Autotuning a single-electron transistor as a charge sensor

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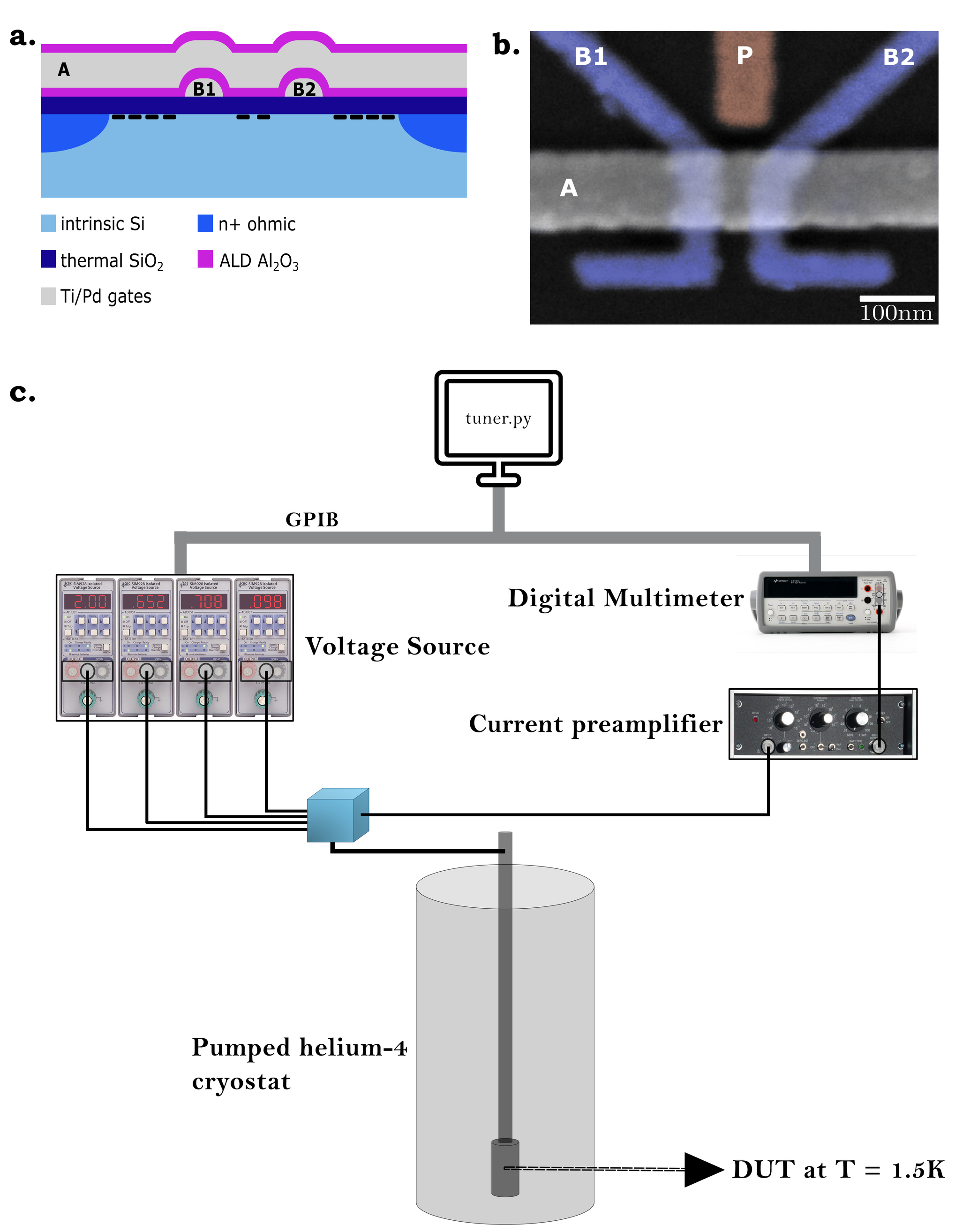
Introduction

- Single-electron transistors (SETs) are used as precise charge sensors for charge and spin state readout of spin qubits.
- A charge sensor SET has to be tuned to a point where its current is highly sensitive to changes in the surrounding potential landscape. The tuning process is repetitive and time-consuming, and its automation becomes necessary as semiconductor spin qubit systems scale up [1].
- We demonstrate an automated 3-stage protocol [2] for SET tuning. On a new device that hasn't been measure before, the computer explores the parameter space of SET gate voltages and gets the device to a regime of high sensitivity.

