Floating-Electron-Based Quantum Information RIKEN Hakubi Research Team
（2021）
RIKEN Hakubi Team Leader, Erika Kawakami, Ph.D. Degree

(0) Research field

CPR Subcommittee: Physics, Engineering

Keywords: microwave, qubit, quantum computer, electrons on helium, Rydberg state

(1) Long-term goal of laboratory and research background

Surface state electrons on liquid helium form an exceptionally clean two-dimensional electron system at the interface between liquid helium and vacuum. Thanks to its cleanness, the quantum states of the electrons on helium are expected to have a long coherence time, which provides a perfect platform to realize qubits with. Thus, we aim to realize a scalable quantum computer using electrons on helium.

We also work on developing new technologies which is required when a large number of qubits are prepared in a cryogenic equipment such as a cryogenic microwave source.

(2) Current research activities (FY2021) and plan

(A) Detection of the Rydberg states of electrons on helium

- In the beginning of FY2021, we succeeded in reproducing the result that was achieved at OIST "image-charge detection" of the Rydberg states of electrons on helium [E. Kawakami, A. Elarabi, D. Konstantinov, PRL, 123, 086801 (2019).] at RIKEN.
- We made an LC circuit and cooled down it to a cryogenic temperature and measured the capacitance sensitivity of the circuit.
- Finally, we integrated the LC circuit to the electrons-on-helium experimental setup and we succeeded in detecting the Rydberg states of many electrons on helium.

Future plan: The sensitivity of the home-made LC circuit is high enough to be used to detect the Rydberg state of a single electron. We will fabricate the sample to trap a single electron and integrate the LC circuit to the sample.

(B) Development of a cryogenic microwave source

- Our 1st prototype of the cryogenic microwave worked at 33mK.
- We made a new design of the circuit with which we can tune the frequency of the microwave and we measured that the circuit worked at room temperature.
- We also developed the technique to synchronize the two circuits. This synchronization technique may allow us to improve the readout fidelity of the qubits further.

Future plan: We will cool down the new circuit and measure that the frequency of the microwave can be tunable even at a cryogenic temperature. We will start using the cryogenic microwave source with a real qubit device.

(3) Members

	Name
RIKEN Hakubi Team Leader	Erika Kawakami
Technical Scientist	Ivan Grytsenko

Postdoctoral fellow	Asher Jennings
Technical Staff I	Hiromi Ito
Secretarial assistant	Yuko Taki
Research Part-timer	Rajesh Mohan

(4) Representative research achievements

1. E. Kawakami, A. Elarabi, D. Konstantinov, “Relaxation of the Excited Rydberg States of Surface Electrons on Liquid Helium.” Physical Review Letters, 126, 106802 (2021).
2. A. Elarabi, E. Kawakami, D. Konstantinov, “Cryogenic amplification of image-charge detection for readout of quantum states of electrons on liquid helium. ” Journal of Low Temperature Physics volume 202, 456 (2021).
3. Erika Kawakami, “Dispersive read-out of the Rydberg states of electrons on helium”, DAQS2022, Online, February 21-23 (2022).
4. Erika Kawakami, “Towards realizing spin qubits using electrons on helium”, QFS2021, Online, August 10-19 (2021).
5. Erika Kawakami, “Radio-Frequency Measurements of the Rydberg States: towards realizing qubits using electrons on helium”, Online, Quantum matter at ultra-low temperatures, July 20-21 (2022).

Laboratory Homepage

https://sites.google.com/view/febqi/
https://www.riken.jp/research/labs/rqc/floatelectron_based_qtm_inf_riken_hakubi/