A Novel Electronic Mach-Zehnder Interferometer

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Double-slit electron interferometers, fabricated in high mobility two-dimensional electron gas (2DEG), proved to be very powerful tools in studying coherent wave-like phenomena in mesoscopic systems [1]. However, they suffer from small fringe visibility due to the many channels in each slit, and poor sensitivity to small currents due to their open geometry. Moreover, the interferometers do not function in a high magnetic field, namely, in the quantum Hall effect (QHE) regime, since it destroys the symmetry between left and right slits. Here, we report on the fabrication and operation of novel, single channel, closed geometry, two-path electron interferometer that functions in a high magnetic field. It is the first electronic analog of the well-known optical Mach-Zehnder (MZ) interferometer. Based on single edge state transport in the QHE regime the interferometer proved to be highly sensitive and exhibited very high visibility (62%) without phase rigidity. [2]

In the QHE plateaus the current is carried by edge states, moving near the edges of the sample they have definite chirality and extremely long coherence length. We used *quantum point contacts* (QPCs), formed by negatively biased gates, as beam splitters and *Ohmic contacts* as a source and detectors. As shown schematically in **figure a** QPC1 splits the incoming edge current from **S** to two paths, a transmitted *inner path* and a reflected *outer path*, both later recombine and interfere in QPC2 to result with two edge currents (collected by **D1** and **D2)**. The electron microscopy image of the device is show in **figure b**. Measurements were done at filling factor 1 and 2 at an electron temperature of 20mK. The interference signal was measured at some 1.3MHz as function of the magnetic flux or the voltage of the modulation gate. Both parameters lead to a change in the flux that threads the area between the two paths (~45μm^2), hence introducing an Aharonov-Bohm phase difference φ between the two paths [3]. The results, shown in **figure c**, exhibit very high visibility (~60%) and a high sensitivity to extremely weak input signal.

However, a mere increase of the temperature to 100mK (some~9μeV) reduced the visibility to ~1% (plotted with full circles in **figure d**). Moreover, the energy dependence of the AC differential visibility (measured at T=20mK, plotted with empty squares), which is sensitive only to a narrow spectrum of electron energy, was found to be strikingly similar to the temperature dependent visibility - with a scale eV_{DC}~$4k_BT$. The clear similarity between the two results suggests that the dephasing processes might be related. While we do not understand the dephasing process, we show, via shot noise measurement, that it is **not** due to a decoherence process that results from inelastic scattering events.

This novel and powerful electron interferometer, which functions in the QHE regime, allows interference, phase and dephasing measurements to be conducted under strong magnetic fields. As example, an exciting possibility might be the study of coherence and phase evolution of fractionally charged quasiparticles in the Fractional QHE regime [4].

