THE HV WITHSTANDS TEST FOR IN VACUUM BOOSTER KICKER*

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Abstract

The maximum driving voltage of TPS booster extraction kicker is approach to 30 kV, the HV insulation should be carefully noticed. A DC withstand voltage tester MUSASHI 3802 (Model: IP-701G) is used to test the DC breakdown voltage, which the maximum driving voltage is 37 kV. The 10 mm gap between coil and ferrite is designed in order to avoid vibration propagation and increase HV break down voltage. The safety breakdown distance between HV coil and grounding plate was tested in air. Thicker than 10 mm ceramic plate could effectively avoid the breakdown occurred with 37 kV DC charging. The feedthrough also measured the DC withstand ability in air and vacuum condition. Thus HV withstand voltage will be higher in vacuum chamber and the insulation will not be the problem.

INTRODUCTION

The Taiwan photon source (TPS) requires highly precise and stable pulsed magnets for top-up mode operation [1]. Ten pulsed magnets are used for injection and extraction of the electron beam in the booster and storage ring [2]. One injection and two extraction in vacuum kicker magnets in the booster ring are designed for minimizing the gap of magnet and driving voltage. The HV insulation, vacuum feedthrough, and air pressure condition need to be noticed.

The electron beam of the booster synchrotron is injected from 150-MeV linear accelerator and accelerated to operating energy 3 GeV with 3 Hz repetition rate. The beam at full energy is then transferred through the transfer line to the storage ring. According to the booster design, the electron beam is injected into the booster synchrotron along the axis, involving an injection septum (length 0.8 m) and a quick kicker magnet (length 0.5 m) to place the beam on that booster axis. After the electron beam is ramped to 3 GeV, the beam at full energy is extracted from the booster in one turn period using a kicker magnet (length 1.0 m) and septa (0.8 m DC and 0.8 m AC septum).

TPS PULSED MAGNETS LAYOUT AND BOOSTER KICKER SPECIFICATIONS

The pulsed magnets in TPS are divided into 3 parts, shown as figure 1. The first part is booster injection section; there are one booster injection septum and one kicker included. Then, the electron beam extract to the second part - booster extraction section. There are 2 booster extraction kickers and two septa (DC+AC septum) in booster extraction section. Passing by the BTS (booster to storage ring) section, the electron beam is inject to the storage ring by 4 kickers and two septa (DC septum +AC septum). The booster kickers, including one injection and 2 extraction ones, were all rectangular wave type.

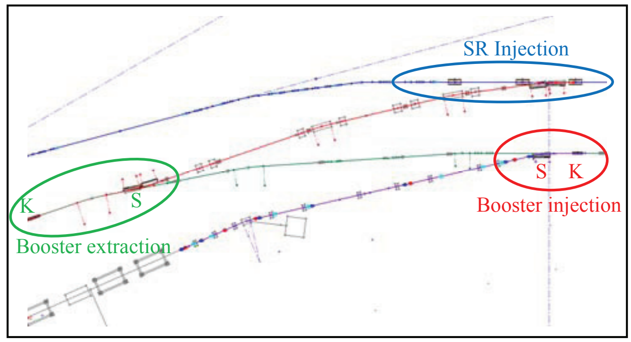

Figure 1: TPS pulsed magnets layout.

Table 1 showed the parameters of booster injection and extraction kickers. Because of the concentric design for booster ring, the length of bunch train could reach up to 1000 ns. The fall time for BR inj. kicker and rise time for ext. kicker is set to be 350 ns within one revolution time. The maximum value for extraction kicker is reach to 30 kV(shown in brackets), this will be severe requirement. The impedance of pulser is 25 Ω for 2 standard parallel 50 Ω cables. The flatness for the flat top is ± 1% and the pulse to pulse stability is within ± 0.1%.

Table 1: Booster Kicker Specifications

Specifications	Booster kicker	
	Injection	***Extraction (2 pieces)***
Electron energy (GeV)	0.15	3.0
Bend angle (mrad)	16 [30]	1.3 [2.0]
Beam aperture (mm)	35*20	35*18
Length (m)	0.5	0.5
Nominal field (T)	0.016 [0.03]	0.026 [0.04]
Mag. aperture (mm)	80*20	80*18
Nominal current (A)	267 [501]	372 [573]
Pulse shape	Flat top	Flat top
Fall time (ns) 95%-5%	<350	<350
Pulse duration (ns)	1000ns-FT	1000ns-FT
Energy in magnet (J)	0.058 [0.203]	0.146 [0.345]
Impedance (Ohm)	25	25
Inductance (μH)	2.4	3.0
Drive voltage (kV)	13.4 [25.1]	18.6 [28.65]
Pulse to pulse stability(%)	± 0.1	± 0.1
Flatness (%)	± 1	± 1

