Experimental progress towards probing the ground state of an electron-hole bilayer by low-temperature transport

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Closely spaced two-dimensional electron and hole gases are of significant interest when the layer separation approaches the excitonic Bohr radius (~10nm in GaAs). The ground state phase diagram of such a system is anticipated to be rich, including an excitonic superfluid predicted over 30 years ago [1], a BEC-BCS crossover and density modulated phases including charge density waves and Wigner crystals [2].

Experimental realisation however, has proven extremely difficult. Only recently has it been possible to design independently contacted electrically generated electron-hole bilayers (EHBLs) where exciton formation is considered likely. Devices have reached carrier densities less than 5×10^{10}cm^{-2} in each layer and a separation of 10–20nm in a GaAs/AlGaAs based system [3,4]. In these EHBLs, the interlayer interaction can be stronger than the intralayer interactions.

In these devices, the interlayer interaction can be probed directly using the Coulomb drag technique. A current is passed in one layer, and momentum transferred to the other layer is detected as a voltage. Experiments have revealed that the Coulomb drag on the hole layer shows strong nonmonotonic deviations from the behaviour expected for Fermi-liquids at low temperatures [3,4]. Simultaneously, an unexpected insulating behaviour in the single-layer resistances (in a highly "metallic" regime with $\rho \ll h/e^2$) also appears in both layers despite electron mobilities of above ~10^6cm^{2}V^{-1}s^{-1} and hole mobilities above ~10^5cm^{2}V^{-1}s^{-1} [5]. Experimental data also indicates that the point of equal densities ($n=p$) is not special.

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