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Progress on Design and Testing of ITER ECH&CD Transmission Line Components

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***Abstract*—The ITER Electron Cyclotron Heating (ECH) and Current Drive (CD) transmission line components will need to be suitable for 2 MW cw operation, although initially they may be used only for 1 MW cw operation. The high heat loads compared to existing transmission lines will require enhanced cooling and, for some components, new or modified designs. Testing at representative ITER conditions of some components has been conducted at the JAEA 170 GHz gyrotron test stand at Naka, Japan. GA has delivered additional components to JAEA for testing which will begin in July 2008. Test plans are given below, and preliminary test results will be presented at the IRMMW-THz 2008 Conference.**

I. INTRODUCTION AND BACKGROUND

Excellent progress is being made in developing transmission line components to meet the challenge of high transmission line efficiency and the thermal management demands of 1-2 MW cw operation of the ITER Electron Cyclotron Heating (ECH) and Current Drive (CD) system. While final specifications for the ITER transmission line components have not yet been determined, it is likely that the components will need to be designed for 2 MW cw operation, although initial operation may only be at 1 MW cw. This 2 MW cw objective appears to be feasible, but it is critical to test components at the high power, long pulse ITER conditions to determine where improved designs may be needed.

JAEA has agreed to test prototypical ITER ECH transmission line components at their 170 GHz gyrotron test stand at Naka, Japan, under the US/Japan RF Technology Exchange. The JAEA facility has already demonstrated gyrotron operation at 1 MW for 800 s and 0.6 MW for 1 hour. Testing at representative ITER conditions of some components has already been conducted at the JAEA test stand [1], and General Atomics (GA) is providing additional components for installation and testing beginning July 2008. In order to develop and qualify the ITER transmission line components prior to procurement of the full set of 24 transmission lines, a 170 GHz prototype transmission line is being planned by the US ITER team [2], and GA is providing components for that facility.

II. COMPONENTS TO BE TESTED AT JAEA

Details of improved waveguide switches, dc breaks and polarizer miter bends have been reported previously [3–5]. The GA switch has been redesigned so that it can operate with a switching time of ~1 second for the requisite 30,000 shots during the ITER lifetime without fatigue failure of the copper mirror. The dc break has been redesigned using ceramic insulators to accommodate high-power long-pulse operation. Fast rotation (~0.1 s) polarizer miter bends have been built, based on a prototype made for use at TRIAM-1M. A new low diffraction loss miter bend has been developed to increase transmission line efficiency and reduce heating in adjacent waveguides (Fig. 1). A new high-order-mode-absorbing waveguide section has been fabricated and attached to miter bend housings for testing at JAEA (Fig. 2). These waveguide sections have much deeper corrugations than in regular corrugated waveguide to dissipate these modes more rapidly.

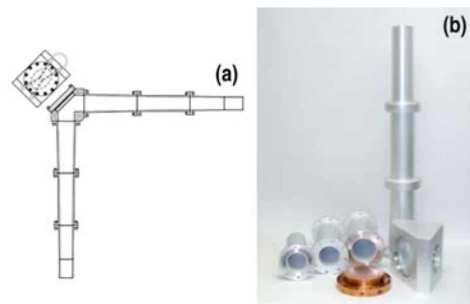

Fig. 1. (a) Schematic of low diffraction loss miter bend, (b) assembly of tapers and housing for low diffraction loss miter bend.

Fig. 2. Miter bend with higher-order mode absorbing sections on miter bend arms.

III. TESTING PLANS

As part of their 170 GHz gyrotron test stand, JAEA has installed a 63.5 mm transmission line that runs 32 meters from a waveguide switch in the main gyrotron room to an adjacent room with a gate valve and dummy load (Fig. 3).

The GA switch will be installed and tested in the main room. The switch port for the diverted beam will be connected to a dummy load made by Calabazas Creek Research. If JAEA's Russian dummy load is available, it may be connected to the straight-through port of the GA switch so that the switching function can be tested. If it is not available, the straight-through port will be capped off, and only the thermal performance of the switch mirror and adjacent waveguides will be monitored.

The polarizer miter bends will be tested by exchanging them for two of the existing miter bends in the dog-leg section of the transmission line in the main room (Fig. 3). The critical tests on the polarizer mirrors will be to measure the temperature rise in the water-cooling circuit for each of the two mirrors. These measurements will be made as a function of the two mirror rotation angles. Losses at each mirror will be calculated from the water temperature increases and compared with results of a GA microwave absorption model for the same rotation angles and input polarization. The temperature of the waveguides adjacent to the polarizer miter bends will be measured at various positions along the waveguides, using both RTD temperature sensors and IR camera measurements. The corresponding losses in the waveguide will be calculated and compared with the expected diffraction losses in higher order modes near cutoff generated by the miter bends.

Fig. 3. Transmission line at JAEA 170 GHz gyrotron test stand.

The dc break, low diffraction loss miter bends, and miter bends with higher order mode absorbing sections will be tested using the layout shown in Fig. 4.

The main measurements that will be made for the low diffraction loss miter bends will be measurements of temperature along the length of the tapers and waveguides. If the design calculations are correct, the losses ideally will only be ~35 W/MW-m for HE_{11} propagation, especially for the section between the two low diffraction loss miter bends. The actual losses will undoubtedly be higher than this due to the presence of higher order modes generated at other miter bends in the transmission line.

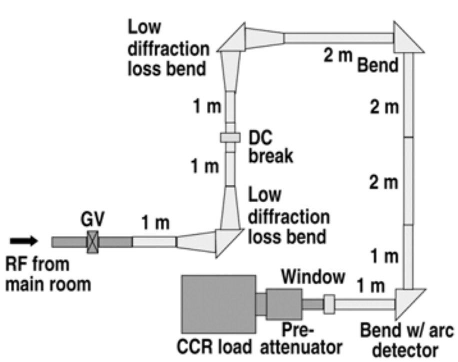

Fig. 4. Layout of testing components in the experiment room adjacent to the main room.

The measurements on the dc break will include temperature measurements of the alumina insulating ring and dc break waveguide segments. For 1 MW HE_{11} propagation, the calculated temperature rise of the ceramic for long pulse operation is about 5°C higher than that of the waveguide segments [3]. The RF leakage through the ceramic will also be measured. Since the dc break is located between the two low loss diffraction miter bends, the higher order mode content at that location should be relatively low.

The main measurements on the other pair of miter bends in Fig. 4 will be measurements of the water temperature rise in the cooling tubes wrapped around the high-order-mode-absorbing sections. The temperature of the adjacent waveguides will also be measured. These measurements should confirm that the high order modes generated at the miter bend attenuate more rapidly in the deep groove sections than in regular corrugated waveguide. The miter bend near the diamond window incorporates an arc detector so, if an arc is detected, the gyrotron can be turned off before the window and/or gyrotron are damaged. The diamond window is being provided to JAEA by the EU.

The water-cooling bars described in Ref. [4] will be tested at various locations along the transmission line. The most important use will be to confirm the waveguide temperature reduction achieved in waveguide sections adjacent to miter bends.

In addition to measuring the performance of individual components, overall transmission line efficiency will be measured through the use of calorimetric loads and calorimetry and temperature measurements of the individual components. These results will be compared to the theoretical value of losses for the transmission line. The results will also be extrapolated to the ITER transmission line configuration to determine if 20 MW of ECH power can be injected into the ITER plasma from 24 MW power at the gyrotron matching optics unit.

ACKNOWLEDGMENT

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