Coherent and Incoherent Current Drag in Coupled Quantum Dots

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When two mesoscopic regions are coupled by the Coulomb interaction, the current through a region induces the current through the other region, reflecting the correlated motion of electrons. This current drag was recently observed in a pair of double quantum dots (DQDs).[1] We theoretically study the current drag considering the coherent motion of electrons in a nonequilibrium situation and the dephasing effect by the phonon emission. The coherence of this system is an important issue to perform the two-charge-qubit operations for the quantum information processing.[2] We examine two DQDs (DQD1, DQD2) in parallel. The level spacing between the quantum dots in DQD1 (DQD2) is denoted by Δ_1 (Δ_2). A large bias is applied to DQD1, whereas no bias to DQD2. The current I_1 (I_2) through the DQD1 (DQD2) is formulated using the density matrix method. In the absence of phonon emission, the coherent motion of electrons result in a large drag current $\pm I_2$ when $\Delta_1 \approx \mp\Delta_2$ (quantum mechanical regime). The ratio of I_2/I_1 is determined by the Coulomb interaction between DQDs and tunnel coupling to the leads. When the phonon emission is dominant in the transport, the current drag is still observed by the correlated sequential tunnelings (classical regime), where I_2/I_1 is small. We examine the crossover between the two regimes to explain the experimental data.[1]

[1] G. Shinkai *et al.*, Appl. Phys. Exp. **2**, 081101 (2009).
[2] G. Shinkai *et al.*, Phys. Rev. Lett. **103**, 056802 (2009).