DEVELOPMENT OF AN R&D ELECTROSTATIC SEPTUM FOR THE 50-GEV PROTON SYNCHROTRON

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Abstract

The electrostatic septum for the slow extraction system of the JHF 50-GeV proton synchrotron is one of the crucial hardware components. Its required electric field strength is 6.8 MV/m in the gap of 25 mm and the length of 1.5 m. The voltage across the gap becomes 170 kV. In order to achieve these design goals, we started R&D by making a septum model. The feedthrough has a ceramics cylinder filled with Fluorinert™ as an insulating material. The wires are 80 μm in diameter and arranged with a 1.25 mm spacing; the material is W(97%)-Re(3%). The cathode material is stainless steel (SUS304), and the length is 0.7 m. We have attained a field strength of 7.3 MV/m (183 kV/25 mm), which is higher than the goal of 6.8 MV/m (170 kV/25 mm), and 10.5 MV/m with a gap of 10 mm.

1 INTRODUCTION

JHF (Japan Hadron Facility) is a joint project on high-intensity proton accelerators between KEK and JAERI (Japan Atomic Energy Research Institute). It comprises a 400-MeV linac, a 3-GeV booster synchrotron, and a 50-GeV synchrotron [1]. An electrostatic septum is used in the slow extraction system of the 50-GeV synchrotron. The extracted beam is deflected by 0.2 mrad through the septum. The required electric field strength is 6.8 MV/m; the gap is 25 mm and the length is 1.5 m. A beam loss during the slow extraction must be less than 1%. The detail of the slow extraction scheme is described elsewhere [2].

In order to achieve these design goals, we started R&D by making a septum model. This model has the following features:

- a target value of vacuum pressure is lower than 0.1 μPa to prevent continuous discharges;
- thin wires are adopted as a septum instead of a foil to reduce a beam loss during slow extraction;
- a compact high-voltage feedthrough that could stand voltages higher than 200 kV is required;
- a fine-adjustment system of the gap width and the cathode angle is installed.

We have started the conditioning of the R&D septum. The design and the progress of the R&D are described below.

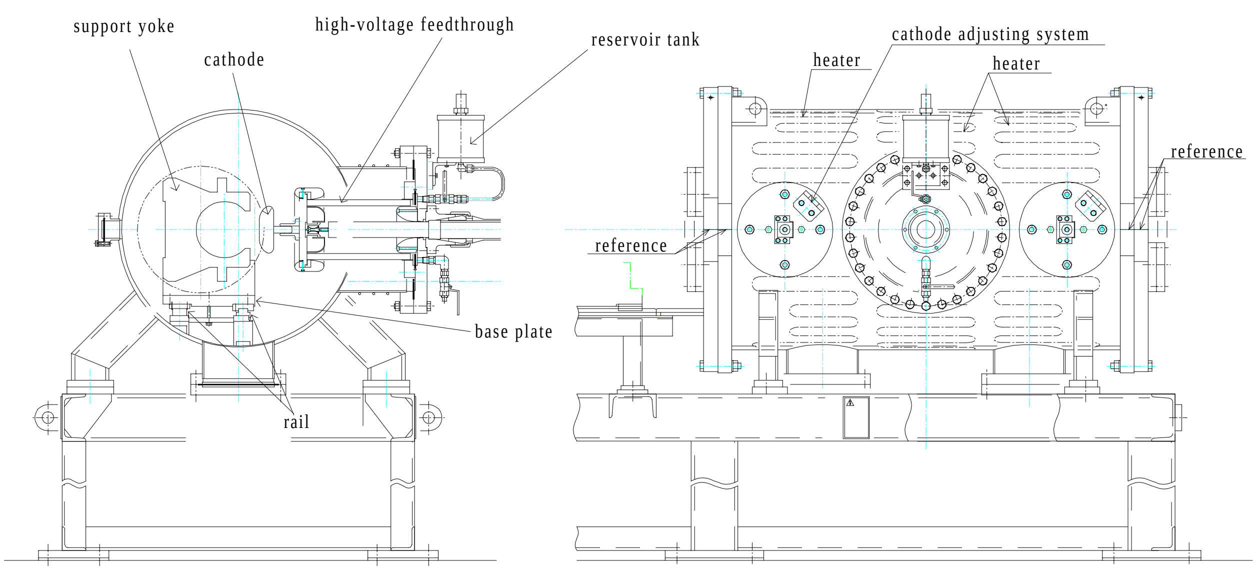

Figure 1: Front (left) and side (right) views of the R&D septum model.

