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Design and Testing of an Internal Mode Converter for a 1.5 MW, 110 GHz Gyrotron with a Depressed Collector

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Abstract—We report experimental results on a 1.5 MW, 110 GHz, 3 microsecond pulsed gyrotron with a single-stage depressed collector. A simplified mode converter with smooth mirror surfaces has been installed in the tube. The converter was designed with the code SURF3D. We present the hot and cold test results of the internal mode converter. The hot and cold test measurements show good agreement.

I. INTRODUCTION AND BACKGROUND

MEGAWATT gyrotrons are under development for the electron cyclotron heating (ECH) of plasmas, including ITER. Aside from power and frequency requirements, such gyrotrons also require high efficiencies to minimize the prime power and improve reliability. The efficiency or output power of such high power gyrotrons is often limited by mode competition and by the recently discovered after cavity interaction (ACI), an effect in which the microwave power is reabsorbed beyond the cavity [1,2]. Components such as the internal mode converter (IMC) also impact the gyrotron's overall efficiency and should be optimized. In addition, IMCs should provide an output beam that is as close to Gaussian as possible since poor beam quality will generate higher order modes in the transmission systems which will lead to higher losses [3].

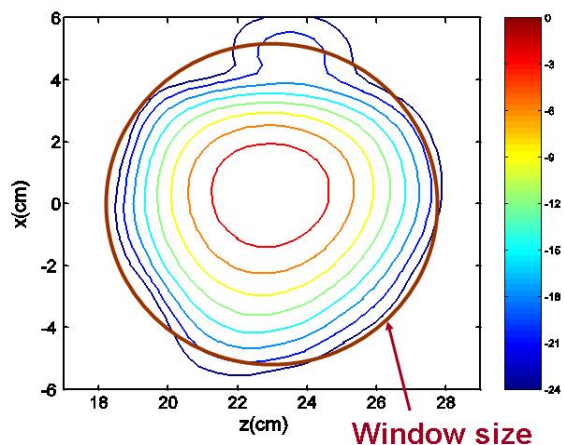


Fig. 1 Theoretical output beam from the internal mode converter at the window location. Gaussian beam waist size along each axis is 2.9 cm.

II. MODE CONVERTER DESIGN

The helically-cut launcher for the TE_{22,6} 110 GHz internal mode converter was designed using the code SURF3D [4],

and was fabricated at CPI. To optimize the beam from the launcher, we designed a set of three smooth curved mirrors along with a fourth flat mirror to output a beam at the gyrotron window that is nearly Gaussian. The theoretically predicted output beam profile is shown in Figure 1. The Gaussian beam waist along each axis is 2.9 cm. A novel feature of this mode converter is that the beam from the launcher has a very high Gaussian mode content. The mirrors have been designed with smooth surfaces, that is, without local phase correction. It is hoped that these mirrors will be less sensitive to tilt or offset errors in their production or location inside the gyrotron.

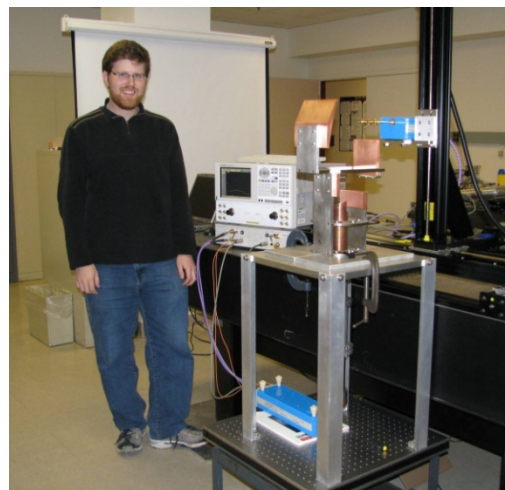


Fig. 2 Experimental setup for the cold test showing the vector network analyzer with transmitting Oleson millimeter-wave head connected to a TE_{22,6} mode generator and the internal mode converter (IMC). The receiving head, on which a cut waveguide antenna is connected, is mounted to the 3-axis scanner facing the IMC's fourth mirror.

III. COLD TEST RESULTS

To verify the design of our internal mode converter, we performed both hot test and cold test experiments. For the cold test, we used a vector network analyzer (VNA) along with a TE_{22,6} mode generator [5]. A cut waveguide antenna was attached to the receiving Oleson millimeter-wave head, which is mounted on a 3-axis scanner, allowing us to obtain accurate 2D field plots in several planes. The experimental setup is shown in Figure 2. Figure 3 shows the field profile measured in cold test where we measured a Gaussian beam waist of $W_z = 2.9$ cm and $W_x = 2.7$ cm at the window location. This compares well to the theory value of $W_z = W_x = 2.9$ cm.

