Exciton-polariton Bose-Einstein Condensation

Yoshihisa Yamamoto[1,2], Shoko Utsunomiya[2], Hui, Deng[1], Chih-Wei Lai[1], Georgios Roumpos[1], Andreas Löffler[3], Sven Höfling[3], and Alfred Forchel[3]

[1] Edward L. Ginzton Laboratory, Stanford University, Stanford, California, 94305-4085, U.S.A.

[2] National Institute of Informatics, 2-1-2 Hitotsubashi, Chiyoda-ku, Tokyo 101-8430, JAPAN

[3] Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, GERMANY

An experimental technique of controlling spontaneous emission of an atom by use of a cavity is referred to as cavity quantum electrodynamics and has been extensively studied for atoms[1] and excitons[2]. Due to a strong collective dipole coupling between microcavity photon fields and QW excitons, a semiconductor planar microcavity features a reversible spontaneous emission or normal mode splitting into upper and lower branches of exciton-polaritons[3]. A metastable state of lower polariton at zero in-plane momentum (k=0) has emerged as a new candidate for the experimental study of Bose-Einstein condensation (BEC) in solids[4]. An exciton-polariton has an effective mass of four orders of magnitude lighter than an exciton mass, so the critical temperature for polariton BEC is four orders of magnitude higher than that for exciton BEC at the same particle density. An exciton-polariton can easily extend a phase coherent wavefunction in space through its photonic component in spite of crystal defects and disorders, which is known as a serious enemy to exciton BEC.

In this talk we will discuss the recent progress on the dynamic condensation experiments of exciton-polaritons. Quantum degeneracy at thermal equilibrium condition was achieved by using a cooperative cooling with two spin components, evaporative cooling with a weak lateral trap and a blue detuning regime[5]. The formation of a first order coherence (off-diagonal long range order) was confirmed by the Young's double slit interferometer[6] and the excess intensity noise (photon bunching effect) was observed by the Hanbury-Brown and Twiss interferometer[7]. The spontaneous spin polarization was confirmed at condensation threshold[8], and the Bogoliubov excitation spectrum was observed above threshold[9]. The Landau's criterion for superfluidity is satisfied with a critical velocity of $\sim 10^8$ cm/s. Finally the Bose-Hubbard model was implemented in a one-dimensional array of polariton condensates, in which the competition between a coherent zero state and pi state was observed[10].

References

[1] P. R. Berman, Cavity Quantum Electrodynamics (Academic Press, Boston, 1994)

[2] Y. Yamamoto et al., in Coherence and Quantum Optics VI, p.1249 (1989)

[3] C. Weisbuch et al., Phys. Rev. Lett. 69, 3314 (1992)

[4] A. Imamoglu et al., Phys.. Rev. A53, 4250 (1996)

[5] H. Deng et al., Phys. Rev. Lett. 97, 146402 (2006)

[6] H. Deng et al., Phys. Rev. Lett. 99, 126403 (2007)

[7] H. Deng et al., Science 298, 199 (2002); G. Roumpos et al., APS Meeting (March 2008)

[8] H. Deng et al, Proc. Natl. Acad. Sci. USA 100, 15318 (2003)

[9] S. Utsunomiya et al., Nature Physics (online published on August 1, 2008)

[10] C. W. Lai et al., Nature (London) 450, 529 (2007)