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INJECTION MAGNET SYSTEM FOR KOREA-4GSR FACILITY*

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Abstract

A 4th generation storage ring based light source is being developed in Korea since 2021. It features < 100 pm rad emittance, about 800 m circumference, 4 GeV e-beam energy, full energy booster injection, and more than 40 beamlines which includes more than 24 insertion device (ID) beamlines. For extraction/injection to the booster and storage ring, it needs 4 septums, and 6 kickers. Particularly, for SR injection needs an eddy current septum with 1 mm septum thickness for 10 mrad bending, and a thick septum with 5 degree direct current driven septum. In this report, the design of the injection magnets (kickers, septums) for Korea-4GSR will be discussed.

INTRODUCTION

Third generation storage ring based light sources have been used as a bright light source for many years. Recently multi-bend achromat (MBA) lattice presents a further decrease in the electron beam emittances and becoming a new standard for next generation light source like MAX-IV in Swden, ESRF-EBS in France, SIRIUS in Brazil. Many other laboratories are also preparing their own version of 4th generation light sources. In this context, Korea is trying to build a 4th generation light source (Korea-4GSR) based on modified hybrid multi-bend achromat lattice (MHMBA). The Korea fourth-generation storage ring (Korea-4GSR) adopt H7BA considering better nonlinear beam dynamics compared to the conventional 7BA and lower emittance compared to MH6BA [1,2]. The facility uses full energy booster injection as a injection system. The injection system assumes conventional 4 kicker scheme as a baseline design and application of nonlinear multipole kicker magnet is envisaged as a alternative scheme.

SR INJECTION SCHEME

Figure 1 shows the layout of injection straight. The injection straight is 11.6 m long with 6 quadrupole magnet with 4 kicker magnet. After passing thorough two septum magnet, the injected beam is parallel with store beam with 5 mm offset at 3rd kicker position. The horizontal offset of the injected beam from the storage ring center has 12mm offset. Four kickers, two for 3.1 mrad kick and two for 2.4 mrad were considered similar to PLS-II case. For septum magnets, one in-vacuum thin septa with blade thickness 1 mm and three out-vacuum thick septas with 2.5 mm blade were being considered. Detailed trajectory of injected beam is shown in Fig. 2.

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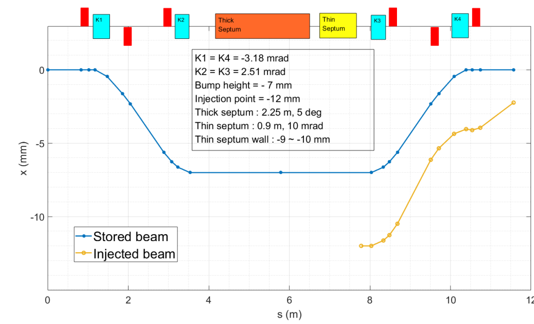

Figure 1: Storage ring injection layout.

MAGNET SYSTEM

Injection Kicker Magnet

The extraction from the booster and injection into the storage ring use the same type of kicker magnets to reduce development and maintenance costs. Four kickers are used for this purpose, with kickers 1 and 4 providing a deflection of 3.178 mrad, and kickers 2 and 3 providing 2.513 mrad. Due to the limited saturation magnetization of the ferrite, the central magnetic field is set to around 0.1 T, resulting in core lengths of 368 mm for kickers 1 and 4, and 284 mm for kickers 2 and 3.

The kicker magnet is powered by a 1:1:1 transformer to reduce effective impedance, which impacts the maximum power supply voltage. The transformer is mounted on top of the magnet, with one turn exciting the left conductor and the other turn exciting the right conductor. This configuration reduces voltage stress on the kicker power supply by doubling the current compared to the magnet current. For more technical details, see Fig. 3, Fig. 4, and Table 1.

Table 1: Major Parameters of SR Kicker1,4

Parameters	Values
Max kick angle@4GeV	3.179 mrad
Field integral	4.24×10^{-2} Tm
Vertical Gap	30.0 mm
Horizontal Clearance	64.0 mm
Core Length	368.0 mm
Effective Lengthy	412.0 mm
Conductor Current	2.5 kA
Central field @ Imax	0.1030 T
Inductance before transformer	0.55 μH

Injection Kicker Power Supply

Figure 5 shows simplified schematic diagram of the kicker power supply. The charging structure mostly consists of

