Measurement of a W-band gyro-TWA experiment based on a helically corrugated interaction region

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***Abstract*— Measurements of an upgraded W-band gyro-TWA with a helically corrugated waveguide and a cusp electron gun are presented. With upgraded input coupler and output systems a gain of ~37 dB was measured from the experiment with a maximum output power of over 2 kW. The amplification from the gyro-TWA was measured in the frequency range of 90 GHz to 96 GHz.**

Keywords—gyrotron traveling-wave amplifier; gyro-TWA; helically corrugated interaction region; cusp electron gun.

I. INTRODUCTION

The Gyrotron traveling wave amplifier (Gyro-TWA) has promising applications in areas such as RADAR, telecommunications, plasma diagnostics and electron spin resonance spectroscopy due to its excellent combination of high power and broad bandwidth. In the past gyro-TWAs and gyrotron backward wave oscillators based on helically corrugated interaction regions (HCIR) have achieved unprecedented power-bandwidth performance [1-4]. A W-band gyro-TWA has been experimentally studied at Strathclyde University. The gyro-TWA is designed to be driven by a 40 kV, 1.5 A annular shaped large-orbit electron beam.

A photo of the W-band gyro-TWA is shown in Fig. 1. The gyro-TWA includes magnetic coils, a cusp electron gun, an input coupling system, an elliptical converter, a HCIR and an output system [5-12].

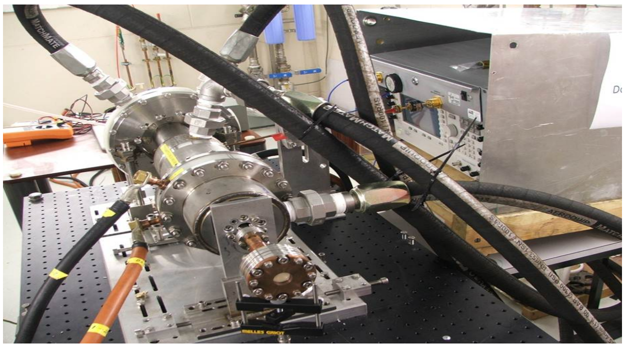

Fig. 1. A photo of the W-band gyro-TWA.

A 1.5 W Quinstar signal source operating over the range 90-96 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 input wave was converted into a circularly polarization wave from a linearly polarized wave by the elliptical converter before reaching the HCIR. The eigenwave in the HCIR could resonantly interact with the axis-encircling electron beam generated from the cusp electron gun, which resulted in transfer of the electron beam power into microwave power and hence the amplification of the input microwave signal.

II. THE PRINCIPLE

To increase the bandwidth of the amplifier a three-fold HCIR has been used. The resonant coupling of the TE_{21} mode and the first spatial harmonic of the TE_{11} mode in the HCIR gives rise to an "ideal" eigenwave for the amplifier. The eigenwave, which has an almost constant value of group velocity over a wide frequency band in the region of small axial wave numbers [7], can be readily matched by the dispersion line of an electron cyclotron mode or its harmonics allowing broadband microwave amplification to be achieved in a gyrotron traveling wave amplifier.

The large-orbit electron beam, generated from a cusp electron gun [5], is ideal for harmonic operation of gyro-devices as the mode selectivity nature of such a beam requires that the harmonic number is equal to the azimuthal index of a waveguide mode for effective beam wave coupling, which leads to a reduced possibility of parasitic oscillations.

A T-junction was used to convert the TE_{10} mode in rectangular waveguide into the TE_{11} mode in circular waveguide. To enhance the coupling coefficient, a broadband reflector was used. The performance of the T-junction with the Bragg reflector was measured by a W-band vector network analyzer (VNA) and an average 1.0 dB transmission loss was measured.

III. THE RESULTS

The input coupler is required to have a good transmission coefficient and sufficient bandwidth for the operation of the gyro-TWA [6, 10, 11]. A Bragg reflector [12] and the pillbox window were optimized for microwave transmission and broad bandwidth. It could be easily connected to the input source with standard WR-10 waveguide. The overall transmission loss of the whole input coupler system was calibrated by a W-band VNA to be about 2 dB which included a 0.6 dB loss from the pillbox window and 1.4 dB loss from the rectangular waveguides.

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The output system of the wideband gyro-TWA consisted of a high performance profiled sine squared/parallel corrugated horn integrated with a broadband multi-layer window. The major design requirements were that the horn/window combination must have an input reflection coefficient lower than -30 dB over the 10 GHz bandwidth of the gyro-TWA, provide a high quality output beam pattern, and operate under ultra-high vacuum conditions. The coupler would convert a circular waveguide TE_{11} mode into the free space Laguerre Gaussian LG_{00} mode over the frequency band of 90-100 GHz with a measured reflection coefficient of between -30 and -40 dB, and a high Gaussian coupling efficiency of over 99% at 94 GHz.

Far-field radiation measurements of the co-polar E-plane, H-plane and the cross-polar D-plane components were carried out at 94 GHz and are shown in Figure 2. Low sidelobe levels of -35 dB were in excellent agreement with simulations and demonstrate that the addition of the window has a negligible effect on the antenna pattern. The cross-polar measurement was also in good agreement with the simulations, with a maximum of -31.8 dB, compared to a simulated maximum of -34.2 dB. The maximum power was measured to be 2 kW at 94 GHz which corresponded to an amplification gain of 37 dB. Output power of the gyro-TWA as a function of the frequency was also measured. A typical microwave pulse observed through a W-band crystal detector is shown in Fig. 3.

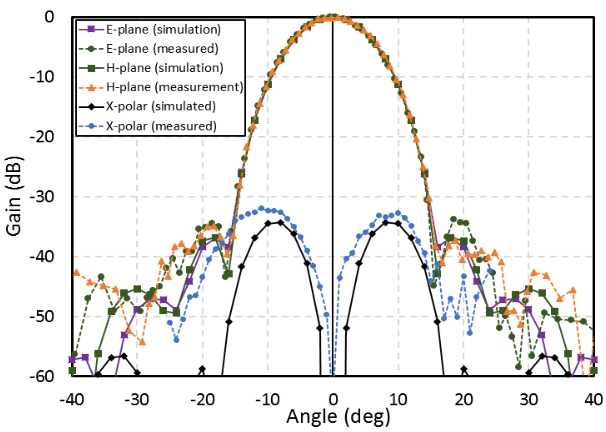

Fig 2. The measured and simulated co-polar E-plane, H-plane and cross-polar D-plane scans of the output coupler with window at 94 GHz.

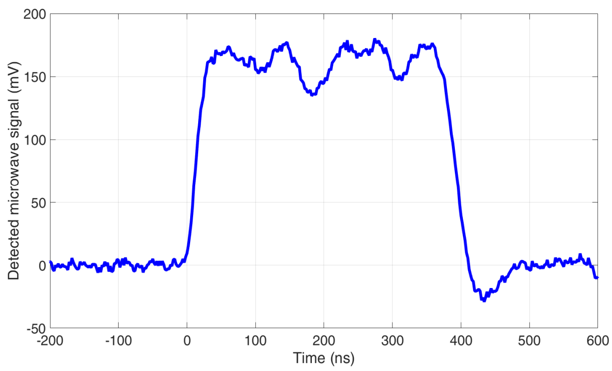

Fig 3. A typical microwave pulse output from the gyro-TWA.

IV. Acknowledgments

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