Semiconductor Circuits for Quantum Computing with Electron Wave Packets

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Conventional approaches to quantum computing require significant overhead to correct for errors. The hardware size for conventional quantum processors in solids often increases linearly with the number of physical qubits, such as for transmon qubits in superconducting circuits, or electron spin qubits in quantum dot arrays. While photonic circuits based on flying qubits do not suffer from decoherence or lack of scalability, they have encountered significant challenges associated with loss and quantum manipulation in units of single photons. We propose an alternative approach that utilizes flying electronic wave packets propagating in solid-state quantum semiconductor circuits. Using a novel time-bin architecture for flying electronic wave packets, hardware requirements are drastically reduced because qubits can be created on-demand and manipulated with a common hardware element, in contrast to the localized approach of wiring each qubit individually. The electronic Coulomb interaction enables reliable coupling and electronic readout of qubits. Improving upon previous devices,[1] we realize electronic interference at the level of a single quantized mode that can be used for manipulation of electronic wavepackets. We also confirm from the two-particle interference experiment that the electron-electron interaction in the interferometer is strong enough to induce quantum entanglement. These important landmarks lay the foundation for fault-tolerant quantum computing with a compact, scalable architecture based on electron interferometry in semiconductors.

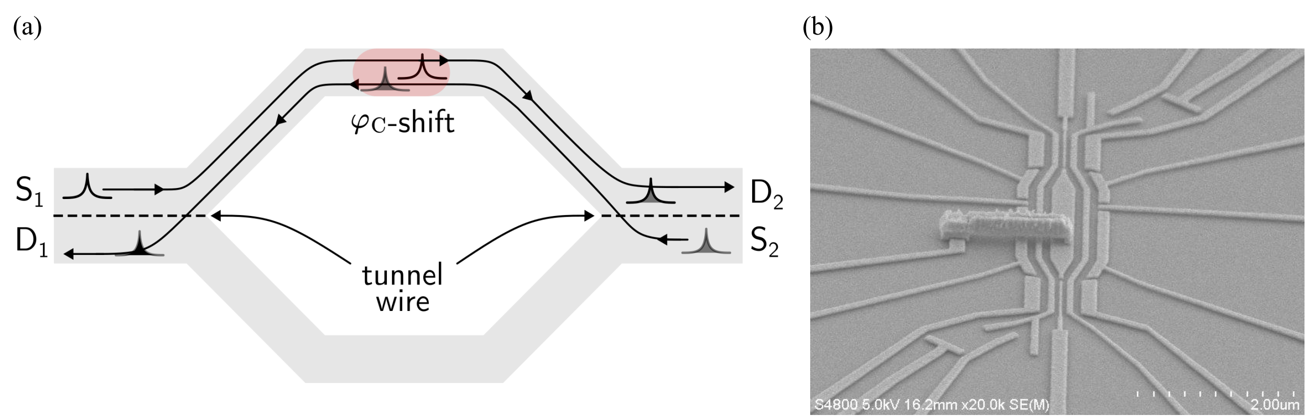

Figure 1 (a) Schematic of an electronic Mach-Zehnder interferometer illustrating the two-particle interference experiment (b) Scanning electron micrograph image of the flying qubit device.

References

[1] M. Yamamoto, S. Takada, C. Bäuerle, K. Watanabe, A. D. Wieck, S. Tarucha, Nat. Nano 7 **4**, 247 (2012)