Spectroscopic evidence for a first-order transition to the orbital Fulde-Ferrell-Larkin-Ovchinnikov state

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A Cooper pair in a superconductor may be driven into a distinct state with non-zero total momentum when the time reversal symmetry is broken. Recently, a new type of finite momentum superconducting pairing, namely the orbital Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state, has been proposed in superconductors with strong spin-orbit coupling materials such as multilayer NbSe2. Experimental demonstration for this state is limited to resistance measurements, which is not enough to establish the full physical picture. In this talk, I will show the first thermodynamic evidence for the orbital FFLO state. A first-order phase transition from the Ising pairing to the orbital FFLO state in NbSe2 is directly observed. By carrying out tunneling spectroscopy measurements with atomically flat Van der Waals tunneling junctions, we discover a discontinuity in the superconducting gap value as a function of the in-plane magnetic field. The phase transition shows clear hysteresis behaviors when sweeping the magnetic field back and forth. The observation matches our theoretic calculation by taking into account the melting of the Josephson vortex lattice.