

Exploring non-Abelian geometric phases with mobile spins

General Scope:

When a quantum system performs adiabatically a closed loop in a parameter space, its state undergoes a transformation determined solely by the geometry of the path followed. In the non-degenerate case, this transformation reduces to the accumulation of a phase factor, usually referred to as the Berry phase. However, when the system is degenerate, the geometric transformation becomes matrix-valued and it modifies the state of the quantum system within the degenerate subspace. These transformations are, in general, non-commutative and are therefore referred to as non-Abelian geometric phases. Both Berry phases and non-Abelian geometric phases have numerous consequences in condensed matter systems. While many experiments have demonstrated the existence of Berry phases in electronic systems, experimental studies of non-Abelian geometric phases remain scarce. Beyond their fundamental interest, evidencing these phases and being able to harness them could enable the development of holonomic quantum computing, a more robust form of quantum information processing.

Research topic and facilities available:

We will develop an experiment where single holes are displaced along closed loops inside 2D arrays of quantum dots in germanium, a material with a strong intrinsic spin-orbit interaction, and at zero magnetic field. By studying the evolution of their spin states depending on the trajectory followed, we will evidence the non-Abelian geometric phases experienced by single spins during their motion in a spin-orbit field. We will investigate the properties of these transformations and their potential for quantum information processing. The experiments will be implemented in a dedicated dilution fridge and the fabrication of the quantum devices will be done in the clean room of Néel Institute.

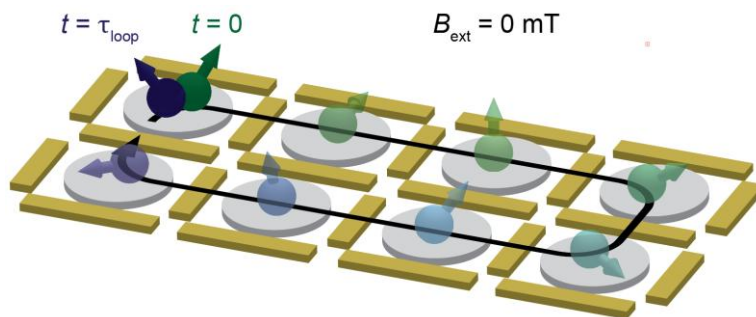


Figure: Studying geometric phases with single-spin transport experiments. Conceptual illustration of the proposed single-spin transport experiments. A spin is displaced inside a two-dimensional array of quantum dots at zero magnetic field by successive transfers between neighbouring quantum dots. When the spin is brought back to its initial point, it has experienced a geometric rotation induced by the spin-orbit field.

Possible collaboration and networking:

Local collaborations with groups in CEA Grenoble are being considered as well as international collaborations with groups in Delft (the Netherlands) and in Budapest (Hungary).

Possible extension as a PhD:

Extension of the project as a PhD is supported and subject to successful applications to local funding programs.

Required skills:

Knowledge in quantum mechanics and a strong taste for experimental physics are essential. Knowledge in condensed matter, semiconductor or spin qubit physics will be highly appreciated. Experience with cryogenic setups or in interfacing electronics using Python will be a plus.

Starting date: Spring 2027

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