Voltage Noise in Multi-Terminal Quantum-Wire Interferometers and Mode-Coupled Quantum Point Contacts

B. Düzel[1], D. Nickel[1], O. Chiatti[1], C. Riha[1] and S. F. Fischer[1,2]

[1]*Novel Materials Group, Institut für Physik, Humboldt-Universität zu Berlin, 10099 Berlin, Germany*
[2] *Center for the Science of Materials Berlin, Humboldt-Universität zu Berlin, 12489 Berlin, Germany*

sfischer@physik.hu-berlin.de

Voltage noise measurements are useful to investigate electron gases in thermodynamic equilibrium, they are commonly takes as a direct measurement for the electron gas temperature. Here, we investigate the thermal noise and electrical properties of *multiply-connected* quantum structures with distinctive one-dimensional electronic subband separation. We discuss the noise spectral density in terms of Johnson-Nyquist (JN) noise $S_V = 4kBTR$, for single quantum wires/quantum point contacts and identify particularities which occur in quantum wire structures such as multi-terminal quantum-wire ring (QWR) interferometers and tunnel-coupled double quantum point contacts (QPCs) of various GaAs/AlGaAs heterostructures at T = 4.2 K and below. Voltage noise measurements are performed using the cross-correlation technique in etched quantum structures defined by methods of nanolithography and on various AlGaAs/GaAs-based heterostructures.

We show that in thermal equilibrium the measured two-terminal voltage noise depends on the detail of the contact configuration in multiply-connected QWR [1,2] and on the available electron paths in tunnel-coupled QPCs. Phase coherent electron transport is detected by Aharonov-Bohm magneto-resistance oscillations in QWRs and phase-coherent ballistic transport is evident in single and double QPCs by quantized conductance and by level crossings and anti-crossings according to the state of wave function hybridization as controlled by top- and back-gate voltages in transport spectroscopy.

Multiply-connected QWR and tunnel-coupled QPCs show additional noise beyond the two-terminal JN noise of singly connected quantum structures: It occurs in QWR when quantum-wire cross-junctions are part of the measured system (Fig. 1 bottom left) and in the case of tunnel-coupled QPCs when mode-coupled or degenerate states dominate the phase-coherent transport. The increase in voltage fluctuations is discussed in relation to quantum resonances and backscattering in cross-junctions, shot noise through a tunnel barrier and correlations between noise sources or electron paths.

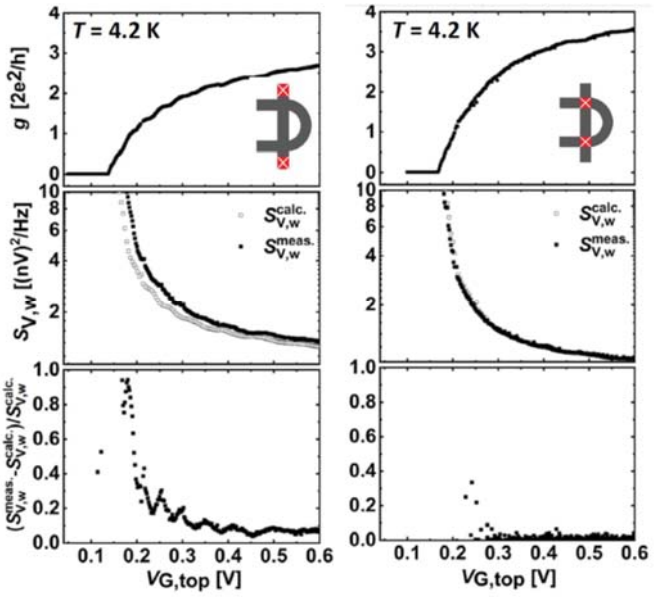

Fig. 1: Example measurements from a four-terminal quantum-wire ring structure of the two-terminal conductance (top), the power spectral density of two-terminal voltage noise (middle) and the additional noise w.r.t. the calculated Johnson-Nyquist noise from the two-terminal resistance (bottom). Additional voltage noise occurs where single-mode occupancy of 1D subbands prevails *and* quantum-wire cross junctions are in the electron paths (left bottom). It disappears if the two-terminal measuremtn is situated in the crossjunctions (marked by the red cross).

References

[1] C. Riha *et al.*, Appl. Phys. Lett. 117, 063102 (2020).
[2] B. Düzel *et al*., 2023 Int. Conf. on Noise and Fluctuations (ICNF), IEEE, in press.