Characterization of Windows for Fusion Applications using a D-Band Network Analyzer

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***Abstract*—In gyrotrons, as well as in evacuated vessels for fusion plasma experiments, dielectric windows are used to extract or to deploy the heating energy in form of an electromagnetic wave. These dielectric materials have to be permeable with a minimum of reflection. To verify the design of the windows, this reflective behavior is measured and then analyzed with a home-made scalar network analyzer.**

I. Introduction

Dielectric materials are widely used in microwave engineering and physics. For high power microwave applications in fusion plasma experiments these materials are used as windows to extract or deploy the necessary energy for the experiment. Gyrotrons, as one of the possible sources use such a window to separate the vacuum from the atmospheric pressure and to transmit the electromagnetic wave into the transmission line towards the plasma torus vessel. At the vessel we have the reverse problem to couple the electromagnetic wave through another window into the plasma. An example of such a broadband window is shown in Figure 1.

These windows are designed to a minimum of reflection at the desired operating frequency or frequencies, because reflections degrade the gyrotron operation and reduce the maximum deployable power. To verify the design of the dielectric windows, the reflection is measured using a scalar home-made D-band network analyzer.

II. Basic Concept

The self-designed scalar network analyzer used to measure the reflections employs a quasi-optical test-set including horn antennas and a Gaussian telescope. These components are needed to replicate the propagation scenario in gyrotrons and transmission lines. The Gaussian telescope allows the system to be useable in a very broad frequency range. The range of this network analyzer also used in [1] has been extended to the frequency range from $f = 110$ GHz to 172 GHz.

To calibrate the scalar network analyzer a metallic plate of the same dimensions as the device under test is used as a reference for maximum reflection. Then the window reflection is measured and the calibration measurement is taken into account to determine the corrected reflective behavior of the window.

Fig. 1. Broadband double disk window with tunable disk distance for the Tokamak experiment ASDEX Upgrade

III. Results

Figure 2 shows a comparison of the measured reflection of a CVD diamond disk together with the calculated reflection and in Figure 3 the comparison for a SiO_2-disk brazed into the flange is shown. The dimensions and dielectric properties of the disks used are shown in Table I:

	CVD diamond disk	SiO_2 disk window
Diameter	124 mm	132 mm
Thickness	1.611 mm	6.795 mm
Dielectric constant	5.67	3.78

TABLE I
DIMENSIONS AND DIELECTRIC CONSTANT OF THE WINDOWS USED

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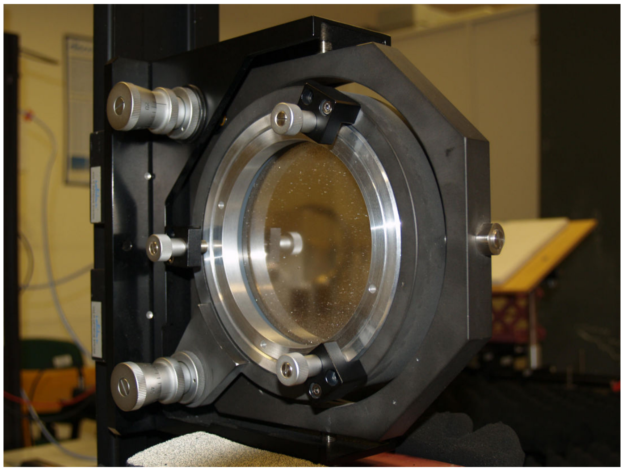
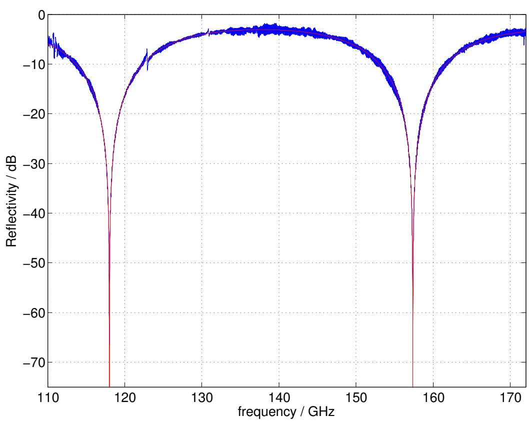
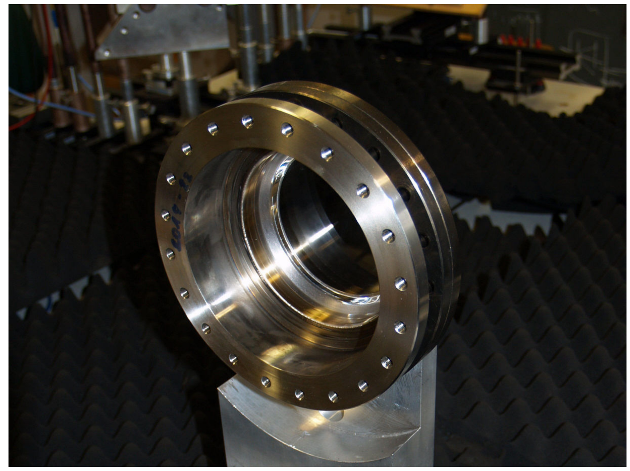


(a) CVD diamond disk

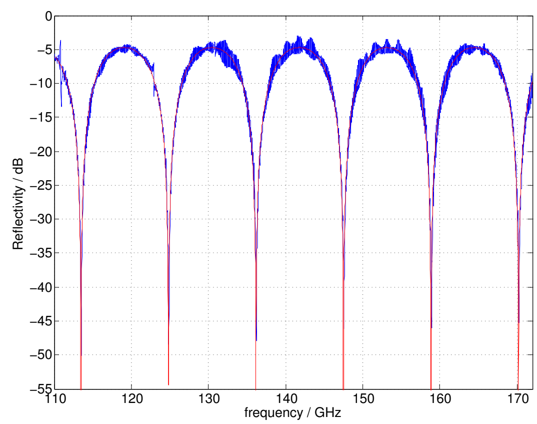


(b) Comparison of measurement and calculation of the reflectivity of a CVD diamond disk

Fig. 2. Characterzation of a CVD diamond disk for a 118 GHz gyrotron



(a) Silicon oxide disk window with flange



(b) Comparison of measurement and calculation of the reflectivity of a SiO_2 disk window

Fig. 3. Characterzation of a SiO_2 disk window for the pre-prototype coaxial cavity 170 GHz gyrotron

One can see an excellent agreement of calculation and measurement for both windows. The dynamic range of the measurement is up to $70\ \mathrm{dB}$ for the CVD diamond disk whereas for the SiO_2 disk window the dynamic range is only up to $55\ \mathrm{dB}$. This difference in dynamic range of the two disks is due to the different quality factors of the two disks. Since CVD diamond has very low losses, the expected difference due to absorption is negligible. The losses for SiO_2 are higher, but still low enough. The small ripples are due to standing waves, which can not be calibrated out using the scalar method.

The double disk window is currently in production. As soon as the double disk window is ready, the measurements will be performed and presented at the conference.

Acknowledgements

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References

[1] J. Flamm et al., *Measurements on a Brewster Window for a High Power Gyrotron*, Conference Digest of the 31^{st} International Conference on Infrared and Millimeter Waves & 14^{th} International Conference on Terahertz Electronics, Shanghai, China, 2006, pp. 89