UPGRADE OF SEPTUM MAGNETS OF THE TRANSFER LINE IN TPS

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ABSTRACT

Taiwan Photon Source (TPS) is a 3-GeV light source. The full current of the storage beam and commissioning of insertion devices are still in progress. An improved injection between the booster ring (BR) and the storage ring (SR) was implemented to increase the efficiency of injection and the reliability of the electrical parts. A DC septum (length 0.8 m) was replaced with an AC septum (length 1 m, type C) to decrease the leakage field and to relax the loading of the power supply. Mapping the field with μ-metal shielding was also implemented to diminish the leakage field from the AC septum. The lattice of the transfer line between the booster ring and the storage ring, BTS, was also rearranged to meet the new injection requirements. The performance of the AC septum with μ-metal shielding and the upgrade of the BTS lattice are discussed in this paper.

INTRODUCTION

Taiwan Photon Source requires highly precise and stable pulsed magnets for its top-up injection mode. In the electron beam-extraction system of the booster ring, one AC septum, one DC septum and one kicker magnets are installed. A DC septum magnet is more effective to decrease the driving voltage and current of the power supply than an AC septum (type A) magnet, but the electron beam is perturbed by the leakage field from a DC septum. Shielding of the leakage field of the DC septum is thus necessary. The shielding components include μ-metal sheet and a corrector magnet [1]. The DC septum magnet was commissioned at TPS, but the μ-metal sheet and the corrector magnet were unable to shield fully the leakage field from the DC septum. The layout of the extraction section of the BR septum magnet appears in Fig 1.

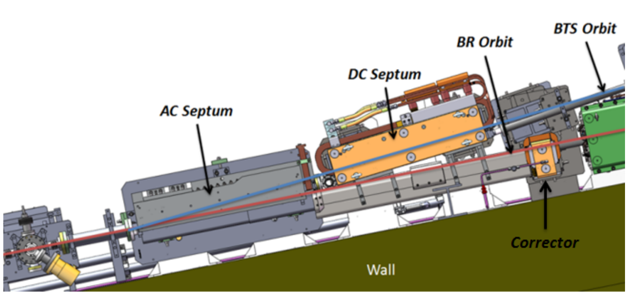

Figure 1: TPS booster-ring extraction-system layout.

The injection system of the BTS was twice upgraded. To improve the injection efficiency, the DC septum magnet was first replaced with a spare AC septum (type B) magnet. The pole length of the AC septum (type C) magnet was then increased from 0.8 m to 1 m, which relaxed by 20 % the loading of the power supply [2]. The DC septum magnet was thus replaced with an AC septum magnet, displayed in Fig. 2.

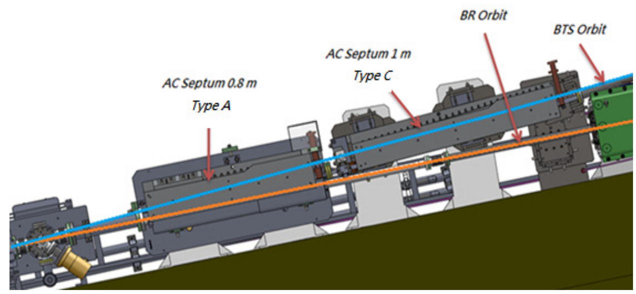

Figure 2: TPS booster-ring extraction-system layout; a DC septum was replaced with an AC septum.

An AC septum magnet was fabricated and applied to the extraction system of the booster ring at TPS. The lattice of the transfer line was also rearranged to meet the new injection requirement. The pre-AC septum (type B) magnet of the storage-ring injection system also relaxed the loading of the power supply by increasing the bending angle of two dipole magnets. This change is shown in Fig. 3. These two-step upgrades of the septum magnet improved the injection efficiency of TPS.

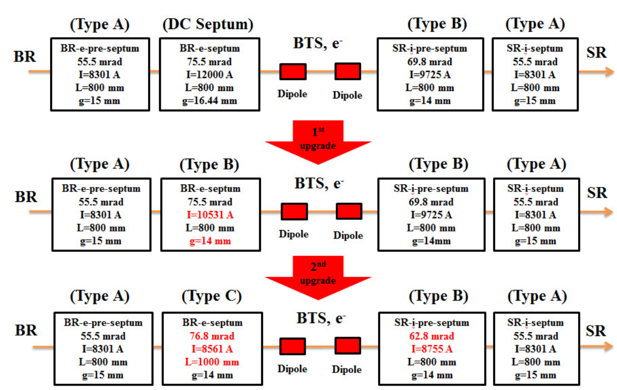

Figure 3: Two-step upgrade of septum magnets for BTS.

