Choke Flange Type Waveguide DC Break for Microwave Ion Source

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1. Introduction

Typical 2.45 GHz microwave ion sources and ECR ion sources are composed of a magnetron with the power supply for microwave generation, a microwave circulator to protect the microwave source, three-stub tuner for impedance matching, a vacuum window to separate the plasma chamber and the ridged waveguide and a plasma chamber, where plasma discharge takes place. To extract the ion beam, high voltage is applied to the plasma chamber. To make the maintenance easy and to operate the ion source more reliably, it is preferable to locate the microwave circuit at ground potential. In addition, we can remove the heavy isolation transformer by locating the solenoid magnet and microwave unit at ground potential.

In this case, to transfer the microwave power from the magnetron to the plasma chamber, we need a DC break, which acts as a high voltage insulator. There are several design options. For example, a multilayer waveguide DC break was successfully developed and used for KOMAC 100-MeV linac as shown in Fig. 1 [1]. A choke flange type DC break is typically used for higher frequency range (several tens of GHz). In this study, we designed a choke flange type DC break, which is compatible with WR340 standard rectangular waveguide. A choke flange DC break is far more compact compared with a multilayer type. Though the bandwidth of the choke flange is very narrow, it is not a great demerit for single frequency applications such as 2.45 GHz fixed frequency microwave ion source.

2. Design of the DC Break

We have to consider several factors when designing a waveguide DC break. First, it must provide reliable high voltage insulation performance. Second, we have to minimize the reflection of microwave power back to the microwave source. Third, the microwave power leakage through the insulation to surrounding space should be minimized to ensure the safe working conditions and reduce the effect on the devices nearby during the ion source operation.

To separate the high voltage parts from the grounded one, we insert a dielectric layer with high dielectric strength into the waveguide, which inevitably causes abrupt change of waveguide impedance, leading reflection of the microwave power. Therefore, the thickness of the dielectric layer should be as thin as possible, while ensuring reliable high voltage insulation. We choose a Teflon as a dielectric layer material with dielectric strength of 22 kV/mm. Thickness of the Teflon layer is 3 mm. Basic shape of the designed choke flange type DC break is shown in Fig. 2. The depth and radial distance of the choke flange was optimized by sweeping the geometric parameters with monitoring S-parameters.

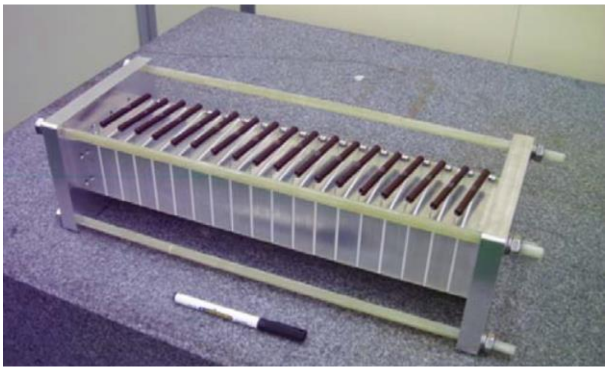

Figure 1. Multilayer type waveguide DC break

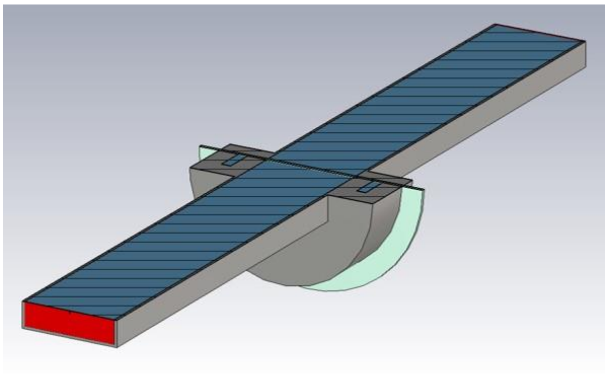

Figure 2. Choke flange type waveguide DC break

Figure 3 shows the CST simulation results of the optimized choke flange geometry. Reflected power (S11) at 2.45 GHz is better than -70 dB, while transmitted power (S21) is practically 100%. One thing noticeable is found in Fig. 3 at around 2.67 GHz. At that frequency, S11 is nearly zero, which means almost 100% microwave power is reflected. We may make use of this feature to realize microwave power switch or microwave power regulator. Figure 4 shows the determined dimension of the optimized DC break.

