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Energy Distribution Function of Quasiparticles in Mesoscopic Wires

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between quasiparticles only. The boundary conditions are imposed by the reservoir electrodes: $f(0,E) = [1 + \exp(\frac{E}{k_B T})]^{-1}$ and $f(1,E) = [1 + \exp\{\frac{E+eU}{k_B T})]^{-1}$. If no scattering between quasiparticles occurs during the diffusion time, the distribution function is the solution $f_0(x,E)$ of Eq. (1) with no collision integral [8]:

$$f_0(x,E) = (1 - x)f(0,E) + xf(1,E). \qquad (2)$$

The function $f_0(x,E)$ has a well-defined intermediate step for $|eU| \gg k_B T$, as shown in Fig. 1 as solid lines.

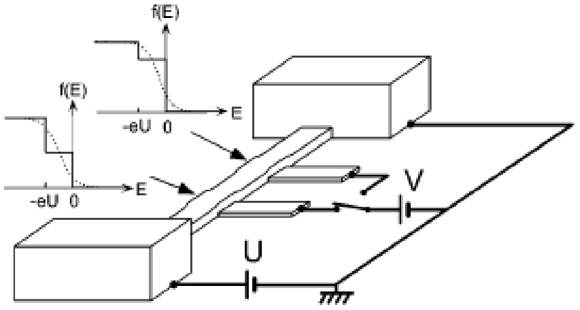

FIG. 1. Experimental layout: a metallic wire of length L is connected at its ends to reservoir electrodes, biased at potentials 0 and U. In the absence of interaction, the distribution function at a distance $X = xL$ from the grounded electrode has an intermediate step $f(E) = 1 - x$ for energies between $-eU$ and 0 (solid curves) (we assume $U > 0$). When interactions are strong enough to thermalize electrons, the distribution function is a Fermi function, with a space-dependent temperature and electrochemical potential (dotted curves). In the experiment, the distribution function is obtained from the differential conductance $dI/dV(V)$ of the tunnel junction formed by the wire and a superconducting electrode placed underneath.

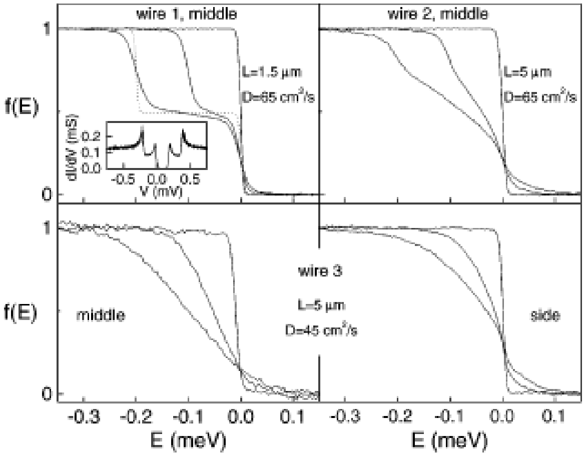

FIG. 2. Inset of the top left panel: Measured $dI/dV(V)$ of the tunnel junction to wire 1 for $U - 0.2$ mV. In the four panels, distribution functions, obtained from the deconvolution of such $dI/dV(V)$ curves, for $U - 0$, 0.1, and 0.2 mV in the middle of a 1.5-μm-long wire with a diffusion constant $D \sim 65$ cm^2/s (wire 1, top left); in the middle of a 5-μm-long wire with the same diffusion constant (wire 2, top right); in the middle (bottom left) and at 1.1 μm from the grounded reservoir electrode (bottom right) of a 5-μm-long wire (wire 3) with $D \sim 45$ cm^2/s. Also plotted as a dotted line in the top left panel is the prediction for the noninteracting distribution function [Eq. (2)] for $U - 0.2$ mV. All measurements were performed at 25 mK. The cross-sectional area of the three wires is nominally the same: 45×110 nm^2. The tunnel resistances of the junctions were $R_T - 10$ kΩ for wires 1 and 2, $R_T - 200$ kΩ for the middle junction on wire 3, and $R_T - 75$ kΩ for the side junction on wire 3.

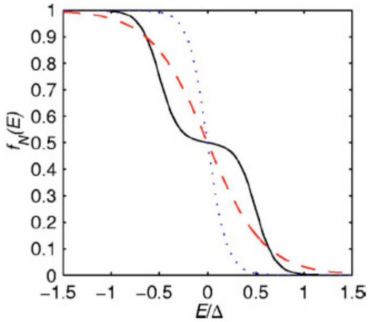

FIG. 3. (Color online) Quasiparticle energy distribution function in the center of a normal-metal wire placed between two normal-metal reservoirs and biased with a voltage $eV = 10k_BT$. The three lines correspond to three extreme limits: solid line, $L \ll \ell_{e\text{-}e}, \ell_{e\text{-ph}}$ (nonequilibrium limit); dashed line, $\ell_{e\text{-}e} \ll L \ll \ell_{e\text{-ph}}$ (quasiequilibrium limit); and dotted line, $\ell_{e\text{-}e}, \ell_{e\text{-ph}} \ll L$ (equilibrium limit).