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Design and experiment of a broadband W-band gyro-TWA based on a helically corrugated interaction region

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Abstract— **The design and experiment of an upgraded W-band gyrotron travelling wave amplifier (gyro-TWA) based on a helically corrugated interaction region is presented. The upgrade of the input coupler, output window, corrugated output mode converter enabled a measured output power of a few kWs from the gyro-TWA with an unsaturated gain of up to 40 dB and a 3 dB frequency bandwidth of at least 5.5 GHz.**

I. INTRODUCTION

Recently gyro-devices in the form of both a gyrotron traveling wave amplifier (gyro-TWA) [1] and a gyrotron backward wave oscillator [2,3] have been developed at the University of Strathclyde. An existing W-band gyro-TWA was upgraded to achieve an output power of nearly 5 kW with a 3 dB frequency bandwidth of 90-96.5 GHz and a saturated gain of 40 dB at the University of Strathclyde. The gyro-TWA was driven by an annular shaped large-orbit (axis-encircling) electron beam. The gyro-TWA has promising applications in areas such as RADAR, telecommunications, plasma diagnostics and electron spin resonance due to its excellent combination of high power and broad bandwidth.

When a helically corrugated interaction region is used, an “ideal” eigenwave having an almost constant value of group velocity can be created over a wide frequency band in the region of small axial wave numbers [4]. This dispersion can be designed to match the dispersion line of an electron cyclotron mode or its harmonics, allowing broadband microwave amplification to be achieved in a gyro-TWA [5].

II. EXPERIMENT

As shown in Fig. 1, the gyro-TWA includes magnetic coils, a cusp electron gun, an input coupling system, an elliptical converter, a helically corrugated interaction region (HCIR) and an output system [6-12]. A 1.5 W Quinstar signal source operating over the range 90-96.5 GHz was fed into the gyro-TWA using the input coupling system which consisted of an in-band pillbox window, waveguide bends and a Bragg reflector. The output system of the wideband gyro-TWA consisted of a high performance, profiled, ‘sine-squared’ horn [12] integrated with a broadband multi-layer window [13] (Fig. 2).

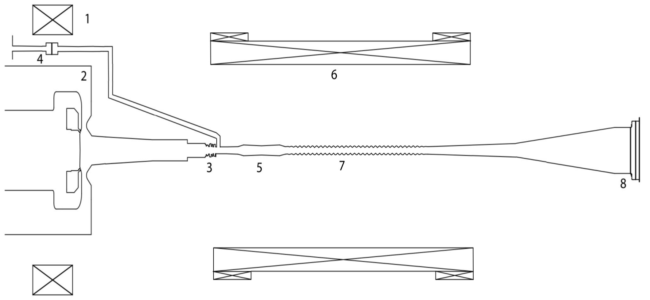

Fig. 3 A schematic drawing of the mm-wave gyro-TWA. (1, 6 - coils, 2 - cusp electron gun, 3 - Bragg reflector, 4 - input coupler, 5 - Elliptical converter, 7 - HCIR, 8 - Corrugated mode converter and output window)

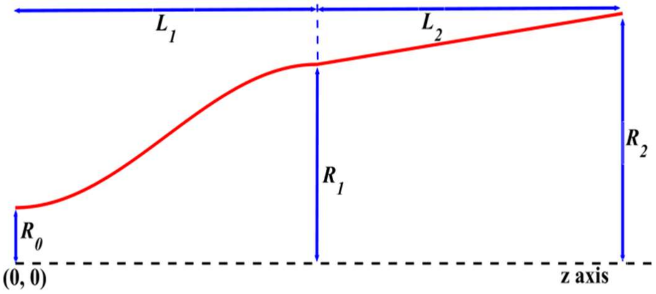

Fig. 1 The profile of the output horn used in the experiment.

The horn/window output system had a reflection coefficient better than -33 dB over the 10 GHz operating bandwidth. This resulted in the output of a high quality LG_{00} mode into free space with a high Gaussian coupling efficiency of over 99% at 94 GHz.

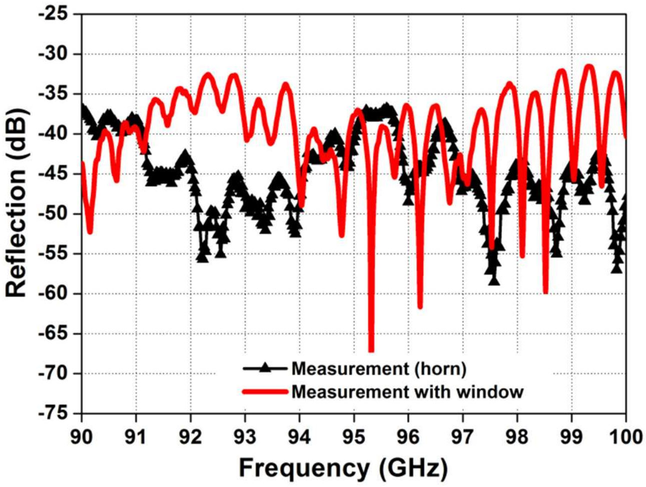

Fig. 2 The measured reflection of the smoothly profiled horn with and without the addition of a multilayer microwave window.

