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Release Date	2020.10.20	

Professor Yong-Joo Doh's research team is the first to observe phase quantum interference pattern... expected to be utilized for quantum computing

☐ GIST (Gwangju Institute of Science and Technology, President Kiseon Kim) Department of Physics and Photon Science Professor Yong-Joo Doh observed the theoretically predicted topology* quantum interference pattern** and succeeded in implementing an experimental technique that selectively controls the phase quantum interference phenomenon.

* topology: Topology is a branch of mathematics that studies the properties of objects that do not change even with continuous deformation. The application of topological physics to various materials has emerged as an important research field for understanding the properties of solid materials as graphene and topological insulators that were discovered about 10 years ago.

** interference pattern: The interference pattern is a pattern made of light and dark bands created by overlapping two or more waves.

- Topological insulator is a nonconductor inside a material, but the surface of the material is a unique material through which electricity flows. Because the electrons of the surface conductive layer are in a quantum state that is topologically protected, it is attracting attention as a quantum material for the next-generation quantum computer*.

* quantum computer: The concept was proposed in 1982 by Professor Richard Feynman, a Nobel Prize in Physics (1965) winner, and it uses quantum states as a basic unit of information. Quantum computers are the next generation computers that perform

calculations more efficiently than conventional computers using the quantum superposition principle. It has been predicted that future information technology such as artificial intelligence will be revolutionized to the next level, but it is difficult to put it into practice as errors in calculation accuracy such as accumulation of errors are pointed out.

☐ When metals or semiconductors are cooled to cryogenic temperatures, electrons have a wave function that follows quantum mechanics, and these material waves generate unique resistance signals due to mutual interference.

- Until now, there have been difficulties in implementing the theoretically predicted topological quantum interference patterns through experiments or selectively controlling the topological quantum interference phenomena that occur in phase insulators.

☐ The research team produced a quantum device using bismuth selenide (Bi_2Se_3) phase insulator nanorods, which is attracting attention as a three-dimensional phase insulator material consisting of bismuth (Bi) and selenium (Se) and then produced a quantum device with an absolute temperature* of less than 3 degrees Celsius. By measuring the magneto-resistance of the phase quantum device in the environment according to the gate voltage, they succeeded in continuously observing the topological AB vibration, which alternates between two types of AB vibrations** in which the phase is reversed.

* absolute temperature: The standard temperature for thermodynamics, also known as Kelvin temperature, and zero (0 Kelvin) corresponds to minus 273.15 °C.

** Aharonov-Bohm vibrations: In the case of a tube-shaped metal or semiconductor, if resistance is measured while applying a magnetic field in the axial direction, it is possible to observe that the magnetoresistive value vibrates with a certain period due to the quantum mechanical interference phenomenon, which means magnetoresistive vibration. It is known that the vibration period is constant with the magnitude of magnetic flux quantum ($\Phi 0 = h/e$).

- In addition, another quantum interference effect, AAS (Altshuler-Aronov-Spivak) vibration*, which vibrates exactly twice as fast as AB vibration was observed. It was experimentally implemented, and the relative magnitudes of AB vibration and AAS vibration can be artificially controlled.

* AAS (Altshuler-Aronov-Spivak) vibration: When time-reversal symmetry is maintained, it is quantum mechanically possible for electrons that have collided several times to return to their original position by retrieving the previous collision path. It is a phenomenon in which the magneto-resistance vibrates with a period of h/2e.

☐ Professor Yong-Joo Doh said, "The results of this study are the first experimental results to implement the theoretically predicted topological quantum interference fringes, and it is of academic significance to establish an experimental technique to selectively control the topological quantum interference phenomena occurring in the phase sub-conductor. In the future, it is expected that various topological quantum information devices can be developed by combining a topological nonconductor nanorod with a superconductor, a magnetic material, or a nano vibrator."

☐ This research was conducted by GIST Professor Yong-Joo Doh's (corresponding author) research team with KAIST Department of Physics Professor Heung-sun Sim in collaboration with University of California (Davis) Department of Physics Professor Dong and was supported by the NRF of Korea through the Basic Science Research Program and the SRC Center for Quantum Coherence in Condensed Matter and by the "GIST-Caltech Research Collaboration" grant funded by GIST and was published on October 8, 2020, in the online edition of *ACS Nano*, which is a specialized journal in the field of nano materials/element (IF = 14.6, top 5.3% of JCR journal rankings).

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