GA–A26816

DESIGNS OF NEW COMPONENTS FOR ITER ECH&CD TRANSMISSION LINES

by
R.A. OLSTAD, J.L. DOANE, C.P. MOELLER
and C.J. MURPHY

JULY 2010

GENERAL ATOMICS

DISCLAIMER

GA–A26816

DESIGNS OF NEW COMPONENTS FOR ITER ECH&CD TRANSMISSION LINES

by

R.A. OLSTAD, J.L. DOANE, C.P. MOELLER
and C.J. MURPHY

This is a preprint of a paper to be presented at the 35th Int. Conf. on Infrared Millimeter and Terahertz Waves, September 5-10, 2010 in Rome, Italy, and to be published in the *Proceedings*.

Work supported by
the US Department of Energy
under DE-FC02-04ER54698 and
General Atomics Internal Funding

GENERAL ATOMICS PROJECT 30200 & 49008
JULY 2010

GENERAL ATOMICS

Designs of New Components for ITER ECH&CD Transmission Lines

R.A. Olstad, J.L. Doane, C.P. Moeller, C.J. Murphy
General Atomics, P.O. Box 85608, San Diego, CA 92186-5608

Abstract—**The ITER Electron Cyclotron Heating and Current Drive (ECH&CD) transmission line components will need to be suitable for 2 MW cw operation and have high transmission efficiency. The high heat loads compared to existing transmission lines will require enhanced cooling and, for some components, new or modified designs. Portions of the transmission line between the closure plate and the tritium barrier window have special design considerations to assure that tritium from the tokamak plasma does not leak into the tokamak building. Design aspects of new components meeting the ITER requirements are 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 2 MW cw operation at 170 GHz. The 2 MW requirement was made to accommodate the 2 MW co-axial cavity gyrotron under development in the EU, as well as >1 MW gyrotrons expected to be developed by other parties during the ITER lifetime.

The 2 MW cw requirement has led General Atomics (GA) to design modified power monitor miter bends capable of operation at this power and pulse length. The present transmission line layout now calls for the tritium barrier CVD diamond window to be located some distance back from the closure plate and launchers. This has led to the probable requirement for double seal waveguides and double seal miter bends to assure tritium retention in this region, and GA has developed designs for these components. In addition, motion of the torus during bakeout has led to the probable need for bellows or sliding waveguide joints with double bellows and double seals suitable for use in the region between the closure plate and tritium barrier window. Mechanical considerations for the ITER transmission line layout have led to the need for compact switches to accommodate 300 mm spacing between adjacent waveguides and non-90° (e.g. 140°) miter bends. Other components under development to reduce transmission losses and to improve alignment of the mm-wave beam into the transmission line include waveguide mode analyzers, waveguide alignment monitors and MOU-to-waveguide gaussian tapers.

II. NEW COMPONENTS UNDER DEVELOPMENT

Thermal analyses of the standard GA power monitor miter bend show that the design with closely spaced coupling holes radiating into a fused silica disk is suitable for 1 MW cw operation when the H-field is in the plane of the miter bend. For 2 MW cw operation a modified design is being developed. This new design uses coupling holes with greater spacing and closer proximity to thick metal by radiating into an evacuated rectangular waveguide on the low-power side of the mirror oriented parallel to the high-power reflecting surface. An outline drawing of the new power monitor design is shown in Fig. 1. The increased coupling hole spacing allows for better cooling than in the 1 MW design. The coupled power in the small rectangular waveguide is transmitted through alumina windows to WR6 rectangular waveguide at atmospheric pressure. A thin copper foil gasket is used between the hard copper insert and the Glidcop® mirror body in the region near the small rectangular waveguide to provide good thermal contact in this critical area. Finite element thermal and stress analyses have been performed for 1700 watt power absorption at the mirror surface at room temperature, corresponding to H-plane polarization at 2 MW incident power. Results of the thermal analysis are shown in Fig. 2. These analyses give a peak mirror temperature of 90°C and a peak stress of 290 MPa (42.1 kpsi). This stress is under the 300 MPa (43.5 kpsi) yield stress of the Glidcop® used for these mirrors. Refinements in the design and modeling are being made to increase the margin between calculated stress and yield stress of the material.

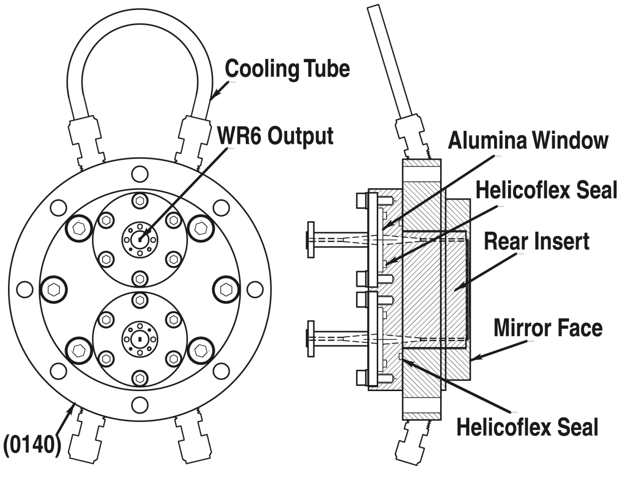

Fig. 1 Outline drawing of miter bend mirror suitable for 2 MW cw 170 GHz operation in 63.5 mm miter bend housing.

