Macroscopic electron quantum coherence in a solid-state circuit

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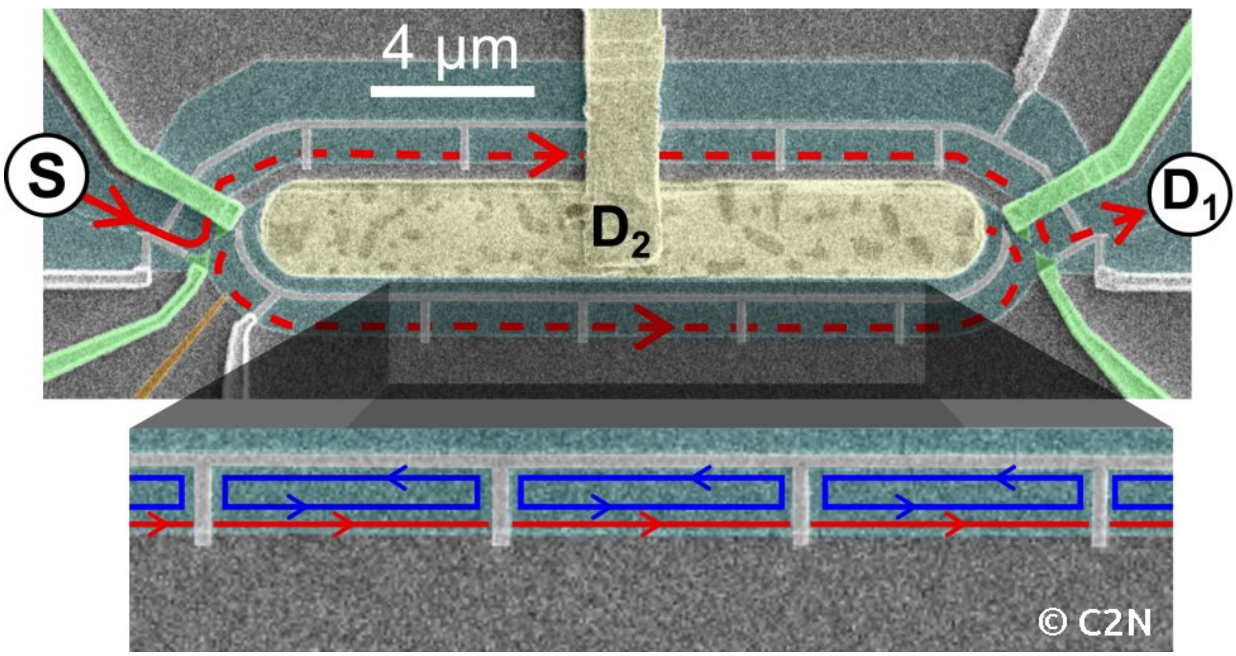

Colored scanning electron micrograph of the sample: Mach Zehnder interferometer and confinement strategy used to obtain and demonstrate a record electronic coherence length of 0.25 mm. Credit: © C2N

A team of researchers at the Centre de Nanosciences et de Nanotechnologies (C2N, CNRS/Univ. Paris-Saclay) has experimentally achieved the coherent propagation of electrons in circuits over macroscopic distances through a novel nano-engineering strategy.

The quantum coherence of electronic quasiparticles underpins many of the emerging transport properties of conductors at small scales. Novel electronic implementations of quantum optics devices are now available with perspectives such as 'flying' qubit manipulations. However, electronic quantum interference in conductors (quantum coherence length) has been limited to propagation paths shorter than 30 µm, independently of the material, geometry and experimental conditions. Remarkably similar maximum values were obtained in ballistic semi-conductors, diffusive metals and 2-D materials like graphene.

Using circuit nano-engineering, researchers from the team led by Frédéric Pierre (CNRS) and Anne Anthore (Université de Paris) at C2N have achieved a macroscopic value of the quantum coherence length—0.25 mm, visible with the naked eye. It occurred along edge channels that guide electrons in the quantum Hall regime. Normally in this setup, coherence is limited by electron coupling between adjacent channels. To prevent inter-channel collisions, the researchers fabricated a nanostructure that confines electrons to small loops within compartments lining the inner channel wall. This confinement forces the inner channels to stay in their ground state, which makes inelastic collisions between electrons impossible. They find that this, combined with outstanding isolation from other decoherence mechanisms, boosts the coherence length by roughly an order of magnitude.

This work extends the possibilities of exploiting electron quantum behaviors up to macroscopic-length scales, and opens new perspectives in quantum electronic optics.

More information: H. Duprez et al. Macroscopic Electron Quantum Coherence in a Solid-State Circuit, *Physical Review X* (2019). DOI: 10.1103/PhysRevX.9.021030

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