Condensed Matter Physics Seminar Series

Cavity QED with multi-electron flopping-mode spin qubits

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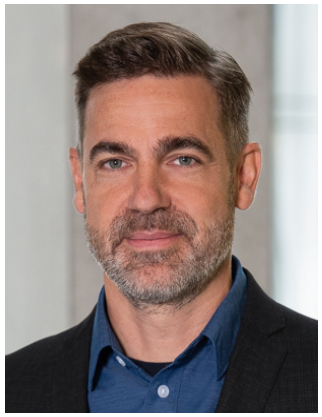

Semiconductor spin qubits placed inside superconducting microwave cavities are rapidly emerging as a powerful platform for achieving fast, fault-tolerant qubit control with long-range two-qubit interactions. A central player in spin-based cavity QED is the flopping-mode spin qubit—a single electron confined in a double quantum dot (Fig. 1a). This hybrid of charge and spin qubits excels at cavity-mediated long-range gates thanks to its tunable coupling to the cavity.

In parallel, multi-electron qubits—such as singlet-triplet and exchange-only qubits—offer the advantage of baseband electrical control over spin states. In this work, we bring these two approaches together, showing that, in a triple quantum dot occupied by two electrons, a singlet-triplet (ST_0) spin qubit can be coupled to a charge qubit that interacts both transversely and longitudinally with the cavity (Fig. 1b). Crucially, both couplings are highly tunable, and the presence of strong longitudinal coupling sets this system apart from the traditional flopping-mode qubit. This longitudinal interaction enables non-dissipative, universal qubit control, in close analogy to superconducting transmons.

We further extend the concept to a system of four quantum dots occupied by three electrons, which realizes an effective exchange-only qubit (Fig. 1c). In this case, electrical control over exchange interactions makes the qubit–cavity coupling fully tunable. Using input-output theory, we extract these couplings directly from the cavity transmission, providing a clear path toward versatile, cavity-mediated spin-qubit architectures.

Guido Burkard is a professor of theoretical physics at the University of Konstanz. His research is devoted to the physics of quantum computing, specifically on systems that can efficiently store, process, and transmit quantum information, with focus on solid-state and hybrid quantum systems. After obtaining his PhD in physics from the University of Basel, Burkard worked at the IBM T. J. Watson Research Center before joining the faculty at the University of Basel, RWTH Aachen University, and the University of Konstanz. Burkard is a Fellow of the American Physical Society (APS), and was serving as chair of the quantum information division of the German Physical Society (DPG) between April 2023 and April 2025.

Friday, October 10th at 12pm
Astro Reading Room (3-326 PAB)