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DC BREAK DESIGN FOR A 2.45 GHz ECR ION SOURCE

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Abstract

New 2.45 GHz Electron Cyclotron Resonance Ion Source (ECRIS) is under development at NRNU MEPhI. The transmission line is designed for transmitting the microwave power into the ECRIS. A DC break up to 80 kV was designed for the electrical insulation between the microwave supply system and the plasma chamber applied to high DC voltage. Current study considers the investigation results as well as the optimization of numerical simulations of the 2.45 GHz DC break with low losses and low emission into the surrounding space.

INTRODUCTION

ECR sources are often used to obtain ion beams. Microwave power system of the ion source consists of a magnetron with the power supply, circulator, tuner, vacuum window, double-ridged waveguide adapter and a plasma chamber. Ion source is situated on the high-voltage platform. For ease of maintenance the microwave units are preferably located at the ground potential. In this case to transfer the microwave power to the plasma chamber of the source a waveguide DC break is used which acts as a high-voltage insulator. There are different device designs. For example, it can be a multilayer waveguide [1], waveguide gaps [2], or others.

WAVEGUIDE DC BREAK

To separate the high-voltage part of the transmission line from the grounded one, a 2.45 GHz 80 kV DC break based on WR340 waveguide has been designed with the support of the MW Studio electromagnetic simulator.

Several conditions must be met when developing DC break. It must provide reliable high-voltage insulation, minimum reflection of microwave power and minimize microwave emission into the surrounding space to ensure the safe working conditions during the source operation. The operating voltage of the ECR source requires not to use an air gap as an insulator and to insert a dielectric layer with a high dielectric strength into the waveguide. The dielectric layer causes an abrupt change in waveguide impedance which leads to reflection of the microwave power. As a result, on the one hand, the dielectric must be as thin as possible. On the other hand, it must withstand the applied voltage which implies an increase of the thickness.

The DC break is based on a half-wave choke which consists of two quarter-wave segments of radial and coaxial lines. Two sections of WR340 waveguide have specially shaped circular flanges with a diameter of 200 mm.

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The space between them is filled with an insulator. Several types of insulators made of aluminum oxide and teflon are considered. One of the simple 40 kV DC break design modifications in which PTFE with dielectric strength of 22 kV/mm is used as the dielectric is shown in the Fig. 1.

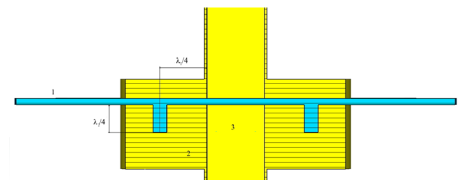

Figure 1: 40 kV DC break design with PTFE. (1) Insulator. (2) Waveguide flange. (3)WR340 waveguide.

The results of numerical simulation shown in the Fig. 2 demonstrate good transmission properties at the operating frequency.

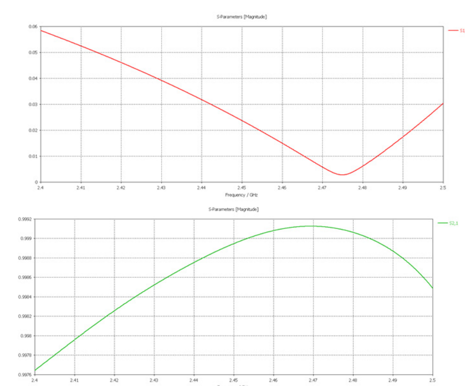

Figure 2: Scattering parameters of the simple 40 kV DC break section.

WAVEGUIDE DC BREAK WITH COMBINED DIELECTRIC

Another type of DC break is shown on the Fig. 3. This DC break model uses composite insulator.

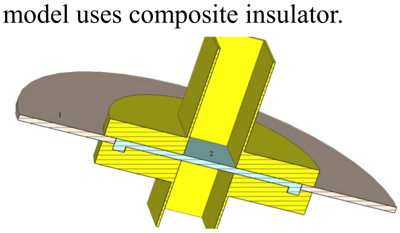

Figure 3: 40 kV DC break design with composite dielectric. (1) Alumina. (2) PTFE.

