【Grant-in-Aid for Specially Promoted Research】

Science and Engineering (Mathematics/Physics)

Title of Project : Novel quantum phenomena at Liquid He suface – Verification of Majorana state

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Research Area : Mathematics/Physics
Keyword : Ultralow temperature physics/Quantum condensed matter system

【Purpose and Background of the Research】

We have carried out creative study of quantum phenomena at the free surface of liquid He. We aim to deepen our study to discover novel quantum phenomena unique to the surface.

The following two subjects are emphasized in the project. 1) To prove the Majorana surface states at superfluid ^{3}He free surface. 2) To find the mechanism of microwave induced zero (magneto-)resistance states (ZRS). We will apply the obtained knowledge to fabricate single electron qu-bits on liquid He surface.

Hear, "Majorana" is associated with the name of a theoretical Fermi particle which has no distinguish between particle and anti-particle.

【Research Methods】

The prerequisite condition for the Majorana surface states is specular scattering of ^{3}He atoms at the surface. This condition is most ideally fulfilled

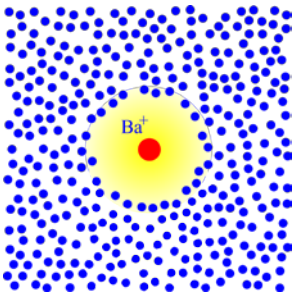

Figure 1 Ba ion in liquid He

at the free surface of liquid ^{3}He. It was predicted that a smoking gun evidence of the Majorana states is to detect a magnetic anisotropy. It was also proposed to measure a spin relaxation rate anisotropy near the surface.

In this project, we propose to employ an optical pumping technique with Ba ions, which are introduced in the vicinity of the free surface. A Ba ion forms a bubble like structure inside liquid He and keeps high optical activities (Fig. 1).

As for the microwave induced ZRS, simultaneous irradiation of microwave and conductivity measurement is employed. The ion conductivity measurement is used to investigate anisotropic properties of superfluid ^{3}He surface.

【Expected Research Achievements and Scientific Significance】

Majorana particle is a mysterious theoretical particle and the discovery of physically equivalent state brings a big impact to the academic world. Microwave induced ZRS (Fig. 2) is presumably associated with a dissipative structure. The elucidation of this phenomena in a clean and simple system should provide a universal understanding of the phenomena. Superfluid ^{3}He will provide a nice model to understand our universe in the context of symmetry breaking.

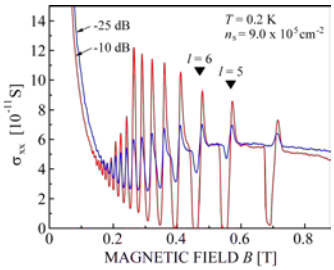

Figure 2 Microwave induced zero resistance (conductance) states.

【Publications Relevant to the Project】

1. S. B. Chung and S.-C. Zhang: "Detecting the Majorana Fermion Surface State of ^{3}He-B through Spin Relaxation", Phys. Rev. Lett. 103, 235301 (2009).
2. D. Konstantinov and K. Kono: "Detecting the Majorana Fermion Surface State of ^{3}He-B through Spin Relaxation", Phys. Rev. Lett. 105, 226801 (2010).

【Term of Project】 FY2012-2016

【Budget Allocation】 203,000 Thousand Yen

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