Stability of an ensemble of excitons in a quantum degenerate regime in a bulk semiconductor of Cu_2O - Search for Bose-Einstein Condensation of excitons

Kosuke Yoshioka and Makoto Kuwata-Gonokami

1Department of Physics, Graduate School of Science, The University of Tokyo, and CREST-JST, 7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-0033, Japan
2Photon Science Center, Graduate School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-8656, Japan

At low temperature and high density, an ensemble of electrons and holes is predicted to form a Bose-Einstein condensate (BEC) of excitons: quasi-bosons of electron-hole pairs. The observation of an exciton BEC has been eagerly sought in the past half-century. The electron-hole system is in nature a complex many-body quantum system, since electrons and holes are very light particles with strong Coulomb interactions. Therefore it is a non-trivial question whether nature chooses the exciton BEC as the ground state of electrons and holes. Various systems have been examined in bulk [1-3] and two-dimensional semiconductors [4,5]. In a single crystal of Cu_2O, the 1s paraexcitons, pure spin triplet excitons, have been a prime candidate for realizing three-dimensional BEC. The large binding energy and long lifetime enable preparation of cold excitons in thermal equilibrium with the lattice being decoupled from the radiation field. By using the excitonic Lyman transitions, from 1s to np states, we can visualize the optically silent paraexcitons. Recent systematic experiments revealed that the inelastic collision cross-section of 1s paraexcitons diverges when the temperature is lowered, as a universal quantum mechanical feature of cold s-wave inelastic collisions as shown in Fig.1. [6] This process severely limits the conditions to accumulate excitons to a quantum degenerate regime above the liquid helium-4 temperature. On the other hand, the high density super-cooled excitons can be directly generated by the resonant two-photon transition using phase manipulated pulses.[7] We confirmed the robustness of the excitons at least up to the density of 10^{16} cm^{-3}. These results imply that the exciton BEC phase could be observed at moderate density if we cool the excitons below 1 K. In this presentation, we will update the current status of our search for BEC phase of 1s paraexcitons under the presence of the strong inelastic collision process[8].

Fig. 1 Inelastic scattering cross section of 1s paraexcitons in Cu_2O as a function of temperature. [6]

References

This work was supported by Grant-in-Aid for Scientific Research on Innovative Area 'Optical science of dynamically correlated electrons (DYCE)' 20104002.