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2 DESIGN OF THE R&D MODEL

2.1 Vacuum Chamber

Front and side views of the R&D model are shown in Figure 1, and the specifications are listed in Table 1. The vacuum chamber is made of stainless steel (SUS304), 886 mm in length and 496 mm in inner diameter. Thickness of the chamber wall is 8 mm. Electro-chemical polishing was applied to the inner surface. Two types of gasket are used for vacuum seal. One is silver-plated metal O-ring used for the end flanges, another is ConFlat® type gasket used for other flanges. To attain low pressures, below 0.1 μPa, the chamber is designed for baking up to 200°C. Sheath heaters are attached on the end flanges and the chamber wall. A septum yoke is mounted on a base plate which can slide on the rails along the chamber axis. The extended rails can be connected outside the chamber for easy installation.

Table 1: Specifications of the R&D septum

chamber	
material	SUS304
length	886 mm
inner diameter	496 mm
vacuum	< 0.1 μPa
bake-out temperature	200 °C
septum	
type	wire septum
material	W(97%)-Re(3%)
wire diameter	80 μm
wire pitch	1.25 mm
length	700 mm
cathode	
material	SUS304
length	680 mm
height	100 mm
gap	10 ~ 30 mm
feedthrough	
maximum voltage	> 200 kV
insulating material	Fluorinert™

2.2 Septum

Thin wires are adopted for the septum. The wire material is W(97%)-Re(3%). The diameter is 80 μm, and the wire is arranged with a 1.25 mm spacing along the chamber axis. Each wire is stretched with a tension of 300 gf and fixed to the yoke of stainless steel. The height of the wire is 80 mm, and the length of the yoke is 700 mm. The wire diameter and the pitch were determined by calculating the electric field that leaks out into the circulating beam area [3]. According to the calculation executed by POISSON code [4], the field drops in the range of the wire diameter.

2.3 Feedthrough

A high-voltage feedthrough was designed for the R&D septum. The side view of the feedthrough is shown in Figure 2. A high-voltage cable of 38 mm in outer diameter can sustain 250 kV. The cylindrical insulator, made of alumina ceramics (99% purity), is 225 mm in length and 101 mm in inner diameter. The thickness of the cylinder is 13 mm. Fluorinert™ is filled inside the ceramics cylinder. The applicable voltage is higher than 200 kV. Two-dimensional electric field calculation at 200 kV has done. The shape of the outer ring was optimized so that the field on the surface might not exceed 10 MV/m. The plot of equipotential lines is shown in Figure 3.

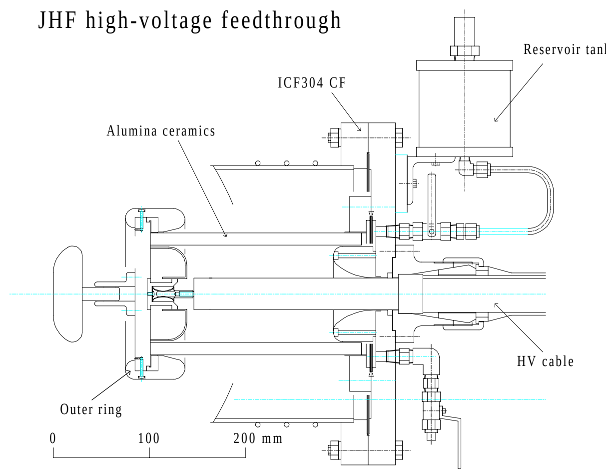

Figure 2: Side view of the high-voltage feedthrough.

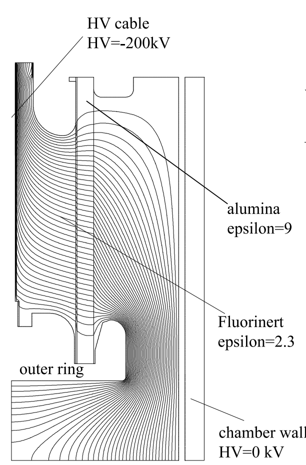

Figure 3: The plot of equipotential lines in a high-voltage feedthrough. Epsilon means a dielectric constant.

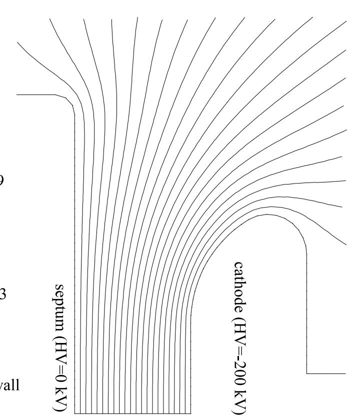

Figure 4: The plot of equipotential lines in a gap of 30 mm.

