Usage Report for Fiscal Year 2015

Project Title:

Topological properties of spin interferometers

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The research project belongs to the field of condensed matter physics in low-dimensional mesoscopic semiconductor systems. In mesoscopic quantum system interesting spin-related effects as well as topological phenomena are predicted to arise in phase coherent regime. These topological phenomena are often related to the geometric phases, namely Berry phases in the adiabatic limit as well as Aharonov-Anandan phase in the nonadiabatic case. Phase coherence length in semiconductor systems is of the order of micrometers which allows detection of phase coherent phenomena in mesoscopic systems. Fascinating physical phenomena in this regime have been predicted and signatures of such phenomena in experimental mesoscopic systems needs simulations. The project specifically studies topological transitions in the geometric phases. Signatures of such transitions in loop-shaped interferometers were predicted in a recent work by the applicant and his collaborators (H. Saarikoski et al., Phys. Rev. B 91, 241406(R) (2015)). It was shown that topological transitions of the geometric phase leads to characteristic interference pattern in conductance. This may be used as a robust control of phase of electron spin in spin interferometers. The spin interference and its associated topological transition has a close analogy in a classical systems of a precessing micromagnet. The geometric phase obtains just different values being 2π in the adiabatic limit which is in contrast to Berry phase π. This was studied in a recent manuscript (H. Saarikoski et al., arXiv::1511.0815) which has been submitted to Journal of Physics: Condensed Matter.

The research project has been performed in collaboration with a research group at University of Seville by prof. Diego Frustaglia, prof. Jose-Pablo Baltanas and PhD student J. Enrique Vazquez (now holding a PhD student position at Nanophotonics research center at University of Valencia, Spain). Their role in the project has been calculations of spin transport in 1D semiclassical ballistic systems. Experimental aspects of this work was discussed with prof. Junsaku Nitta and Dr. Fumiya Nagasawa at Tohoku University.

The supercomputer system has been used extensively in the simulations of realistic spin interference devices with disorder added in the system as well 2D effects resulting in multiple transport modes. These calculations are very useful in predicting expected experimental outcomes in the search for topological phenomena in spin interference. Many of the central theoretical findings are still waiting for experimental confirmation and simulations of realistic systems are essential in the research work and helps experimentalists to choose appropriate materials as well as a suitable transport regime. Recent results suggest that Zeeman oscillations in spin interferometers persist in the presence of moderate disorder that is good news for eventual future observation of topological phenomena in spin interference. These results are being prepared for publication.

The calculations in the supercomputer system are performed using Kwant code (www.kwant-project.org) which is a python-based software package developed to solve transport and structural properties of quantum systems. As of 15th of February the project had consumed 3.2 million core hours both at Massively Parallel Computer as well as Large Memory Application Computing Server (ACSL). This is 39% of the maximum number of core hours allocated for the project. High usage percent of the supercomputing system has prevented from using all the allocated computing time. Modeling of disorder requires averaging procedures, which consumes lots of computing time. Simulations of large systems with high precision also need a large memory capacity (over 2.8 Gb core memory) and therefore the ACSL has been used extensively.

Future prospects include changing geometry of the system towards polygonal structures instead of round shapes. This may bring benefits experimentally as well as may give rise to new physical phenomena. Large-scale quantum networks are also under consideration. This would, however, consume a lot of computing memory as well as computing time. Currently a plan is being devised to perform simulations of quantum networks of moderate size in the supercomputing system in the next fiscal year. If the initial results are promising computations on large-scale systems will be performed in the future.

To conclude, the results provide very fascinating results of spin interference phenomena with topological properties and the calculations indicate that the phenomena are observable in experiments in near future. Furthermore the results are promising for future developments in the field towards simulations of large-scale quantum networks

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Fiscal Year 2015 List of Publications Resulting from the Use of the supercomputer

[Publication]

Peer-reviewed publication :

H. Saarikoski, J. Enrique Vázquez-Lozano, José Pablo Baltanás, Fumiya Nagasawa, Junsaku Nitta, and Diego Frustaglia, Topological transitions in spin interferometers, Phys. Rev. B 91, 241406(R) (2015).

Preprint in the arXiv preprint server :

H. Saarikoski, José Pablo Baltánas, J. Enrique Vázquez-Lozano, Junsaku Nitta, and Diego Frustaglia, Effective geometric phases and topological transitions in SO(3) and SU(2) rotations, arXiv::1511.0815 (2015), submitted to Journal of Physics: Condensed Matter. Acknowledgement of the ACCC role will be added in the proof stage.

[Oral presentation at an international symposium]

Topological transitions in spin interferometers, APS March Meeting, San Antonio, US, March 2015 (Talk)

Topological transitions in the geometric phase in spin interferometers, DPG spring meeting, Berlin, Germany, March 2015 (Talk)

Topological transitions in effective geometric phases in SO(3) and SU(2) rotations, EP2DS/MSS conference, Sendai, Japan August 2015 (Poster)

Topological transitions for nonadiabatic SO(3) and SU(2) rotations, 3rd CEMS research camp, Kinugawa, Japan, Oct 2015 (Talk)

Topological Transitions In Spin Interferometers, ISNTT2015 conference, Atsugi, Japan Nov 2015 (Poster)

Low Domain-Wall Threshold Current Density in a Synthetic Antiferromagnet, MMM-Intermag 2016 conference, San Diego, US, Jan 2016 (Poster)