



Contribution ID: 206

Type: **Contributed Oral**

Integrating gate-defined quantum dots with nuclear spin qubits in silicon

Thursday 4 December 2025 11:10 (15 minutes)

High-dimensional qudit systems yield the exciting prospect of hosting error-correctable logical qubits [1]. The antimony (^{123}Sb) donor in silicon is ideal for this purpose, because its spin-7/2 nucleus embeds an 8-dimensional Hilbert space (or 16-dimensional, including the electron [2]) that can encode Schrödinger cat states [3].

Scaling up this donor nuclear qubits requires using electrons to mediate the interaction between distant nuclei [4]. Using ion-implanted donors in metal-oxide-semiconductor devices opens the possibility of using the electrons in gate-defined quantum dots as the mediators of the interaction between multiple nuclei.

Here, we present experiments on a device that combines an implanted ^{123}Sb donor in silicon with gate-defined quantum dots. We demonstrate tunability of the electron occupation in the donor-dot system, and measure strong exchange interaction between the donor- and dot-confined electrons when two electrons are loaded into the system. Additionally, we operate the device with only one electron and demonstrate controlled shuttling of the electron between the donor and the dot. This capability is key to operating the electrically-driven 'flip-flop' qubit [5] at the maximum speed, and opens the possibility of coupling distant flip-flop qubits via their induced electric dipole.

Our results open new pathways for donor-dot hybrid devices, where mobile electrons can be coupled to highly coherent, high-spin donor nuclei that locally encode logical qubits.

[1] J. Gross, Phys. Rev. Lett. 127, 010504 (2021)

[2] I. Fernandez de Fuentes et al., Nature Comm. 15, 1380 (2024)

[3] X. Yu, et al., Nature Physics 21, 362 (2025)

[4] H. Stemp et al, arXiv:2503.06872 (2025)

[5] R. Savytskyy et al., Science Advances 9, eadd9408 (2023)

Authors: ZINGEL, James (School of Electrical Engineering and Telecommunications, UNSW Sydney, Sydney, Australia); WILHELM, Benjamin (School of Electrical Engineering and Telecommunications, UNSW Sydney, Sydney, Australia); SU, Rocky Y (School of Electrical Engineering and Telecommunications, UNSW Sydney, Sydney, Australia); NURIZZO, Martin (School of Electrical Engineering and Telecommunications, UNSW Sydney, Sydney, Australia); KRUSKIC, Sarah (School of Electrical Engineering and Telecommunications, UNSW Sydney, Sydney, Australia); BOTZEM, Tim (School of Electrical Engineering and Telecommunications, UNSW Sydney, Sydney, Australia; Diraq, Sydney, Australia); LIM, Shao Qi (School of Physics, University of Melbourne, Melbourne, Australia); LIM, Wee Han (School of Electrical Engineering and Telecommunications, UNSW Sydney, Sydney, Australia; Diraq, Sydney, Australia); JAKOB, Alexander M (School of Physics, University of Melbourne, Melbourne, Australia); HUDSON, Fay E (School of Electrical Engineering and Telecommunications, UNSW Sydney, Sydney, Australia; Diraq, Sydney, Australia); ITOH, Kohei M (School of Fundamental Science and Technology, Keio University, Kohoku-ku, Japan); DZURAK, Andrew S (School of Electrical Engineering and Telecommunications, UNSW Sydney, Sydney, Australia; Diraq, Sydney, Australia); JAMIESON, David N (School of Physics, University of Melbourne, Melbourne, Australia); HOLMES, Danielle (School of Electrical Engineering and Telecommunications,

UNSW Sydney, Sydney, Australia); MORELLO, Andrea (School of Electrical Engineering and Telecommunications, UNSW Sydney, Sydney, Australia)

Presenter: ZINGEL, James (School of Electrical Engineering and Telecommunications, UNSW Sydney, Sydney, Australia)

Session Classification: Quantum Science and Technology

Track Classification: Topical Groups: Quantum Science and Technology