論文の内容の要旨

EXCITON POLARITON CONDENSATION IN TWO DIMENSIONAL PERIODIC LATTICE POTENTIALS

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Bose-Einstein condensation was first predicted by Bose and Einstein, and originally defined as a macroscopic occupation of bosonic particles in the ground state. After first demonstration of nearly ideal BEC in 1995 with ultra cold atoms, many research have been done, such as BEC in two-dimensional system, such as observation of quantised vortex.

Exciton polaritons (EPs) are quasi-particles resulting from the strong coupling between (cavity) photons and (quantum well) excitons, and have been considered candidates for BEC in solids. Because of their photonic components, their mass is much lighter than that of atoms or excitons, which leads to much higher critical temperature for BEC in EP systems. The observation of BEC in EP systems has been reported by several groups}. Because Eps have short lifetime ~ps they decay from the system before reaching the thermal equilibrium. Although the continuous pump replenishes EPs in the system, they keep the phase coherence for a time longer than their lifetime. Therefore it has been considered dynamic condensation of EPs (though there are a few papers reporting thermal equilibrium).

In atomic systems, other research direction has attracted a large amount of attention in recent years,quantum simulation. The aim of quantum simulation is to give another way to investigating difficult quantum many-body problems by simulating quantum models experimentally on other quantum devices. This is advantageous because it is often easier to control the model parameters in the artificially fabricated device, rather than the original system being examined. Currently, most researchers working on quantum simulation have been working with cold atom systems and ion trap systems. For the quantum simulation, the implementation of models is an important task. In cold atom systems, 'optical lattice' opens a way to create periodic lattice potentials. On the other hand, in EP systems, several ways to create potentials have been suggested and demonstrated and weak one dimensional lattice potentials have been implemented.

In this thesis, we implemented several two dimensional lattice potentials in EP systems and explore the physics. Dynamic nature of EPs give us rich physics, especially the meta-stable condensation. In EP systems, it is easier for excited state condensations to be formed.

The periodic lattice potentials are implemented by deposited patterned thin metals. They change the boundary condition of photons and make the cavity resonance higher in energy, which leads to the potential walls for EPs ~200μeV. In two dimensional square lattice potentials, we have observed d-orbital wave condensates at M-points. The order parameter of this meta-stable condensation has 2D atomic d-orbital symmetry, and two-fold rotational symmetry against the trap center. We detect this d-orbital wave through the momentum space distribution, and the real field distribution. In two dimensional triangular lattice potentials, we observed several results indicating the formation of vortex-antivortex lattices, which originates from the single particle wave function of the meta-stable state at M-points. The polariton distribution in the momentum space and the real field distribution are promising for this peculiar superfluid.