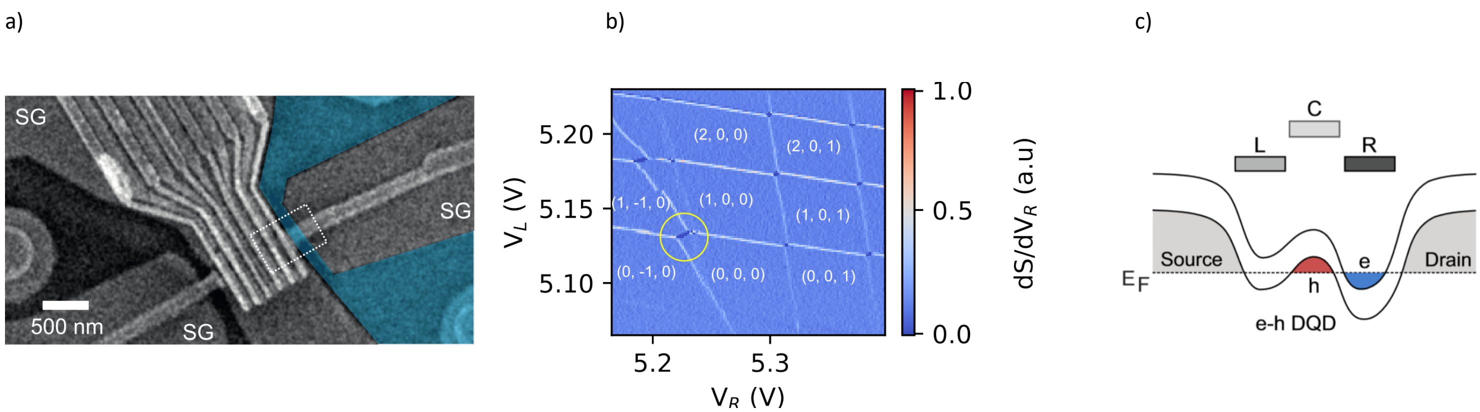
Aachen Graphene & 2D Materials Center

2D Materials and Quantum Device Group

RWTH AACHEN UNIVERSITY

Master Thesis: Towards spin qubits in bilayer graphene quantum dots

Motivation: Research in two-dimensional (2D) materials such as graphene and hexagonal boron nitride (hBN) is among modern solid-state physics's most exciting and fastest-growing fields. Bilayer graphene (BLG) is especially attractive as it offers an electric field-tunable band gap, low spin-orbit interaction, and low hyperfine coupling, promising long spin and valley coherence times for qubit operations.
Today’s technology allows the fabrication of highly tunable single and multi-quantum dot (QD) devices in bilayer graphene, in which we are able to measure single charge carrier tunneling events. However, further research is needed to realize the initialization, control, and readout mechanisms for spin state manipulation.



(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 the electron-electron and electron-hole double quantum dot (DQD) regimes. Each line corresponds to the addition of one charge carrier in one of the QDs. (c) A 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).

Aim of the thesis: *The goal of your thesis is to realize a mechanism to manipulate quantum states in time-resolved experiments, utilizing either electron spin resonance (ESR) by applying microwave radiation or electron dipole spin resonance (EDSR) by using gate voltages and a micromagnet in different regimes in a bilayer graphene double quantum dot, aiming to identify the most suitable regime for creating a qubit.*

Your tasks: You will contribute to fabricating and measuring bilayer graphene quantum dot devices. You are free to choose which topic to focus on. The fabrication includes working in a clean room environment, characterizing samples with tools like Raman spectroscopy or 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 20mK and evaluate the recorded data with self-developed Python-based evaluation scripts.

You will gain experience in the following topics:

- Quantum physics, quantum dots, electronic transport experiments
- Fabrication of state-of-the-art quantum devices
    - Clean room experience
    - Spectroscopy and Microscopy tools like Raman microscopy and AFM
    - Electron-beam lithography
- Performing measurements on a dilution refrigerator
- Data evaluation and simulations with *Python* or another programming language of your choice

Furthermore, you participate in group seminars and journal clubs where you follow current developments in this field of research and discuss recent experiments.

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