

Interference between two independent electrons: observation of two-particle Aharonov-Bohm interference

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arXiv/cond-mat/ 0705.0173 ; Nature (in press)

Recommended with a Commentary by Bertrand I. Halperin, Harvard University

This paper reports the experimental observation of *two-particle* Aharonov-Bohm (AB) interference effects for electrons traveling along the edges of a GaAs quantum Hall device, at Landau level filling factor $\nu=1$. The experiments are an elegant realization of an earlier theoretical proposal by Samuelson, *et al.*[1]

The experimental device employs two independent electron sources and four-drains, in a geometry which gives no AB effect in single-electron transport, and no AB effect in the mean current through any drain. Noise correlations between different drains show AB oscillations, however, due to a two-electron interference effect, which arises from the Fermi statistics, and is ultimately related to the famous Hanbury Brown and Twiss effect.

The attached figure shows a schematic of the device [lower panel, (c)] and an abstract representation of the interferometer paths [upper panel, (a)]. The geometry is multiply-connected, as the 2D electron system has two internal "holes". Air bridges are used to reach contacts on the inner edges. Electrons flow along edges in the directions indicated by arrows. A voltage V is applied to the source contacts S1 and S2, while the drains D1-D4 are grounded, and current noise correlations are measured between D2 and D4. Gate voltages on quantum point contacts, labeled A, B, C, D, are adjusted so that in each case, one-half of the electrons are transmitted along the originating edge, and one-half are back-scattered to opposite edge. Every injected electron is absorbed at one of the four drain contacts. As there is only a single path from any one source to any given drain, there is no interference of single-particle trajectories, and there are no AB oscillations in the current at any drain. If a pair of electrons is emitted simultaneously from the two sources, however, and one computes the amplitude for detecting one electron at D2 and one at D4, there can be an interference term because the particles are indistinguishable, and one does not know which electron was emitted by which source. (Two electrons cannot be emitted simultaneously from the same source, due to the Pauli exclusion principle, as the sources are spin polarized.)

Let us write the two-body amplitude for finding the electrons at drains D2 and D4 as

$$A = A_{12}A_{24} \exp[i (\phi_1+\phi_4)] - A_{14}A_{22} \exp[i (\phi_2+\phi_3)]$$

where A_{ij} is the magnitude of the transmission amplitude for an electron from source i to drain j , and ϕ_k , for $k=1,2,3,4$, are the phases accumulated along the links, as labeled in the figure. The magnitude $|A|$ thus depends on the phase difference $(\phi_1+\phi_4-\phi_2-\phi_3)$, which, in turn, depends on the magnetic flux through the closed loop S1-D2-S2-D4-S1. Hence, current correlations between D2 and D4 should show AB oscillations, as a function of the applied magnetic field, or of the loop area, which can be varied by voltages on gates MG1 and MG2.

The authors state that their measured amplitudes of the AB oscillations in the noise correlations were about 25% of the theoretical amplitude for an ideal interferometer at zero temperature.

Reference: [1] P. Samuelsson, E. V. Sukhorukov, and M. Büttiker, Phys. Rev. Lett. 92, 026805 (2004). See also references therein.

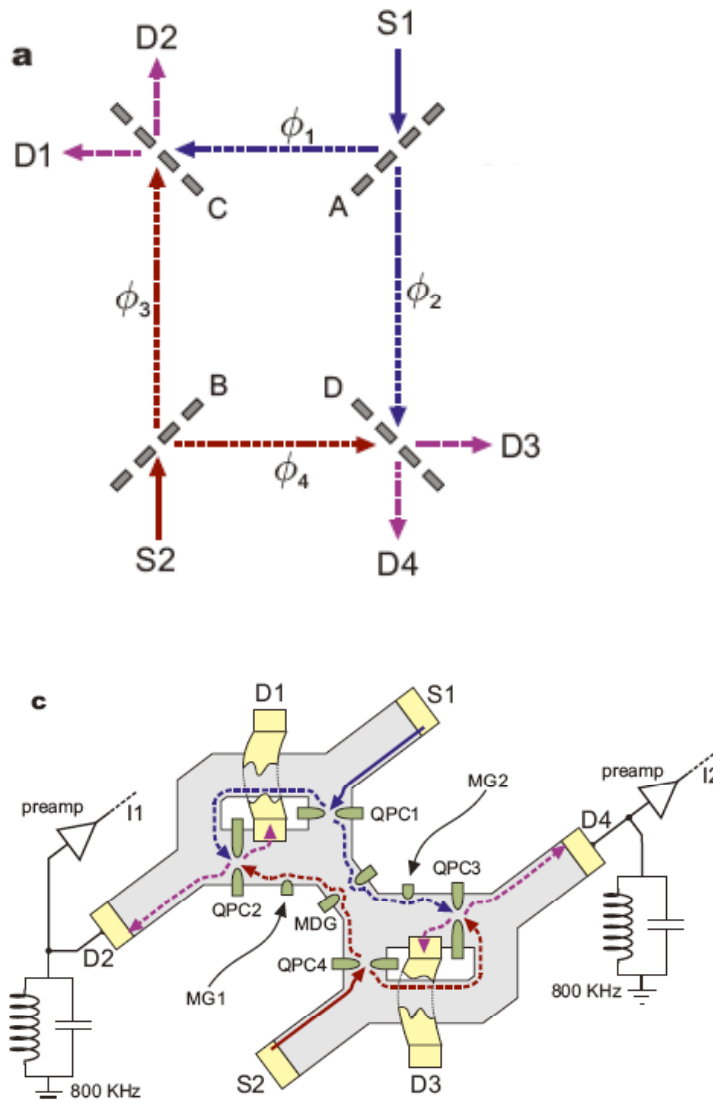


Figure caption: Lower panel (c) shows a schematic of the measuring device, while upper panel (a) is an abstract representation of the interference paths.