

Spontaneous coherence and kinetics of macroscopically ordered exciton state

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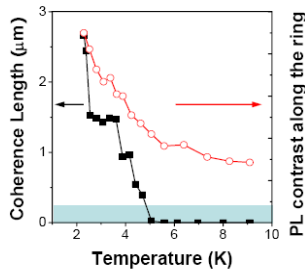
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Recently, a spatial photoluminescence (PL) pattern including internal and external exciton rings, localized bright spots, and the macroscopically ordered exciton state (MOES) was observed [1]. The external rings and localized spots are observed up to high temperatures, where the exciton gas is classical, and are attributed to exciton generation at the border between the electron- and hole-rich regions [2,3]. While the external ring is a classical object by itself it is the region where the coldest exciton gas is created: the external ring is far from the hot excitation spot and the excitons in the ring are formed from well-thermalized carriers. In contrast, the MOES - an array of beads with spatial order on macroscopic length - is a low-temperature state, which appears abruptly in the ring at temperatures below a few Kelvin, where the thermal de Broglie wavelength is comparable to the interparticle separation and the exciton gas is nonclassical. Here we report on the experimental study of coherence and kinetics of this cold quantum gas.

1. Coherence Length of Cold Exciton Gases

Spontaneous coherence is a basic property of condensed states, which can be described by spontaneous macroscopic occupation of a single mode, such as superconductors, superfluids, and atomic Bose-Einstein condensates (BEC). Spontaneous coherence was also predicted for exciton systems, namely it was predicted to



be a signature of exciton BEC. Here a Mach-Zehnder interferometer with spatial and spectral resolution was used to probe spontaneous coherence in cold exciton gases, which are implemented experimentally in the ring of indirect excitons in coupled quantum wells. A strong enhancement of the exciton coherence length is observed at temperatures below a few Kelvin. The increase of the coherence length is correlated with the macroscopic spatial ordering of the excitons. The coherence length reaches about 2-3 microns at the lowest temperature (1.5K). This corresponds to a very narrow spread of the exciton momentum distribution, much smaller than that for a classical exciton gas. (Ref. [4,5])

Fig. 1: The exciton coherence length (squares) and contrast of the spatial intensity modulation along the ring (circles) vs. T . The shaded area is beyond experimental accuracy.

2. Kinetics of the external ring, localized bright spots, and macroscopically ordered exciton state

The ring kinetics was studied by time-resolved imaging of the indirect exciton PL using rectangular laser excitation pulses (pulse duration was in the range 0.3-10 μ s, edge sharpness about 1 ns, repetition frequency 50-75 kHz). After the start of the excitation pulse, the external ring appears, expands, and eventually reaches its equilibrium size. After the laser switching off, the ring contracts and disappears. On the contrary, the localized bright spots expand and form the rings inside the external ring after the laser switching off. The ring expansion and contraction times were measured as a function of carrier densities. These times are on the order of 1 μ s. The emergence and decay of the MOES occurs over a time period on the order of 100 ns.

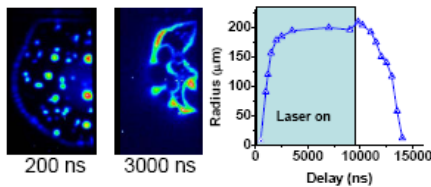


Fig. 2: (left two) snapshots of PL of indirect excitons. The time is respect to the end of laser pulse. (right) The radius of external ring vs. time.

This work is supported by NSF grant DMR-0606543, ARO grant W911NF-05-1-0527, and the Hellman Fund.

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