FROM AN EMPTY LAB TO CUSTOMIZED SETUPS AND GERMANIUM QUANTUM DOTS

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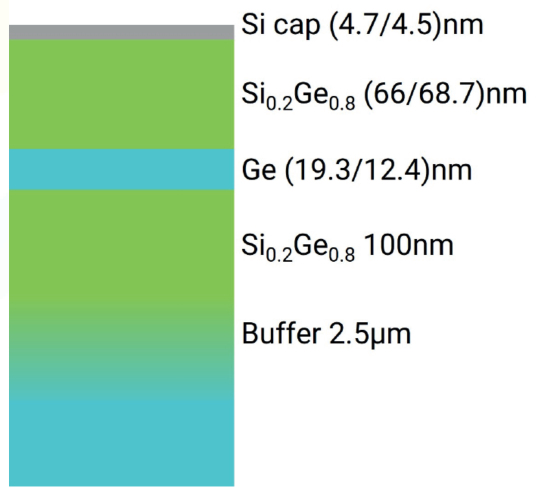
LAB INFRASTRUCTURE AND MOTIVATION

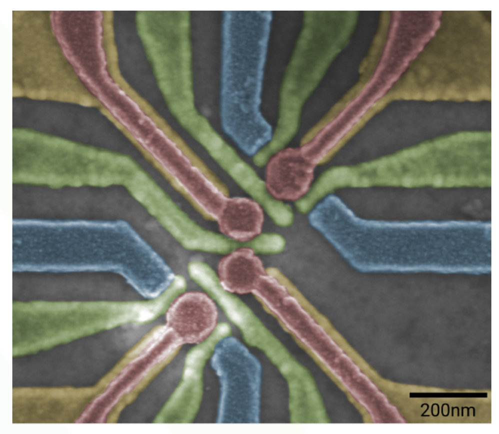
- Newly funded research group at FZ Jülich
- Investigate spin qubits and super-semi devices in Germanium quantum wells
- Growth of heterostructures done at Leibniz IHP
- Access to state-of-the-art cleanroom in FZJ[1] with our own AJA deposition tool
- Two Bluefors dilution refrigerators and one Entropy adiabatic demagnetization refrigerator (ADR)



Layer stack of the two wafers investigated (wafer 1/wafer 2)

QUANTUM DOT SAMPLES

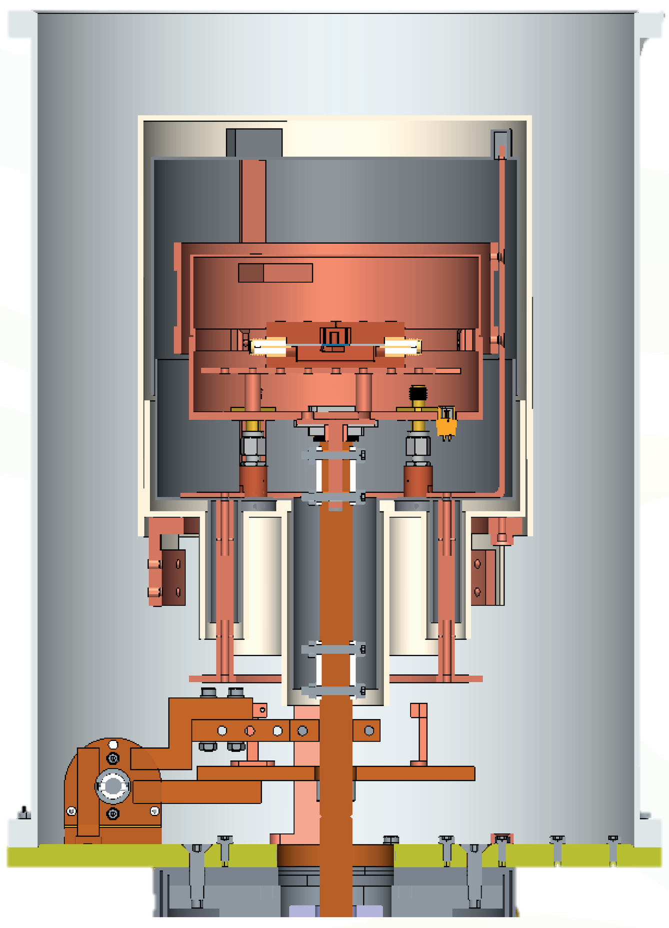
- Single layer devices for faster device and wafer iterations
- Two layer devices in fabrication for improved electrostatic control
- DQDs as initial device layout to establish qubits
- Qubits as a tool to investigate g-factor[4] and spin orbit interaction[5]



