Aachen Graphene & 2D Materials Center

2D Materials and Quantum Device Group

RWTH AACHEN UNIVERSITY

Master Thesis:
Towards qubits in bilayer graphene quantum dots

Motivation: 2-D materials such as graphene and hexagonal boron nitride (hBN) provide a versatile platform for exploring electronic and quantum phenomena in the solid state. Bilayer graphene (BLG) is particularly attractive because its band structure and band gap can be tuned by electrostatic displacement fields, while its weak hyperfine interaction and intrinsically low spin-orbit coupling (SOC) make it a promising host for long-lived spin and valley states. At the same time, combining BLG with transition metal dichalcogenides (TMDs) such as WSe2 enables proximity-induced SOC and additional control knobs without sacrificing the high electrostatic tunability of BLG devices.
Recent progress has enabled highly tunable single- and double-quantum-dot devices in BLG, including charge sensing down to the level of individual tunneling events. A particular advantage of this platform is the ability to access both electron and hole quantum dots within the same device. The next step is to move from static characterization to time-dependent control and spectroscopy of quantum states in these devices. This requires identifying suitable material stacks and device geometries, understanding the relevant energy spectra and selection rules under confinement, and establishing robust routes toward initialization, manipulation, and readout of spin and/or valley degrees of freedom.

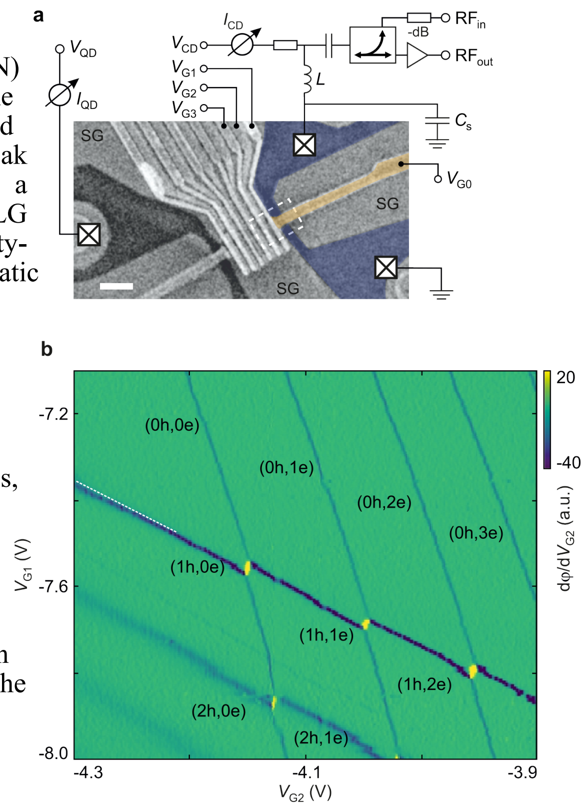
Aim of the thesis: The aim is to design, fabricate, and investigate gate-defined quantum dot devices based on bilayer graphene and BLG/TMD heterostructures, with the goal of developing time-resolved control concepts for confined quantum states. The overarching objective is to identify regimes and design principles that bring these systems closer to the feasibility of qubit operation.

Your tasks: You will contribute to the fabrication and measurement of bilayer graphene quantum dot devices. You may choose which topic to focus on. The fabrication process includes working in a cleanroom environment, characterizing samples using techniques such as Raman spectroscopy and atomic force microscopy, and designing masks for electron-beam lithography. You will perform transport measurements in a dry dilution refrigerator at a base temperature of 20 mK and evaluate the recorded data using self-developed Python-based evaluation scripts.

You will gain experience in the following topics:

- Quantum dot physics, 2D material heterostructures, electronic transport experiments
- Fabrication of state-of-the-art quantum devices
- Performing measurements on a dilution refrigerator
- Data evaluation using self-developed analysis methods

Furthermore, you participate in group seminars and journal clubs, where you follow current developments in the field and discuss recent experiments.
As this Project is part of the ML4Q Excellence Cluster, you will also be able to take part in joint activities (internal Conferences/ Workshops) organised by the Cluster.



(a) SEM Image of a double T-junction sample for charge detection. The quantum dots (QDs) are formed by the finger gates and then sensed by the quantum point contact (QPC) in the sensing channel (blue overlayed area).

(b) A charge stability diagram recorded with a charge sensor, showing an electron-hole double quantum dot (DQD) regime. Each line corresponds to the addition of one charge carrier in one of the QDs. schematic of the band edges with respect to the Fermi energy along the conducting channel from source (S) to drain (D), showing the creation of an electron-hole DQD (yellow circle).

Contact: For further information, please contact Hubert Dulisch (hubert.dulisch@rwth-aachen.de) or Lars Mester (lars.mester1@rwth-aachen.de). More information about our work can be found at stampferlab.org and www.graphene.ac.