Observation of enhanced interactions between dipolar polaritons

Hyang-Tag Lim[1,2], Emre Togan[1], Stefan Faelt[1,3], Werner Wegscheider[3], and Atac Imamoglu[1]

[1] Institute of Quantum Electronics, ETH Zurich, CH-8093 Zurich, Switzerland

[2] Center for Quantum Information, Korea Institute of Science and Technology (KIST), Seoul, 02792, South Korea

[3] Solid State Physics Laboratory, ETH Zurich, CH-8093 Zurich, Switzerland

Abstract

We present a substantial increase in interaction strength between dipolar polaritons as the size of the dipole is increased by tuning the applied gate voltage. Here, we use coupled quantum well structures embedded inside a microcavity where coherent electron tunneling between the wells creates the excitonic dipole. The factor of 6.5 increase in the interaction-strength-to-linewidth ratio that we obtain indicates that dipolar polaritons could constitute an important step towards a demonstration of the polariton blockade effect, and thereby to form the building blocks of many-body states of light.

Realization of a strongly interacting photonic systems is one of the essential issues in quantum optics. In solid-state systems, exciton-polaritons in micro-cavities, consisting of a cavity photon and a quantum well exciton, have interactions based on short-range exchange interaction between direct excitons. These interactions have lead to manifestation of a number of intriguing collective phenomena such as formation of spontaneous coherence, observation of vortex-antivortex pairs and dark solitons, and realization of polariton Josephson effect. However, a mean field approach has been successful to describe all these observations accurately. Increasing interactions between polaritons further is crucial to explore physics beyond mean-field description and to explore a new regime of strongly correlated photons.

One way to enhance interactions between polaritons is to exploit polaritons with a permanent dipole moment. In a coupled quantum well system, an indirect exciton which consists of an electron in one quantum well and a hole in the other quantum well, has a permanent dipole moment along growth direction due to the separation of electron and hole wave functions. By embedding a coupled quantum into a micro-cavity, dipolar polaritons can emerge as elementary optical excitations when direct excitons in a quantum well are strongly coupled to both micro-cavity photons and indirect excitons [See Fig. 1(a)]. A number of studies have shown that interactions between polaritons can be enhanced by increasing the size of dipole moments of polaritons, or alternatively, increasing the indirect exciton content.

In this presentation, I will report that interaction between dipolar polaritons are substantially increased by increasing size of the dipole moment of the polaritons [1]. In our structure, one can tune the dipole size of dipolar polaritons by tuning the applied gate voltage, which controls growth directional electric fields. We observed factor of 6.5 enhancement in the interaction-strength-to-linewidth ratio [See Fig. 1(b)]. Based on the results, we believe that dipolar polaritons could be used to demonstrate a polariton blockade effect and thereby form the building blocks of many-body states of light.

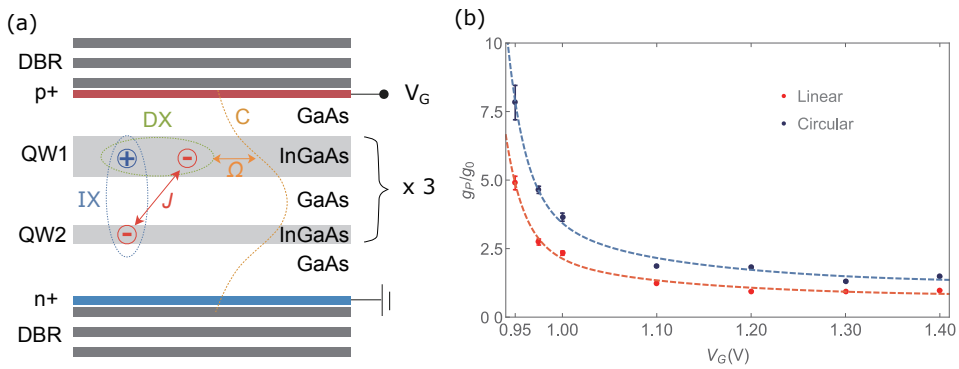

Figure 1: (a) Schematic of the sample structure. (b) Changes in polariton interaction strength g_{P} as a function of V_{G} for linearly and circularly polarized input pump beams, respectively. See Ref. [1] for details.

[1] E. Togan, H.-T. Lim, S. Faelt, W. Wegscheider, and A. Imamoglu, *Enhanced Interactions between Dipolar Polaritons*, Phys. Rev. Lett. **121**, 227402 (2018).