ELECTROSTATIC BEAM SEPARATION SYSTEM OF TRISTAN MAIN RING

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Abstract

Sixteen electrostatic separators have been installed in TRISTAN Main Ring. The maximum designed voltage is 240 kV, across a gap of 8 cm between 4.6 or 3.2 m long titanium electrodes.

In order to make the H.V. sparking rate as low as possible, the chemical cleaning process of the electrodes and the chamber surfaces were studied carefully. Every one of the H.V.-bushing and ceramic supports were tested by applying H.V. up to 150 kV, and assembled into the separator chamber in a clean room.

Special care was taken to secure the passage of the wall current produced by the passing bunched beam, so that no H.V. breakdown will occur.

The power of the parasitic mode was pulled out and damped by the ferrite microwave absorbers inside the shield box, so that the direct cooling of the electrodes became unnecessary, and the structure of the separator became very simple.

The separator showed excellent H.V. properties, i.e., no H.V. spark was observed over two days for 16 separators at 240 kV without the beam circulating the ring. With beams of 9 mA total current, neither beam loss nor sparks were observed at the separation voltage of 200 kV.

Fig.1 The electrostatic separators installed in the TRISTAN Main Ring.

Introduction

It was estimated that the required maximum separating electric field intensity was 20 kV/cm to avoid the beam loss due to beam-beam effect at the injection and acceleration[1]. We designed the maximum operational field strength of the separator to 30 kV/cm, and the gap voltage to 240 kV. The electrode gap was set to 8 cm considering the acceptance for the beam and synchrotron radiation

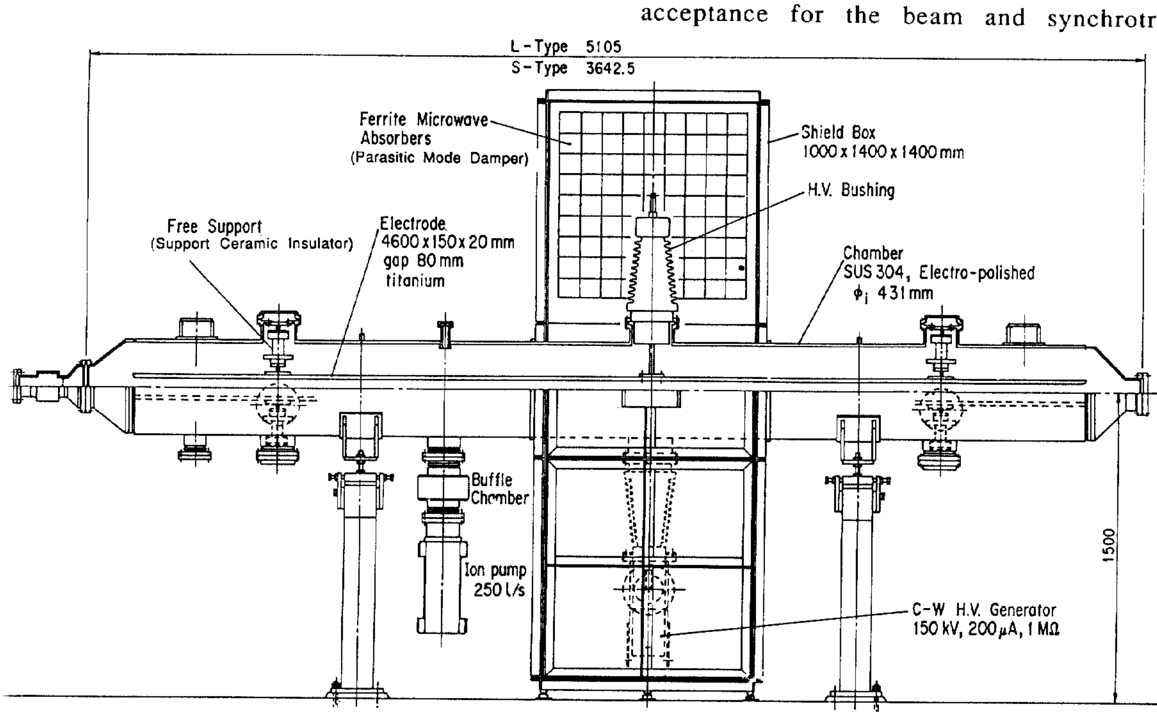

Fig.2 Separator chamber.

