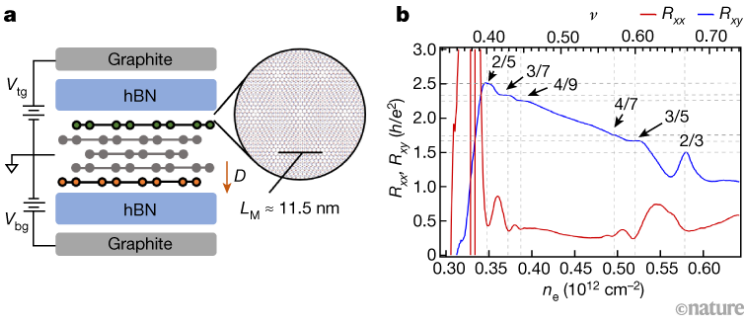
Aachen Graphene & 2D Materials Center

2D Materials and Quantum Device Group | RWTH AACHEN UNIVERSITY

Master Thesis:

Fractional quantum anomalous Hall effect in graphene moiré materials

Are you fascinated by the mysteries of quantum physics and eager to push the boundaries of scientific discovery? Join us for your MSc thesis and explore the remarkable physics of **the fractional quantum anomalous Hall effect**, a recently observed phenomenon at the forefront of quantum research.



(a) Sketch of a device used to measure FQAHE in pentalayer multilayer graphene. (b) Observation of FQAHE by the transverse and longitidinal resistance at zero magnetic field. From Ref. [2].

Motivation: The fractional quantum Hall effect (FQHE), traditionally observed in strong magnetic fields, arises from composite fermions—quasiparticles formed by binding charges to magnetic flux quanta. While integer quantisation at zero magnetic field is well documented (leading to the quantum anomalous Hall effect), the existence of fractional quantum Hall effects (FQAHE) without a magnetic field was a long-standing mystery.

In 2023, groundbreaking discoveries revealed fractional quantum anomalous Hall effects (FQAHE) in twisted $MoTe_2$ [1] and pentalayer rhombohedral-stacked graphene forming a moiré pattern with hexagonal boron nitride (hBN) [2]. These discoveries open an exciting new frontier in quantum physics.

Aim of this thesis: Your aim is to reproduce and further explore the fractional quantum anomalous Hall effect in rhombohedral multilayer graphene (thickness between 2-50 layers). Key objectives include:

- Establish protocols for fabricating devices from rhombohedral-stacked multilayer graphene within our group. This will be the most time-intensive part of your thesis.
- Perform electronic transport experiments at ultralow temperatures and in magnetic fields to observe quantum anomalous Hall effects, with the ambitious goal to reproduce the observation of FQAHE.
- Investigate how factors such as the number of layers and applied electric fields influence the anomalous Hall effect.

What will you gain? This project places you at the forefront of **condensed matter physics** and offers unparalleled opportunities to develop your skills in:

- Advanced **nanofabrication** techniques for quantum devices.
- Hands-on experience in **cryogenic transport experiments**.
- Deepen your understanding of **quantum phenomena, topological states, and strongly correlated systems.**

You will be part of a dynamic and collaborative research environment, where you will make meaningful contributions to an exciting and fast-evolving field of study. In addition, you will participate in group seminars and journal clubs, keeping up with the latest developments in the field of two-dimensional materials.

Contact us: For further information contact Dr. Robin Dolleman (dolleman@physik.rwth-aachen.de). More information about our work you can find at www.stampferlab.org and www.graphene.ac.

References

[1] Park, H., *et al. Nature* **622**, 74–79 (2023). https://doi.org/10.1038/s41586-023-06536-0
[2] Lu, Z., *et al. Nature* **626**, 759–764 (2024). https://doi.org/10.1038/s41586-023-07010-7