

ELECTROSTATIC SEPTUM FOR 50GEV PROTON SYNCHROTRON IN J-PARC*

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Abstract

The two electrostatic septa(ESS) are one of the most important device for the slow extraction in 50GeV proton synchrotron. We have developed the thin ribbon type septum in order to reduce the beam loss. If alignment of ribbons is poor, the effective thickness seen from the beam become large, and it would increase the beam-hitting rate. The alignment of ribbon over 1.5m long septa was measured by a laser-focus displacement meter. The achieved effective thickness of septa is estimated to be 0.075mm and 0.080mm respectively. We will report a high voltage conditioning and a performance under beam commissioning.

INTRODUCTION

Main Ring(MR) comprises three straight sections and three arc sections. two electrostatic septa and ten magnetic septa are located between two sets of bump magnets. Fig. 1 shows the schematic view of MR. Most of devices for a resonant slow extraction were installed in MR by the end of 2008, and first beam was successfully provided into Hadron target in January 2009. Since the high intensity acceleration will cause the issue of radiation damage for the device and radio activation, the beam loss should be as small as possible. The beam tracking simulation predicts that the beam loss will be less than 1%, if the thickness of septum seen from the beam is less than 0.1mm[1, 2]. A ribbon type septum with thickness of $30\ \mu\text{m}$ was developed instead of $80\ \mu\text{m}$ wire. Prior to the fabrication of ESS, R&D test piece was made to establish the technique of fixing the ribbon to the yoke. On the other hand, The R&D electric septum was manufactured which length is shorter than actual ESS. The high voltage test was carried out to ensure the performance[3]. We achieved design voltage for 50GeV stably after exchanging of cathode material from stainless steel to Titanium[4]. The actual ESS was installed in tunnel in Oct 2008. we could obtain the stable operation in beam time after the conditioning of 130kV with the Gap of 30mm in Sep 2009.

Cable connection device was introduced for relaying ESS and power supply which include the register near to the ESS. The cable can be exchanged in case of deterioration due to radiation or the failure of ESS. Fluorinert is used as an insulation liquid. The circulation system was developed in order to eliminate the dust and

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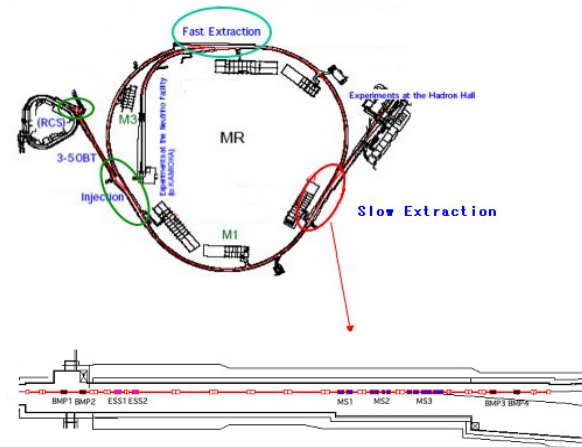


Figure 1. The schematic view of MR.

Table 1: Main Specifications of ESS.

Deflection angle	0.2 mrad
Energy	30 GeV (50 GeV)
Electric field strength	4.2 MV/m (6.8 MV/m)
Cathode Voltage	104 kV (170 kV)
Ribbon cross section	0.03 mm x 1 mm
Ribbon spacing	2 mm
Cathode length	1480 mm

degradation product. Hardware which related to electrostatic septum are presented.

ELECTROSTATIC SEPTUM

The cross section of ESS are shown in Fig. 2. The cathode is made of titanium, it's surface has oxide layer of 5nm ~10nm after finishing MCP. The cathode plate and feedthrough are connected with finger-contact so that the gap size is variable. Septum ribbon itself is made up of $30\ \mu\text{m}$ tungsten alloy(W74%, Re26%). The ribbon is stretched to C-shaped yoke by tension spring. Tension is 1.15kg. In case that the ribbon is cut by accident, the ribbon is suspended so as not to interfere the beam. The material of the yoke is SUS304, its surface is finished with the electro-chemical polishing(ECP) except the

attachment base after mechanical polishing. In order to minimize the beam loss, the position of septum is adjustable by moving the yoke which is connected to the pulse motor, the specification of pulse motor is radiation proof. The resolution is $0.05 \mu\text{m}/\text{pulse}$. The backlash is minimized by adding tension spring to the septum assembly. Two potential meter is attached to the chamber in case of failure. The high voltage cable is plugged into feedthrough. Radiation resistant Hayakawa EPDM rubber is used as a seal. The inner plate with the thickness of 2mm is prepared inside the yoke for suppressing the electron cloud in case of high intensity operation. The inner surface of the chamber is also finished with ECP, and are prebaked before assembly.

