $I^\pm$ denote emission intensities co- and cross-polarized to the excitation beam, respectively. In the linear regime the optical orientation of excitons is transferred to the final k=0 polariton state, resulting in an initial value of the polarization of +20%, which vanishes in 30-40 ps. In the nonlinear regime, the time integrated polarization is strongly dependent on the k vector. For $k \approx 0$ the polarization is negative. Increasing k, the polarization increases and becomes positive at k vectors corresponding to the relaxation bottleneck. We find that this polarization is related to a spin splitting of the lower polariton: at $k \approx 0$ the cross-polarized component has a lower energy than the co-polarized one. The splitting is of the order of 300 μeV, decreases with increasing k and vanishes at the bottleneck. In the saturation regime the polarization values become smaller, but the qualitative behavior remains the same as in the nonlinear regime.

Furthermore, above the stimulated emission threshold, we observe strong temporal oscillations of the emission intensity. The period of these oscillations is 28 ps, independent on k vector and excitation power within the accuracy of our experiments. Besides the intensity oscillations, we also detect polarization oscillations with the same period. The change in the degree of polarization amounts to 80% in a time of 65 ps. These oscillations remain also in the saturation regime, although the polarization amplitude is smaller.