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from the Q-magnets around the collision point. The main parameters are listed in Table-1.

Fig.1 shows the separators installed in the beam line, where 4 separators are used for a collision point. Total number of 16 separators were installed in Main Ring.

Structure of Separator Chamber

Fig. 2 shows the structure of the separator. The titanium electrodes are supported by H.V.-bushings at the center and ceramic supports at the both side. The field distributions were studied by a computer simulation code DENKAI[2], and the shapes of the electrodes, the chamber and the ceramic parts were optimized, taking into account the limit of Kilpatrick Criterion[3].

Electrode and Chamber

We employed the pure titanium electrode because of its excellent high voltage characteristics[4] and mechanical properties.

For the purpose of making the H.V. spark rate as low as possible, the following chemical cleaning was employed. The electrodes were degreased and pickled in acid mixture of HF 2 % and HNO_3 10 % for 10 minutes, and rinsed by running deionized water for 5 seconds, next, rinsed in the deionized tap water about 5 minutes scrubbing the surface with a brush in order to remove the smut formed by the pickling process. Finally the electrodes were rinsed in deionized tap water of 55 °C about 10 minutes. In this process, the surface layer of about 20 μm thick was stripped, at the same time the machining grease and residual emery were removed perfectly.

For the same purpose, inner surface of the stainless SUS304 chamber was electrolytic polished up to the surface roughness of better than 1 S.

H.V.-bushing and Ceramic Support(free support)

If the electrical contacts between metal parts are poor, micro-sparks will be produced by the intense wall current induced by passing bunched beam. In order to avoid H.V. breakdown resulted from the micro-sparks, it is necessary to make the electrical contact as tight as possible. The connector flange of the H.V.-bushing and ceramic supports, by which the titanium electrodes are mounted, has a rim(edge) of 2 mm width and 1 mm height at the bottom surface.

In order to prevent the ceramic support from mechanical breaking by the thermal expansion of electrodes, the support has two plates of 2 mm thickness at both ends. The ceramics of 46^{ϕ}x163^{l} mm were made from the alumina Al_2O_3 of 95 %, and their surfaces were not glazed. The shield electrodes of SUS316L were electrolytic polished.

Every one of the H.V.-bushings and ceramic supports were tested by applying H.V. up to 150 kV, and assembled into the separator chamber. All of 41 H.V.-bushings passed the test: 84 ceramic supports were fabricated and 83 of them passed the test.

Parasitic Mode Damper

It was estimated that the loss factor k was 0.5 V/pC for a bunch of σ_z=1cm by taking into account the data of model measurements by J. N. Weaver[5], and the maximum loss power was 500 W at a beam current of 5 mA/bunch, 4 bunches and 100 kHz revolution frequency. This power was pulled out through the H.V.-bushing, and damped by the ferrite microwave absorbers[6] inside the shield box. Fig. 3 shows the measured and calculated Q-factors of the chamber. The Q-factors were measured from the spectrum of beam induced pulse inside shield box. The calculated Q-factors were given by solving the equivalent circuits of the chamber. As shown in Fig. 3, the Q-factors were lowered by factor 10 or more. It was estimated that almost all of the power was absorbed by the ferrite microwave absorbers, and the electrode heating was less than 25 W and the temperature rise was less than 50°C. With this much temperature rise, no significant deterioration of vacuum pressure was expected. The direct cooling of the electrodes became unnecessary, and the separator structure became very simple.

Table-1
Main Parameter of ES-separator

	L-type (S-type)
Chamber dimension	431^{ϕ}, 5105^{l}mm (3643^{l}mm)
material	SUS304(electrolytic polished)
Electrode dimension	150^{w}, 20^{t}, 4600^{l}mm (3200^{l}mm)
gap	80 mm
material	pure titanium
cooling	none
Maximum operating voltage	240 kV (30kV/cm)
Conditioning voltage	260 kV
High Voltage Power Supply	
max. output voltage and current	±150 kV, 200 μA
drive frequency	50 kHz(= f_r/2)
ripple rate	<1%
Total number of separators	16

