# Design and High Power Testing of ITER ECH&CD Transmission Line Components

R.A. Olstad[a], R.W. Callis[a], J.L. Doane[a], H.J. Grunloh[a], K. Kajiwara[b], A. Kasugai[b], C.P. Moeller[a], C.J. Murphy[a], Y. Oda[b], K. Sakamoto[b], and K. Takahashi[b]
[a]General Atomics, P.O. Box 85608, San Diego, CA 92186-5608
[b]Japan Atomic Energy Agency (JAEA), 801-1, Mukoyama, Naka, Ibaraki, Japan

***Abstract*—The ITER Electron Cyclotron Heating and Current Drive (ECH&CD) transmission line components will need to be suitable for 1-2 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 key components has been carried out at the JAEA 170 GHz gyrotron test stand at Naka. Preliminary test results and a discussion of new ITER-relevant components will be presented.**

## I. Introduction and Background

The critical issue for ITER Electron Cyclotron Heating and Current Drive (ECH&CD) transmission line components is to assure that they will perform with high transmission efficiency over the ITER lifetime when used for 1 (or possibly 2) MW cw operation at 170 GHz. Most experience with megawatt-level ECH evacuated waveguide transmission lines has been obtained with transmitted power less than 1 MW and with pulse lengths less than 10 s. Over the last several years, development of 170 GHz gyrotrons for ITER has yielded gyrotrons with both high power and long pulse length capability. In particular, the 170 GHz gyrotron at the JAEA gyrotron test stand has generated 0.8 MW/1 hr and 1 MW/800 s. This capability has enabled the possibility of testing prototypical ITER ECH transmission line components at representative ITER conditions. The US Department of Energy and JAEA have established a collaboration to test prototypical components at the JAEA test stand.

The high ITER heat loads resulting from 1-2 MW cw operation will require enhanced cooling and, for some components, new or modified designs. The components must also be designed to have very low losses in order to meet the ITER transmission line efficiency requirements.

## II. Components Tested at JAEA

Testing at representative ITER conditions of some components (waveguide switch, waveguides, miter bends, gate valve, and waveguide window) was carried out at the JAEA 170 GHz gyrotron test stand at Naka, Japan late in 2006 [1]. Additional components provided by GA were tested during August–December 2008, and more tests are planned in 2009. These GA components include polarizer miter bends, very low diffraction loss miter bends, DC break, waveguide switch, and waveguide water cooling bars. Test results obtained on these components will be presented. The $HE_{11}$ mode purity of the mm-wave beam in the JAEA transmission line has been estimated by analyzing the field patterns radiated from the waveguide output [2]. The tests conducted at the JAEA test stand are valuable in validating designs and determining where design improvements are needed. In addition, the US ITER Project Office (USIPO) plans to test a complete prototype ITER transmission line in order to validate the designs for use on ITER, and GA has provided some components to the USIPO for initial tests.

## III. New Components Under Development

Several other components are under development at GA to meet the needs of the ITER ECH transmission lines, namely: (a) sliding joint waveguide to use as an alternative to waveguide bellows, (b) 170 GHz mode analyzer/beam splitter for measurement of $HE_{11}$ mode content during high power long pulse operation, and (c) alignment monitor for aligning the mm-wave beam into the 170 GHz 63.5 mm waveguide with minimal tilt and offset error to minimize the generation of higher order modes at the waveguide entrance.

A prototype of the sliding joint waveguide was fabricated and is shown in Fig. 1. It is capable of 30 mm of compression and is made of hard copper with high thermal conductivity so it can be used in the presence of significant high order mode content.

Fig. 1 Prototype of 63.5 mm diameter sliding joint waveguide, shown without protective shield that normally surrounds the bellows section.

## Acknowledgment

This work supported by the U.S. Department of Energy under DE-FC02-04ER54698 and General Atomics internal funding.

## References

[1] K. Takahashi et al, “Investigation of Transmission Characteristic in Corrugated Waveguide Transmission Lines for Fusion Application,” Proc. 8th IEEE International Vacuum Electronics Conf., Kitakyushu, Japan, 2007.

[2] Y. Oda, K. Kajiwara, K. Takahashi, A. Kasugai, and K. Sakamoto, “Gyrotron Beam Coupling Method into Corrugated Waveguide”, this conference.