Quantum cooperative phenomena in photoexcited insulators: Exciton Mott transition and electron-hole pair condensation

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We study theoretically quantum cooperative phenomena in "electron-hole (e-h) systems," which are photoexcited states of solids, composed of electrons in a valence band and positive-charged holes (whose number is identical to that of electrons) in the valence band. In the lower-density regime, an electron and a hole form a quasi-bosonic bound state "exciton," resulting in an insulating exciton gas phase. In the higher-density regime, excitons break to electrons and holes due to the screening and the Pauli blocking, and the metallic "e-h plasma" appears. The transition between these two phases is called the "exciton Mott transition," which is investigated with the dynamical mean-field theory (DMFT) and with the slave-boson mean-field theory for the high-dimensional e-h Hubbard model [1]. In lower temperature, the bosonic exciton gas can be turned into the Bose-Einstein condensed (BEC) phase; on the other hand, the fermionic e-h plasma may be condensed to a superconducting-like state (e-h BCS state). We discuss relation between these two condensates using the self-consistent t-matrix and local approximations [2]. At the Conference, we will mention also lower-dimensional cases, where the biexciton crystallization is expected [3]. We shall also compare the e-h systems with other physical systems, e.g., plasmas, cold atoms, and hadron systems.

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