18pE-6

Progress of development for JT-60SA electron cyclotron heating system
-Achievement of gyrotron development target-
JT-60SA電子サイクロトロン加熱装置に向けた技術開発の進展
-ジャイロトロン開発目標の達成-

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The 7 MW, dual-frequency electron cyclotron heating (ECH) system having 9 gyrotrons and 4 launchers is planned for the JT-60SA. In the gyrotron development for the ECH system, oscillations of 1 MW, 100 s at both 110 GHz and 138 GHz have been achieved. The result is not only the completion of the development target, but also the new record as the 1 MW multi-frequency gyrotrons. Steady progresses were made in detailed design of the system and development on the launcher equipping linearly moved mirrors. Development of the waveguide components applicable to the two frequencies made an advance.

1. Introduction

The electron cyclotron heating (ECH) system for the JT-60SA [1] will be utilized for localized heating and current drive at the second harmonic EC resonance at 110 GHz and at 138 GHz. Plasma start-up assistance and wall conditioning by ECH system will also be expected [2]. The development target of the ECH system performance is 1 MW/gyrotron for 100 s. In the initial research phase of the JT-60SA, 4 gyrotrons and 2 launchers will be installed and additional 5 gyrotrons and 2 launchers will be installed in the integrated research phase as shown in Table 1 and Fig. 1.

Table I. Specification of JT-60SA ECH system

	gyrotron	launcher	power to torus
Initial Phase	4	2	3MW
Integrated Phase	9	4	7MW

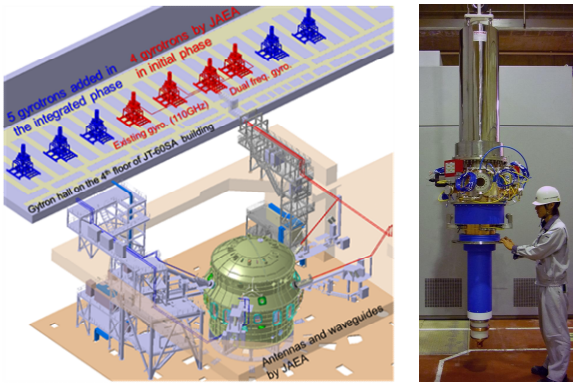

Fig.1. ECH system and dual-frequency gyrotron

2. Gyrotron

Oscillations at 1 MW for 100 s as the development target of the JT-60SA gyrotron have been achieved at both 110 GHz and 138 GHz in June 2014 as shown in Fig. 2. The gyrotron is the first ñ1 MW multi-frequency gyrotronò reached the pulse duration of 100s at two frequencies. The details of the gyrotron design and the test results will be shown in [3]. The advantage of the triode type gyrotron to attain good oscillation condition at both two frequencies by adjusting electron pitch angle has been proved. From a view point of the loss evaluation in the gyrotron, longer pulse operation is expected. In addition, 82 GHz oscillation was tested up to 0.4 MW for 2 sec, at a moment, by this gyrotron. This additional frequency would be applicable to plasma start-up assistance and wall conditioning at the fundamental EC resonance in JT-60SA [4-5].

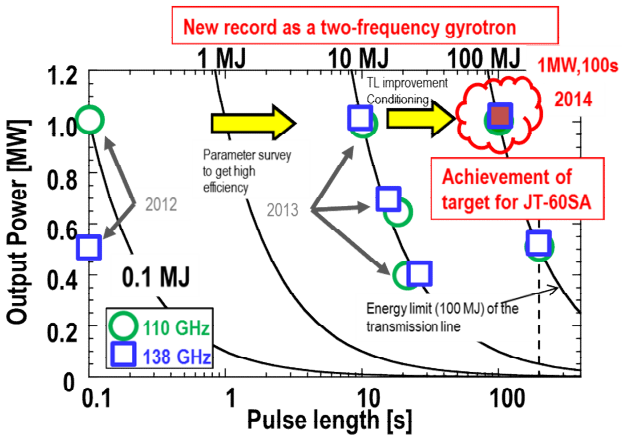

Fig.2. Achievement of gyrotron development target

3. Launcher

Active cooling of the mirrors in the launcher is needed for the high-power, long-pulse injection. Moreover, wide range steering is required in both poloidal and toroidal directions for various experiment scenarios in JT-60SA. In order to minimize a risk of water leakage in the vacuum vessel with the required steering capability, a linear-motion antenna concept was adopted. Based on this concept, detailed design and mock-up test are in progress toward finalization of the design [6].