For long pulse power monitoring, a modified miter bend with thermally isolated mirror is being designed so that calorimetry on a water-cooling circuit can provide a measure of absorbed power. The absorbed power can be calculated theoretically from the water temperature rise as a function of incident polarization, incident power and pulse length, and can be calibrated at discrete points. The thermal isolation is needed to prevent heat deposited in the miter bend waveguide arms from contributing to the power deposition measured in the mirror cooling circuit. The concept can be adapted to a version incorporating double seals if desired.

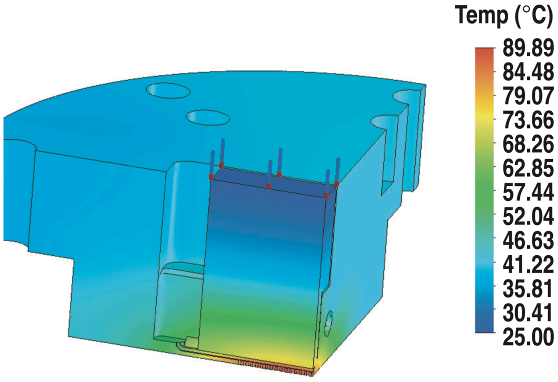

Fig. 2 Result of finite element thermal analysis of mirror depicted in Fig.1, showing peak temperature of 90° C in the area of the coupling holes.

A mode analyzer using an all metal water-cooled beam splitter is being developed for use to measure in real time the HE_{11} content, higher order mode content or total power. The first successful prototype of this device has recently been used on DIII-D to help in the optimization of waveguide alignment to achieve maximum transmission efficiency [1].

Waveguides and miter bends with double seals are being designed for use in the tritium retention area of the ITER transmission lines. The machined outside diameter of the 63.5 mm waveguide at the waveguide couplings for double Helicoflex® seals is increased to 100 mm from 74.6 mm for standard seals. An outline drawing of the end of a waveguide designed for use with two Helicoflex® all-metal seals is shown in Fig. 3. A shallow plenum between the two seals is provided for monitoring for leaks of the seals and/or the presence of tritium. In the version shown, a radial hole is drilled into the thick waveguide wall to connect to the axial hole that intersects the plenum. This radial hole is tapped for a Swagelok® fitting that has a copper gasket to make the vacuum seal in the waveguide wall. The other end of the fitting can accept a standard metal tube using either a standard Swagelok fitting or, if desired, a custom-welded VCR® fitting with copper gaskets on both ends. Waveguide couplings with a hole in one of the clamshell halves to accommodate the Swagelok fitting would be installed after the fitting is attached, but before the external tubing is connected to the fitting. If desired, an additional pair of radial and axial holes can be machined into the waveguide at another circumferential location and fitted with a Swagelok connection to provide for flow of a sweep gas though the plenum to monitor for tritium.

A prototype of the sliding joint waveguide with single seals and single bellows was fabricated and successfully tested at the JAEA RF Test Stand [2,3]. 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 lossy high order mode content. A version with double seals and double bellows for tritium retention is under consideration.

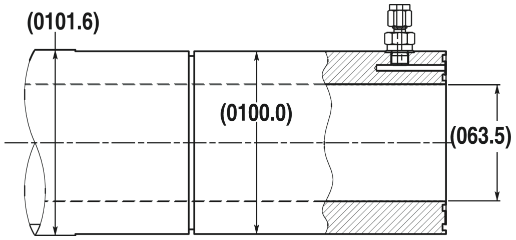

Fig. 3 Outline drawing of the machined end of a double seal waveguide showing provision for monitoring for leaks in a seal.

A compact waveguide switch has been designed for potential use at the wall between the ITER Assembly Hall and the Tokamak Hall. It has a rotary mirror design rather than the linear plunging block design in the standard GA switch and fits within the 300 mm spacing between transmission lines. In this switch, a rotary actuator rotates a mirror block in less than 1 s to change the direction of the output beam from the straight-through output waveguide to the 90° diverted beam output waveguide.

For injection of the mm-wave gaussian beam from the MOU directly into 63.5 mm waveguide, approximately 2% of the beam power is lost due to spillover and mode conversion. A taper 838 mm in length between the MOU and waveguide has been designed to reduce the loss to approximately 0.06%, thereby increasing the overall transmission line efficiency. Similar gaussian tapers have been successfully demonstrated at the JAEA RF Test Stand as the arms in low diffraction loss miter bends designed to eliminate mode conversion to higher order modes close to cutoff. It is these modes which get absorbed in waveguide arms and adjacent waveguides in normal miter bends [3].

Acknowledgment

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

References

[1] M. Cengher et al, “Transmission Line Power Measurements for the 110 GHz Electron Cyclotron Heating System on DIII-D and the Gyrotron Operational Performance,” this conference.

[2] R.A. Olstad et al, “Design and High Power Testing of ITER ECH&CD Transmission Line Components,” Proc. of the IRMMW-THz 2009 Conf., Busan, Korea, paper R2D05.0437.

[3] R.A. Olstad et al, “Progress on Design and Testing of Corrugated Waveguide Components Suitable for ITER ECH&CD Transmission Lines,” submitted for publication in Proc. of 16th Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating, April 12-15, 2010, Sanya, China.