Ka-band gyro-TWA waveguide severs for circularly polarized waves.

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Abstract

This paper presents the latest results from a second harmonic gyro-TWA experiment at Strathclyde University. The experiment uses a helically corrugated interaction region and operates at Ka-band. Simulations have been performed to predict the amplifier gain and bandwidth using linear theory. Amplifier stability margin can be improved with the addition of a sever. A sever has been designed and manufactured, results of simulations and measurement are shown.

Introduction

In a number of applications, wideband amplifiers¹⁻⁵ provide significant advantages over oscillators of similar output power. For instance, in spherical tokamak fusion plasma heating, frequency agility allows targeted heating of specific plasma layers, possibly providing an additional plasma stabilization technique.

Of the many types of microwave tube developed to operate on the CRM instability, the gyro-TWA has generated particular interest due to its potential to efficiently generate high power, broadband microwave radiation. However, conventional gyro-TWAs did not fully fulfill this early potential due to the nature of the dispersion relations of the electron beam and the interacting cylindrical waveguide mode. These problems were alleviated through the development of a helically corrugated waveguide interaction region⁶⁻⁹, figure 1.

Figure 1. Helically corrugated waveguide mandrel.

This waveguide radically alters the dispersion relation of the interacting mode such that it matches the electron beam dispersion over a broad range of frequencies⁴. This waveguide was found to be a significant improvement over the conventional smooth cylindrical waveguide in gyro-amplifier systems by improving sensitivity to electron velocity spread, stability to parasitic self-oscillations and frequency bandwidth. When the Bragg conditions are satisfied, the helical corrugations couple two partial rotating waves; one near-cut-off partial wave with a small axial wavenumber, and the other partial wave, a travelling wave, with a large axial wavenumber. The eigenwave so produced has the attractive combination of linear dispersion in the region of low axial wavenumbers, allowing easy coupling to the electron beam-line. Appropriate choice of the coupled modes allows operation at the second harmonic of the fundamental frequency, reducing the magnetic field required. The amplifier has the attractive feature that, when a circularly polarized output is used, two round trips are required before a reflected signal returns to the interaction region with the correct sense of circular polarization to experience gain. This enhances the stability of the amplifier. Stability can be further improved with the addition of a sever to the gain section.

Design and Simulation

The sever was designed using CST microwave studio. Two types of sever were designed using two types of lossy material, SiC/BeO and a new form of silicon carbide previously untested. SiC/BeO is a well known lossy material of high thermal conductivity. We recently completed a design and build study on a SiC/BeO sever where the materials dielectric constant and loss tangent were derived by matching measured results to simulation output. There has been considerable effort to move away from BeO for safety reasons hence our investigation of alternative materials. Thick-walled tubular samples of the new material material were obtained for test purposes. This were measured on a VNA in a co-axial test set to determine the complex permeability. The measured values were then used in the design process.

The sever design is limited by the requirement to maintain the clear bore of the device to allow passage of the gyrating

electron beam. A pillbox type design was produced using a co-axial insert to provide the necessary loss. In this case a lossy material with a low dielectric constant is desirable because this reduces the angle at which total internal reflection occurs and thus increases the penetration of the propagating wave into the lossy material. Tapering of the cavity provides a significant improvement in return loss. Tapering of the loss element is truncated to preserve robustness in the ceramic components.

Figure 2. CST sever model and cross section.

Measurement

The severs were constructed in two parts from brass for ease of manufacture. The ceramic loss element was inserted and held in compression by the assembled fixture. This provided axial and radial alignment of the loss element. For cold test purposes rectangular to circular waveguide transitions are required, standard Flann stepped converters were used. The experimental components were then analysed using a 60GHz VNA. The VNA was calibrated at the rectangular waveguide ports using an LRL calibration.

Results

Figure 3. S_{11} and S_{21} parameter for SiC/BeO sever.

Figure 3 above shows the measured response of the SiC/BeO sever. The through loss is largely flat across the frequency range of interest (35GHz $\pm$ 10%) and the return loss stays above 20dB over the same range. These figures are sufficient that the sever will provide a significant improvement in stability to the amplifier.

The dielectric constants of the materials are shown below

	Dielectric constant	Loss tangent
SiC/BeO	34	0.25
SiC	7.5	0.2

Results from the new material will be presented at the conference.

Conclusion

Simulations have been performed to design a sever for use in a Gyro-TWA amplifier. Two designs were developed and manufactured. Measured results are presented and compared to simulations.

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