NONLINEAR POLARITON EFFECTS IN PHOTONIC STRUCTURES BASED ON III-NITRIDES AND MONOLAYERS OF TRANSITION METAL DICHALCOGENIDES

Dmitry Krizhanovskii

Department of Physics and Astronomy, University of Sheffield, Sheffield S3 7RH, United Kingdom

Strong exciton-photon coupling in semiconductor microcavities and waveguides gives rise to formation of hybrid light-matter 2D quasiparticles, so-called polaritons. Giant Kerr-like optical nonlinearity arising from the excitonic component resulted in a number of remarkable observations: superfluidity of light, bright and dark solitons, vortices limited by interactions and continuum generation have been reported in GaAs-based systems[1,2]. Very recently weak antibunching (polariton blockade) has been also observed in 0D GaAs-based microcavities.

Here I focus on polaritons in photonic structures based on III-nitrides and monolayers of transition metal dichalcogenides materials (TMDC). While in GaAs exciton-polaritons exist at T up to 50-70 K the larger exciton binding energy in these materials makes polaritons stable at temperatures up to 300 K, which is potentially useful for applications utilizing strong optical nonlinearites. Moreover, the strong oscillator strength in TMDCs enables polaritons with just a single monolayer. Remarkable compatibility of TMDCs with various semiconductor/dielectric substrates also paves the way towards development of active nanophotonic devices of new generation.

Firstly, we investigated AlGaN waveguide with 20 embedded GaN quantum wells (QWs)[3]. Strong coupling between the waveguide photonic mode and QW excitons leads to formation of UV high-velocity polaritons emitting at ~350 nm and characterized by a Rabi splitting up to 90 meV. The resonant excitation of propagating polariton fluid with a strong laser pulse results in a significant energy broadening of the injected pulse from the initial 10 meV up to ~80 meV and spatial defocussing, which is associated with self-phase modulation, modulation instability and possibly Cherenkov radiation by bright polariton solitons[4]. The strength of polariton-polariton (exciton-exciton) interactions normalized to a single QW is found to be comparable to that in GaAs. The effects persist up to 300 K and to the best of our knowledge this is the first observation of nonlinear polariton fluids in GaN system.

In the second part of my talk I will present studies of nonlinear polaritons in microcavities and photonic crystals with an embedded monolayer of $MoSe_2$. Importantly, the strong Coulomb interactions give rise to very robust 2D trions (charged excitons) in TMDCs, the large oscillator strength of which enables formation of trion-polaritons at low electron density. This leads to very pronounced phase space filling effects resulting in giant trion-polariton nonlinearity comparable to or even stronger than that in GaAs polariton system. The trion-polariton nonlinearity is also found to be 1-2 orders of magnitude stronger than that measured for neutral TMDC exciton-polaritons[5]. I will also discuss the theoretical perspective of reaching strong polariton blockade using TMDC trion-polaritons.

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