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National Institutes for Quantum Science and Technology
CANON ELECTRON TUBES & DEVICES

Development of the world's first 3-frequency gyrotron for nuclear fusion reactors

—Contributing to the realization of a fusion reactor—

【Points】

- The world's first gyrotron, a plasma heating device for nuclear fusion reactors, that generates megawatt-class output power and continuous operation at three frequencies of 104GHz, 137GHz and 170GHz is developed.
- Multi-frequency Gyrotron is essential for realization of fusion reactor.

National Institutes for Quantum Science and Technology (Chairman: Toshio Hirano; hereinafter referred to as "QST") and Canon Electron Tube Devices Co., Ltd. (President: Hironori Nakamuta; hereinafter referred to as "CETD") have successfully developed a gyrotron, which is a fusion plasma heating device that can generate megawatts of high-power microwaves at three frequencies and can operate continuously.

In a fusion reactor, it is necessary to heat hydrogen isotope gas, which is the fuel, to generate ultra-high temperature plasma of hundreds of millions of degrees. There is a method of heating using output microwaves. Electrons in the plasma rotate around magnetic field lines at a frequency proportional to the magnetic field strength in the fusion reactor. In a tokamak fusion reactor, the magnetic field is stronger near the center axis of the reactor and weaker outside, so the resonance frequency changes as the position in the plasma changes. In order to secure a wide operating range by heating various positions, it is preferable to prepare a gyrotron that can generate microwaves of multiple frequencies.

QST and CETD have been researching and developing a large vacuum tube called a gyrotron that heats fusion plasma with microwaves, such as the experimental fusion reactor ITER and QST's JT-60SA fusion experimental device. A gyrotron is a device that generates microwaves from the kinetic energy of electrons rotating in a strong magnetic field. Conventionally, the design was optimized for high power and continuous operation at a single frequency, so the heating of the fusion plasma was also performed only under limited conditions. In order to expand the plasma heating conditions, a gyrotron that can select multiple microwave frequencies is required. However, when generating microwaves at multiple frequencies, even if the optimized frequency achieves high performance, microwaves at other frequencies are scattered at the entrance of the waveguide that propagates the microwaves to the fusion device. The gyrotron developed this time is an improvement of a device called a mode converter. The optimization of the mode converter is performed not only for mode converter itself but also the mirrors that deliver the microwave to the waveguide targeting with the microwave shape at the waveguide input. As a result, we succeeded in suppressing scattering at all three frequencies of 104 GHz in addition to 170 GHz and 137 GHz. In this way, a high output of approximately one megawatt, equivalent to that of the ITER 170GHz single frequency gyrotron, and continuous operation for 300 seconds was realized for the first time in the world at three frequencies.

This achievement paves the way for the development of multi-frequency gyrotrons with three or more frequencies. Since fusion reactors require heating at various positions, a gyrotron that can generate microwaves at even more frequencies is necessary. Japan has led the world in the development of gyrotrons, and at a time when private companies are actively participating in the development of fusion reactors, this achievement embodies the competitiveness of Japan's fusion industry.