論文の内容の要旨

PHOTOLUMINESCENCE OF HIGH DENSITY EXCITON POLARITON CONDENSATES

（高励起領域における

励起子ポラリトン凝縮体のフォトルミネッセンス）

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Bose-Einstein condensation (BEC) is a phase transition where a macroscopic number of bosonic particles occupy the same quantum state. In the last two decades, a large number of bosonic quantum degeneracy phenomena have been demonstrated experimentally. The first was the achievement of BEC of cold atomic gases in 1995 leading to a Nobel Prize. This was followed by the observation of BEC with exciton-polaritons, magnons, and photons. BEC physics attracts the great attention of physicists because it brings quantum mechanics, usually only observable in the microscopic world, into the macroscopic world.

In this thesis we focus on exciton-polaritons, which are half-matter, half-light quasi-particles, originating from the strong coupling of cavity photons and quantum well excitons in a semiconductor microcavity. In exciton-polariton systems, particles need to be continuously pumped due to their short lifetime of the order of picoseconds. This open-dissipative nature of the system brings out the new aspect to traditional atomic BEC systems: the gain and loss of the condensate can no longer be ignored. From an experimental point of view, the photoluminescence (PL) gives access to direct information of the condensate wavefunction, giving a unique opportunity to directly study various properties of the system.

At high density, it has been a controversial issue of whether exciton-polariton BECs would undergo a crossover to photon lasing based electron-hole plasma, or an electron-hole BCS-like phase. Until recently, exciton-polariton BECs were only experimentally possible at relatively low density regimes due to loss of strong coupling when pumped to high densities. Recently, in our group we have been able to achieve strong coupling in a high density regime. This has given us the opportunity to study the various characteristics of exciton-polariton BECs at high density for the first time. At high density, the weakly-interacting bosonic gas picture that is usually used to model exciton-polaritons becomes invalid due to phase space filling effects. This requires an alternative theory in order to calculate experimentally relevant quantities such as the PL.

Here, we discuss the property of the high density exciton-polariton BECs by calculating the photoluminescence spectrum from low to high densities. We present the following two calculation methods: (i)exact diagonalization of a closed exciton and cavity system and (ii)two-time correlation function evaluation of an open exciton and cavity system taking into account of reservoir pumping and cavity, exciton loss. The former is a relatively straightforward and phenomenological approach using the same Hamiltonian which has been used in previous studies to examine the high density model in a BCS regime. The latter is a more rigorous method for calculating the spectrum. We consider a model where the lower polaritons are pumped into the condensate and decay with the finite lifetime. We also consider effects of a time dependent pump, which more closely simulates the experimental situation. Despite the similarity of the model to resonance fluorescence, we find that the PL can give rather different characteristics to the well-known Mollow triplet spectrum.