Further experiments of a W-band Gyro-TWA based on a Helically Corrugated Interaction Region

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***Abstract*—Latest results of a W-band gyro-TWA with a helically corrugated waveguide and a cusp electron gun for operation at a high pulse repetition rate are presented. Performance upgrades of input coupler, output window, corrugated horn, pulsed power system and beam collector with water-cooling capability were realized. With an input seed signal from an 1.5 W, 90-96 GHz solid state source the amplification gain and minimum bandwidth were measured from the experiment.**

I. Introduction

The gyro-devices are suited to high frequency operation due to the fast-wave cyclotron resonance maser instability. Due to these attractive properties there are a number of applications for such devices including high resolution RADAR, plasma diagnostics, communications and medical imaging, based on electron spin resonance in conjunction with magnetic resonance and accurate material analysis based on terahertz spectroscopy. 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. In this paper the latest experimental results of a W-band gyro-TWA are presented.

II. Experiment

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 [6].

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 [7,8]. The gyro-TWA experiments proved successful. A photograph of the device is shown in Fig. 1. Many components have been upgraded for operation at a high pulse repetition rate (PRF) and their microwave properties measured including: broadband input coupler, corrugated quasi-optical mode converter, dispersion of the helical interaction region, broadband microwave window, pulsed power system and beam collector with water-cooling capability.

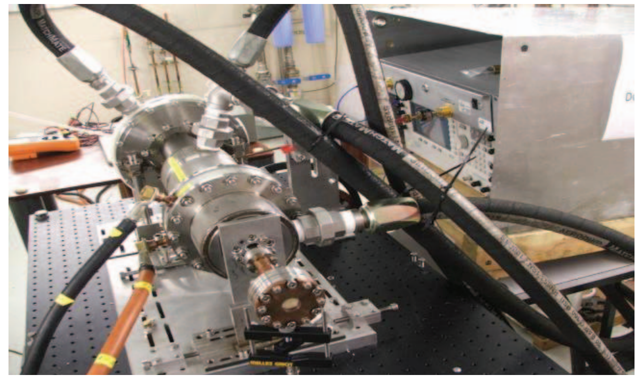

Fig. 1. A photograph of the W-band gyro-TWA experiment.

An upgraded output window (Fig. 2) was designed, manufactured and measured to have a reflection of -27 dB which was a nearly 10 times improvement in comparison to the previous output window.

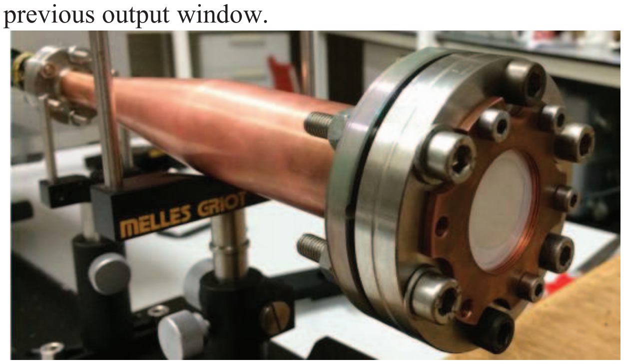

Fig. 2 A photo of the upgraded output window.

The upgraded input coupler (Fig. 3) 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.

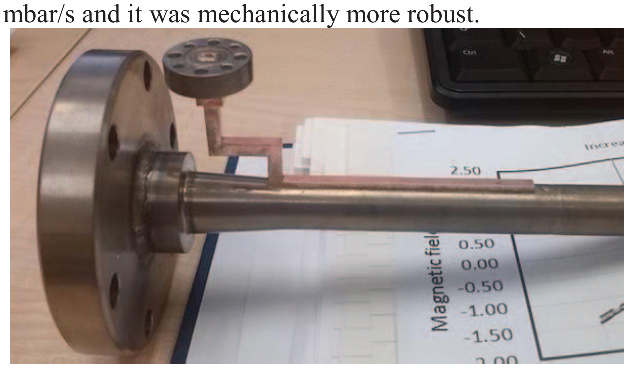

Fig. 3 A photo of the upgarded input coupler.

A water-cooled beam dump to accommodate the higher average power associated with an increased PRF has been designed and optimised through thermal simulations and manufactured (Fig. 4). 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. 4 A photo of water-cooled electron beam dump.

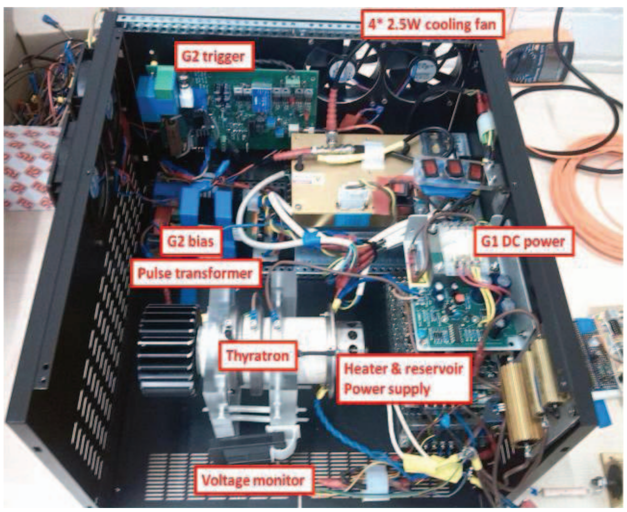

Fig. 5 A photo of thyratron based pulsed power unit.

An upgraded corrugated horn [9] was designed and manufactured and its output performance was measured. 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 [10]. The corrugated horn could also act as a mode converter so that it could convert a cylindrical TE11 mode into the free space TEM00 mode over the frequency band of 90–100 GHz with a reflection better than -30 dB and a coupling efficiency of ~99.4%.

A double-Blumlein pulsed high voltage source was used to provide the accelerating field. Fast electron beam diagnostics were constructed, having response times typically 5-20 ns, which permitted time-correlated observation of the evolution of the pulse parameters. The electron accelerating potential was measured using a resistive voltage divider, while total electron emission current in the gun, typically 1.5 A when the cathode reached operating temperature, was measured using a current shunt in the anode earth connection. A 380 ns nearly flat-topped voltage pulse of up to 60 kV was produced, having a rise time of 30-35 ns. 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 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 measured. 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.

III. Summary

A high power broadband W-band gyro-TWA has been experimentally measured. The measured results were in good agreement with theory and numerical simulations The gyro-TWA was also upgraded to operate at a high PRF rate of 2 kHz..

IV. Acknowledgements

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