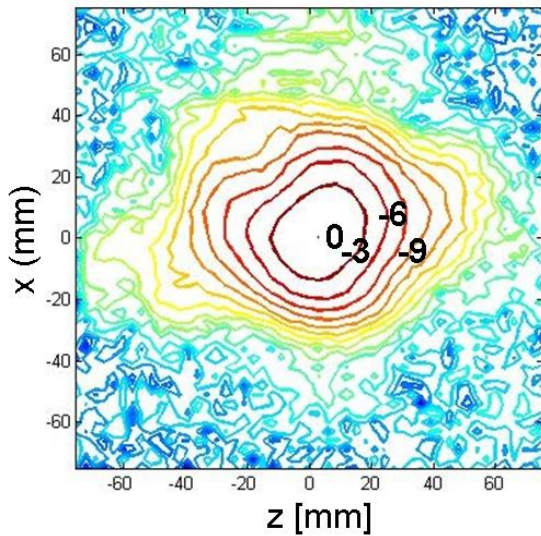


Fig. 3 2D field profile measured in cold test at the window location using a vector network analyzer (VNA). Field values shown are in dB and have been normalized.

IV. HOT TEST RESULTS

For the hot test, we installed the IMC onto our 1.5 MW, 110 GHz gyrotron operating in the $TE_{22,6}$ mode. We operated the gyrotron at a cathode voltage of 98 kV, beam current of 43 A, 3 μ s pulse length, with an output power of 1.2 MW. A schematic of the gyrotron with internal mode converter is shown in Figure 4. We measured the output beam pattern by mounting an rf diode and a variable attenuator to a 2-axis scanner. In order to measure the field profile, we defined a fixed diode reference voltage to be used at all locations in the scanning plane and recorded the attenuation values necessary to maintain this voltage, allowing us to neglect any non-linearity in the diode output. Figure 5 shows the measured pattern 124 cm from the gyrotron window and is in good agreement with cold test measurements as evidenced by the shape of the beam. The measured Gaussian beam waist of $W_z = 4.8$ cm and $W_x = 4.2$ cm agrees well with the theoretical value of $W_z = W_x = 4.7$ cm at the measured location. The signal to noise ratio in these scans exceeds 40 dB, much higher than in similar images of long pulse gyrotron output beams.

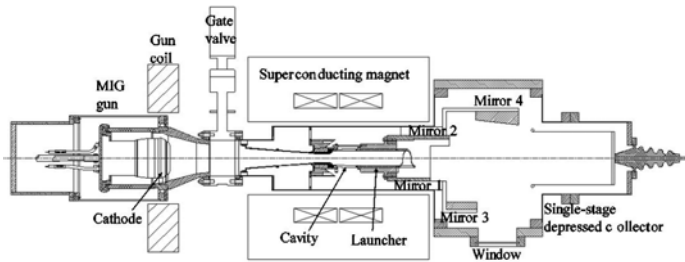


Fig. 4 Schematic of 110 GHz gyrotron with internal mode converter

Evaluation of the mode converter through hot test is ongoing as we are currently in the process of maximizing the gyrotron's power and efficiency, and generating a new mode

map for this latest configuration.

V. CONCLUSIONS

A high efficiency internal mode converter using smooth curved mirrors has been designed. Field profiles of the IMC output beam measured in cold test and in hot test are in good agreement and have shown only a small ellipticity when compared to the theoretically predicted output. Further hot test measurements with the new mode converter are currently ongoing.

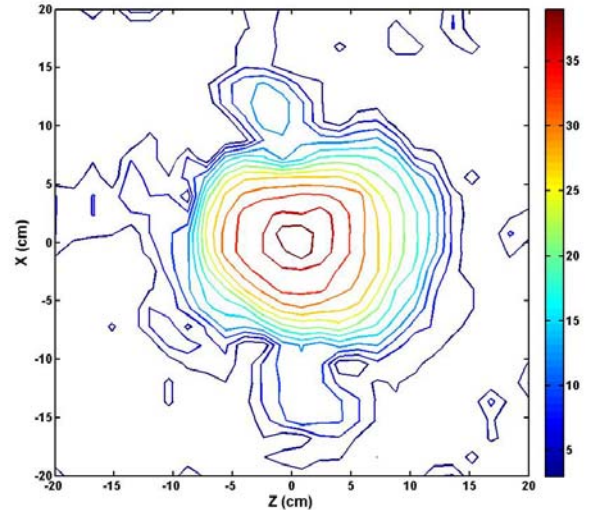


Fig. 5 2D beam profile measured 124 cm from the gyrotron window in hot test. Contour values show the attenuation in dB that maintains a constant rf diode output voltage at each location in the scan. Contours are in increments of 3 dB.

ACKNOWLEDGEMENTS

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