Multilayer microwave windows for wideband gyro-amplifiers

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***Abstract*—This paper presents the design and measurement of a HE_{11} mode multilayer window for a W-band gyro-amplifier. The window acts to seal the vacuum inside the amplifier whilst coupling out microwave power with minimal reflection and absorption. The Gaussian-like HE_{11} mode is used in order to achieve the lowest reflection through the window. Operating over 90-100 GHz the simulated reflection of this window is better than -30 dB. The design, simulation and microwave measurement of the window is presented.**

Keywords— Multilayer window, microwavwe window, Gyro-TWA, W-band gyro-device.

I. INTRODUCTION

Gyro-amplifiers [1-2] which can operate over a broadband and output high power and high frequency are in demand for applications such as dynamic nuclear polarization, electron paramagnetic resonance, high resolution radars and telecommunications. A W-band gyro-amplifier based on helically corrugated interaction region [3, 4, 5] and cusp electron beam source [6, 7] is being developed in the University of Strathclyde. The performance of the amplifiers are often limited by one of their components having a higher than designed microwave reflection. One such critical component that has to have low, better than -20 dB, reflection over the entire operating bandwidth is the microwave window. Acting to seal the amplifier from the atmosphere outside, the window also has to have low reflection, low microwave absorption and have material properties suitable for thermionic cathodes.

Windows based on the multilayer concept have been previously shown to have suitably wide bandwidth performance in X-band [8], Ka-band [9] and recently W-band [10]. The study here is to simulate, optimise and construct a microwave window for W-band that uses the HE_{11} mode as the input to the window. This waveguide mode concentrates the microwave power in the centre of the waveguide so the effect of steps on the waveguide walls is reduced. This property should allow both better microwave reflection and easier construction for the window.

The material choice for the window is very important. It is common to use materials such as ceramics, CVD diamond, sapphire and quartz in a microwave vacuum electronic device (MVED). Ceramics are commonly used due to their low cost, mechanical strength and capability of being brazed, although they have a relatively large loss tangent and dielectric constant.

Windows based on using a dielectric disc to make the vacuum seal are quite common. Such windows can either use a singular disc or multiple discs. The single disc windows, as shown in Fig 1a, have a very narrow bandwidth. In order to increase the bandwidth a multilayer window is used. The window geometry is a central dielectric disc which is flanked by two matching dielectric discs separated by a vacuum gap. The two matching discs are used to create additional resonant passbands on the higher and lower side of the passband generated by the ceramic disc. This configuration means that the window is made up of five different dielectric layers. The window is designed to operate over 90-100 GHz with a reflection of better than -25 dB

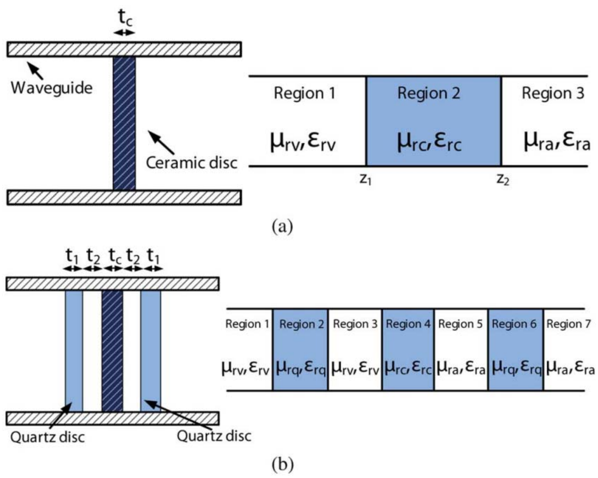

Fig. 1 Schematic diagram of the (a) single-layer microwave window and (b) multi-layer microwave window