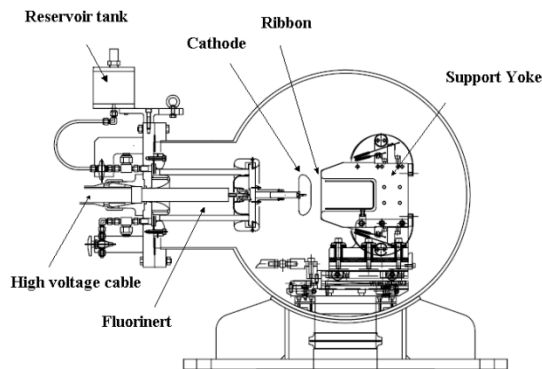


Figure 2. The cross section of ESS.

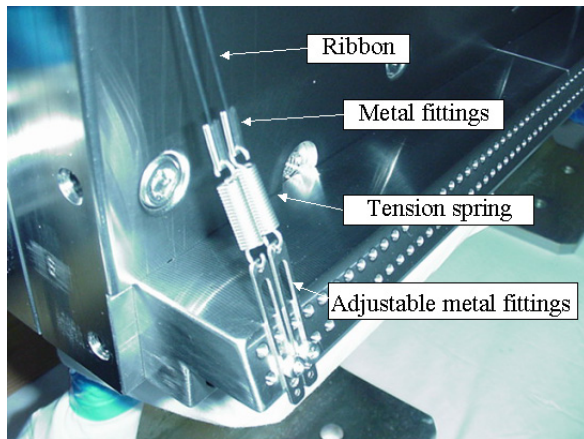


Figure 3. Fixation of the ribbon.

Fig. 3 shows the fixation method of ribbons. The ribbon is choked with the metal fitting which is made of stainless steel. Tension is determined by adjusting the length.

The cross section of ribbon are shown in Fig. 4. The ribbon was fabricated by a process of rolling and annealing. Temperature was controlled so as to keep the

tensile strength $4.6 \text{ kg} \sim 4.7 \text{ kg}$ after annealing. In order to reduce the risk of discharge, the surface of the ribbon is finished with ECP. The edge of the ribbon was scraped and are smoothly round shaped at corner. The roughness of the surface should be $Ra=0.08 \mu\text{m}$.

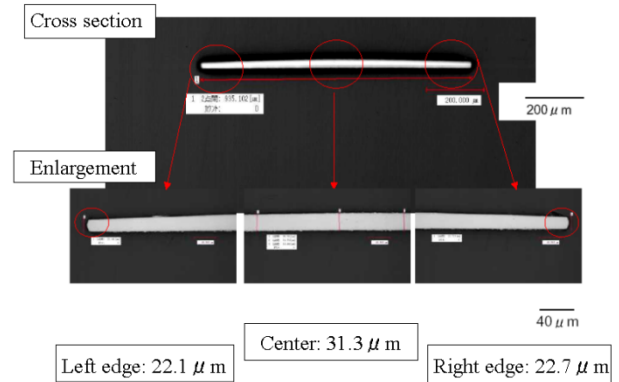
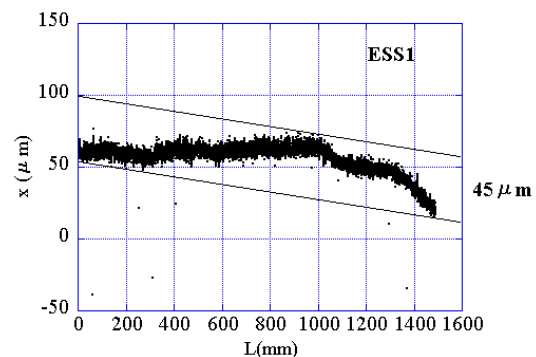


Figure 4. The cross section of the ribbon septum.

Alignment Measurement of Septum

The ribbon septum can make the thickness thinner without reducing the mechanical strength by increasing cross section longitudinally. However, if twisted error is large, that make the alignment worse. The measurement of displacement was performed to inspect the error of the ribbon itself and to estimate the alignment error of the ribbon. Laser head is run by a pulse motor controlled by PC with the speed of $0.25 \text{ mm}/\text{sec}$, the accuracy of linear guide and laser head is $9 \mu\text{m}$ and $0.1 \mu\text{m}$ respectively. The distance between laser head and the ribbon must be set within $5 \pm 0.3 \text{ mm}$. Two ribbons which were remarkably twisted was found in ESS1. The ribbon which seem to cramp the dust upper side of the support yoke was detected in ESS2. These error will make the septum thick that lead to beam loss. Since the ribbon is replaceable one by one, the alignment of the ribbon could be modified. The results after replacing the ribbon are shown in Fig. 5. One can see that the twist error is $\sim 10 \mu\text{m}$. The distance between parallel lines shows the alignment error of septum.



