

Project 4.7 Dynamics of topological defects in quantum environments

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Unit: ON6.4

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Background:

Topology has found a route from purely mathematical concepts to physics applications. The discovery of the quantum spin Hall effect and topological insulators more than a decade ago has revolutionized modern condensed matter physics. One of the most exciting applications is topological quantum computation with topological qubits such as the Majorana fermions emerging as excitations in topological superconductors. It is thus of great importance to investigate the dynamics of these excitations and beyond in the presence of the surrounding environments, such as photons or magnons. In the project, the PhD will investigate theoretically the interplay between the geometry and/or topology of the braiding trajectories and the environmental degrees of freedom. The PhD will also exploit such effects to construct long-range quantum gates between topological qubits and conventional qubits, such as hole-spins in semiconductor nanostructures, and possibly simulating them on the IBM quantum devices.

Aim:

1. Establish theoretically the interplay between the motion of Majorana fermions and/or semiconducting qubits and the quantum environments (e.g. photons, magnons)
2. Extend the framework to hole-spin qubits motion (or shuttling) in two-dimensional semiconductors (germanium and silicon; in collaboration with Prof. Lukasz Cywinski <http://info.ifpan.edu.pl/~lcyw/>)
3. Use the environment and the motion to implementing a universal set of quantum gates (in collaboration with Prof. Lukasz Cywinski <http://info.ifpan.edu.pl/~lcyw/>)

Requirements:

- MSc in Theoretical Physics,
- experience using Mathematica, Python, etc,
- proficiency in English

Funding:

Project "Harnessing the environment for topological quantum computing" under the OPUS grant P-535/O

Scholarship: grant funding of 5000 PLN per month, before subtracting obligatory employer and employee social security contributions (~15%), for 36 months. Afterwards, standard Polish PhD scholarship (about 2360 PLN/month net in years 1-2, 3640 PLN/month net in years 3-4).

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