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High pulse repetition frequency operation of a W-band Gyro-TWA based on a cusp electron beam source

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***Abstract*— The components of a W-band gyro-TWA including input coupler, output window, corrugated output mode converter, pulsed power system and water-cooled beam dump are being upgraded to achieve an output power of 5 kW and a high pulse repetition rate of 2 kHz for cloud radar applications. Latest results of the W-band gyro-TWA with a helically corrugated waveguide and a cusp electron gun are presented.**

I. INTRODUCTION

Recently gyro-devices in the form of both a gyro-TWA [1] and a gyro-BWO [2,3] have been developed at the University of Strathclyde. An existing W-band gyro-TWA (Fig. 1) is being upgraded to achieve an output power of 5 kW with a 3 dB frequency bandwidth of 90-100 GHz and a saturated gain of 40 dB. For cloud radar application the output of the amplifier is also required to operate at a high pulse repetition frequency (PRF) of 2 kHz when the output microwave has a pulse duration of 380 ns (FWHM).

When the interaction region has a helical corrugation on the inner surface there exists an "ideal" eigenwave giving many benefits that can be exploited in novel gyro-devices and in pulse compression [4]. For the gyro-devices the eigenwave has an almost constant value of group velocity over a wide frequency band in the region of small axial wave numbers [5]. 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 gyrotron travelling wave amplifier.

II. EXPERIMENT

To drive the beam-wave interaction an axis-encircling electron beam 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. Such an axis-encircling electron beam can be generated by a cusp electron beam source [6-7]. A photograph of the device is shown in Fig. 1. Many components have been measured including: broadband input coupler, corrugated quasi-optical mode converter, dispersion of the helical interaction region and broadband microwave window. The output microwave radiation was detected by two crystal detectors situated inside screened boxes. The output power was calibrated using a known microwave source. The experimental results including the output powers and operating frequency bands were obtained.

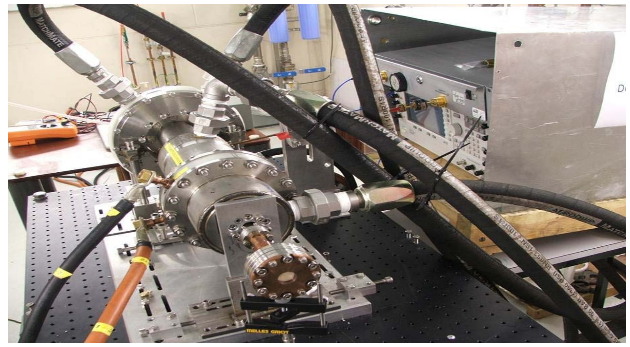

Fig 1. A photograph of the W-band gyro-TWA experiment.

III. RESULTS

Many components have been upgraded for operation at a high PRF and their microwave properties are measured for broadband input coupler, corrugated quasi-optical mode converter, output window, pulsed power system and water-cooled beam dump.

The new corrugated horn and output window assembly [8-10] was optimized through computer simulation, manufactured and measured to have a reflection of -27 dB which was a nearly 10 times improvement in comparison to the previous output window (Fig. 2 and 3).

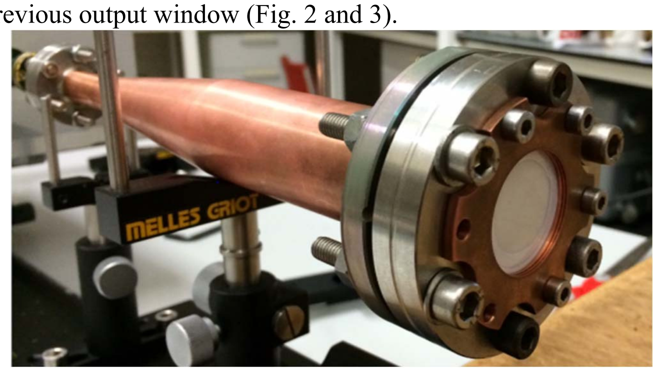

Fig. 2 A photo of the corrugated horn and the output window.

