Coulomb Drag in Vertically-Integrated Quantum Wires

D. Laroche[1,2], G. Gervais[1], M. P. Lilly[2] and J. L. Reno[2]

[1] *Department of Physics, McGill University, Montréal, Canada*
[2] *Sandia National Laboratories, Albuquerque, USA*

One of the challenges quantum circuitry is facing is to understand the mutual interactions between circuit elements closely-packed at the nanoscale. Due to the long-range nature of Coulomb interactions, driving an electrical current in such a circuit may have profound influences on the charge distribution of nearby circuit elements. To address these questions, we have fabricated independently-contacted and vertically-coupled quantum wires with a large degree of tunability and control over their electronic density, making them especially suited to study one-dimensional Coulomb drag between wires separated by only a few tens of nanometres. The wires are fabricated from a GaAs/AlGaAs double quantum well heterostructure with a 15 nm barrier separating the quantum wells.

We report here Coulomb drag measurements where both positive and negative signals are observed as the sub-band occupancy of each quantum wire is varied [1]. Peaks in the positive Coulomb drag signal are observed concomitant with the opening of 1D sub-bands in either wire. Negative Coulomb drag is also observed in two regimes: one at low electronic density when the drag wire is close to or beyond depletion, and one at a higher electronic density when the drag wire has one or more single 1D sub-band occupied. While both the positive and the low-density negative one-dimensional Coulomb drag regimes had been previously observed in horizontally-coupled quantum wires with a larger (~ 100 nm) inter-wire separation [2], we report here the first observation of negative one-dimensional Coulomb drag at high electronic density, *i.e.* when the drag wire is conducting.

The observation of a high-density negative Coulomb drag signal challenges the standard momentum-transfer model for Coulomb drag. However, negative Coulomb drag has been predicted to occur from a charge-fluctuation induced Coulomb drag model in asymmetric mesoscopic circuits[3, 4]. In addition, a fluctuation-induced model also predicts the presence of peaks in the positive Coulomb drag regime concomitant with the opening of 1D sub-bands, which is consistent with our observations. In order to assess the consistency of this fluctuation-induced model for Coulomb drag over the whole phase-space of the Coulomb drag measurement, the temperature dependence of drag signal in the various regimes will be presented, as well as the expectations from Luttinger liquid theory.

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