Local and non-local resistances of the three-terminal hybrid nanostructures

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M. Büttiker first generalized the Ohm's law to mesoscopic systems coherently coupled to multiple terminals [1]. In this approach the information about tunneling processes through the system is obtained by measuring the local and non-local resistances, in response to the driving current. Here we generalize the formalism to probe transport properties of three terminal hybrid systems, consisting of a quantum dot (QD) coupled to two normal (left - L and right - R) and one superconducting (S) lead. By proximity effect the S lead spreads electron pairing on the QD, inducing the subgap states which contribute to the transport *via* Andreev scattering. The presence of two normal terminals allows for local (direct) and non-local (crossed) Andreev reflections. The direct (albeit *via quantum dot*) electron tunneling (ET) between L and R electrodes also contributes to the non-local transport competing with crossed Andreev reflections. We study both non-local transport channels in the limit of bias voltages smaller then the superconducting gap.

Adapting the Büttiker's [1] method we propose to measure the voltage ΔV_{kl} induced between leads k and l, in response to the driving current J_{ij} between electrodes i and j. From the measurements of various local ($ij = kl$) and non-local ($ij \neq kl$) resistances $R_{ij,kl} \equiv \Delta V_{kl}/J_{ij}$ one obtains information *inter alia* about the interplay between normal electron transfer (ET) and crossed Andreev reflection processes (CAR) as well as competition between direct Andreev tunneling processes. Changing the system parameters, e.g. position of the QD level (by an applied gate voltage) or couplings to the leads, one can control amplitude of the local and non-local resistances and even their sign. In particular, we show that the non-local resistance $R_{RS,LS}$ is very sensitive to competition between the ET and CAR processes. Its value is positive when the ET processes dominate and negative when transport is dominated by the CAR processes. The latter case occurs for sufficiently strong coupling to the S lead. On the other hand in a configuration with the floating S lead, one gets information (from the local resistance $R_{LR,LR}$) about the influence of proximity effect on usual electron transfer between the normal leads.

We emphasize, that due to the Andreev bound states induced in the subgap spectrum of QD, the predicted non-local transport properties of the structure substantially differ from the existing experimental data obtained for three-terminal *planar* junctions [2].

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