§22. Development of High-Power, Long-Pulse, High-Frequency Gyrotron and Improvement of Plasma Parameter in LHD by Use of the Gyrotron

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NIFS collaboration research program with University of Tsukuba has been conducted for the sake of development of high-power, long-pulse, high-frequency gyrotron and improvement of plasma parameter in LHD by use of the gyrotrons. Following to the successfully accomplished former program which resulted in three high-power 77GHz gyrotrons actively working for LHD experiment, this new program aims at realization of high-power and higher-frequency 154GHz gyrotron to perform plasma heating at high-density region up to 14.7×10^{19}m^{-3} by 2nd harmonic X-mode heating at the magnetic field of 2.75T.

In 2012, fabrication of the 154GHz gyrotron was completed and applying the gyrotron was started from LHD 16th experimental campaign. After the campaign, the power injection mirrors for it were modified by attaching cooling jackets on the backsides so that the 154GHz EC-waves could be used for long-pulse discharges.

In the early phase of the 17th experimental campaign, the beam direction controllability with the modified mirrors was checked experimentally. The beam direction setting parameter Z_f was scanned in the range of $-0.1 \sim 0.1$m with the step of 0.05m. Z_f denotes the vertical hitting position of the beam center on an imaginary vertical plane placed at R = 3.9m. Another parameter T_f (toroidal position on the same plane) was fixed at 0.6m so that the beam injection was toroidally oblique. The magnetic axis position R_{ax} and the toroidally averaged magnetic field on axis B_t were 3.6m and −2.75T, respectively. The 154GHz EC-waves were injected with power modulation so that the power deposition analysis could be performed using ECE data.

Experimental results revealed that effective on-axis heating was realized by setting Z_f as 0.1m, not as 0m. Figures 1 and 2 show the electron temperature profiles measured with Thomson scattering and the electron temperature modulation amplitude profiles analized from ECE data, respectively. Setting Z_f as 0.1m achieves most center-peaked electron temperature profile and the highest modulation amplitude at the center. It was considered that the beam direction setting was misaligned, and the setting Z_f = 0.1m was used for on-axis heating thereafter.

The 154GHz gyrotron worked well for effective heating and achieving higher parameters of LHD plasmas. The heating efficiency is higher than 80% even in the case of off-axis heating as seen in Fig. 3. Also, the 154GHz EC-wave contributed to achieving high-performance long-pulse 325s discharge having ITB electron temperature profile with $n_{e_ave} = 1.1\times10^{19}$m^{-3} and T_{e0} = 3.5keV.

As the next step of this collaboration research program, 2nd 154GHz gyrotron was fabricated in 2013. Preparation of gyrotron operation for 18th experimental campaign is now underway.

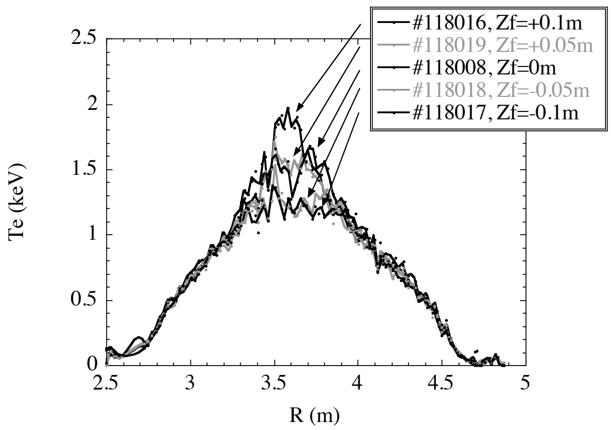

Fig. 1. Electron temperature profiles obtained in the 154GHz EC-wave beam direction scanning experiment.

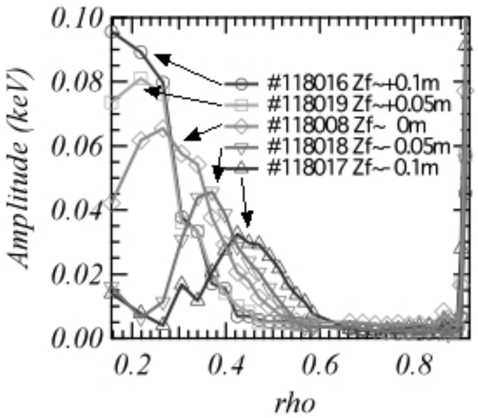

Fig. 2. Modulation amplitude profiles of electron temperature obtained in the 154GHz EC-wave beam direction scanning experiment.

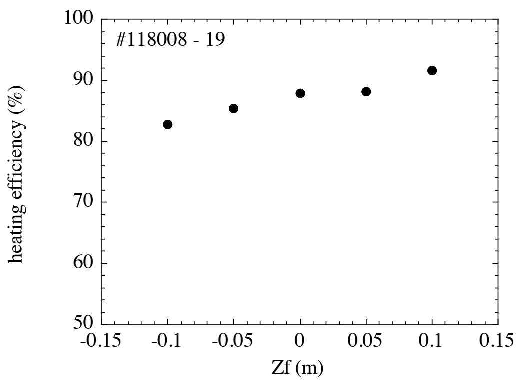

Fig. 3 Heating efficiency as a function of 154GHz EC-wave beam direction setting parameter Z_f.