Quasi-optical characteristics of the antenna mirrors have been studied to evaluate its transmission efficiency and beam focusing property. In calculation, it was found that the antenna is applicable to dual-frequency operation as shown in Fig.3. It was quantitatively shown that the transmission efficiency of ~ 99%, without Ohmic loss, is obtained even with the higher order mode (LP_{11}even) fraction of 10% by optimizations of the shape of the first mirror. These results contribute to optimization/finalization of the launcher design toward fabrication of the launcher for JT-60SA. In addition, methods to enhance toroidal steering range were investigated.

A full-scale mock-up of the steering structure, which enables linear and rotation motions of the first mirror of the launcher, has been fabricated for cyclic durability test mainly for the bellows as shown in Fig. 4. The mock-up design introduced an improved design which enables easy replacement of the bellows even after their life time.

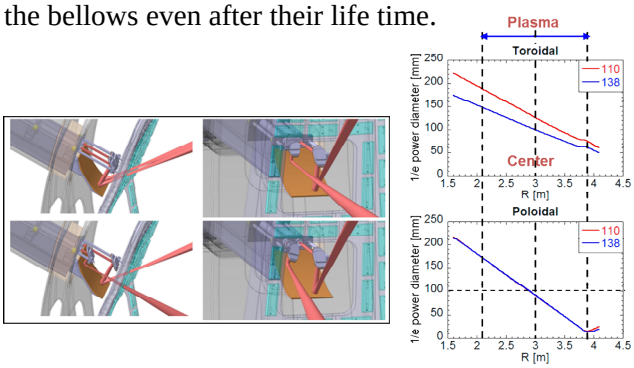

Fig.3. Quasi-optical performance of the launcher

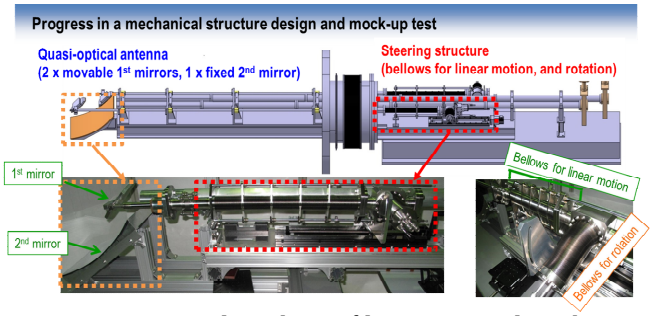

Fig.4. Structure and mock-up of linear motion launcher

4. Waveguide components

As a topic in the development on the waveguide components, the first high power test of the ñpower / beam profile monitorò featuring a fast movable Si_3N_4 disk in the waveguide slit was demonstrated. The disk was pulled out from the slit within ~ 0.2 s after the millimeter wave pulse and its temperature distribution was measured by an IR camera through a vacuum window. Because the heat conductivity of the disk is reasonably low, the profile of the millimeter wave has been easily estimated.

A wideband polarizer optimized for 110 and 138 GHz has been developed [7]. Detailed status of this development is presented in [8].

Calculation on the application of the fast directional switch (FADIS) to realize power modulation for NTM stabilization was progressed. Details are presented in [9].

5. Summary

Preparations of the JT-60SA ECH system including detailed system design and component development make steady progress. Especially, attainment of 1 MW, 100 s oscillation of the dual-frequency gyrotron was not only the completion of the major millstone toward JT-60SA but also a proof of the long pulse operation of the multi-frequency, megawatt-gyrotron for the first time. As a key component development, the full-scale mock-up of the steering structure of the launcher has been fabricated and the cyclic durability test for the bellows will start soon.

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