Cold excitons in a quantum degenerate regime

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Collective quantum mechanical phenomena such as superfluidity and superconductivity are observed for particles at high density and low temperature. These collective effects can also take place in optically manipulated materials through a precise control of light-matter interactions. In particular, photo-generated electrons and holes in semiconductors provide a unique opportunity to examine macroscopic quantum phenomena such as the crossover from quantum degenerate bosonic ensembles (Bose-Einstein condensate states of excitons) to Fermi-degenerate electron-hole ensembles.

The 1s excitons of the yellow series in Cu_2O are the most promising candidate to demonstrate experimentally exciton BEC. Much effort has been devoted to this topic using 1s para-excitons, which have completely parallel electron-hole spin states and an extremely long lifetime. However, the dynamics of para-excitons is not well understood yet since there is no direct and sensitive method for their detection. We developed a time resolved mid-infrared pump and probe spectroscopy technique to detect excitons by measuring the absorption associated with internal excitonic transitions (1s to np) [1,2]. In combination with a phase space compression scheme [3] of pulsed two-photon excitation of ortho-excitons [4], we successfully generated super-cooled ortho excitons and observed excitonic Lyman series transitions from 1s to np ($n = 2, 3, 4, 5$) states [5]. We obtained information on the wavefunction of the lowest 1s exciton state which enables evaluation of density and temperature of para-excitons. We also developed CW laser-based excitonic Lyman spectroscopy to examine the para-exciton dynamics into a longer timescale and determined the lifetime and collision induced loss parameters in a steady state regime [6]. In this talk, novel aspects of collective quantum phenomena obtained from a series of experiments will be discussed, including recent work on para-exciton trapping in a strain potential and high density exciton generation using shaped pulse two-photon excitation [7].

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