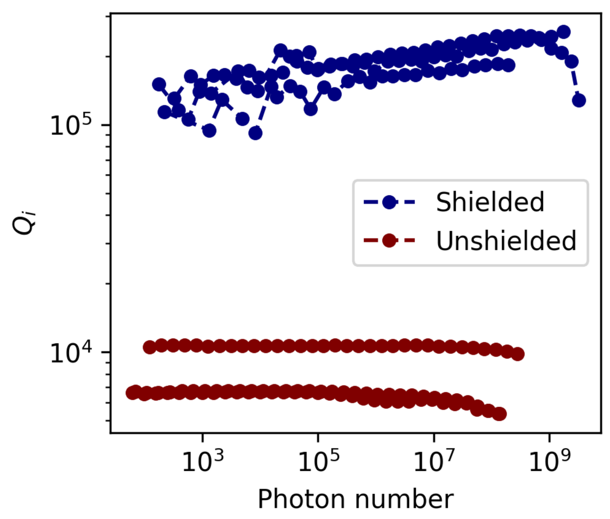
False colored SEM micrograph of a two layer device

CUSTOM SAMPLE SHIELDING IN AN ADR

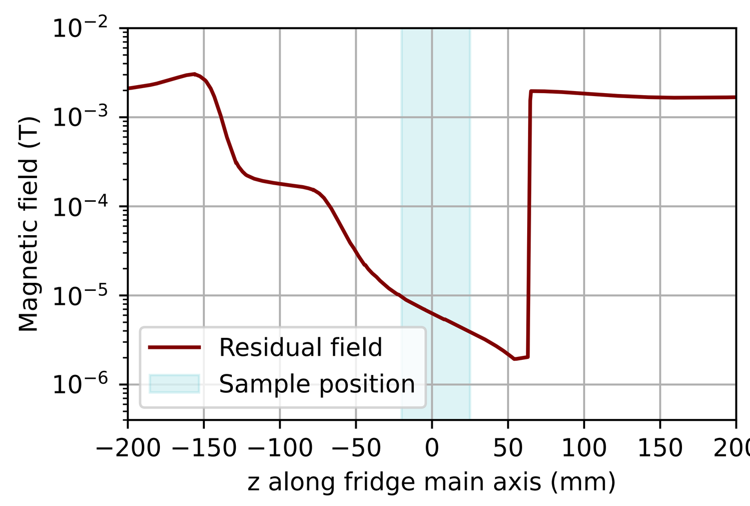
- Resonators studied together with Marc Neis and Rami Barends from PGI-13, FZ Jülich
- **µ-metal and Niobium shields**[2] coupled to 4K stage (PT cooled)
- Feedthrough for 4 RF lines & 48 DC lines
- Light-tight **Radiation shield**[3] coupled to lowest temperature stage
- Comsol simulations used to simulate shielding factor (B_{res}/B_0>100 at sample)
- Chimneys to compensate feedthroughs
- Significantly increased resonator quality factors (Nb resonators on Si) with magnetic shielding



