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## Development of Over 1 MW and Multi-Frequency Gyrotrons for Fusion

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EC (Electron Cyclotron) scheme is quite promising tool for heating and current drive (H&CD) and plasma control for present and future devices up to Demo and Commercial reactors. Development of gyrotron is a key to open this promising door. Multi-MW and multi-frequency technologies are major issues to challenge for robust and cost effective reactor heating system. In University of Tsukuba, gyrotrons of wide range of frequencies from 14 GHz to 300 GHz have been developed for this purpose in collaboration with JAEA, NIFS and TETD. Over-1 MW dual frequency gyrotron of new frequency range (14 –35 GHz), where the reduction of diffraction loss and cathode optimization are quite important, has been developed for EC/EBW H&CD for GAMMA 10/PDX, QUEST, Heliotron J and NSTX-U. Output power of 1.25 MW at 28 GHz and estimated oscillation power of 1.2 MW at 35.45 GHz from the same tube have been achieved with the cathode angle improvement. This is the first demonstration of the over 1 MW dual-frequency operations in lower frequency, which contributes to the technology of wide band multi-frequency/multi-MW tube for Demo EC/EBW H&CD. The output power of 600 kW for 2 s at 28 GHz is also demonstrated. It is applied to the QUEST and has resulted higher EC-driven current than ever. Further, in the joint program of NIFS and Tsukuba for LHD ECH gyrotrons, a new frequency of 154 GHz has been successfully developed with a TE<sub>28,8</sub> cavity, which delivered 1.16 MW for 1 s, 0.3 MW in CW (30 minutes), and the total power of 4.4 MW to LHD plasma with other three 77 GHz tubes, which extended the LHD plasma to high T<sub>e</sub> region. All these gyrotron performances are new records in each frequency range.

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