*Work supported by NSRRC
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ISBN 978-3-95450-122-9

TPS BOOSTER INJECTION KICKER

The in vacuum booster injection kicker is made by several parts. Fig. 2 showed the booster injection kicker coil and ferrite. The coil is made by OFC with R2 round edge and the curvature of coil bend is R3. The ferrite is made by CMD 5005 used in high vacuum. The gap between coil and ferrite is 10 mm and insulated by ceramic material. The vacuum chamber and pumping port are also showed in Fig. 2. The booster injection kicker was put in a 350 CF chamber, which is fixed on the wall. The outgas rate from ferrite (total surface area 1680 cm^2) and insulators (ceramic or PEEK) will increase outgassing rate. Baking at 150 ^oC for 24 hr could reduce outgassing rate, which could satisfy the design requirement of booster vacuum [3].

The impedance of pulser is 25 Ω for 2 standard parallel 50 Ω cables. Thus, two inlet and two outgo feedthroughs were need in the booster injection kicker. The 75 CF flange was used and two RG-220 cables (standard 50 Ω) were used to connect the pulser and kicker.

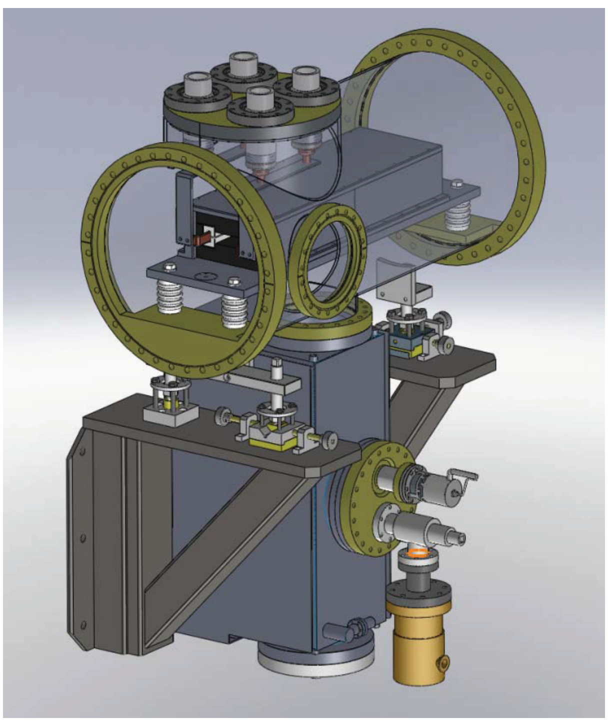

Figure 2: TPS booster injection kicker. (including all the components in the vacuum chamber and girders).

KICKER INSULATION TESTS

Because of the maximum driving voltage of booster extraction kicker is close to 30 kV, the HV insulation should be carefully noticed. The 10 mm gap between coil and ferrite is designed in order to increase HV break down voltage. The HV withstand test was experimented in order to confirm the breakdown voltage is enough.

According to the J-PARC experience, the HV withstand test is very important [4]. A DC withstand voltage tester MUSASHI 3802 (Model: IP-701G) is used to test the DC breakdown voltage. The maximum driving voltage is 37 kV.

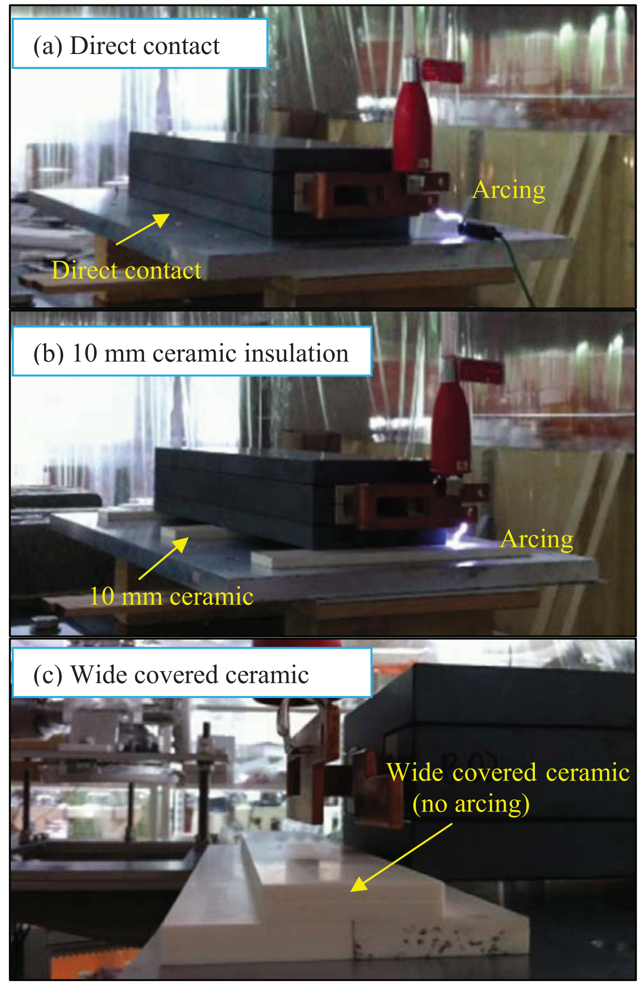

Figure 3: The experimental setup for DC withstand voltage test.

