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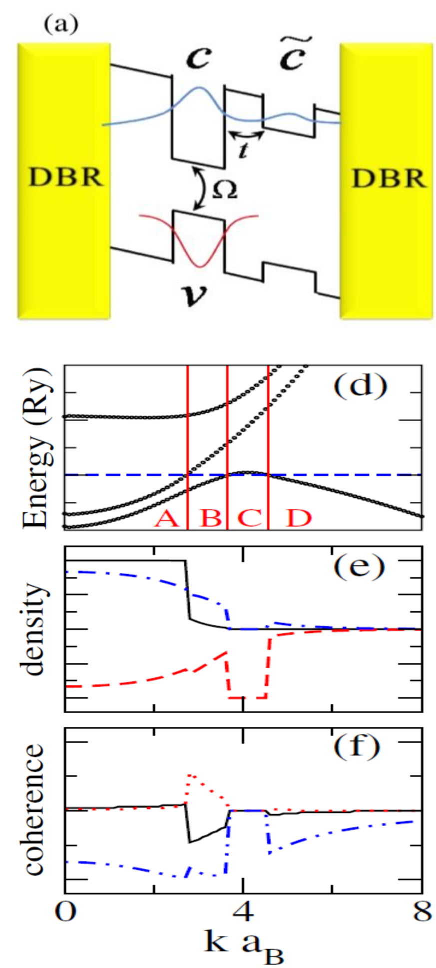
Theoretical Condensed Matter Physics

We investigate theoretically various superfluid phenomena using mainly mean-field theory in describing the many body effect. The systems we consider generally fall into three catogories: **(a) Superconducting effects in exciton systems (Fig. 1):** We identify the possible excitonic condensation states in equilibrium in different systems including semiconductor bilayer, quantum Hall bilayer, as well as novel materials including graphene bilayers. These studies enable us to suggest possible exciton condensate, preferably at high temperature, which might shed light on high temperature superconducting device. **(b) Superfluid of various exciton polaritons (Fig. 2) :** Exciton polariton is the new quasiparticle of exciton and photon. In tackling such systems, we used two approaches in two different pictures: the Bosonic and the Fermionic picture for exciton. The former is more traditional for this polariton and the exciton polariton as a whole is treated by Gross-Pitaevskii equation. The Fermionic approach is newly developed by us in collaboration with the group in University of Texas at Austin and in Stanford. This approach in particular allows us to inspect the electron and hole degree of freedom in the exciton polariton, which is essential for electrical transport of exciton polariton. **(c) Nonlinear Optics and quantum optics:** We study the nonlinear optics not only for the visible light but also in the plasmon system. In this categories the emphasis is on the photon component. We find that the fundamental properties of light, e.g. the absorption spectrum can be vastly altered by the coupling to the matter.

Fig. 2



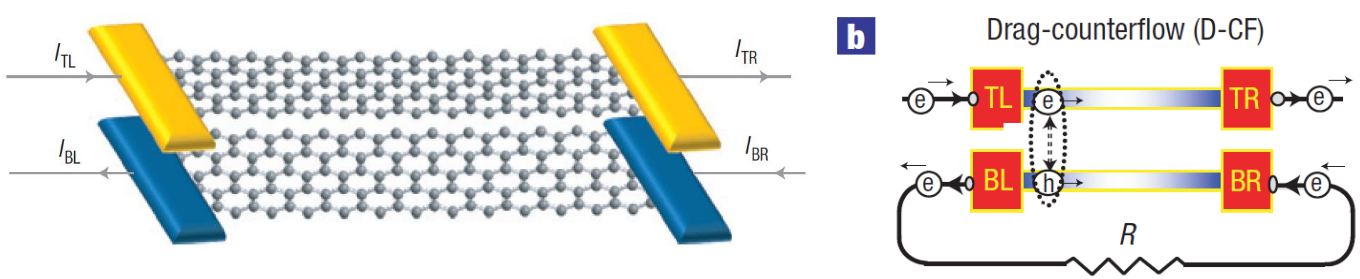


Fig. 1