Transmission Line Power Measurements for the 110 GHz Electron Cyclotron Heating System on DIII-D and Gyrotron Operational Performance

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Abstract — **Operational trends for the six-gyrotron electron cyclotron heating system on DIII-D are presented. Losses in the transmission lines were measured and values close to theoretical ones were attained for one of the lines with the existing components. Improved alignment and reduction of the number of miter bends in the lines will increase the power transmitted through the waveguide to the DIII-D tokamak.**

I. Introduction And Background

The electron cyclotron heating (ECH) system on the DIII-D tokamak consists of six gyrotrons operating at 110 GHz. The typical rf power injected into the tokamak at the end of each of the 90 m long, 31.75 mm diameter corrugated waveguide transmission lines ranges from 479 kW to 650 kW per gyrotron. Trends in the operational performance of the gyrotrons focusing on the generated power and pulse length are discussed.

Measurements of the losses in the corrugated circular waveguide transmission lines were performed. Re-alignment of the beam at the waveguide input is in progress and is expected to increase the rf transmission for the lines where the possibility of improvement was identified.

Different sources of losses were considered: number of miter bends in the line, length of the transmission line, mode purity, and rf beam angle at the gyrotron output. We are in the process of addressing these sources of power loss in the transmission line.

II. Results

In the past years the power generated in the ECH system was gradually increased as more gyrotrons were added to the system. Up to 16.5 MJ were injected on a single tokamak shot over 5 seconds (3.3 MW total injected power) from the six gyrotrons. For shorter pulses (250 ms) up to 3.5 MW of ECH power were delivered to the tokamak. The power injected into the tokamak is monitored for each shot and the measurements take into account the losses in the transmission line.

High power measurements of the losses in the transmission lines using dummy loads have shown differences between the lines [1]. The transmission line with the best beam alignment at the waveguide input shows losses as low as expected from the theory based on a circular waveguide gap model for miter bends [2]. Improving the alignment for the other gyrotrons is expected to lead to an increase of the transmission in these lines. The previous method of beam alignment at the waveguide input ensured a precise radial positioning of the beam but left room for angular misalignments, which were measured to be as large as 1.9 degrees. Work is underway to re-align the bbeams in the higher loss transmission lines.

Several new diagnostics were developed and tested for the alignment and power measurement. A new 4-port miter bend, which allows the sampling of 1 W per 1 MW transmitted power, can be used as an rf monitor and shows promise as a beam alignment tool in combination with other diagnostics. A new mode-selective directional coupler samples three modes that can be found in the waveguide: HE_{11}, TE_{01} and HE_{21}. The directional coupler was installed at a low power port of the 4-port miter bend and was used for improving the beam alignment at the waveguide input. The mode content in the line was monitored as the beam angle and axial offset of the beam at the waveguide input were changed. The best alignment should correspond to maximum HE_{11} and minimum TE_{01} and HE_{21} signals, so this setting was used to indicate the final alignment.

The rf losses in the first section of the transmission line were estimated based on the measurement of the temperature rise at the miter bends in the first several meters of the transmission line, and were used in the transmitted power balance and to confirm reduction of losses after re-alignment.

Improvements in the single mirror matching optics unit design, and beam alignment procedure are expected to lead to an increase in the power delivered at the tokamak end of the transmission line. A new layout of the transmission lines will reduce the number of miter bends and the length of the lines, leading to an estimated 150 kW total rf power increase for the entire system at DIII-D with no additional gyrotron power.

Acknowledgment

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References

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