Scanning gate microscopy of electron flow from a spin-orbit-coupled quantum point contact

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Scanning gate microscopy (SGM) is a technique that allows for spatial mapping of current flow and charge densities in semiconductor nanostructures. This technique has been used to map electron flow from a constriction introduced in a quantum channel – quantum point contact (QPC). The experiments observed branching of electron flow [1] and angular dependence of the flow that corresponds to the number of conducting modes through the QPC [2]. Moreover the measured conductance maps exhibit fringes that are separated by the half of the Fermi wavelength due to the interference between the coherent waves propagating through the QPC and scattered back from the tip [3].

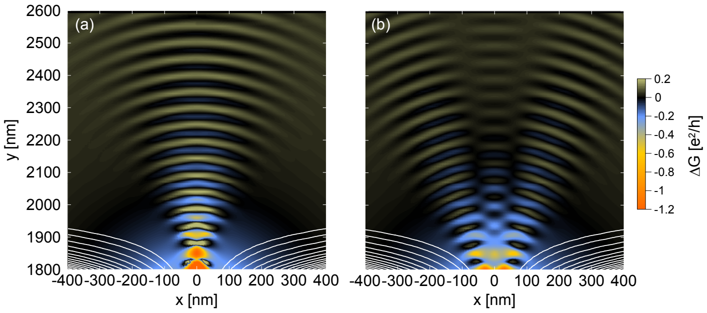

Figure 1: Maps of the conductance changes as a function of the scanning gate tip position obtained on the first (a) and (b) second conductance step in the presence of SO interaction. Distinct radial interference fringes are present in both maps and mode mixing in (b) is visible.

Currently there is a growing interest in spin phenomena in semiconductor media that focuses the attention to materials that provide strong coupling between orbital and spin degrees of freedom – spin-orbit (SO) interaction – and allow for electrical control of the electron spin. In the present work we investigate the influence of strong SO coupling that is present in InGaAs on the maps of electron flow from QPC obtained by the SGM [4]. We find that the angular dependence measured on the conductance plateaux [$2e^2/h$, $4e^2/h$, ...] is lost as SO interaction mixes the orbital modes that enter the QPC. On the other hand on the maps gathered for the QPC tuned to the conductance steps the mode mixing is still visible but the distinct radial fringes are preserved despite the presence of the two different Fermi wavelengths that results from lifted by SO interaction spin degeneracy. We explain that the spatial separation of the fringes is determined by the mean value of the two Fermi wavevectors.

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