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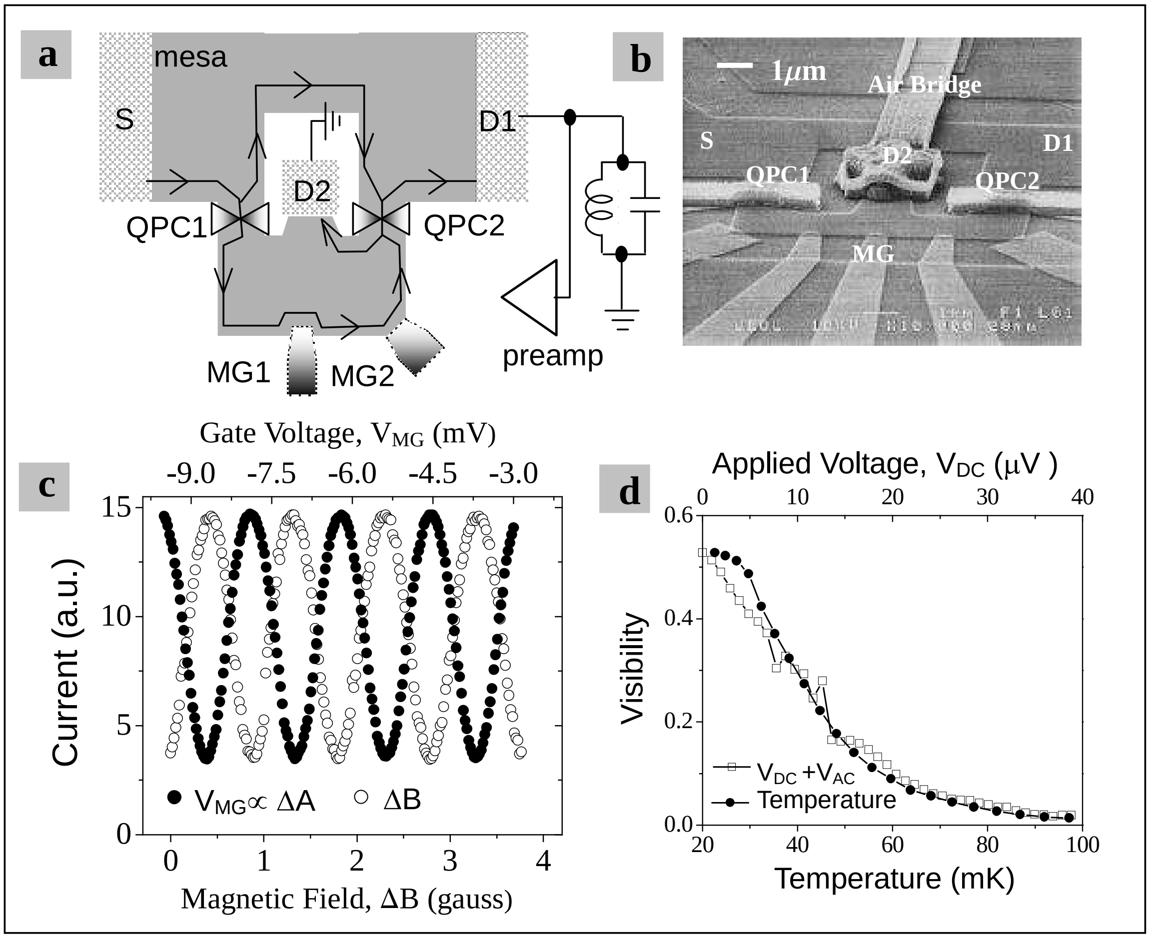

(a) Schematics of the electronic Mach-Zehnder interferometer and the measurement system. Edge states are formed in a high perpendicular magnetic field. The incoming edge state from **S** splits by **QPC1** (quantum point contact) to two paths, of which one moves along the inner edge and the other along the outer edge of the device. The two paths meet again at **QPC2**, interfere, and result in two complementary currents in **D1** and in **D2**. By changing the contours of the outer edge state and thus the enclosed area between the two paths, the modulation gates (**MG**) tune the phase difference between the two paths via the Aharonov-Bohm effect. A high signal-to-noise-ratio measurement of the current in **D1** is performed at 1.4MHz with a cold LC resonant circui, as a band pass filter, followed by a cold, low noise, preamplifier. **(b)** SEM picture of the device. A centrally located small Ohmic contact ($3x3\mu m^2$), serving as **D2**, is connected to the outside circuit by a long metallic air-bridge. Two smaller metallic air-bridges bring the voltage to the inner gates of **QPC1** and **QPC2 -** both serve as beam splitters for edge states. The five metallic gates (at the lower part of the figure) are modulation gates (**MG**). (**c**) The current collected by **D1** is plotted as function of the voltage on a modulation gate (filled circle) and as function of the magnetic field (hollow circle). The visibility of the interference is ~62%. (**d**) The dependence of the visibility on temperature and applied voltage. Visibility as a function of temperature at small excitation voltage and $V_{DC}=0$ (filled circle), and as a function of V_{DC} with a small AC voltage V_{AC} superimposed on it at electron temperature 20mK (empty square). Both QPCs were set to $T_1=T_2=0.5$.