2.4 Cathode

The cathode is made of stainless steel (SUS304) finished electro-chemical buffing (ECB). The length is 670 mm, and the height is 100 mm. The cross-sectional shape of the cathode is determined from the results of the electric field calculation in the gap. The edge curve comprises two arcs with different curvatures approximated to Logowskii curves. The plot of equipotential lines in a gap of 30 mm is shown in Figure 4.

2.5 Adjusting System

An electrode-adjusting system with two moving axes is installed in the chamber; thereby the gap width and the cathode angle are controlled from the outside of the chamber. The system consists of universal couplings, alumina rods with a length of 240 mm, and moving handles with lock. The system can not only adjust a gap width from 10 to 30 mm, but also adjust the cathode angle from –33 to 33 mrad.

3 HIGH VOLTAGE TEST

3.1 Test-stand Layout

The layout of the test stand is shown in Figure 5. High voltage is fed from a power supply (300 kV max), surrounded by a grounded shield. The damping resistance of 500 Ω is installed between the high-voltage cable and the power supply. Maximum voltage of the resistance is 100 kV. Two vacuum pumps are used. One is a turbo-molecular pump (550 l/s), and the other is an ion-sputter pump (140 l/s). The base pressure in a chamber is 2 μPa or lower, measured by an ionization gauge. To prevent X-rays caused by field-emission electrons, the chamber is shielded by 5-mm-thick lead plates.

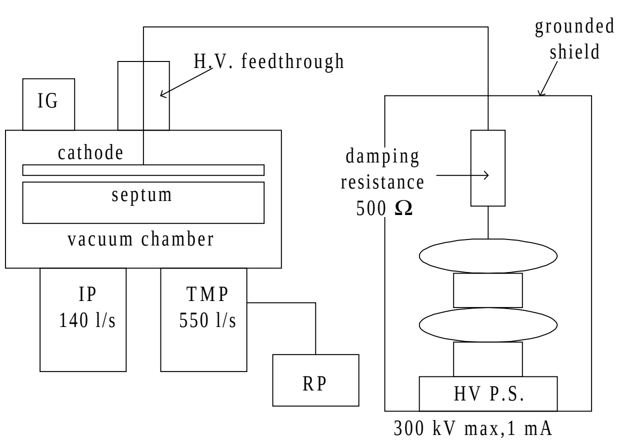

Figure 5: Layout of the test stand. Abbreviations are as follows; IG: ionization gauge, IP: ion sputter pump, TMP: turbomolecular pump, RP: rotary pump.

3.2 Conditioning of the septum

Before installing the septum electrode, we started the conditioning of the feedthrough. We raised the voltage gradually up to 170 kV, the aimed voltage. We paid attention to the deterioration of a vacuum pressure caused by discharge, and kept the pressure below 100 μPa, and the aimed voltage was attained after a 15-hour conditioning.

After the installation of the septum electrode, the gap was at first set to 30 mm. The conditioning procedure is the same as that of the feedthrough. We attained 170 kV after 26 hours. The leakage current of the power supply is about 25 μA at 5 μPa. Then the gap was decreased to 25 mm, the design value. The aimed field strength of 6.8 MV/m (170 kV/25 mm) was obtained after the 7-hour conditioning. In the successive conditioning of 18 hours, the attained field strength increased to 7.3 MV/m (183 kV/25 mm). Discharge, probably surface flushover on the ceramics insulators, occurs regularly once a few minutes at the design voltage.

The maximum field strength, 10.5 MV/m, was obtained at the gap of 10 mm. At this condition, the voltage was quite stable, without discharge during one hour.

4 CONCLUSION

At the design gap of 25 mm, we have attained 183 kV (7.3 MV/m), which is higher than the goal of 170 kV. At a narrower gap of 10 mm, the maximum field strength is 10.5 MV/m. For a stable operation at 170 kV, further conditioning would be necessary. It might be effective to raise the voltage to 200 kV or higher and then decrease to 170 kV. After finishing tests with the stainless-steel cathode, we will replace it with the one of oxidized aluminum.

REFERENCES

[1] Y. Yamazaki, "High-Intensity Proton Accelerators for the JAERI/KEK Joint Project", these proceedings.
[2] M. Tomizawa *et* al., "Design of Small-Beam Loss Slow Extraction in a High Intensity 50-GeV Proton Synchrotron", these proceedings.
[3] T. Watanabe *et* al., "Calculation of Field Configurations of the Electrostatic Septum and Massless Septum Magnet for the Slow Extraction System of the JHF Main Ring", KEK Preprint 97-167, Oct. 1997.
[4] POISSON is an improved version of TRIM and was developed by J. R. Spoerl, R. F. Hoisinger and K. Halbach.