Dark lakes of cold dipolar exciton fluids

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Fluids of dipolar (or indirect) excitons offer an interesting test bed for studying emergent collective states of strongly interacting two-dimensional bosons in the presence of disorder. Exciton fluids hosted by GaAs-based coupled quantum wells (QWs) have been shown to exhibit a rich variety of many-body phenomena: gas-liquid transition, superfluidity, vortex formation, Mott insulator states, and Bose-Einstein condensation (BEC) [1]. The salient feature of the excitonic BEC state is its vanishingly weak optical emission, since the lowest-energy exciton state is spin-forbidden in GaAs heterostructures. Therefore, on the phase diagram of the exciton fluid, the density/temperature range in which darkening of the optical emission is observed, is expected to correspond to the condensation.

In this work, we explore the phase diagram of dipolar excitons confined in single wide GaN/AlGaN QWs. In these materials, many-body states may form at temperatures higher than in GaAs, because excitons are more robust. The giant built-in electric field along the QW growth axis makes excitons spatially indirect (Fig. 1 (a)), so that no external electric bias is required to induce exciton dipolar moment. By depositing metallic patterns on the surface of the sample, it is possible to efficiently trap excitons in the bare surface areas of the QW plane, see Fig. 1 (b). We have demonstrated, that electrostatic trapping prevents exciton fluid from fast radial expansion and dilution [2]. This allows us to study emission of the excitonic fluids tens of microns away from the laser excitation spot, in the excitonic "lake" (Fig. 1 (b)), at macroscopic thermodynamical equilibrium with well-defined temperature close to the sample temperature. The density of the thermalised exciton fluid can be controlled by changing the laser excitation power.

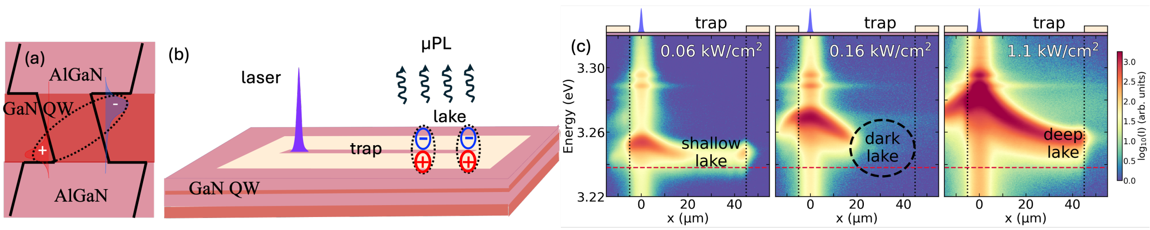

Figure 1: (a) Sketch of the GaN/AlGaN QW band diagram; (b) Artist view of the studied structure; (c) Color-encoded spectral map of the μPL intensity measured at T=8 K under three different excitation powers: below, above, and within power range required for the darkening. Red dashed line indicates zero-density exciton energy.

Our recent micro-photoluminescence (μPL) experiments under CW point-like excitation exploit this approach. We found that, at T< 15 K and excitation powers between two temperature-dependent critical values (Fig. 1 (c)), the emission of the excitonic fluid from the "lake" formed in the linear-shape trap fades out dramatically, as compared to either emission of the fluid excited below/above the critical power range, or the emission of the non-thermalised fluid created outside of the trap under the same excitation power. Time-resolved experiments confirm the dramatic reduction of the exciton fluid radiative rate at low temperatures and under powers within a specific, temperature-dependent range. We will discuss possible interpretations of this "darkening" in terms of collective quantum effects: either as the onset of the condensation into the lowest energy spin-forbidden state, or formation of a collective subradient state [3].

Acknowledgments

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References

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