Demonstration of Steady State Operation with 1MW of 170GHz gyrotron for ITER

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The Japan Atomic Energy Agency is developing a 170GHz gyrotron using the $TE_{31,8}$ oscillation mode and aiming to achieve high power, long pulse and high efficiency operation for ITER. In the previous experiment, the gyrotron experienced a change in mode as the beam current decreased, which limited the extension of the output power and pulse length. In addition, a higher level of stray radiation caused excessive heating inside the gyrotron. To solve these problems, the internal mode converter and mirror optics were modified, which drastically decreased the stray radiation from about 8% down to ~2%. Furthermore, the beam current was controlled by pre-programming of the cathode heater voltage (stabilizing the current and avoiding the change in mode oscillation) and the electron beam quality was improved increasing the oscillation efficiency. As the result of these improvements, the steady state operation of 1 hour with the output power of 0.6 MW was achieved, which significantly exceeded the typical ITER operation time of 400 s.

The operation of a 0.6 MW/1hour was obtained by the usual operation method (or soft self-excitation regime) that fixed the cavity magnetic field and the pitch factor of the electron beam. However, the long pulse operation permits optimizing the state of oscillation by controlling the operating parameters during the shot and accessing an advanced operation region (or hard self-excitation regime) achieving output powers up to 0.82MW with the same beam power (identical beam current and voltage) as the 0.6MW/1hour operation. The oscillation characteristics in the long pulse operation has been well characterized, such that reliable access to the advanced operation mode of the gyrotron at high oscillation efficiencies has been accomplished by controlling the electron beam pitch factor and the cavity magnetic field. The beam current has been increased up to 38 A in the advanced operation scenario, achieving output powers up to 1.0 MW in the 170 GHz gyrotron. The oscillation was kept for 1100 s of which about 800 s with the power of 1.0 MW. At these parameters the oscillation efficiency was 36.5% and total electrical efficiency was 55% with the depressed collector voltage of 24.5 kV. As a result of the high power and long pulse experiment in the 170GHz gyrotron, the steady state operation exceeding 1MW/400s of the performance required in ITER has been demonstrated.

[1] A.Kasugai, et al., Conference digest of IRMMW-THz 2006, September 18-22, 2006, Shanghai, China.
[2] K.Sakamoto, et al., Conference proceedings of 21th IAEA fusion energy conference, October 16-22, Chengdu, China.
[3] A.Kasugai, et al., Fusion Science and Technology, (to be published).