Schematic cross-section of mounted shields



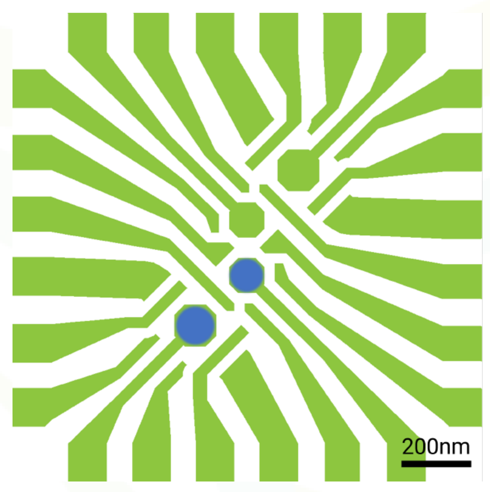
Internal quality factor of resonators with and without magnetic shielding



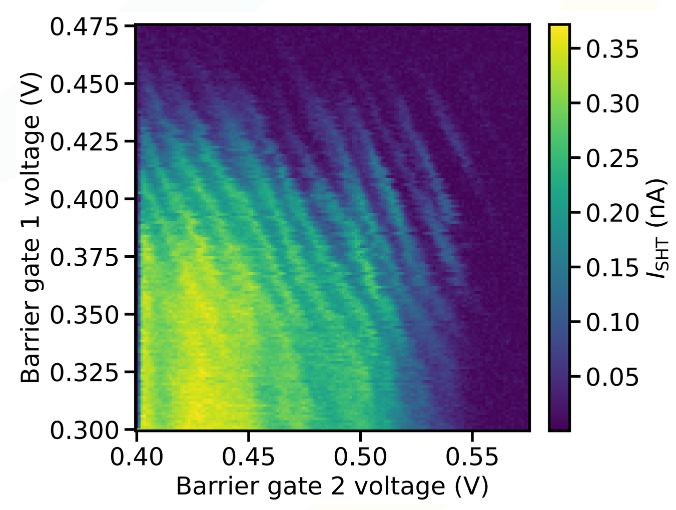
Comsol simulation of full geometry of both magnetic field shields

QUANTUM DOT MEASUREMENTS

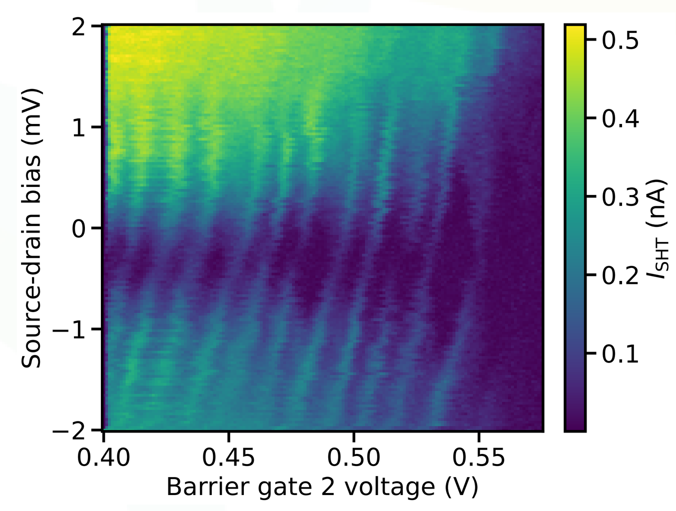
- Wafers require depletion mode quantum dots (wafer 1 used below)
- Well controllable sensing dot
- Both individual quantum dots formable
- DQD limited by interdot barrier formation in depletion mode wafer