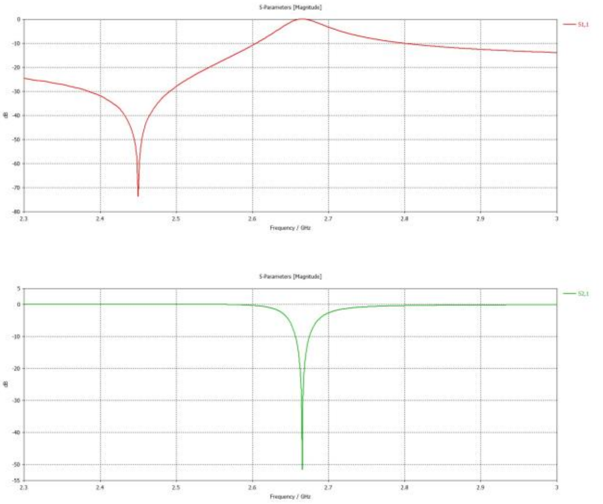

Figure 3. S11 (top) and S21 (bottom) of designed choke flange type waveguide DC break

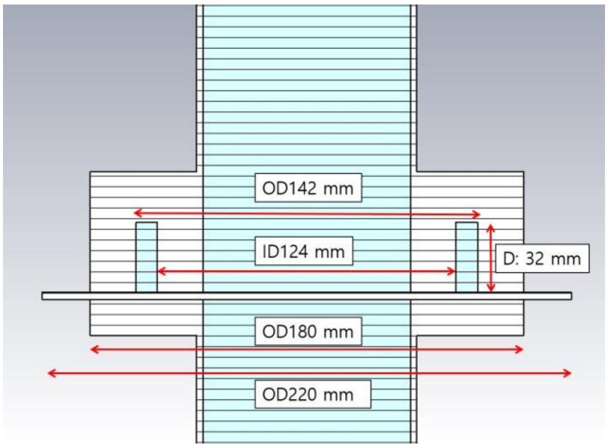

Figure 4. Dimension of designed DC break. Thickness of the inserted Teflon insulator is 3 mm.

3. Fabrication and Measurement

Designed DC break was fabricated and its performance was checked with a network analyzer, as shown in Fig. 5. To assemble the choke flange and Teflon insulator, we used plastic casing around the DC break assembly. Measured result shows that the S11 is minimum at 2.474 GHz (Fig. 6). S11 at 2.450 GHz is better than -23 dB, which means the reflected power is less than 0.5% of the input power. Even though 2.45 GHz is not on the minimum point, the measured S-parameter is good enough for practical DC break. Figure 7 shows the comparison between the simulation and measurement. Large part of the difference between them may be explained when we consider the exact values of the insulation material properties (dielectric constant, loss tangent etc.) are hardly known.

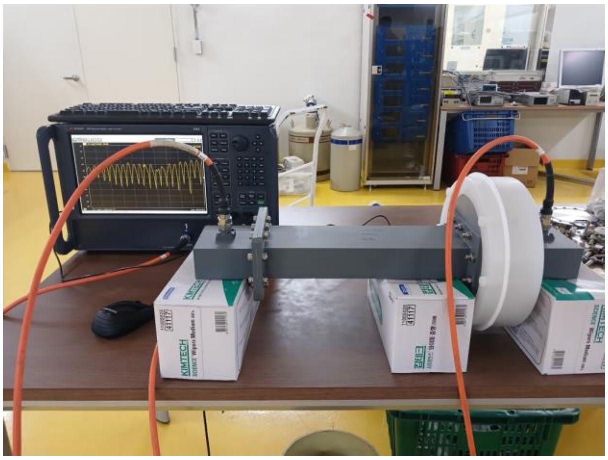

Figure 5. Fabricated choke flange waveguide DC break

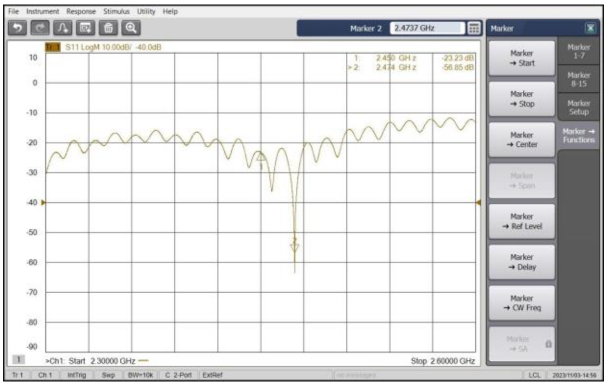

Figure 6. S11 measurement result

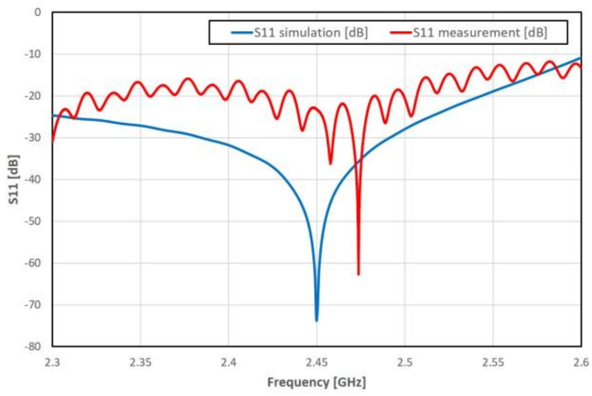

Figure 7. Comparison between simulation and measurement of S11

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REFERENCE

[1] Y. S. Cho, et al., Journal of the Korean Physical Society, vol. 63, no. 11, pp. 2085-2088, Dec. 2013.