A spark-gap based trigger system was used in conjunction with a double-Blumlein pulse forming network to provide the accelerating field for the electron beam. The electron accelerating potential was measured using a resistive voltage divider, while electron current, typically 1.5 A at operating temperature, was measured using a current transformer. The beam current was measured in the cavity using a Faraday cup, inserted into the beam tube. This beam current of 1.5 A was measured at the normal operating cathode temperature, although it was variable by adjusting the heating power applied to the cathode

The output microwave radiation signal (detected by two crystal detectors situated inside screened boxes) and its far-field mode pattern were measured and are shown in figure 4 and Fig. 5.

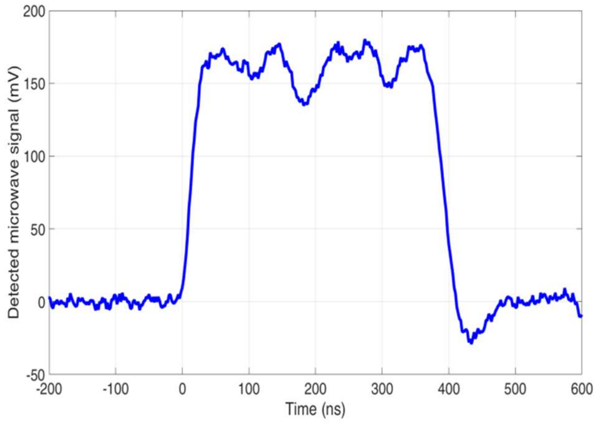

Fig. 4. Measured microwave signal of the broadband W-band gyro-TWA.

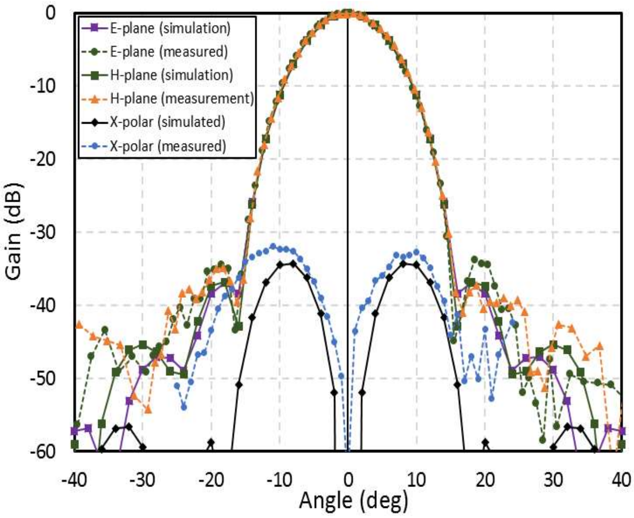

Fig.5 Measured far-field radiation pattern of the broadband W-band gyro-TWA.

The sensitivity of the crystal detector at different input power level was carefully calibrated before the gyro-TWA experiment. Then the detector was positioned at a far enough position away from the output window of the gyro-TWA to avoid any possible reflection from the screened box itself. The transmission loss of the whole gyro-TWA was carefully measured by a W-band Vector Network Analyzer. From the measurement it was found that 1.5 W at the input of the gyro-TWA was attenuated to ~0.5 W at the output window of the gyro-TWA. From the detector outputs in the “cold” and “hot” (without and with electron beam operating in amplification mode) experimental conditions, the amplification gain and the output power of the gyro-TWA at different input levels were measured. The experimental results of the output power and amplification gain as a function of driving frequency were also measured.

III. SUMMARY

The high power, broadband W-band gyro-TWA was experimentally studied and the measured results were in good agreement with theory and numerical simulations. In the W-band gyro-TWA experiment, stable amplification over the frequency range of 90 – 96.5 GHz was achieved driven by the axis-encircling electron beam with a velocity alpha value of ~1. The maximum gain was measured to be nearly 40 dB at 94 GHz with a maximum input power of ~0.5 W, which gives a maximum output power of ~5 kW. The output at higher input power levels and frequencies above 96.5 GHz were not measured due to the lack of an input signal. The results were in good agreement with the simulated output power and frequency bandwidth of 90-100 GHz. From the simulation this experiment could be scaled up to operate in the higher terahertz frequency range.

IV. ACKNOWLEDGEMENTS

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