RICC Usage Report for Fiscal Year 2013

Project Title:

Spin Transport in Quantum Rings

Name: ○Henri Saarikoski

Laboratory at RIKEN: Center for Emergent Matter Science / Spin physics Research Team

Background：The research project belongs to the field of condensed matter physics in low-dimensional mesoscopic semiconductor systems. Spin transport in semiconductor quantum rings was studied theoretically using a numerical quantum transport method based on the Recursive Green's function (RGFM) algorithm. In quantum ring system interesting spin-related effects as well as topological phenomena are predicted. Results of calculations are compared to experiments in samples consisting of quantum ring ensembles performed in Prof. Nitta's group in Sendai. Now the aim is to do calculations for in the regime of large in-plane magnetic fields. Interesting physical phenomena in this regime have been predicted and signatures of such phenomena in experimental quantum ring systems needs to be calculated. The project aims specifically to study topological transitions of the Lyanda-Geller type (Y. Lyanda-Geller, Physical Review Letters 71, 657 (1993)) in the geometric phases (Berry's phase in the adiabatic limit), and the interplay between the topological transitions and Landau-Zener transitions between the energy bands split by the spin-orbit interaction.

Calculation method：Spin transport in semiconductor quantum ring systems is calculated by using the recursive Green's function method (RGFM). The method is a widely used method and proven to be effective in quantum transport calculations. Recently general purpose RGFM codes have been made public for the scientific community such as the KWANT software package which is based on the Python programming language (http://kwant-project.org/, C. W. Groth, M. Wimmer, A. R. Akhmerov, X. Waintal, *Kwant: a software package for quantum transport*, arXiv:1309.2926). So far 220,000 core hours have been used at RICC and first results in disordered systems have been obtained. The RICC has been used to the maximum level possible.

Results：The transport calculations indicated that the geometric phase of spins can be manipulated using an in-plane magnetic field. These findings were confirmed in experiments. Part of the results were published in F. Nagasawa, D. Frustaglia, H. Saarikoski, K. Richter, and J. Nitta, Nature Communications 4:2526, September 26 (2013)). This part of the research was completed in Regensburg, Germany. I have begun my new position as a research scientist in September 2013 at Riken. The project has since then focused on spin transport in high magnetic fields using RICC computing cluster. Topological transitions of Lyanda-Geller type may be found in this regime. Initial results indicate phase shifts of pi in this regime which are consistent with a topological transition (see Figure 1). However, to confirm the finding additional calculations are needed in the disordered regime. If the signal persists despite disorder the effect can be observed in experiments. Preliminary results indicate that at least weak disorder does not ruin the effect and the effect can be observed in experiments.

Conclusions：The cluster has been used in large scale computations of quantum transport and initial results are consistent with theoretical prediction that a topological transition in the geometrical phase (Berry's phase) is observable in interference pattern in the current through an ensemble of quantum rings. The calculations provide very important information about a real signal in experiments and can be used to prepare experiments.

Future Plans：Calculations in disordered systems require multiple calculations at different disorder configurations. The plan is to use large-scale many-parameter simulations to extract a reliable signal of topological transitions in the Berry's geometrical phase in interference experiments. The non-adiabatic counterpart of the Berry's phase, the Aharonov-Anandan phase, is also studied. The first diagrams of the interference signal can be calculated using roughly 200,000 core hours. Subsequent work at medium accuracy would need approximately 500,000 core hours. High accuracy diagrams for publications would require 1,000,000 core hours.

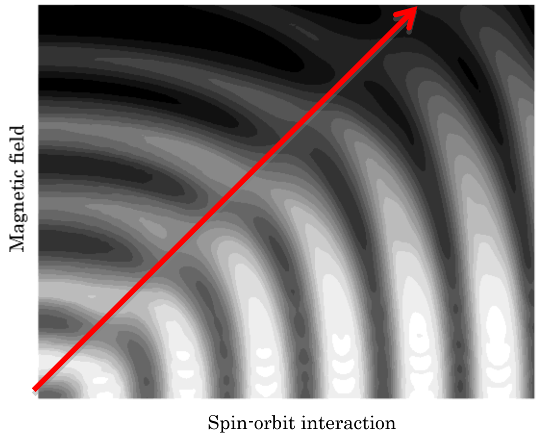

Figure 1 Calculated interference pattern in the current through a ballistic quantum ring shows a possible topological transition in the geometric phase as calculated with the RGFM method using the RICC. A phase change of pi along the arrow direction can be seen as the destructive interference changes to constructive interference and the other way round. The phase change of pi may indicate a topological transition in the geometrical phase (unpublished).

Fiscal Year 2013 List of Publications Resulting from the Use of RICC

The applicant has not yet published the results obtained using the RICC.

The most relevant recent publication in this topic has been published last year
F. Nagasawa, D. Frustaglia, H. Saarikoski, K. Richter, and J. Nitta,
Nature Communications 4:2526, September 26 (2013)). The paper can be accessed on-line (open access) via : http://www.nature.com/ncomms/2013/130926/ncomms3526/full/ncomms3526.html
These results were obtained using University of Regensburg computers and subsequent calculations have been performed using the RICC.

[Others]

Results using the RICC were presented in a poster at FIRST International symposium on Topological Quantum Technology at University of Tokyo, January the 29th, 2014.