Measurement of a W-band output launcher system for a broadband gyro-TWA

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Abstract—An output system for a W-band (90-100 GHz) gyrotron-traveling wave amplifier is designed, simulated, measured and the results are presented. This is an updated system based on a previous design and the output shows more favorable properties for the amplifiers intended application, as a millimetre wave source in a cloud sensing radar. A greater than -30 dB reflection was measured over the frequency range and high Gaussian content obtained.

Keywords—*gyro-amplifier, corrugated horn, multilayer window, output launcher*

I. INTRODUCTION

High power, broadband microwave amplifiers are in demand in applications such as Dynamic Nuclear Polarisation of Nuclear Magnetic Resonance and Electron Paramagnetic Resonance spectroscopy. Over the millimeter and sub millimeter wavelength range the gyro-devices excel in their ability to output high powers due to their larger waveguide circuit geometry compared to the conventional devices. At the University of Strathclyde both a W-band gyrotron backward wave oscillator (gyro-BWO) and gyrotron traveling wave oscillator (gyro-BWO) [1] based on a cusp electron beam source [2] and a helically corrugated interaction region (HCIR) [3] have been developed to provide a continuously tunable and continuous wave (CW) source with a power output of ~10 kW and ~2 kW respectively. The gyro-BWO demonstrated a tuning range of 88-102.5 GHz with an output power of 12 kW while the gyro-TWA is designed to have a frequency bandwidth of 90–100 GHz. The gyro-TWA has many components which have to have low reflection over a broad bandwidth including: the input coupler [4], Bragg reflector [5]. microwave polarizer [6], interaction region [7], output horn and microwave window {Can you insert a ABP conference paper here, please ask LZ}. For many applications it is preferable to have the microwave output microwave in the form of a Gaussian beam. The helically corrugated waveguide has an output mode of the circularly rotating TE_{11} mode and so a mode converting horn is used to transfer this into the hybrid HE_{11} mode. This mode has a close correlation with the fundamental free space Gaussian mode.

This type of output coupler, the corrugated horn, is advantageous compared to the other methods of mode conversion due to the greater bandwidth and the capability to operate with a source that is continuously tunable.

Initially a corrugated horn [8] was developed which The input wave was converted into a circularly polarization wave from linearly polarized wave by the elliptical converter situated before 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

achieved both a modest Gaussian content of, ~98%, with a low reflection of under -30 dB over a 10GHz the frequency range. In this improved design the objective was to keep the same low reflection of better than -30 dB while both increasing the purity of the Gaussian content to ~99.4% while at the same time incorporating a multilayer microwave window into both the assembly which is essential to incorporate the horn into the gyro-TWA assembly. The microwave window was designed to be placed at the aperture of the horn where mostly all the microwave signal is converted into the hybrid mode. This location means the microwave window is easier to design and construct as the hybrid mode has most of the microwave power in the center of the waveguide thus removing the effect of radial steps or discontinuities in the output waveguide. The window [9] was based on a multilayer [10] design as this is known to be able to operate over a bandwidth of 10%, and has been realized at X-band, Ka-band and W-band {Can we find a reference to insert here to back up this statement?}. The structure of the 3 layer window is a central dielectric disc brazed into a housing with a matching dielectric disc located at each side of the central disk separated by a small gap. The inclusion of the window means that the horn would have to be optimized to take into consideration the effects the window has on the output mode. The geometry of the corrugated horn and window in the gyro-TWA can be seen in Fig 1.
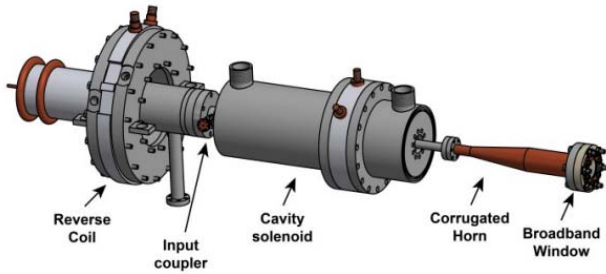
Fig 1. Schematic of the gyro-TWA with the corrugated horn and multilayer window.

III. SIMULATION

The corrugated horn structure was simulated and optimized using a mode matching method using the commercial software μ-Wave. Due to the number of corrugations and the overall length of the horn the mode matching method meant that a simulation can take a few minutes compared to hours when using a full 3D simulation software, such as CST Microwave Studio. Initially the simulation used the $\sin^2$ profile for the horn geometry and concentrated on reducing unwanted reflections. To gauge the mode content at the horn aperture the field at this point was compared to the fundamental Gaussian mode. It was found that the coupling efficiency can be increase to greater than 99.8% when the mode mixture had higher order HE1n modes introduced. To do so a phase matching straight corrugated waveguide section was added which allowed combination of the HE_{11} and HE_{12} modes with correct amplitude and phase at the aperture. The structure of the corrugated horn is shown in Fig 2.
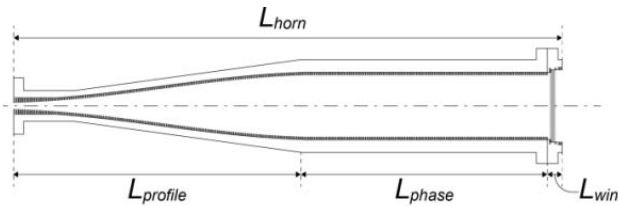

Fig 2. Schematic of the corrugated horn and multilayer window.

The corrugated horn was constructed through the electroforming method. Direct machining was not possible due to the reduced diameter at the throat region. Electroforming involves manufacture of the negative former, growth of oxygen free copper onto the surface and then removal of the former to leave the positive copper horn. The microwave window was manufactured by first vacuum brazing the central dielectric disc into a titanium housing and then pressing the matching discs tightly to the central disc, keeping the small vacuum/air gap by a copper ring between the discs. The horn and window were joined using regular ConFlat flanges and is shown in Fig. 3. After manufacture and joining both structures were able to maintain vacuum to the UHV level of 1×10^{-8} mbarr when pumped using a tubomolecular pump backed by a scroll pump.

The detailed design, measurement, construction and measured microwave properties of the corrugated horn and microwave window assembly will be presented.
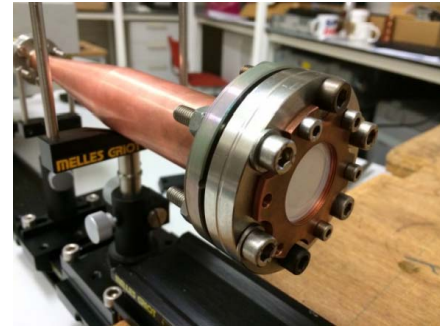

Fig 3. Schematic of the corrugated horn and multilayer window.

IV. CONCLUSION

The corrugated horn has been designed in conjunction and inclusive of a multilayer microwave window to be used as the output coupler for a W-band gyro-TWA. Both horn and window were numerically optimized using the mode-matching method. They were constructed and assembled to form a vacuum tight UHV, structure. Their microwave properties have been measured and show excellent comparison to the simulations.

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