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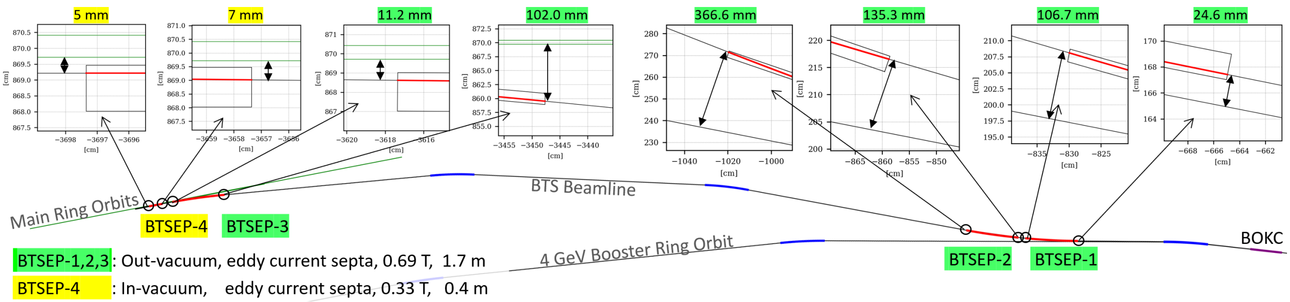

Figure 2: The detailed beam trajectory from the booster extraction kicker (BOKC) to the final thin septa (BTSEP-4) for injection into the storage ring.

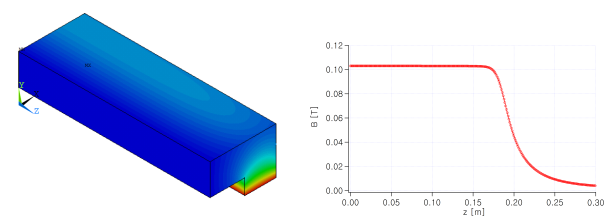

Figure 3: 3D model of the kicker magnet 1,4 (left), longitudinal By profile of the kicker field (right).

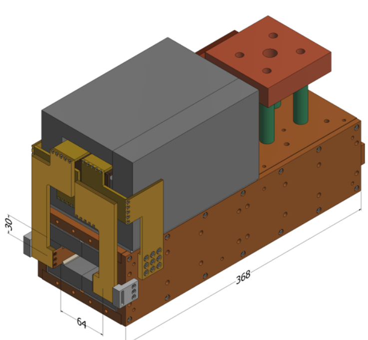

Figure 4: 3D drawings of the SR injection kicker magnet.

protection resistor, protection diode, and main capacitor. The main components of discharging structure consists of thyratrons, tail diode and tail structure, and RC snubber to suppress transient behavior. RC snubber is connected with magnet load in series, and maintain the continuity of load current after discharge. Maintaining load current is helpful to minimize the reverse voltages applied to thyratrons and capacitors. Limiting the reverse transient voltage on the thyratrons and capacitors are important to meet the thyratron specification, and to guarantee long life time of the capacitors [3]. Table. 2 summarizes the key parameters of the kicker power supply.

SEPTUM MAGNET

As illustrated in Fig. 6, the simulations were conducted using Opera2D, with plans for further 3D simulations to optimize field-map at the entrance and exit of septas. The thick-septa (BTSEP-1, 2, and 3) was designed to have 2.5 mm eddy current septum blade with μ-metal (NETIC S3-

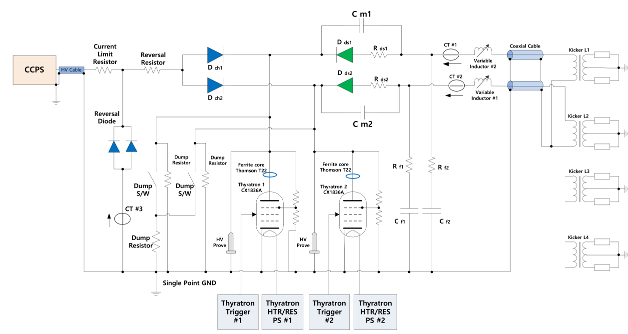

Figure 5: Schematic diagram of SR kicker power supply.

Table 2: Major Parameters of SR Kicker Power Supply

Parameters	Values
Pulse Current (Max)	7 kA
Pulse-width	< 5.0 μs
DC voltage at thyratron anode	14 kV
Flat-top width	200 ns
Repetition Rate	2 Hz
Energy per Pulse	70 J
Magnet Inductance	0.54 μH
Power Supply System Inductance (coaxial cable, variable inductance, line inductance, and others)	< 2.3 μH
Pulse Current Difference	± 0.2 %
Maximum Operable Beam Energy	4 GeV

6) shielding of 0.5 mm thickness [4]. The leakage field of thick septa is about 0.3 ± 0.1 Gauss which meets the typical technical requirement (See Fig. 7) in all shielded region [5]. The increase in magnetic field stored energy due to sagitta leads to an increase in inductance, making the pulse power system expensive. Therefore, we minimized the size of the field stored volume by designing the yoke of thick septa curved with a radius of curvature of approximately 20 m, rather than being stacked straightly.