The considered insulator consists of two parts: ceramics based on the aluminum oxide and PTFE. Ceramic disc provides a rigid structure for the device. As it is shown in the Fig. 4 the results of numerical simulation also demon-

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strate good transmission properties at the operating frequency.

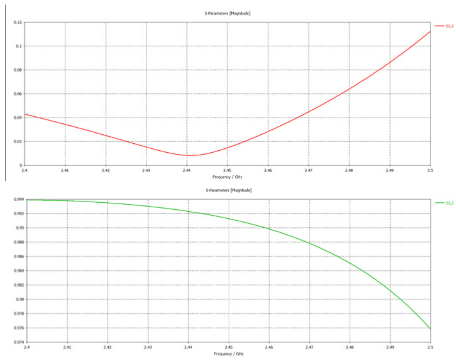

Figure 4: Scattering parameters of the 40 kV DC break section with composite dielectric.

TWO-SECTION WAVEGUIDE DC BREAK WITH COMPOSITE DIELECTRIC

DC break designs presented allow obtaining the low emission of microwave power into the surrounding space. Increasing the dielectric thickness makes it possible to increase the operating DC break voltage but the emission of microwave power significantly increases at the same time. Therefore, to increase the operating voltage a modification of a two-section DC break shown in the Fig. 5 has been proposed. The presented in the Fig. 6 numerical simulation results demonstrate satisfactory transmission properties at the operating frequency.

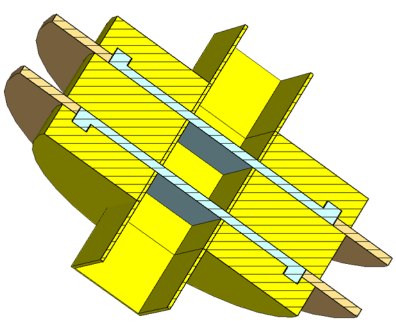

Figure 5: Two-section 80 kV DC break with the composite insulator.

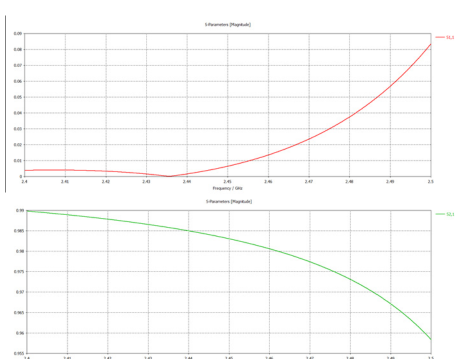

Figure 6: Scattering parameters of the two-section 80 kV DC break with the composite insulator.

Summary of the results calculated is specified in Table 1 and 2 for 40 kV DC break with PTFE and composite insulator respectively and in Table 3 for two-section 80 kV DC break with composite insulator.

Table 1: 40 kV DC Break Section with PTFE

Parameter	Value
Maximum of the transmission coefficient	0.999
Minimum of the reflection coefficient	0.0027
Average microwave power flux density at the distance of 0.5 m and the microwave power of 1 kW [W/m^2]	0.174
Dielectric losses	0.02%

Table 2: 40 kV DC Break Section with Composite Insulator

Parameter	Value
Maximum of the transmission coefficient	0.994
Minimum of the reflection coefficient	0.0089
Average microwave power flux density at the distance of 0.5 m and the microwave power of 1 kW [W/m^2]	29.2
Dielectric losses	0.03%

Table 3: Two-Section 80 kV DC Break with Composite Insulator

Parameter	Value
Maximum of the transmission coefficient	0.989
Minimum of the reflection coefficient	0.0010
Average microwave power flux density at the distance of 0.5 m and the microwave power of 1 kW [W/m^2]	46.4
Dielectric losses	0.05%

CONCLUSION

The waveguide DC break for insulation from the high voltage in the ECR ion source has been designed. It is shown that simple DC breaks with an electrical strength of 40 kV provide good performance. To increase the operating voltage a modification of a two-section 80 kV DC break has been proposed. Simulation results are found to reveal the low power loss in the surrounding space as well as the high gain.

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