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MAST-Uにおける電子バーンシュタイン波加熱電流駆動のための28GHz/35GHzジャイロトロンの試験

Testing activities of 28 GHz/35 GHz gyrotron for the electron Bernstein wave heating and current drive system of MAST-U

岡田麻希[1]、平田洋介[1]、吉岡悠人[1]、假家強[2]、南龍太郎[2]、Helen Webster[3]、Mark Henderson[3]、Grace Brett-Drinkwater[3]、坂本慶司[1]

Maki Okada[1], Yosuke Hirata[1], Yuto Yoshioka[1], Tsuyoshi Kariya[2], Ryutaro Minami[2], Helen Webster[3], Mark Henderson[3], Grace Brett-Drinkwater[3], Keishi Sakamoto[1]

[1]京都フュージョニアリング株式会社、[2]筑波大学、[3]UK Atomic Energy Authority

[1]Kyoto Fusioneering Ltd., [2]University of Tsukuba, [3]UK Atomic Energy Authority

1. Introduction

The UKAEA spherical tokamak MAST-U in the UK plans to use electron Bernstein waves (EBWs) for plasma heating and current drive, and Kyoto Fusioneering is procuring two 28 GHz and 35 GHz dual-frequency 1 MW-class gyrotrons for this purpose. The gyrotrons are based on those developed for the GAMMA-10 at Tsukuba University. At present, the gyrotron has achieved output powers in excess of 1 MW in short pulses at both 28 GHz and 34.8 GHz. This report will focus on the test results of high-power tests carried out on the first tube as a joint research project with the University of Tsukuba.

2. Main Specification for MAST-U

The gyrotron output power couples with transmission mode of the corrugated waveguide after two phase correction mirrors in the matching optics unit (MOU). The coupling power with the transmission line should be > 800 kW (> 3 sec) at both frequencies. The input electron beam is 80 kV/50 A. To increase the efficiency and to operate using the 55 kV main power supply, the collector potential depression (CPD) is employed, which requires the CPD voltage V_{CPD} = 25 kV or more. It is requested to demonstrate the power output at wide range (0.1 MW ~ 1 MW) without other mode excitation to observe the plasma response at the wide range of the mm wave power inputs. In addition, availability of the 1kHz power modulation is requested. Here, the modulation is executed by the voltage modulation of the main power supply V_M (= V_k - V_{CPD}, where V_k is the beam acceleration voltage). As the feeding voltage to the anode terminal V_a is constant, the anode-cathode voltage V_{ak} (= V_M - V_a), which determines the pitch factor, is also modulated. Therefore, rapid power stop is expected with the small voltage modulation.

3. Results and Discussion

At first, 1 MW power output was demonstrated at both frequencies at short pulse. At 28 GHz and V_{CPD} = 28 kV, the output power of 1.09 MW, the output efficiency of 34.2% and the total efficiency of 49.8% were obtained. At 34.8 GHz and V_{CPD} = 25 kV, the output power of 1.03 MW, the output efficiency of 31.4% and the total efficiency of 48.3% were obtained. The total efficiency with CPD is $\eta_{cpd} = \eta_o V_k/V_M$, and the efficiency is enhanced.

The power controllability was tested by changing the V_M. Fig. 1 shows the output power vs. V_M. Here, the V_{ak} is optimized for each V_M. The power control from 0.1 MW ~ 1 MW was demonstrated at V_{CPD} = 25 kV. By the simultaneous control of V_{ak} with V_M, power control during the pulse will be achievable.

In the case of power supply operation with V_a being kept constant, V_{ak} reduces as with V_M. This operation is equivalent to that of the UKAEA power supply system. In this case, the gyrotron oscillation stops when the V_M is reduced only by 1 ~ 2 kV. The power modulation will be realized with the < 2 kV voltage modulation. In the next stage, pulse extension will be executed with the parameter of 1 MW operation.

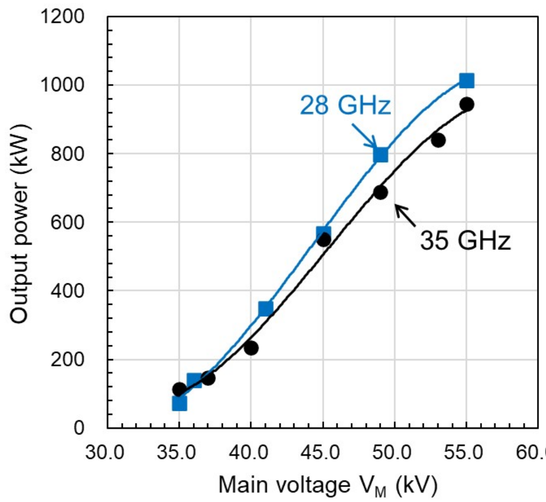

Fig. 1: Power variation by voltage control.

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