Electronic properties and coherent phases in graphene and graphene structures

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Electronic properties and possible phases in graphene and bilayer graphene are discussed. The BCS-like pairing of electrons(e) and holes(h) due to their Coulomb attraction in two parallel, independently gated graphene layers separated by a barrier is considered. Despite the fact that electrons and holes behave like massless Dirac fermions, the problem of BCS-like electron-hole pairing in graphene bilayer turns out to be rather similar to that in usual coupled semiconductor quantum wells. The essential distinctions are due to Berry phase of electronic wave functions and different screening properties. The energy gap in one-particle excitation spectrum *vs.* interlayer distances and carrier concentrations is calculated. Influence of disorder is discussed. Weak and strong-coupling regime are discussed. Localized electron-hole pairs are absent in graphene, thus the behavior of the system *vs.* coupling is cardinally different from usual BCS-Bose condensate crossover.The e-h condensation in coupled graphene sheets can be observed through essential rise of e-h drag, Josephson-like phenomena etc.

One and coupled graphene layers in strong perpendicular magnetic field is considered. Magnetoexciton spectra and their effective magnetic mass in one and coupled graphene layers is studied in detail. The energy spectrum of collective excitations and quasi-condensation is studied. Composite fermion formation in graphene and bilayer graphene in strong magnetic field corresponding to 1/2 and 1/2 +1/2 Landau level filling and coherent state formation originated from composite fermions pairing are considered. Plasma oscillations and polaritons in graphene will be discussed.

Possible superconductivity of graphene is analyzed.

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