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Direction Controlled Coulomb Drag in Coupled One-Dimensional Quantum Wires[1]

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In a one-dimensional electron gas (1DEG) with sufficiently low density at low temperature, Coulomb interaction becomes so dominant that Wigner crystallization can occur. Wigner crystal (WC) is generally characterized by collective motion of electrons and strong incompressibility. Therefore, in the presence of an external electrostatic potential, electrons forming a WC do not contribute to microscopic screening and only respond rigidly, whereas those of a Fermi liquid (FL) freely move to screen the external potential and produce a correlation hole. In this work we show that the difference between WC and FL allows us to control the direction of Coulomb drag in coupled pairs of 1DEG wires, each having two 2DEG leads. We prepare parallel coupled pairs of quantum wires in a 2DEG defined by Schottky gates to study the current drag between the two wires. The distance between the two wires and the electron density in each wire are all tunable with gate voltages. We inject a constant current into one of the wires (drive wire) and measure the induced drag current (or voltage drop for $I_{drag} = 0$) in the other wire (drag wire). Electrons in the drive wire usually drag electrons in the drag wire in the same direction because momentum is conserved in Coulombic scattering between the wires. However, when the electron density in the drive wire is sufficiently low that the drive wire has charge inhomogeneity and the electrons in the drag wire are strongly correlated, i.e. at low density, high perpendicular magnetic field and low temperature, the direction of the drag current can be reversed. The sign reversal occurs only when the drive wire is adjacent to the boundary between the drag wire and its lead, and can be controlled by changing the geometry of the coupled wires. These behaviors can be modeled by electron pump from WC in the drag wire to its 2DEG lead, driven by particle-like electrons in the drive wire. The drive wire electrons induce a positive screening charge only in the FL lead, which attracts WC in the drag wire.

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