International Workshop on Nanotechnology (Tnano20)
October 5 – 8, 2020, in Tbilisi, Georgia

PHASE TRANSITIONS AND EXCITON SUPERFLUIDITY IN DOUBLE LAYERS OF NOVEL TWO-DIMENSIONAL NANOMATERIALS

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This talk reviews the theoretical studies of the Bose-Einstein condensation (BEC) and superfluidity of indirect excitons in quasi-two-dimensional (quasi-2D) van der Waals nanomaterials such as transition metal dichalcogenide (TMDC) heterostructures and phosphorene. Indirect excitons are the Coulomb-bound pairs of electrons and holes confined to different parallel monolayers of a layered planar nanomaterial structure. The high-T superfluidity of the two-component weakly-interacting Bose gas of the A-type and B-type indirect excitons in the TMDC heterostructures is proposed [1,2]. The critical temperature and superfluid velocity of the indirect excitons in a bilayer phosphorene nanostructure is shown to be anisotropic, dependent strongly on the particular direction of the exciton propagation [3]. We propose to control of electron-hole superfluidity in semiconductor coupled quantum wells and double layers of 2D material by an external periodic potential [4]. The latter can either be created by periodic gates attached to quantum wells or the double layers of 2D material or by the Moiré pattern of two twisted layers. Treating the electron-hole pairing within the mean-field approach, we apply the tight-binding approximation of the single electron spectrum and study the effect of the additional periodic potential on the electron-hole plasma-superfluid transition. The electron-hole pairing order parameter as a function of the temperature, the charge carrier density, and the gate parameters are obtained by minimization of the mean-field free energy. The second order phase transition between superfluid and electron-hole plasma, controlled by the external periodic potential, is studied for various parameters.

References

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