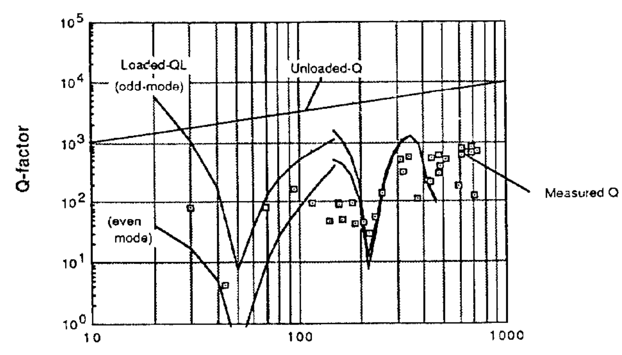

Fig. 3. Q-factors of the chamber.

H.V. conditioning

The chambers were tested and conditioned by applying H.V. up to 260 kV before the installation. In order to make the outgassing rate accompanied with a leak current as low as possible, the H.V. was applied on two electrodes with following ten combinations, (+130kV,0), (0,-130), (+130,-130), (0->+130, -130), (+130, 0->-130), (-130kV,0), (0,+130), (-130,+130), (0-> -130, +130), (-130, 0->+130). Typically, this conditioning took about 2 days, and only a few sparkes were observed.

In some chambers, a stable leak current flowed on the negative electrode. The gas conditioning by introducing the N_2 gas of 10^{-5} Torr was very effective to deliminate this leak current.

The installed separators showed excellent H.V. properties, i.e., no spark was observed over two days for 16 separators at 240 kV without the beam circulating the ring.

Beam Test

The electron and positron beams of 9 mA were injected at the separation voltage of 100-200 kV, and accelerated to the collision energy of 30 GeV. Neither beam loss nor H.V. sparkes was observed. However, small leak current flowed on the positive electrode as shown in Fig. 4. The leak current changed with the beam current almost linearly, but did not depend upon the separation voltages, so that it was expected that the leak current was photoelectron current produced by the synchrotron radiation from the Q-magnets around the collision points. Fig. 5 shows the vacuum pressure dependence on the beam current at the separation voltage of 164 kV. The pressure was influenced by that of the neighborhood, so we could not know the intrinsic pressure of the separator. However, the pressure is enough for the beam operation at the present beam current.

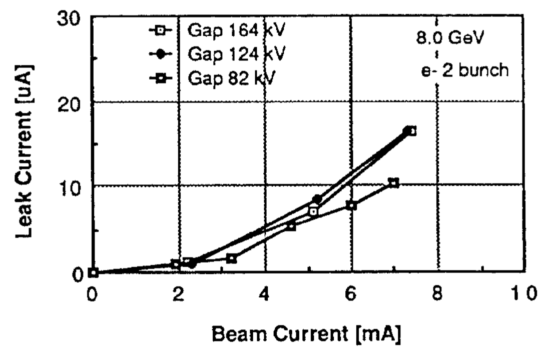

Fig. 4 Leak current as a function of the beam current.

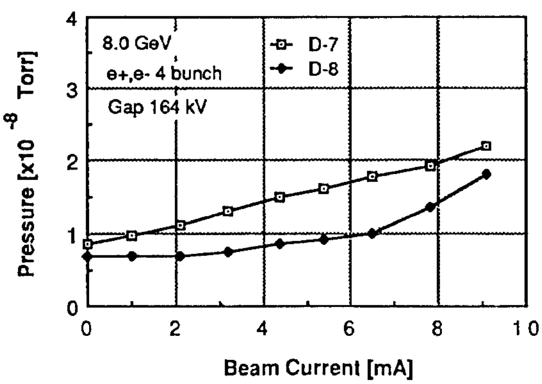

Fig. 5. Vacuum pressure v.s. beam current.

Conclusions

Sixteen electrostatic separators have been installed in TRISTAN Main Ring , and showed excellent H.V. properties. The separators will be used for the beam separation to avoid the beam loss at the beam injection and acceleration.

Acknowledgements

We would like to thank to T. Nishikawa and Y. Kimura for their support and encouragement on our project. We would like to say thank K. Takata, Y. Yamazaki and H. Mizuno for their helpful discussions on the design and construction. We are pleased to acknowledge on the suggestion by M. Fukumoto and A. Yamamoto concerning to the high voltage technology.

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