Electrical control of coupling characteristics in vertically-stacked double-quantum-point-contact

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A coupled double quantum-point-contact (D-QPC) has received much interest as fundamental quantum nanostructure where charge and spin interactions play an important role. Here, we fabricated vertically-stacked D-QPC starting from bilayer (20-nm GaAs/2.2-nm $Al_{0.33}Ga_{0.67}As$/20-nm GaAs) quantum well. As schematically shown in Fig. 1, the fabricated D-QPC has a pair of split Schottky gates and a fine center gate. Si-doped GaAs substrate operates as a back gate. In this D-QPC, we can control electron density independently in the upper and lower QPCs by using biases applied to the center and back gates. The bias applied to the split Schottky gates is used to constrict the one-dimensional (1D) channel.

The fabricated two split gates originally have some asymmetry in depletion spreading probably arising from a difference in etching depth and surface condition before Ti/Au gate deposition. We can thus realize asymmetrically confined D-QPC when equal biases are applied to the two split gates. Figure 2(a) shows transport characteristics obtained for such a condition. To clarify the 1D-subband diagram, transconductance data are grey-plotted as a function of V_{bg} and $V_{sgR}=V_{sgL}=V_{sg}$, where V_{bg}, V_{sgR} and V_{sgL} are voltages applied to back gate, right split gate, and left split-gate, respectively. Asymmetric alignment between upper and lower QPC results in anti-crossing behavior of 1D subbands, manifested by checker-board type behavior reflecting 1D-subband diagram schematically shown in the inset of Fig. 2(a). On the other hand, the original asymmetry can be cured by applying an asymmetric bias between V_{sgR} and V_{sgL}. Figure 2(b) shows transconductance behavior observed in such a symmetric condition. The obtained characteristics agree with the 1D-subband configuration (inset of Fig. 2(b)) expected for the center-aligned D-QPC, in which anti-crossing occurs only between the subbands of same symmetry. These results indicate successful control of coupling characteristics by electrical means. Although coupling control was reported by using a parallel magnetic field [1], electrical control provides additional freedom to tune QPC coupling in zero and a constant magnetic field, and is helpful to use D-QPC devices for various purposes.

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[1] K. J. Thomas *et al.*, Phys. Rev. B59, 19 (1999).

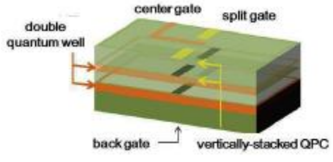

Fig. 1 Schematic diagram of the fabricated D-QPC.

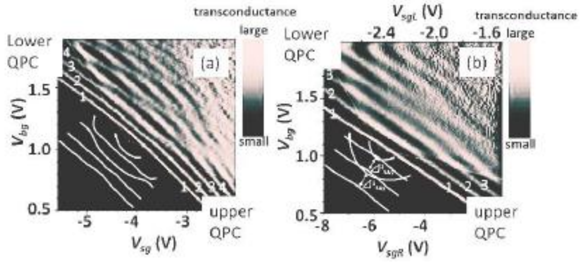

Fig. 2 (a) Grey-plot of transconductance of asymmetrically confined D-QPC, where upper and lower QPCs are staggered. (b) Grey–plot of transconductance of symmetrically confined D-QPC, where the center of upper and lower QPCs is aligned.