【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project : Nonequilibrium states of low-dimensional quasiparticles in a mesoscopic quantum Hall system

FUJISAWA, Toshimasa
(Tokyo Institute of Technology, School of Science, Department of Physics, Professor)

Research Project Number : 19H05603 Researcher Number : 20212186

Keyword : mesoscopic system, quantum Hall system, low-dimensional quasiparticle, nonequilibrium state

【Purpose and Background of the Research】

Quasiparticles play essential roles in condensed matter physics, where collective motion that cannot be explained with a single-particle picture can be understood with quasi-particles. The quantum Hall system, which is a kind of two-dimensional topological insulators that appear in a high magnetic field, shows intriguing excitation modes in the insulating bulk states and peculiar non-equilibrium states in the unidirectional chiral edge states. These characteristics can be explained with low-dimensional quasiparticles, such as fractional charges like *e*/3 and *e*/5 and skyrmions (spin texture) in the bulk and plasmons (charge) and spinons (spins) in the edge, as shown in Fig. 1. It would be innovative if one can find a novel application scheme by controlling nonequilibrium states of these characteristic quasiparticles.

The objective of this work is to explore novel nonequilibrium dynamics of such low-dimensional quasiparticles and to develop application schemes for nonequilibrium thermodynamics and topological quantum engineering. The specific focus of interest in this project is controlling quasiparticles toward braiding operations and quantum-Hall heat engines.

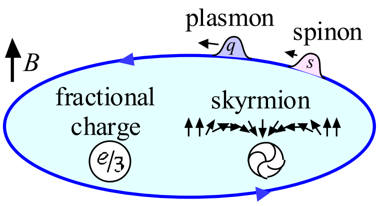

Fig. 1. Low-dimensional quasiparticles.

【Research Methods】

We develop mesoscopic quantum Hall systems by fabricating nanostructures on an AlGaAs/GaAs heterostructure. Nonequilibrium quasiparticles can be controlled and analyzed with a tailored mesoscopic quantum Hall system. One can integrate functional devices such as quantum point contacts (QPCs), quantum dots (QDs), and quantum anti-dots to construct a circuit for low-dimensional quasi-particles, as shown in Fig. 2.

Nonequilibrium charge, spin, and heat transport associated with quasiparticles can be investigated for example with an ultra-fast scanning optical polarization microscope. A wave packet can be injected by applying a pulse to a QD (charge injector) and can be analyzed with a QD energy spectrometer, a time-resolved charge detector, and a current noise analyzer. Microscopic edge structure can be identified particularly in the fractional quantum Hall regime. Manipulation of single quasiparticles can be extended to design a braiding operation. A quantum-Hall heat engine can be implemented by designing an efficient conversion between heat and work.

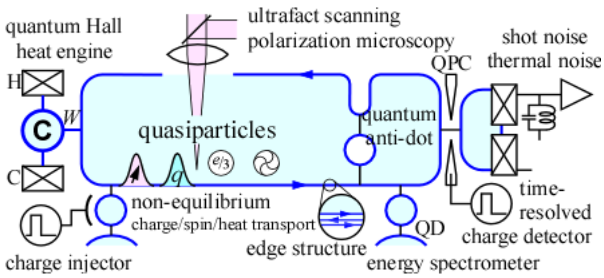

Fig. 2. A mesoscopic quantum Hall system.

【Expected Research Achievements and Scientific Significance】

Experimental and theoretical studies on mesoscopic quantum Hall system will be devoted to exploring non-equilibrium dynamics of low-dimensional quasiparticles. We will develop manipulation schemes for single quasiparticles that can be used for topological quantum engineering and quantum-Hall heat engines.

【Publications Relevant to the Project】

・K. Itoh, R. Nakazawa, T. Ota, M. Hashisaka, K. Muraki, and T. Fujisawa, "Signatures of a nonthermal metastable state in copropagating quantum Hall edge channels", Phys. Rev. Lett. 120, 197701-1-5 (2018).

・M. Hashisaka, N. Hiyama, T. Akiho, K. Muraki and T. Fujisawa, "Waveform measurement of charge- and spin-density wavepackets in a chiral Tomonaga–Luttinger liquid", Nature Physics 13, 559-562 (2017).

【Term of Project】 FY2019-2023

【Budget Allocation】 153,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://fujisawa.phys.titech.ac.jp
fujisawa@phys.titech.ac.jp