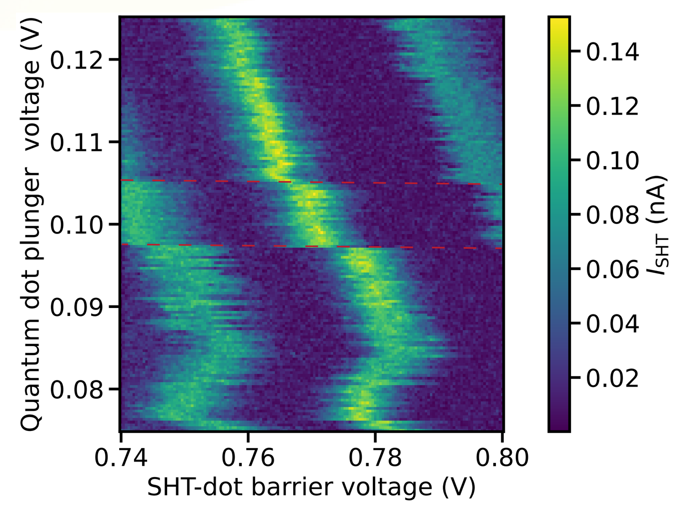
Gate layout of single layer devices used to measure an SHT and neighboring quantum dot



Single hole transistor barrier-barrier sweep



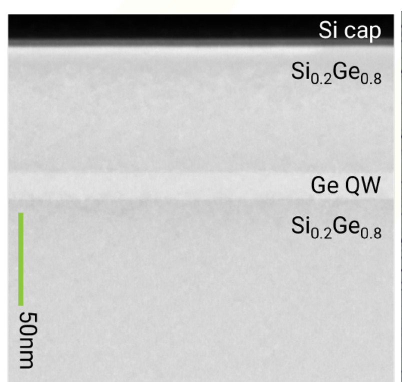
Coulomb diamonds in single hole transistor



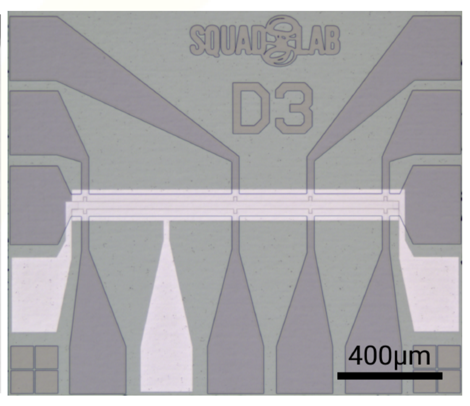
Charge sensing of a neighboring quantum dot dashed lines as visual guide

HETEROSTRUCTURE OPTIMIZATION

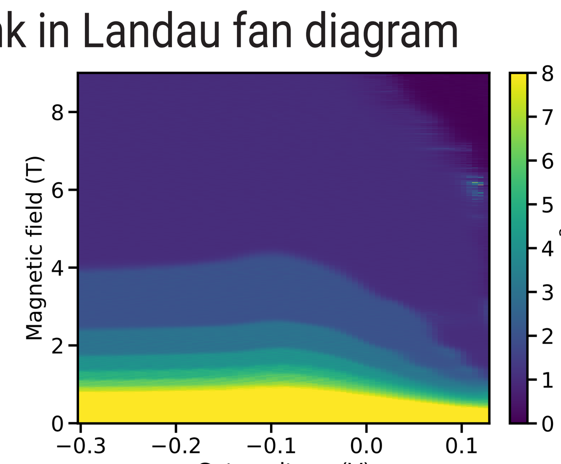
- Feedback loop with IHP
- Screening gates to compensate always-on wafers
- Edge currents or charged cap might lead to kink in Landau fan diagram