Experimental setup



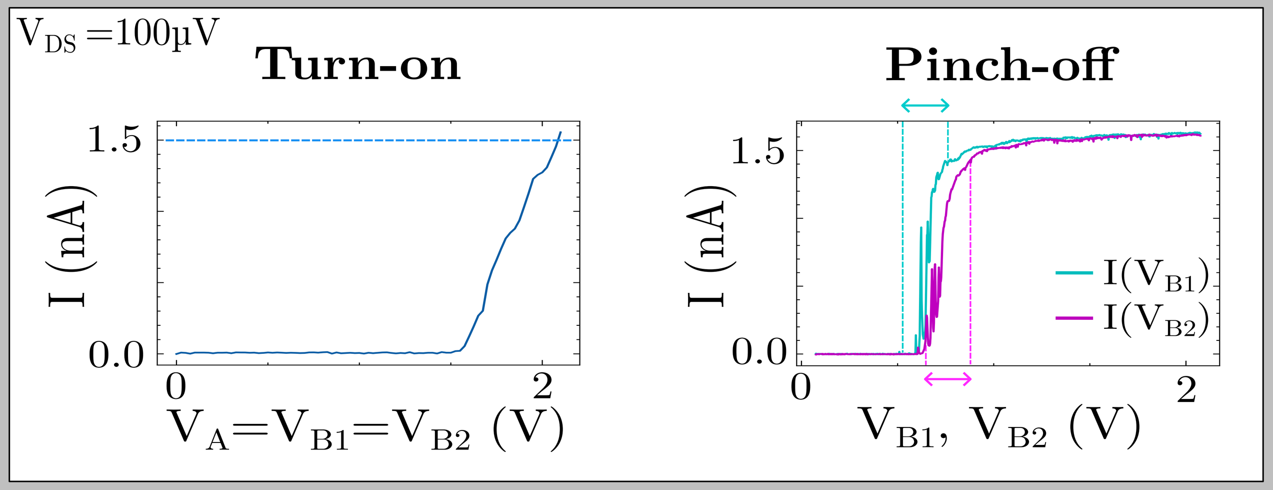
a. Cross-section schematic of the SET.

b. False-color scanning electron micrograph of the sample.

c. The measurement setup, where the lab PC uses QCoDeS for data aquisition from the instruments. The PC and instruments are in a GPIB network. The cryostat maintains the device at 1.5K.

