[QMS2020 invited talk]

Dirac Electron in a Partially Filled-Landau Level

Youngwook Kim

Department of Emerging Materials Science, DGIST
email: y.kim@dgist.ac.kr

In two dimensional electron systems (2DESs) within a magnetic field, the kinetic energy of electrons is quenched and Landau levels (LL) are gradually depopulated. Clean 2DESs host various correlation-driven ground states at partially filled LL such as fractional quantum Hall effect, charge density waves (CDW), and Wigner crystallization. These correlated-phenomena strongly depend on the orbital character of the LL the electrons at the chemical potential occupy. For example, in GaAs fractional quantum Hall states (FQHSs) which take an odd denominator are dominant in the lowest LL of quantum number $N = 0$. In $N = 2$, however, FQHSs are absent and instead CDW phases takes over the ground state. In $N = 1$ FQHSs and CDW phase coexist, and in addition a paired composite fermion state arises which results in an even-denominator FQHS. Recent experiments on ZnO/MgZnO have demonstrated a similar trend of ground states. In monolayer graphene, various correlated ground states have been predicted, however, only odd-denominator states have been observed and more generally experiments have focused primarily on the $N = 0$ and $N = 1$ LL.

Here, we present FQHSs in monolayer graphene which is encapsulated by thicker hBN layers that are additionally sandwiched between graphite. A variety of odd denominator FQHSs, as previously reported, are observed in $N = 0$ and 1. However, surprising is that robust four-flux FQHSs are clearly resolved instead of usual two-flux FQHSs at $N = 2$. Also, multiple incompressible even-denominator FQHSs are observed in $N =3$ without any additional odd- denominator FQHSs.

In twisted bilayer graphene, we observe unexpected signatures of interlayer coherence resulting in odd-integer quantum Hall states (QHSs) at a balanced density between the layers (e.g $\nu_{tot} = 1 = 1/2 + 1/2$). We attribute the emergence of these QHSs to spontaneous layer coherence driven by interlayer Coulomb interactions, which are tunable using the magnetic field and the layer carrier densities. At fixed field a phase transition from the layer coherent state to the layer incoherent state is induced upon increasing density. This phase transition weakens and finally vanishes with increasing magnetic field.