【Grant-in-Aid for Specially Promoted Research】
Science and Engineering (Mathematics/Physics)

Title of Project：Dynamics of electron wavepackets in semiconductor quantum structures

Toshimasa Fujisawa
(Tokyo Institute of Technology, Research Center for Low Temperature Physics, Professor)

Research Area：Physics

Keyword：Mesoscopic systems, semiconductor physics

【Purpose and Background of the Research】

Since semiconductor superlattices were proposed in 1969, technologies and physics for controlling electron wave have been developed in novel semiconductor nanostructures. Recently, coherent control of electronic states has been demonstrated by many groups (including us) for realizing quantum information devices.

In this project, we extend the technique used for controlling quantum states of stationary electrons to that of traveling electrons (wavepacket). We would like to study quantum electron optics and engineering by controlling electron wavepacket in both time and space domains. Specifically we focus on one-dimensional dispersionless edge channel formed in the quantum Hall regime, and investigate intriguing electron dynamics and their application by developing generation, control and measurement schemes.

【Research Methods】

We will design various components such as electron beam splitters, voltage-controlled delay lines, single-electron generators/detectors, and electron interferometers in semiconductor heterostructures. Various interferometric experiments developed in quantum optics can be reproduced in solid state devices. The variation of quantum statistics and interactions can be discussed with the dynamical behaviors.

For example, a voltage-controlled delay line can be designed by using edge channel traveling along a metallic gate electrode [See Fig. 1(a)]. The local electric field and screening effect for the edge channel can be controlled by the gate voltage, and affects the group velocity of the charge transport. A charge pulse generated from an Ohmic contact is successfully delayed by shown in Fig. 1(b).

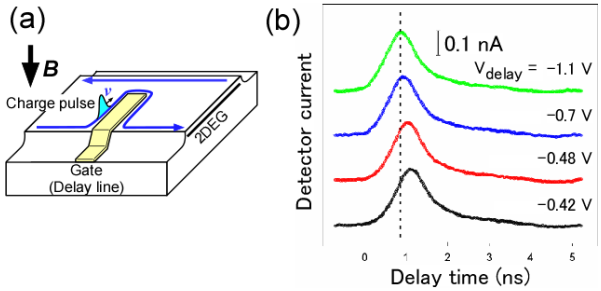

Fig. 1 (a) A delay line for an edge channel. (b) Delay characteristics of a charge pulse.

【Expected Research Achievements and Scientific Significance】

The electron wavepacket travels as edge magtetoplasmon mode, whose velocity is typically 10^5 - 10^6 m/s. We would like to investigate fundamental dynamics of electron wave packet in the time and space domain shown in Fig. 2, where novel charge dynamics, coherent wavepacket transport and high-speed electronics are expected.

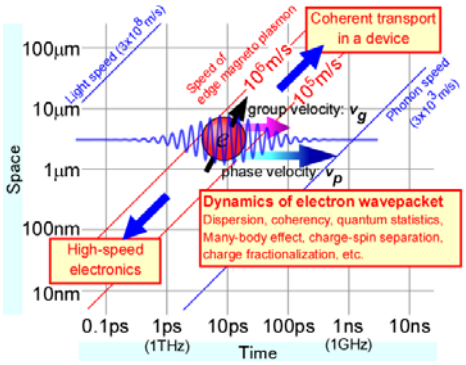

Fig. 2 Edge magnetoplasmon mode in time-space domain.

【Publications Relevant to the Project】

[1] H. Kamata, T. Ota, and T. Fujisawa, "Correlation Measurement of Time-Dependent Potentials in a Semiconductor Quantum Point Contact", Jpn. J. Appl. Phys 48, 04C149(2009).
[2] G. Shinkai, T. Hayashi, T. Ota, and T. Fujisawa, "Correlated coherent oscillations in coupled semiconductor charge qubits", to be published in Phys. Rev. Lett. (2009).

【Term of Project】 FY2009-2013
【Budget Allocation】 421,400 Thousand Yen
【Homepage Address and Other Contact Information】
http://fujisawa.phys.titech.ac.jp/
fujisawa@phys.titech.ac.jp