Giant switching efficiency in electron Y-Branch Switches

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Switching effects in low-dimensional conductors are of fundamental interest from a physics point of view as well as for future applications [1-4]. As distinct from 3D conductors, in low-dimensional conductors the electrical field is not screened [1] and the total capacitance depends sensitively on the density of states [2]. As a result giant capacitance and self-switching in narrow current channels are expected to permit drastically enhanced switching efficiencies. In order to observe non-ohmic potential drops in the switching the geometric dimensions of the switch have to be comparable to or below the Fermi wavelength and the screening length.

We have realized electron Y-branch switches (YBSs) consisting of a 1D stem which splits along a branching section into two 1D branches using electron beam lithography and wet etching of GaAs/AlGaAs heterostructures with a highly mobile electron gas 50 nm below the surface [3]. In addition to voltages applied between the stem and the branches, the YBS is controlled by side gates separated by narrow trenches from the YBS. We have fabricated YBSs with switching lengths of a few 10 nm and studied their transport characteristics at 4.2 K.

We present switching curves of the YBS in a sub-threshold regime, in which the right branch was pinched off for small bias voltages by a lateral electric field whereas the channel between the stem and the left branch was conductive. Tuned in this way, bias voltage sweeps at the right branch were found to be transformed into voltage changes at the left branch with gain. We observed voltage gain exceeding values of several 100. At the threshold voltage when a leakage of the current from the right branch serving as nanometric-gate sets in, surprisingly, the inverter-like switching is found to increase drastically up to a critical leakage current above which an abrupt increase in the channel current is observed. We were able to detected voltage gain in the injection regime of the YBS. We interpret the giant switching efficiency in terms of a non-linear voltage dependency of the electrochemical capacitance of nanoscale conductors due the finite density of states [4]. Our results provide new insights in the switching properties of low-dimensional 3 terminal junctions.

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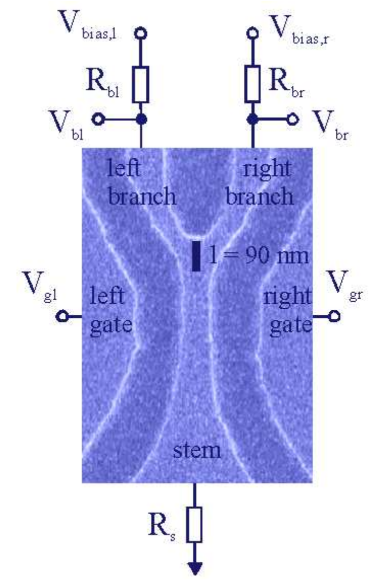

Fig. 1. SEM image of a YBS and schematic view of the measurement configuration.

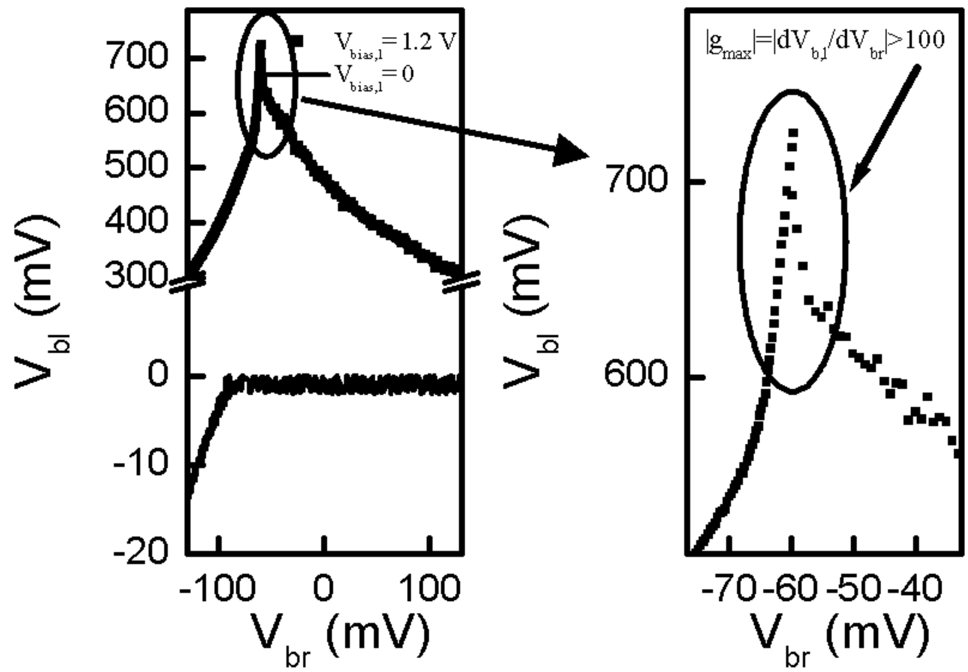

Fig. 2: Left part: Voltage V_{bl} detected at the left branch versus V_{br} the voltage at the right branch when voltages $V_{bias,l}$ =0 and 1.2 V were applied in series with a resistor to the left branch reservoir (the corresponding circuit diagram is sketched in Fig. 1). For $V_{bias,l}$ =0 V_{bl} remains 0 and thus no current is flowing through the left branch as long as V_{br}>-90 mV. A further decrease of V_{br} leads to an onset of a leakage current through the right branch into the left branch. In contrast when $V_{bias,l}$ =1.2 V_{bl} increases for decreasing V_{br} >-60 mV. Thus the right branch serves as efficient gate.

Right part: Close to threshold voltage of –60mV, V_{bl} increases significantly and drops down abruptly with decreasing V_{br}<-60 mV. Here the differential gain of the YBS exceeds values of 100 in the leakage regime.