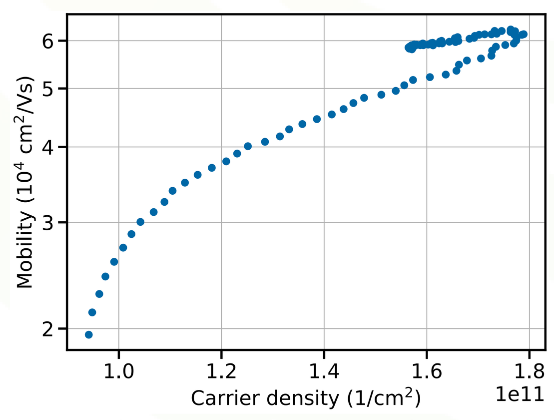
TEM image of wafer 2



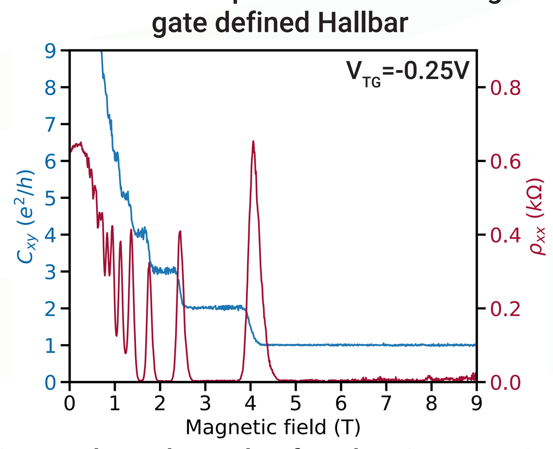
Hallbar with screening gates and identical dimensions to the one used



Conductance plateaus in screening gate defined Hallbar



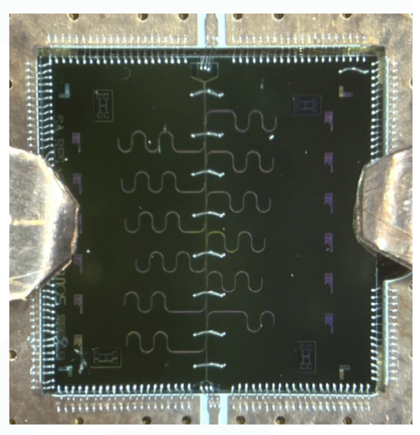
Mobility vs carrier density showing an increase in carrier density until V_{TG}=-0.1V following a drop at constant µ



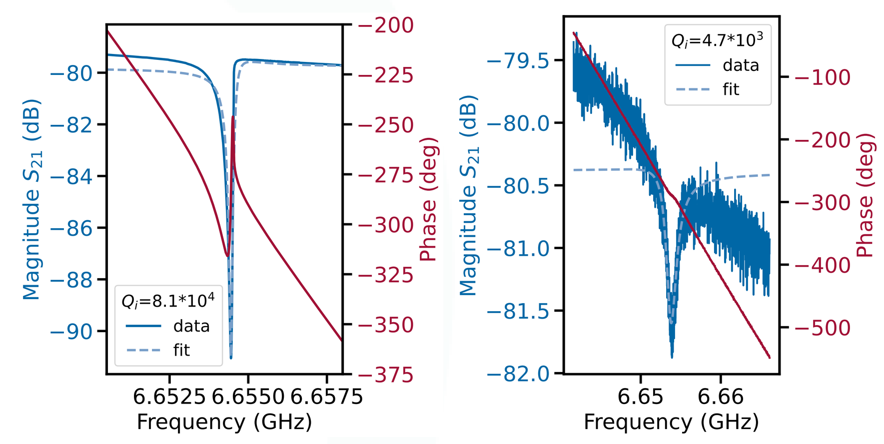
Linecut through Landau fan showing quantized conductance and Shubnikov-de-Haas oscillations

RESONATORS ON GERMANIUM

- NbTiN resonators on Ge/SiGe with resonance frequencies between 5.5-7.5GHz
- Single photon quality factor Q_i≈5x10³, high power quality factor Q_i≈8x10⁴



Mounted resonator sample. Stripline is connected to 12 quarterwave resonators at different frequency



NbTiN resonator on wafer 1 with extracted quality factors at input powers of -55dB and -130dB

OUTLOOK AND REFERENCES

- Magnet inside ADR shields for co-integration of superconducting circuits and spin qubits
- Characterize g-factor tensor with Germanium spin qubits
- Measure spin-orbit interaction with spin qubits and in super-semi devices

[1] Albrecht, W., Moers, J. & Hermanns, B. JLSRF 3, A112 (2017)
[2] Bergen, A. et al., Rev. Sci. Instrum. 87, 105109 (2016)
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