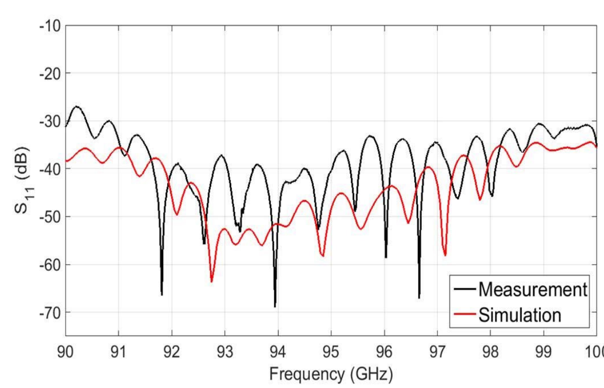

Fig. 3 Measured reflection of the corrugated horn and output window assembly.

The upgraded input coupler [11-13] (Fig. 4) was improved from its predecessor in three aspects. Its reflection was measured to be 2 dB better, its vacuum leak rate was improved 10 times to 10^{-9} mbar/s and it was mechanically more robust.

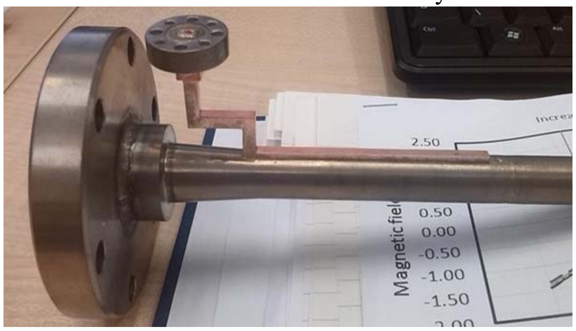

Fig. 4 A photo of the upgraded input coupler.

A water-cooled beam dump to accommodate the higher average power associated with an increased PRF has been designed and optimized through thermal simulations and manufactured. Also a newly designed pulsed power unit (Fig. 5) based on a thyratron as the closing switch has been designed and measured to be able to operate at a PRF of 2 kHz.

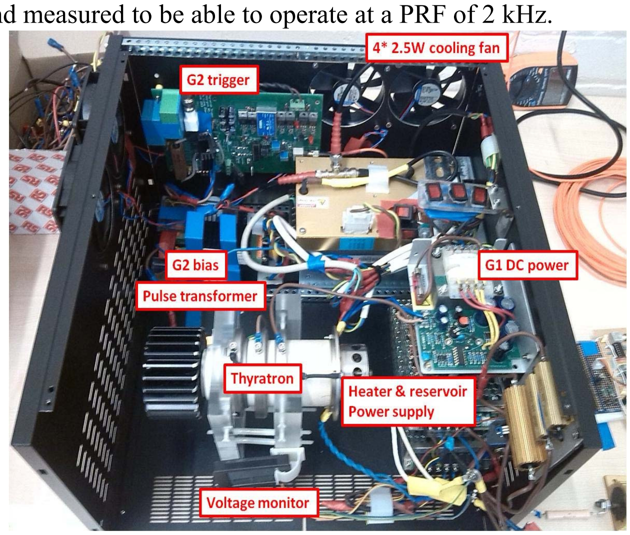

Fig. 5 A photo of thyratron based pulsed power unit.

The corrugated horn could be used to separate the output electromagnetic wave from the spent electron beam so that the energy of the spent electron beam could be recovered by a depressed collector system. The corrugated horn could also act as a mode converter so that it could convert a cylindrical TE_{11} mode into the free space TEM_{00} mode over the frequency band of 90–100 GHz with a reflection better than -30 dB and a coupling efficiency of ~99.4%.

New thyratron based trigger system was designed and manufactured in conjunction with a double-Blumlein pulsed forming network which was used to provide the accelerating field for the electron beam. The electron accelerating potential was measured using a resistive voltage divider, while electron beam current, typically 1.5 A at operating temperature, 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 was detected by two crystal detectors situated inside two screened boxes. The output power was calibrated using a known microwave source. The experimental results including the output powers and operating frequency bands were obtained. With an input seed signal from an 1.5 W, 90-96 GHz solid state source a gain of 27 dB was measured from the experiment. The bandwidth was measured to be at least 5 GHz.

IV. Summary

The high PRF, high power, broadband W-band gyro-TWA experimental results are presented. The measured results were in good agreement with theory and numerical simulations.

IV. Acknowledgements

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