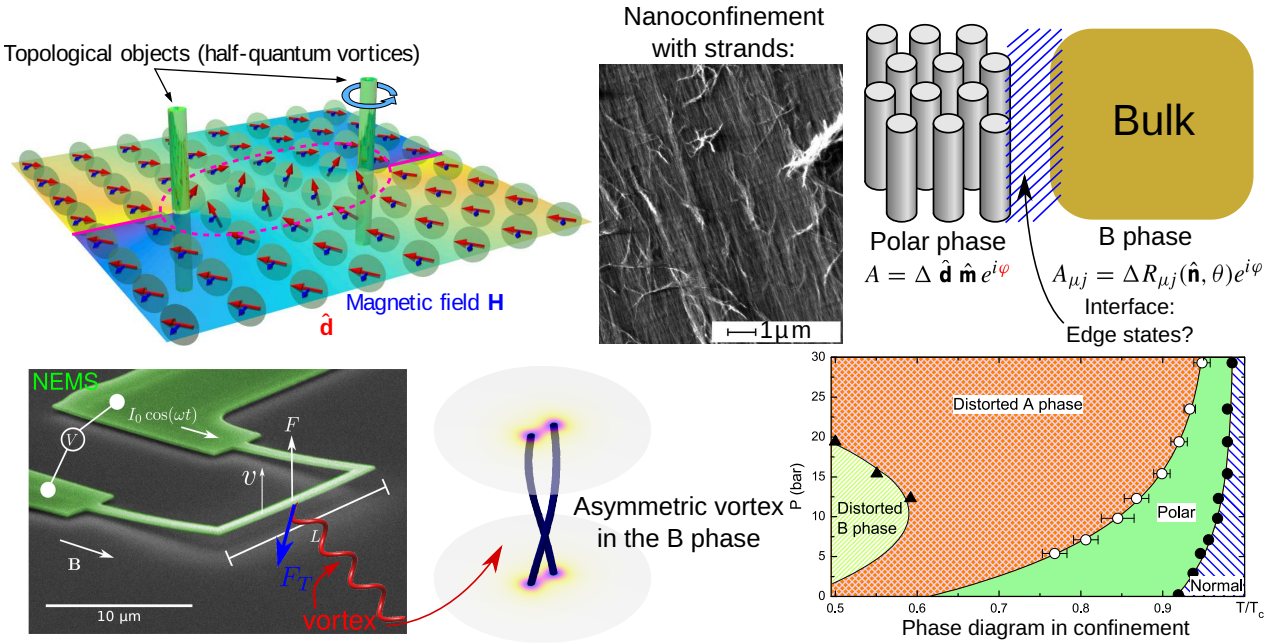
Simulation of topological superfluid interacting with nanostructures

Superfluidity is the result of quantum coherence on a macroscopic scale. Because of the macroscopic coherence, superfluid cannot flow like a regular fluid when rotated, but instead forms quantized vortices. A quantum vortex is a linear topological defect, with a thickness on the order of tens of nanometers. In the topological superfluid helium-3, the vortex cores can have a complicated internal structure and can host bound excitations including Majorana fermions, which are of great interest in topological quantum computing. Recently, new superfluid phases of ^{3}He have been observed in nanoconfined samples, with the fluid immersed in structures composed of solid thin nanoscale strands. Adjusting the design of the confining structures could be used to find new novel superfluid phases.

The goal of this project is to understand the interaction between the nanoscale objects and superfluid helium-3, especially with vortices in the system. Vortices can be pinned to nanodevices such as beams or nanomechanical oscillators, which could allow for fine control of individual vortices. Manipulating the positions of vortices could lead to the implementation of new techniques like Majorana braiding, which could be used for topologically protected quantum computations. Another question is what happens to vortices at the interfaces between bulk and confined superfluid phases. Different phases support different internal structures for vortices, which can lead to various edge states at the boundary with unique properties.



In practice, the work involves designing and running computational simulations of superfluid helium-3. The simulations will use a pre-existing code designed for large scale simulations utilizing the massive parallelization capabilities of modern GPUs. The simulation is based on the Ginzburg-Landau formalism and supports fully 3D meshes with arbitrary geometries. Experience in programming and C++ is not required, but is beneficial. The simulation projects are closely related to the experimental work of the group and there is a possibility of realizing the simulated systems in experiments in the future.

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