Investigation of polariton-polariton interactions in monolayer $MoSe_2$

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Owing to their giant binding energy and versatile excitonic transitions, lamellar semiconductor materials such as hexagonal boron nitride or transition metal dichalcogenides (TMDC) are technologically appealing potential building blocks for photon-based quantum circuits. It was recently shown that they can exhibit quantum dot like behavior and they could thus be used to manipulate light down to the quantum level. Another approach to do so is to harness the two-body interaction between excitons propagating freely in the plane and exploit it within an optical cavity. Provided the interaction is strong enough, the light can be manipulated at the quantum level without the need for quantum dot like confinement. Proof of principle demonstration in Arsenide based materials have shown the feasibility of this approach [1] but in this case the small binding energy forbids room temperature applications. We have thus started to explore this strategy, known as polariton quantum blockade, using monolayer of TMDC. We study a single layer of $MoSe_2$ in the strong-coupling regime with the photonic resonance of an optical microcavity. We characterize quantitatively the magnitude of the two-body interaction between exciton-polaritons by optical micro-transmission spectroscopy. Upon increasing the optical excitation power, we observe a strongly non-linear behavior as a result of the interactions (see Figure). Eventually, the polariton gap closes at maximum power. This indicates that the microscopic mechanism governing the interaction is dominated by saturation of the electron-hole density of states, rather than by Coulomb interaction. We also find an unusual spin anisotropy of the interaction. These results are significantly different from semiconductor materials better known in this context, such as Arsenides or Tellurides and open up new perspectives for the manipulation of light using excitons in TMDC.

References

[1] A. Delteil et al. Nature Materials, 18 (2019) 219. G. Munoz Matutano et al. Nature Materials, 18 (2019) 213

Figures

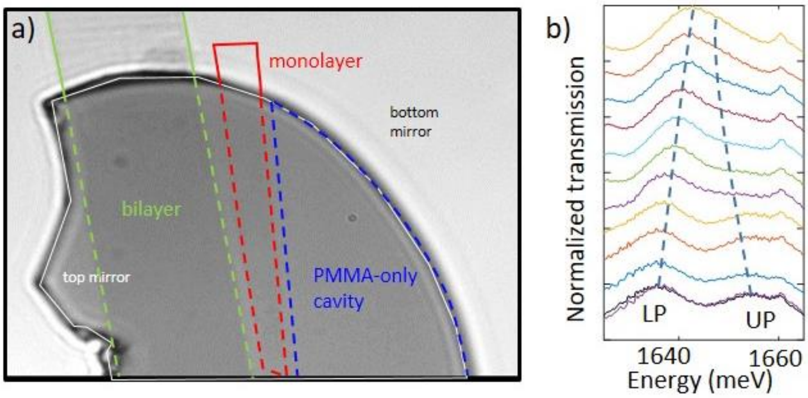

Figure 1: Non-linear polariton transmission in a TMDC monolayer. Optical image of the microcavity with the detail of the different parts (a). (b): Evolution of the transmission spectrum as function of excitation intensity (from bottom, low power, to top, high-power). We observe a closing of the polariton gap, i.e. the separation between the lower (LP) and upper (UP) polariton branches.