Light-enhanced dipolar interactions between exciton polaritons

Yasufumi Nakano, **Olivier Bleu, Brendan C. Mulkerin, Jesper Levinsen, Meera M. Parish**

School of Physics and Astronomy, Monash University, Victoria 3800, Australia
ARC Centre of Excellence in Future Low-Energy Electronics Technologies, Monash University, Victoria 3800, Australia

To achieve strong interactions between exciton polaritons is a current outstanding challenge. A promising route towards enhancing the polariton-polariton interactions is to exploit excitons with long-range dipolar interactions—most notably, spatially indirect interlayer excitons [1]. However, the challenge is to maintain a strong coupling to light while supporting dipole-dipole interactions, since a large dipole moment necessarily requires a sizeable electron-hole separation, which renders the exciton state optically dark. Hybrid interlayer excitons [2,3] have thus emerged as an appealing candidate for dipolar polaritons (dipolaritons), since they inherit a strong oscillator strength from the intralayer excitons, while acquiring a permanent dipole moment from the interlayer exciton [Fig. 1(a)]. Experiments have already observed the formation of dipolaritons in bilayers [4-7]; however, there is currently a lack of theory that can describe the significant enhancement of interactions reported in both GaAs-based quantum wells [5] and transition metal dichalcogenides [6,7].

We consider the scenario of excitons in a semiconductor bilayer that are strongly coupled to cavity photons, leading to the formation of dipolaritons. Using a realistic pseudopotential for the dipolar interactions, we exactly determine the scattering between dipolaritons [Fig. 1(b)], accounting for the hybridization between interlayer and intralayer excitons. We show that the light-matter coupling enhances the interactions between dipolaritons by forcing excitons to scatter at energies that would otherwise be forbidden in ordinary exciton-exciton collisions. Furthermore, we show that this light enhancement is sensitive to the dipole moment and is larger for long-range dipolar interactions than for short-range intralayer interactions. Our results reveal the role of dark exciton states in dipolariton interactions as well as the optimal bilayer properties for achieving strong interactions, which are crucial for quantum photonic applications.

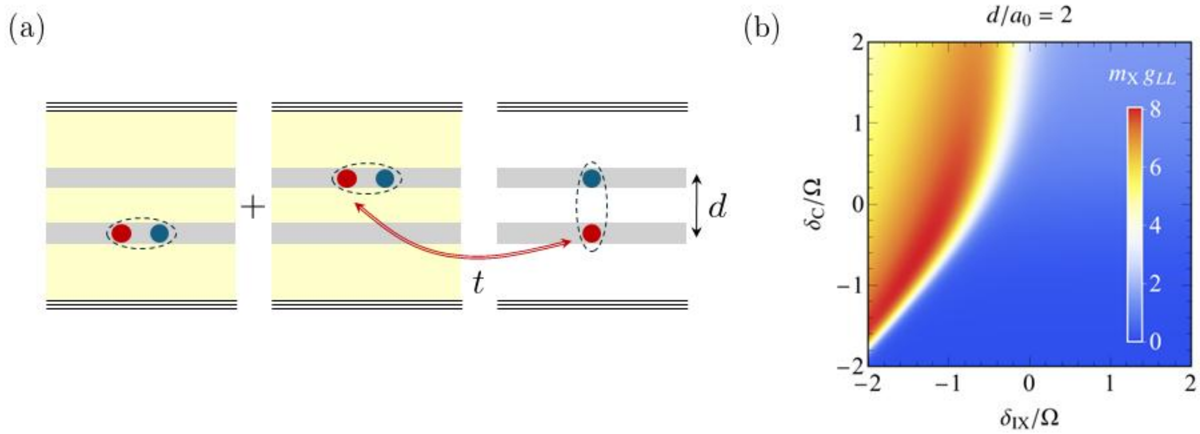

Figure 1: (a) Schematic of the dipolariton in a bilayer. The bright superposition of the direct excitons DX1 (left) and DX2 (center) is coupled to the cavity photon (yellow region), while the DX2 hybridizes with the indirect exciton IX (right) via tunneling t of the hole (red). The IX dipole moment is proportional to the layer separation d. (b) Density plot of the LP-LP interaction constant at $d/a_0 = 2$.

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*Email: Yasufumi.Nakano@monash.edu