Crossover between strongly coupled and weakly coupled exciton superfluids

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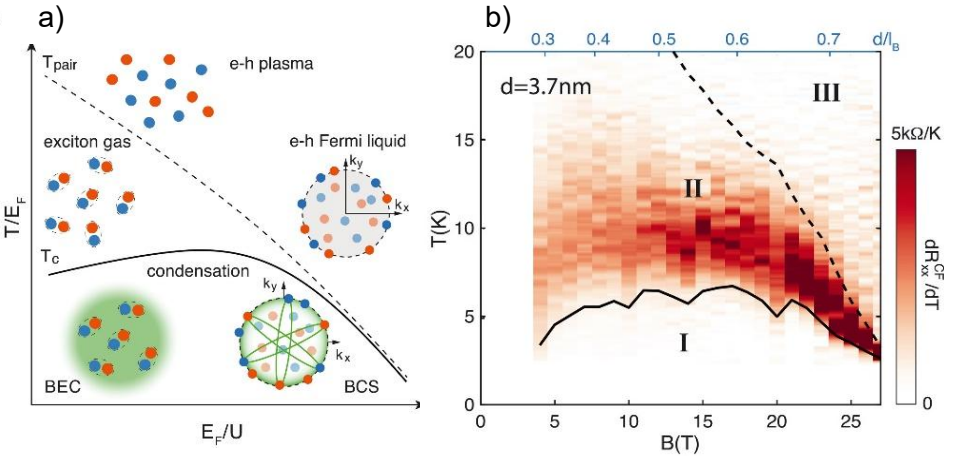
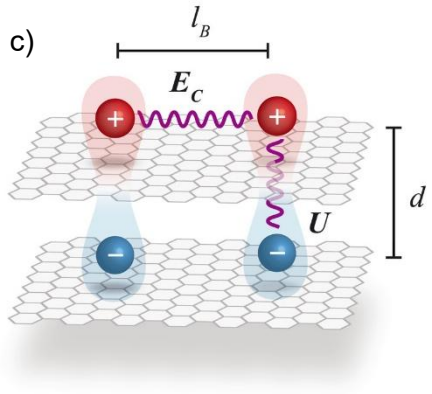
Condensation of paired fermions into a quantum ground state represents one of the most spectacular many-body effects in strongly interacting systems. Depending on the strength of the interactions, the paired fermions can be tightly bound – as in a Bose-Einstein Condensate (BEC) - or can be so large as to overlap with other pairs – as in Bardeen Cooper Schrieffer (BCS) pairing. *Understanding that these two BEC and BCS pairing limits represent a continuum in a single phase diagram is one of the great theoretical achievements over the past century*. Although well established in ultracold Fermi gas experiments, *observation of BEC-BCS crossover in electronic systems has remained challenging owing to the limited ability to tune electron interactions in solid sate materials*.

MagLab users studied graphene double layers separated by an atomically thin insulator. Under applied magnetic field, electrons and holes couple across the barrier to form bound magneto-excitons. *Using temperature-dependent Coulomb drag and counterflow current measurements in bilayer graphene, researchers were able to continuously tune the magneto-exciton condensate through the entire phase diagram from strong to weak* coupling. This tunability of fermion pairing in a solid-state device enables the investigating of fermion condensates of various pairing strengths and may lead to an improved understanding of the connection between the BEC-BCS crossover and unconventional superconductivity.



(a) Theoretical phase diagram for exciton condensates spanning strong to weak coupling regime. (b) Magneto-transport data verifying the expected boundaries of the phase diagram



(c) Illustration of the quantum hall magneto-excitons in graphene double layers. Energy and length scales associated with exciton pairing in a graphene double-layer structure under a magnetic field can be widely tuned since the Interlayer Coulomb coupling *U* depends on the interlayer separation *d*, whereas intralayer Coulomb repulsion E_c is determined by the field dependent magnetic length l_B.

Facilities and instrumentation used: DC Magnet Facility, 31T resistive magnet

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