MERIT Internship Program (Domestic) Report

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MERIT 7th student
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Period

October 1st , 2019～March 31th , 2020

Host organization

NTT Basic Research Laboratories, Physical Science Laboratory, Quantum Solid State Physics Research group

Research theme

Cross-correlation measurement of quantum shot noise in the quantum Hall states.

Overview

From October 1, 2019, I developed a transimpedance amplifier (current amplifier) for measuring current noise under the supervision of Dr. Masayuki Hashisaka in NTT Basic Research Laboratories for 6 months. The NTT Basic Research Laboratories is a research institute that represents Japanese corporate research laboratories in physical science and is known for producing many high-impact results. In my Ph.D. research, I have studied the physical properties of quantum Hall edge states. Dr. Hashizaka is an up-and-coming young researcher in this field and has achieved excellent results using his own technology called current noise measurement. I had an internship under Dr. Hashizaka in order to experience basic research at a corporate research institute and to get hints for career development from senior researchers who are active in the field of material science.

Research

Current noise measurement is a powerful tool for clarifying many-body effects in condensed systems and has contributed to important discoveries such as the detection of fractional charges by the fractional quantum Hall effect. It was an autocorrelation measurement that measures the noise generated at one of the electrodes. On the other hand, cross-correlation measurement, in which noise generated at multiple electrodes is measured separately, is not only expected to dramatically improve measurement accuracy, but also theoretically shown to be capable of detecting entanglement between multiple quasiparticles. However, the conventional voltage measurement method using the LC resonance circuit has a problem that it is difficult to remove the artificial correlation caused by the parasitic capacitance between different electrodes, and there are very few experimental examples.

Recently, the current measurement method developed by Dr. Hashisaka has solved this artificial correlation problem, but the noise of the current amplifier itself is larger than that of the voltage measurement method, and there is room for improvement.

Therefore, in this internship, we aimed to develop a low-noise current amplifier that operates at extremely low temperatures (up to 4 K). First, instead of a commercially available high electron mobility transistor (HEMT), by using a HEMT made by NTT specialized for cryogenic operation, the measurement frequency band was doubled and the amplification factor was tripled. In addition, by adopting a self-bias circuit, the influence of individual differences in HEMTs was suppressed and the number of power supply wirings could be halved.

We tried to evaluate the performance by installing the fabricated current amplifier in a dilution refrigerator and measuring the current noise generated by the sample in the quantum Hall state. Unfortunately, due to the effects of the coronavirus epidemic, we could not take enough time for the experiment, but preliminary measurement results showed that the noise of the measuring instrument was reduced to about 1/5. Considering that the measurement frequency band has expanded, this means that the measurement accuracy has increased about 35 times within the same integration time, which is comparable to the conventional voltage measurement method. If this result is correct, it can be said that the development of a practical high-sensitivity noise measurement system that solves the conventional problem in cross-correlation measurement has succeeded for the first time.

Impression

Regarding the startup of the noise measurement system, I was able to experience the process from manufacturing a current amplifier to mounting it on a dilution refrigerator and measuring it, which was a very meaningful training. I think that I was able to acquire the techniques and tips necessary for noise measurement that cannot be obtained by just using the existing measurement system, and I think that I have cultivated the ability necessary to launch my own noise measurement system in the future.

In addition, since NTT Basic Research Laboratories is a corporate research institute, I feel that knowing the difference from the laboratory of the university was very meaningful in considering my future career. For example, they were highly aware of security and labor management, and I was able to learn the attitude to engage in research as a profession. Furthermore, it seems that the experimental facilities and funds have been systematically maintained and operated from a long-term perspective. It was also very inspiring from the perspective of managing a research institute or laboratory. Besides, most of the researchers were Ph.D. holders, and the level of discussion was high and I was inspired a lot.

Acknowledgement

I would like to express my deep gratitude to Dr. Hashisaka, who kindly accepted my internship offer and gave me a polite instruction even in the busy schedule. I would also like to thank the group leader, Dr. Muraki, for allowing me to accept this internship, and everyone in the Quantum Solid State

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