The autotuning protocol

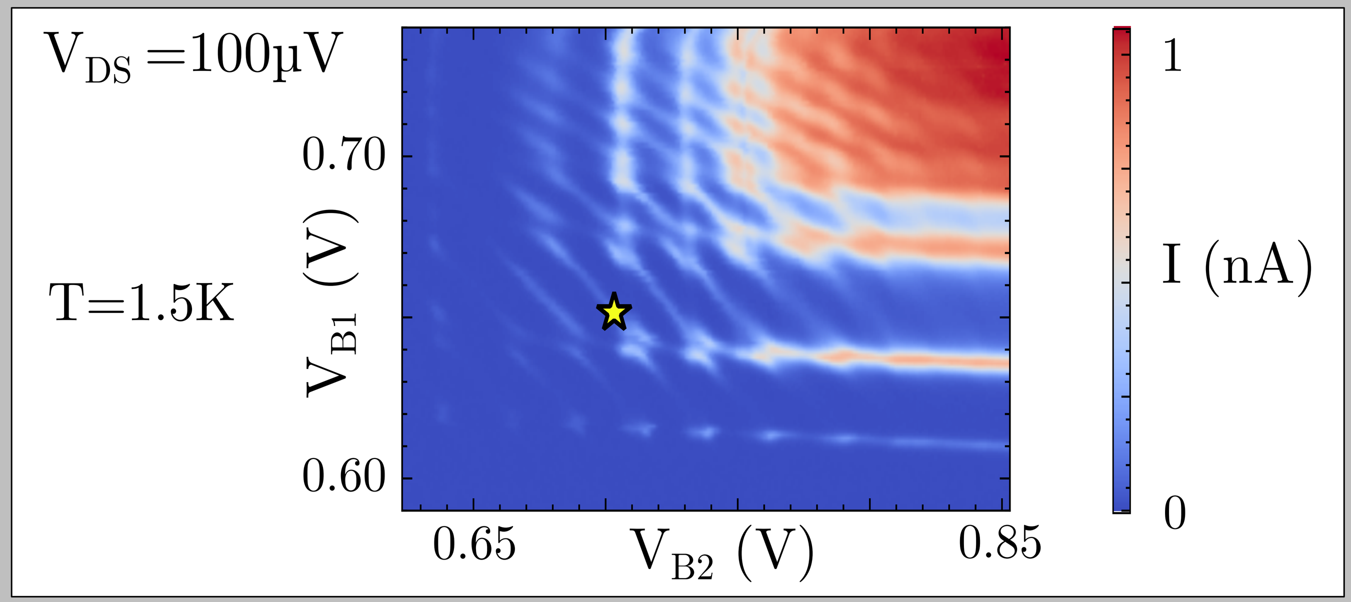
Stage 1: **Initialization**



Outcome

- SET turn-on voltage
- Barrier gates (B1, B2) pinch-off ranges

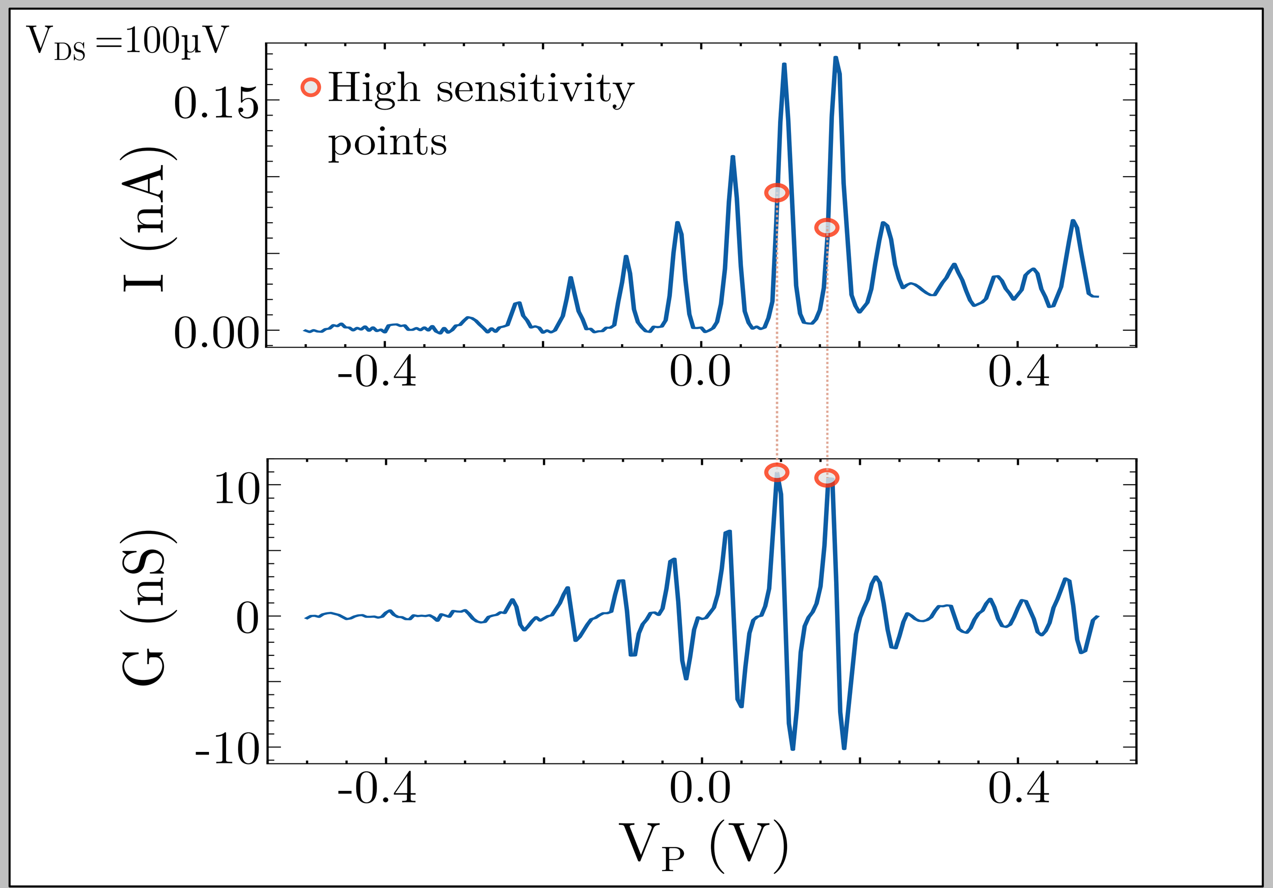
Stage 2: **Bias point selection**



Outcome

- Selected bias point: (V_{B1}, V_{B2})

Stage 3: **Sensitivity tuning**



Outcome

- Plunger voltage V_P for desired sensitivity

Summary and future work

- The current implementation autotunes an SET (or SHT - whichever is specified by the user) in ~30 minutes, with Stage 2 taking ~25 minutes. With faster gate voltage sweeps using FPGA-based instruments, we expect the process to speed up by an order of magnitude.
- To ensure that the device stays tuned to the desired sensitivity, robust to drifts caused by charge rearrangements in the device, dynamic feedback techniques can be implemented to adjust the plunger voltage, maintaining constant sensitivity.

References and acknowledgements

[1] J. Zwolak, J. Taylor, "Colloquium: Advances in automation of quantum dot devices control", Rev. Mod. Phys. 95, 011006 (2023)

[2] Andrija Paurevic, "Quantum Dot Control", github.com/mainCSG/QuantumDotControl (2024)

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