Unconventional superconductivity in twisted transitionmetal dichalcogenides

Master project in the group for
Computational Condensed Matter Theory – Prof. Wehling

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System

The reduced dimensionality of two-dimensional (2D) quantum systems introduces an intriguing twist to the explorable physics and states of matter. Not only the figurative sense of this statement showed to be true: Stacking two layers of 2D crystals with a relative twist of the individual layers leads to the emergence of superlattices with larger lattice constant than the original lattice, so-called moiré patterns (see Fig. 1). These moiré materials host rich phase diagrams with many different ordered states.

In this thesis project, you will investigate the special class of twisted transitionmetal dichalcogenide (TMDC) homobilayers. In particular, the project focuses on twisted WSe_2 which is the only system for which a zero-resistance state, possibly being superconducting, has been experimentally reported [1]. There is currently no theoretical description of the quantum nature of this state.

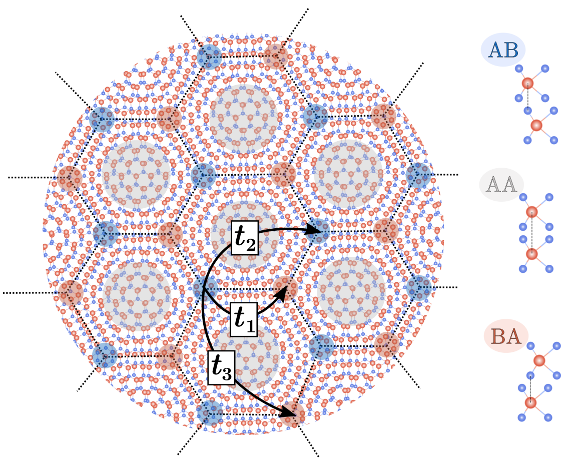

Figure 1: Moiré pattern of twisted transition metal dichalcogenide homobilayers [2].

Methodology

The aim of this project is to investigate the emergence of a possibly unconventional superconducting state in twisted WSe_2. You will use a tight-binding model description of the system developed in our group and apply Green function-based many-body techniques to it. In particular, you will learn about and use the fluctuation exchange (FLEX) approximation to characterize complex spin-fluctuation profiles and analyze the dominant superconducting order.

Similar to earlier approaches to twisted TMDC homobilayers [2], you will sample a phase diagram (electron density, temperature, environmental screening) and identify regions of collective order.

Learning outcome and requirements

During the project you will learn about **diagrammatic many-body techniques** and **(unconventional) superconductivity**. Additionally, the project will train you in the **usage of high-performance computing** and **programming in the context of data processing and visualization**. You will join an international work environment.

A good understanding of **quantum mechanics** and basic knowledge of **condensed matter physics** as well as **many-body physics/quantum field theory** are helpful for successfully working on the topic.

If you are interested, please contact Niklas Witt and Prof. Tim Wehling:

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References

[1] L. Wang et al., Nature Materials **19**, 861 (2020).

[2] N. Witt et al., Physical Review B **105**, L241109 (2022).