The thin septa (BTSEP-4) has the limitation of septum blades to only 1 mm thickness due to the 5 mm gap between injection and bumped orbits (See Fig. 2). To shield the magnetic field with just a 1 mm blade effectively, the operating pulse length of the thin septa has been shortened to less than

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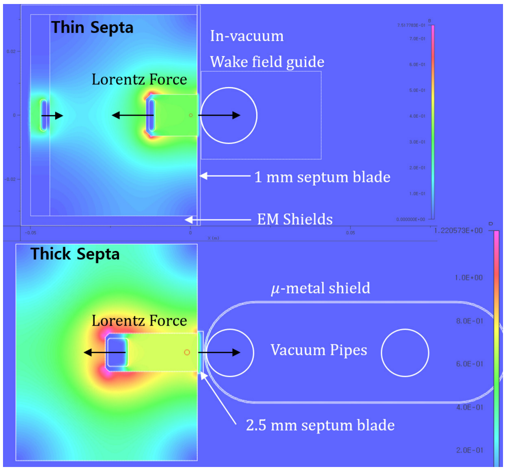

Figure 6: The geometry and magnetic field distribution of two septas implemented in Opera2D.

Table 3: Major Parameters of BTS Septa

Parameters	BTSEP-1,2,3	BTSEP-4
Bending Angle	87.27 mrad	10 mrad
Full Gap	15 mm	13 mm
Full Width	30 mm	14 mm
Magnetic Length	1.7 m	0.4 m
Pulse Current (Max)	8.22 kA	3.42 kA
Number of Turn	1	1
Pulse-width (half-sine)	100 µs	< 20 µs
Magnet Inductance	4.1 µH	0.55 µH
Overall Ohmic Heat (2 Hz)	22.366 W	0.839 W
Max. Force @ Coil	4716 N	223 N
Max. Force @ Septum	4483 N	212 N

20 µs and designed to be installed within the vacuum. As shown in Fig. 8, it is expected to have approximately 0.1 % of the main field (about 3.3 G) at the bumped orbit position with a 20 µs pulse applied.

The total ohmic heat produced by direct pulse current and induced current distributions in thin septa is approximately 0.839 watts, eliminating the need for a water cooling system within the vacuum chamber. However, for the thicker out-vacuum septa, a separate water cooling circuit will be established. A strong and durable framework is essential to adequately support both the coil and septum blade on both septa, given that the Lorentz force acting on them can reach up to 4716 N at maximum. Major parameters of the septum magnets are summarized in Table 3.

SUMMARY

Kicker magnets based on ferrite cores, along with their power systems, and two variations of eddy current septum magnets have been devised for the booster to synchrotron injection of the Korea-4GSR project. We have currently finalized the two-dimensional electromagnetic simulation designs of septa, and we are now in the process of preparing

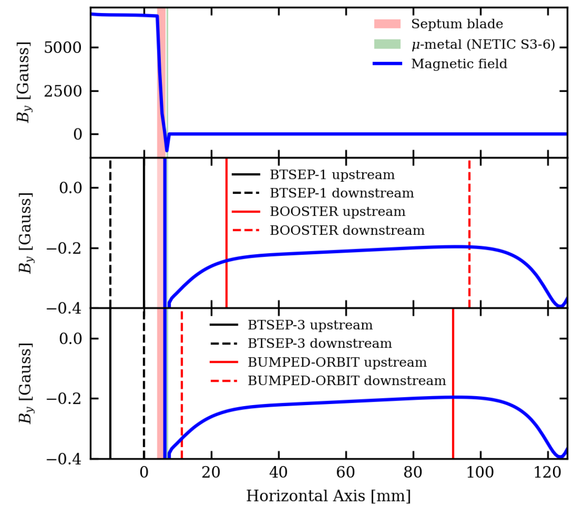

Figure 7: Magnetic field distribution of the thick septa along horizontal axis; upper plot shows the effect of eddy current shield; middle and bottom show leakage field levels on various locations.

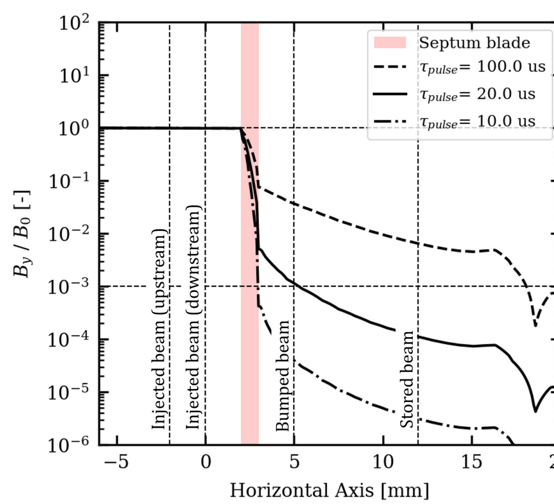

Figure 8: The amount of leakage field variation with pulse length changes (10, 20, and 100 µs) in the thin septa.

engineering drawings and 3D electromagnetic simulations. To assess the effects of heat generation and leakage fields accurately, prototype tests are scheduled for both types of septa.

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