Microwave windows for W-band gyro-devices

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Abstract: The microwave window is used to couple microwave power into, or out from a gyro-device. A multi-layer microwave window, which meets the strict requirements of gyro-amplifiers, is presented. The window was designed, simulated and measured. The measured results showed good agreement with simulations.

Keywords: microwave window, multilayer window.

Introduction

The gyro-devices [1-5] are high power coherent microwave sources that excel at high frequencies (up to terahertz range). They operate in a vacuum, usually ultra high vacuum (UHV), to facilitate the transport of the electron beam. The microwave window acts to separate the high vacuum inside the device from the atmospheric pressure outside, whilst coupling in, or out the microwave power.

The ideal microwave window should have low power absorption, high microwave transmission, high mechanical strength, high thermal conductivity and be vacuum tight. There are many different types of windows that can meet some of these requirements such as the single-disc, multi-layer [6], pillbox and Brewster windows. The desired application for this window is in a broadband gyro-device. The multi-layer window was chosen for this study as it has excellent broadband performance.

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.

The microwave window studied in this paper is for application in a W-band gyro-TWA [7] based on a helically corrugated waveguide [8] and cusp electron gun [9-11]. This device is driven by a 40 kV, 1.5 A annular axis-encircling electron beam. A gyro-TWA is currently being investigated at the University of Strathclyde. It is designed to operate between 90 and 100 GHz with an output power of 5 kW in the TE_{11} mode. A corrugated horn will convert the gyro-TWA output from the TE_{11} mode to a Gaussian beam [12].

Simulation

The single- and multi-layer window, as shown in Fig 1 (a) and (b), can be simulated quickly and accurately using the mode matching method. Initially Mician µWave Wizard was used to optimise the window geometry and then this was verified by the 3D FDTD simulation software CST Microwave Studio.

The three disc window shown in Fig 1(b) has a central ceramic disc and at each side a matching dielectric disc. These extra discs are used to create additional resonant passbands on the higher and lower frequency side of the passband generated by the central disc. There are many options for the matching dielectric disc material. In gyro-devices a thermionic cathode is the common choice for the electron beam source. Therefore, in this case a material compatible with thermionic cathodes and which gives the highest bandwidth performance was chosen.

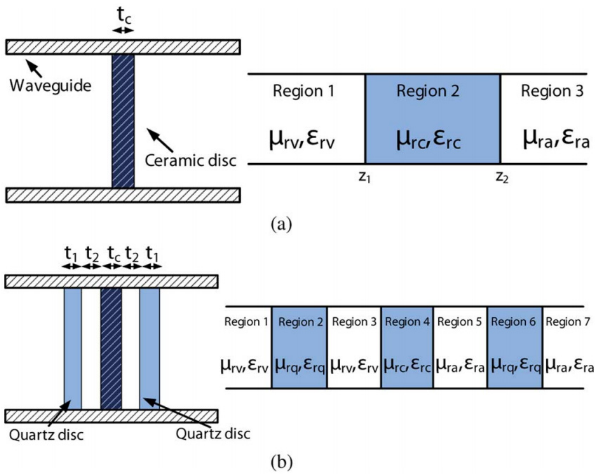

Fig. 1 Schematic diagram of the (a) single-layer microwave window and (b) multi-layer microwave window

The effect of changing the matching disc dielectric constant on the window performance was studied. Through those simulations it was found that single crystalline quartz could be used for the matching disc.

The ideal multi-layer window is one where there are no steps in the diameter of the waveguide. In this case a -30 dB reflection can be achieved 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. In the updated design the ceramic disc was 3 mm thick and the quartz discs were 0.24 mm thick. The simulated reflection was better than -20 dB over the operating bandwidth, as shown in Fig. 3.

Construction

The schematic of the constructed microwave window can be seen in Fig 2. 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 was tested using helium leak detection to be leak tight to at least 10^{-9} mbar pressure. A photograph of the constructed window can be seen inset in Fig 3.

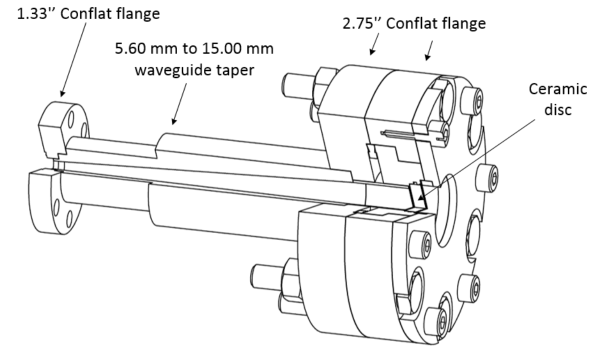

Fig. 2 Technical drawing of the complete three-disc window assembly.

Measurement

The microwave reflection was measured by a W-band vector network analyser (VNA). The measurement setup is shown in the inset of Fig 3. This was measured using one port of the VNA tapering up to the window then the microwaves radiated into free-space. The measured reflection, S_{11}, is shown in Fig. 3. Over 90-100 GHz the measured reflection is -20dB or better. This window is currently being used as the output window for a W-band gyro-TWA

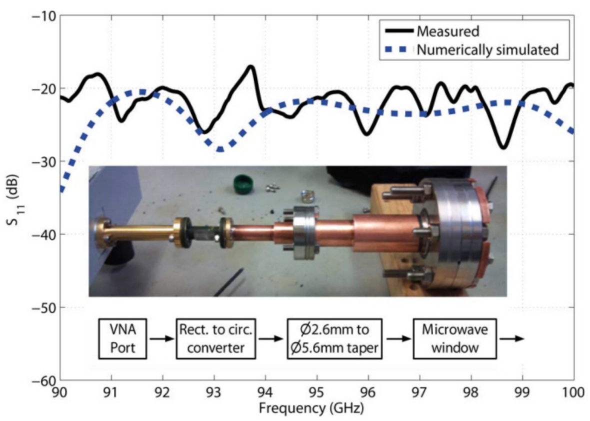

Fig. 3 Numerically simulated and measured reflection of the microwave window. A photo and block diagram of the measurement setup are inset.

Conclusion

This paper presents the design, simulation and measurement of a multi-layer microwave window for application in a W-band gyro-TWA. The measured reflection of -20 dB over the operating frequency range agrees well with the simulated performance.

Acknowledgements

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