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

Broad Section B

Title of Project： Electrical and optical creation and control of non-Abelian anyons

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Research Project Number：19H05610　Researcher Number：40302799
Keyword：non-abelian anyon, topological superconductivity, Majorana Fermion, Exciton-polariton

【Purpose and Background of the Research】

Particles in three-dimensional are classified into either bosons or fermions, acquiring a 0 or π phase as their positions are exchanged, respectively. In contrast, for lower-dimensional systems, this phase can take an arbitrary value, and the resulting particles are called anyons. A more exotic type of anyon, known as a non-Abelian anyon, is known to be capable of performing quantum operations which are inherently robust to errors from environmental noise and thus highly sought-after for a future generation of quantum computer. However, the currently studied platforms have not been able to realize robust and easily controllable non-Abelian anyons, which might be used in the development of *topological quantum computing*.

In this project, we aim to develop accessible platforms exhibiting robust non-abelian anyons, and study both the fundamental physics of these exotic particles, and also evaluate the feasibility of their use in topological quantum information processing. The target systems are (1) superconducting junctions of double nanowires and two-dimensional topological insulators (2) superconducting junctions of three-dimensional topological insulators (3) quantum Hall states of exciton-polaritons in two-dimensional lattices.

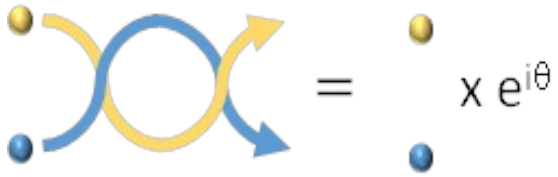

Figure 1:Acquisition of phase by anyon exchange

【Research Methods】

(1) We will detect the signatures of Majorana fermion zero-modes in superconducting junctions of double nanowires and two-dimensional topological insulators without a magnetic field. Furthermore, we will develop the on/off operation of the Majorana fermions by electrical techniques and evaluate the construction of qubits.

(2) We will generate, and implement techniques to control Majorana fermion zero-modes appearing at the center of vortices in Corbino-geometry Josephson junctions of three-dimensional topological insulators.

(3) We will generate robust topological states in structured 2D potentials in exciton-polariton microcavities and investigate new materials and methods for inducing strong particle correlations in these topological bands. Further, we will implement ultra-fast optical methods capable of anyon exchange and detection.

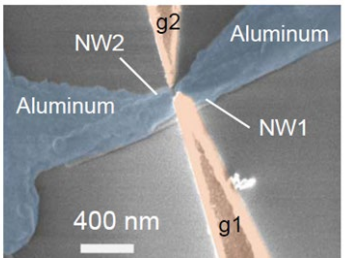

Figure 2: SEM image of a superconducting junction of double InAs nanowires.

【Expected Research Achievements and Scientific Significance】

Non-Abelian anyons are amongst the most exotic particles in condensed matter systems, however platforms exhibiting robust and controllable non-Abelian anyons are yet to be demonstrated. In this project, we will generate, control and study the properties of anyons in several novel and original platforms, investigating both electrical and optical techniques. Our studies toward the generation, exchange and measurement of robust non-Abelian anyons promises a significant advance in the understanding of the fundamental properties and experimental control of these particles, in addition to their applicability in future topological quantum computing applications.

【Publications Relevant to the Project】

- S. Baba, S. Matsuo, S. Tarucha, “Cooper-pair splitting in two parallel InAs nanowires”, New Journal of Physics 20, 063021-063028 (2018).
- R.S. Deacon, J. Wiedenmann, S. Tarucha, “Josephson Radiation from Gapless Andreev Bound States in HgTe-Based Topological Junctions”, Phys. Rev. X, 7, 021011-1-7 (2017).

【Term of Project】FY2019-2023

【Budget Allocation】126,800 Thousand Yen

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