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Scalable Quantum Computing with Trapped Electrons in a Planar Penning Trap

Sugam Kumar

Scientist Inter-University Accelerator Centre New Delhi, India

Abstract

Quantum computers have the potential to solve problems far beyond the reach of classical computers by using the principles of superposition and entanglement. However, existing platforms face challenges such as short coherence times, interference from the environment, and difficulties in scaling up.

Trapped electrons in a planar Penning trap offer a promising alternative. Unlike other qubits, electrons do not interact with nuclear spins, which helps maintain quantum states for much longer. Additionally, their strong confinement allows for fast and precise quantum operations. In our approach, electron spins serve as logical qubits, while their motional states are used for entanglement. Our setup consists of 2-dimensional array of micro-sized Penning traps fabricated on a ceramic chip, placed inside a 1 T superconducting magnet and cooled in a dilution refrigerator to reach millikelvin temperatures. This extreme cooling reduces unwanted motion and makes it possible to entangle electron spins and perform quantum gates with high accuracy. At Inter-University Accelerator Centre (IUAC), New Delhi, India, we are developing a prototype planar Penning trap. This new system offers a stable, scalable, and high-coherence platform for quantum computing.