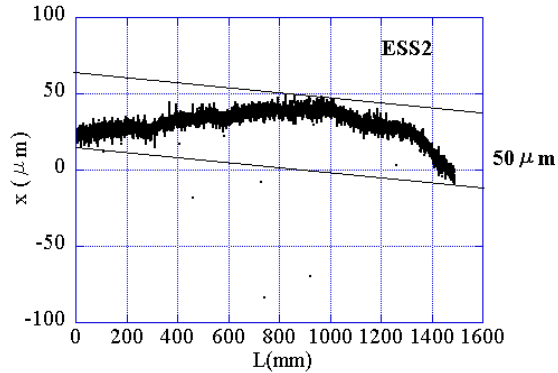


Figure 5. The alignment of the ribbon in ESS.

The gradient of the line means the angle between the scanning direction and alignment of septum. The effective thickness of septum seen from the beam would be $75 \mu\text{m}$ and $80 \mu\text{m}$ respectively.

Circulation System of Fluorinert

Fluorinert(FC40) is used for insulation. Since hydrogen fluoride(HF) is created under the high radiation environment, filtration was done to purify the liquid. Circulation device consist of filter unit, seamless pump, pressure gauge, metal valve and interlock system. The flow rate is adjusted by inverter unit preventing the vibration of the pump. It is set to be between 0.3L/min and 0.5L/min. The concentration of HF would be decreased from 1ppm to less than 0.05ppm once passing through the circulatory system. The creation of HF depends on beam loss and beam power, however, one has to exchange the filter unit when the active alumina absorb 1.7g. Fig. 6 shows circulation system of fluorinert. Two ESS and cable connection device are connected in series and in parallel respectively. Each reservoir tank has a expansion vessel to absorb the pressure rise depending on the temperature in tunnel. The relief valve is prepared for over pressure protection.

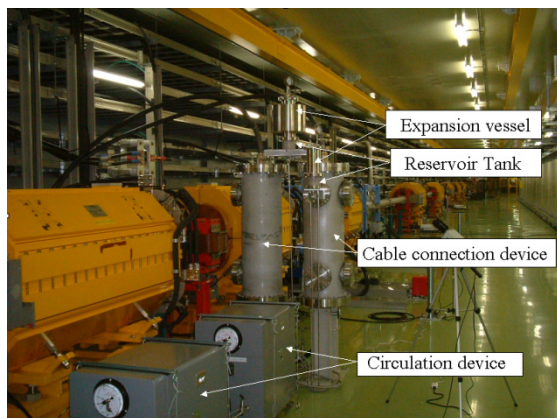


Figure 6. The circulation system of fluorinert.

Conditioning of ESS

The conditioning of ESS was done before beam commissioning. It took two hours to increase the voltage up to 104kV for the first commissioning of slow extraction, because the DC current was fluctuated during operation in ESS1, and changed between $14 \mu\text{A}$ and $26 \mu\text{A}$ at 104kV during several month operation. We tried to increase the voltage up to 130kV with the gap of 30mm, the spike current appeared when the voltage reached to 114kV and 119kV, then the DC current rapidly decreased, and reached to the same level of the ESS2. The vacuum became a little worse in each voltage, but soon got to recovery. We couldn't identified the place where the discharge occurred. However, the DC current of the ESS1 is $\sim 8 \mu\text{A}$ since then. Dark current was measured by digital electro meter directly connected to yoke and inner plate. The result was $\sim 2\text{nA}$ at 104kV. The two ion pump is attached to the ESS chamber. The pumping speed is 1200L/sec in a chamber. The vacuum is kept from 10^{-7}Pa to 10^{-5}Pa during the conditioning. The software is developed for high voltage conditioning, 16bit DAC module is used to control the power supply. Since the rate of discharge become higher during high voltage conditioning, the voltage must be increased finely. The step is set to be 25Volt/min typically. The ESS has been continuously operated over a week in RUN#30, and it was stable during the beam time.

SUMMARY

Measured alignment error in ESS1 and ESS2 were $75 \mu\text{m}$ and $80 \mu\text{m}$ respectively. The performance of the ESS1 became better after conditioning, and stable during the beam time. In order to reduce the beam loss in case of high intensity, the feasibility of other material with low-z such as carbon nanotube or Beryllium will be investigated.

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