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II. SIMULATION

The single- and multi-layer window reflection can be simulated using the mode matching method. [11] Both quick and accurate calculations of the microwave properties can be obtained leading to a short optimisation time. The three disc window, as shown in Fig 1b, has a central disc of Alumina (Al_2O_3) with relative dielectric constant of 9.75. There are many options for the matching dielectric disc material. In the gyro-devices a thermionic cathode is the common choice for the electron beam source. Therefore, in this case a material suitable for a thermionic cathode and which gives the highest bandwidth performance was chosen. The effect of changing the matching disc dielectric constant on the window performance was studied. Through those simulations it was found that Quartz could be used for the matching disc. Quartz, with relative dielectric constant of 3.75, was shown to allow a broadband transmission whilst being compatible with the operation of the thermionic cathode.

The ideal multi-layer window is one where there are no steps in the diameter of the waveguide. The optimized geometry shows a better than -30 dB reflection over a 30 GHz bandwidth. However, the thickness of the ceramic disc in the ideal case is rather small at 0.56 mm and there are no steps to hold the quartz discs in place or to help keep the vacuum gap thickness. So the window was redesigned to facilitate manufacturing and to make brazing the window easier.

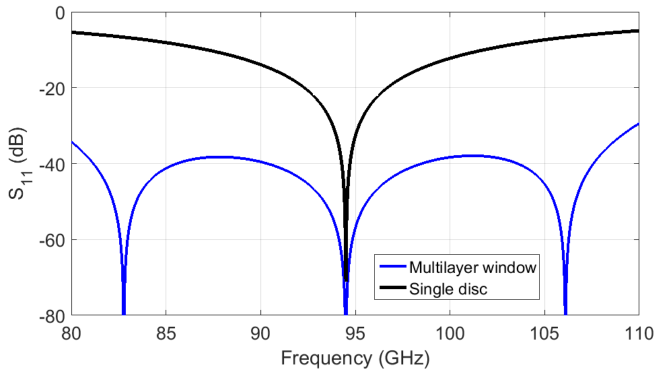

Fig. 2. Simualted ideal multilayer and single disc microwave windows.

In order to create the HE_{11} mode input a mode converting corrugated horn [12] is used before the input of the window. This horn takes a TE_{11} mode input and converts it to 85% TE_{11} and 15% TM_{11} for a hybrid HE_{11} mode. In this design there is some higher order modes present at the output of the horn, used to reduce the beam waist whilst keeping the Guassian coupling high. The simulated microwave window showed that a better than -30 dB reflection can be achieved over the full operating bandwidth.

III. CONSTRUCTION

The schematic of the constructed microwave window can be seen in Fig 3. In this assembly the ceramic disc was brazed into a titanium housing because it has a thermal coefficient close to that of the ceramic disc. The window connects to the end of the corrugated horn through the vacuum flange indicated in the centre of the figure. Once assembled the window was tested using helium leak detection to be leak tight to at least 10^{-9} mbar pressure.

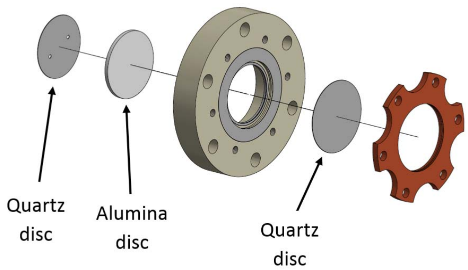

Fig. 3. Technical drawing of the multilayer window and Conflat flange.

IV. MEASUREMENT

The multilayer window was measured using a Vector Network Analyser. Initially the mode converting horn reflection was measured. Then the multilayer window was connected to the end of the horn and the reflection of the assembly measured. At then input to the corrugated horn was the input TE11 mode from the VNA and at the output of the window the microwaves radiated into free-space. The measurement showed good agreement to the simulations.

V. CONCLUSION

This paper presents the design, simulation and measurement of a W-band multilayer window with a HE_{11} mode input. The window is for application in a gyro-TWA over the frequency range 90-100 GHz. The measured results are in agreement with the simulated performance.

VI. ACKNOWLEDGEMENTS

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