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Modeling ballistic magnetoconductance and magnetic focusing in SiGe cavities

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Ballistic transport in mesoscopic structures is characterized by resonance phenomena that are differently influenced by decoherence due to interactions with the environment. Considering chaotic cavities in SiGe heterostructures, it is possible to observe both tunable resonances in the conductance like magnetic focusing or Shubnikov-de Haas (SdH) oscillations, and a superimposed rich structure of oscillations due to multiple reflections inside the cavity. Luckily, it often occurs that experimentally only magnetic focusing and SdH oscillations are observed, that are more robust to the effects of decoherence. Here, we present numerical simulations of magnetoconductance properties of a cavity obtained by shifting the central section of wire in a SiGe heterostructure, and compare them with experimental results.

The subband profile is obtained solving the Schrödinger equation with density functional theory, local density approximation [1] in the wire and in the cavity, and semiclassically elsewhere. In particular, we are able to take into account the the effect of the strain on the minima of the conduction band and on the effective masses. The conductance of the SET is obtained with the scattering matrix (S-matrix) technique in the framework of the Landauer-Büttiker theory of transport [2]. The conductance is related to the transmission probability matrix $T = tt^\dagger$ by the formula $G = g\frac{e^2}{h}\sum_n T_n$, where t is the transmission amplitude matrix, g is a degeneracy factor ($g = 4$ in our case due to the valley degeneracy) and the sum is over all eigenvalues T_n of the transmission matrix T. The partial density of states $\rho(x_i, y_j, E) = |\Psi(x_i, y_j, E)|^2$ at each point (x_i, y_j) of the grid domain is computed to highlight electron trajectories and density patterns. We introduce in our description the effects of decoherence as a dephasing of the wave function [3]. The coherent propagation through the j-th slice is described by a diagonal transmission matrix with elements $e^{ik_{j,m}d_j}\delta_{mn}$, where $d_j = x_{j+1} - x_j$. We modify the transmission matrix by adding to each diagonal term a random phase ϕ_{R} so that the generic element of the transmission matrix becomes $t_{mn} = e^{i(k_{j,m}d_j+\phi_{\mathrm{R}})}\delta_{mn}$. The random phase ϕ_{R} is extracted by a random number generator and obeys a zero average Gaussian distribution with variance $\sigma_j^2 = d_j/l_\phi$. The scattering matrix obtained in such a way only represents a particular occurrence of the reduced scattering matrix of the single particle. The average reduced scattering matrix is obtained by averaging the conductance over a sufficient number of runs, typically of the order of one hundred. In this way we take into account the intrinsic statistical character of the dephasing process.

In Fig. 1 a) we show the magnetoconductance of the SET with a dephasing length $l_\phi = 1\mu$m. It is possible to appreciate the magnetic focusing effect with two minima of conductance at B=0.16 T and B=0.32 T. In Fig. 1 b) we show the partial density of states where the classical trajectory of electrons is visible through the peaks and corresponds to a cyclotron radius of 280 nm. The proposed model allows to recover the main features observed in experiments of magnetoconductance on SiGe cavities [4], as will be detailed in the complete paper.

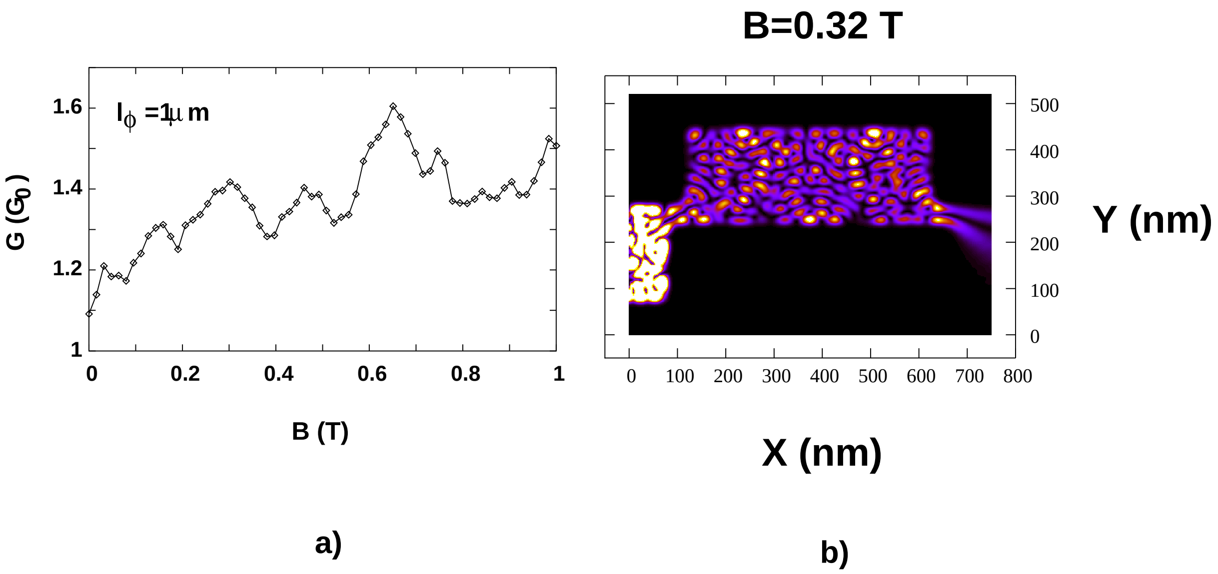

FIG. 1: Left: Magnetoconductance for a dephasing length of 1 μm. Right: Partial density of states in the cavity at B=0.32 T.

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