Conductance fluctuations in mesoscopic quantum wires out of equilibrium

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The conductance of weakly disordered metallic wires of mesoscopic dimensions fluctuates at low temperatures as a function of magnetic field and transport voltage, and these are generally considered to be well understood phenomena. Especially well understood are magneto conductance fluctuations at vanishing bias. The conductance traces, often called fingerprints of the actual configuration of elastical scattering centers, are described by two parameters, namely the rms amplitude δg_{rms} of the fluctuations and the correlation field B_c defined as the half width at half maximum of the autocorrelation function. Provided that neither the temperature nor the physical dimension of the wire is too small or too large, δg_{rms} as well as B_c yield valuable information about the phase coherence length L_φ on which the conductance fluctuations depend very sensitively. In general the relation between L_φ and B_c is as simple as $e/h = B_c L_\varphi^2$ or $e/h = B_c L_\varphi w$, depending on whether $L_\varphi < w$ or $L_\varphi > w$ holds (w is the width of the wire perpendicular to the magnetic field).

The situation gets more complicated if, as a second parameter besides the magnetic field, the transport voltage U_{DC} comes into play. Also in this case a well accepted theory[1] exists. Its most prominent prediction is an increasing rms amplitude δg_{rms} of the fluctuation in the differential conductance with U_{DC}, and indeed such an increase has been reported experimentally[2]. Prerequisite for an increase to happen is that L_φ does not vary too strongly with the transport voltage. However, in many cases a rapid drop of L_φ due to heating effects is observed as soon as the transport voltage rises. At the same time δg_{rms} is reduced, too.

We present data which are not in accordance with the above line of reasoning and need further attention from a theoretical point of view. Even for U_{DC} smaller than the Thouless voltage a rapid decrease of δg_{rms} is observed, which is accompanied by a reduction of B_c (indicating—at least if following the simple relation given above—that L_φ increases). The increase of δg_{rms} predicted in Ref. 1 and observed in Ref. 2 is confirmed at voltages larger than the Thouless voltage.

Our experimental findings question the simple geometrical relation between the correlation field B_c and the phase-coherence length L_φ.

[1] A. I. Larkin and D. E. Khmel'nitskiĭ, Soc. Phys. JETP **64**, 1075 (1982).
[2] R. Schäfer, K. Hecker, H. Hegger, and W. Langheinrich, Phys. Rev. B **53**, 15964-15970 (1996).