The experimental setup was shown in Fig. 3(a), 3(b), 3(c). Because of the HV withstand test was under atmosphere; the basic environmental condition should be noticed. The grounding resistance was 2.6 Ω and the relative humidity was 55 %. There are 3 different contact conditions between ferrite and base plate (made by SUS steel). First, the ferrite was directly put on the base plate, and the charging voltage was charged between coil and base plate. The HV break down at17.5 kV, showed in Fig. 4(blue line). The red line showed in Fig. 4 was the experimental result of adding 1 cm thickness ceramic plate between ferrite and base plate. Through adding distance between coil and base plate, the break down voltage increase to 30 kV. According to the prior experiments, the break down occurred on the edge of coil to base plate through the shortest path. Therefore, increasing distance between coil and base plate with wide covered ceramic was effective to achieve higher than 37 kV break down voltage showed in Fig. 4 (green line).

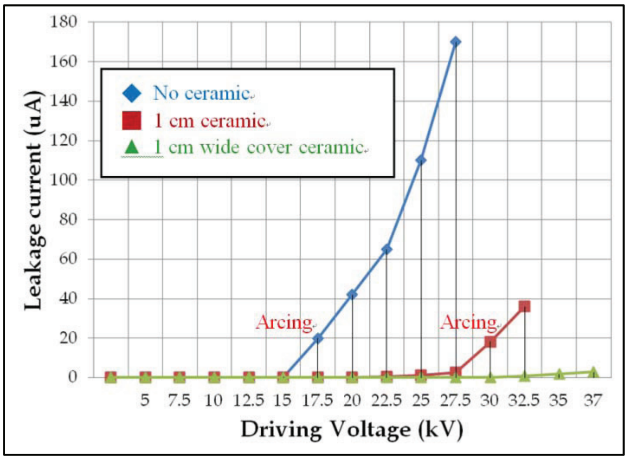

Figure 4: The HV test results.

The insulation layer not only used ceramic material, the wood material also test under the same experimental condition. The dielectric constants of different material could check by many documents. The dielectric constant of wood is 1.4~2.9 and ceramic is 5.2~6.3. The experimental results also showed the HV withstand ability for wood was better than ceramic. But wood is not applicable in vacuum system.

FEEDTHROUGH BREAKDOWN TEST

The vacuum feedthrough is another key component in booster kicker. There are two different prototypes for DC withstand test. The first one is CeramTec 25 kV/185 A/1 pin feedthrough, shown in Fig. 5. The breakdown test was under atmosphere, rough vacuum and $3.5*10^{-3}$ Torr vacuum condition. The breakdown occur at 22.5 kV, 32.5 kV and no arcing until 37 kV maximum voltage drive. The experimental result showed the feedthrough could maintain insulating state under vacuum condition.

Figure 5: Experimental setup with EMI filter.

The second feedthrough was designed by WavePower, which specification is 65 kV/20 A. The insulation ceramic is bigger and taller than CeramTec, shown in Fig. 5. Although the feedthrough was not designed for TPS booster kicker, the DC withstand test was good enough up to 37 kV under atmosphere and vacuum condition.

CONCLUSIONS

A DC withstand voltage tester MUSASHI 3802 is used to test the DC breakdown voltage. The 10 mm gap between coil and ferrite could avoid vibration propagation to kicker ferrite. The support of coil should carefully design. The safety breakdown distance between HV coil and grounding plate was tested in air. In order to avoid HV conduct to the ground, the 40 mm in thickness air gap is designed to insulate the magnet and vacuum chamber. According to the test result, this insulating gap is good enough to avoid arcing in the magnet. Different insulation material between ferrite and base plate with different thickness was tested the breakdown voltage. Thicker than 10 mm ceramic plate between ferrite and base plate could effectively avoid the breakdown occurred with 37 kV DC charging. The feedthrough also measured the DC withstand ability in air and vacuum condition. Two different type of feedthrough both could sustain 22.5 kV and 35 kV withstand voltage in air. Thus HV withstand voltage will be higher in vacuum chamber and the insulation will not be the problem.

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ISBN 978-3-95450-122-9