MECHNICAL DESIGN OF SEPTUM MAGNET

Septum magnets of four types tested in TPS include a DC septum and AC septums of types A, B and C. An AC septum magnet of type direct drive operating with a power supply of half-sine waveform was applied for TPS [4]. The magnet was designed and constructed by the NSRRC magnet group. Septum magnets of three types were designed, listed in Table 1. The pole length of the

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AC septum (type C) magnet was increased from 0.8 m to 1 m, which relaxed by 20 % the loading of the power supply.

Table 1: AC Septum Parameters

Parameters / Units	Type A	Type B	Type C
repetition rate / Hz	3	3	3
energy / GeV	3.0	3.0	3.0
iron length / m	0.8	0.8	1.0
normal field / T	0.69	0.78	0.77
bending angle / mrad	55.5	62.8	76.8
magnet gap / mm	15	14	14
pole width / mm	22	22	22
coil dimension / mm	1 x 98	1 x 98	2 x 98
driving voltage / kV	0.247	0.261	0.321
current / A	8286	8755	8561
pulse duration / μs	300	300	300
leakage field ratio / %	< 0.1	< 0.1	< 0.1

The cross section of an AC septum magnet is displayed in Fig. 4. The main parts of an AC septum include a laminated iron core, a coil plate and the housing. The narrowest gap between the aluminium housing of the magnet and the vacuum chamber is 15 mm, which suffices for installation of the shielding. The minimum distance between the beam center of the booster ring and the BTS in the transverse direction is 57.2 mm.

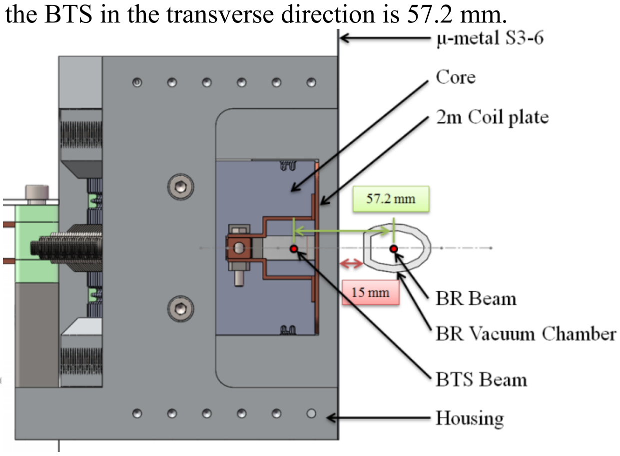

Figure 4: Cross section of an AC septum manget.

The core of a magnet is made of silicon steel (0.35 mm, CS1300) lamination to avoid flows of eddy currents in the AC septum magnet. The dimensions of the coil plate are thickness 2 mm, height 98 mm and length 1100 mm. A cutting gap (length 10 mm) of the coil plate lies along the longitudinal direction, shown in Fig. 5 [3].

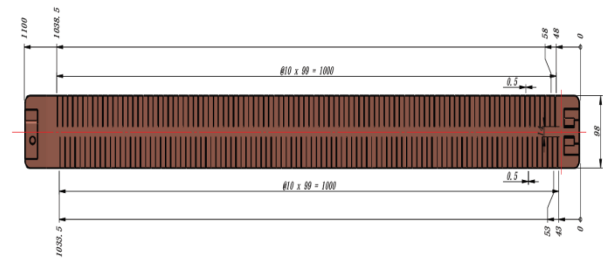

Figure 5: Coil plate for an AC septum magnet.

FIELD SIMULATION OF A SEPTUM MAGNET

The magnetic field of an AC septum magnet of type C was simulated with software TOSCA 2D and OPERA 3D, and is displayed in Fig. 6. The field strength is 0.77 T; the homogeneity ($\Delta B/B$) is better than 0.5% in the region of good field (GFR), ± 5 mm. Figure 7 displays a simulation of the distribution of leakage field of an AC septum along the transverse direction. μ-metal sheet was inserted to shield the field leaking from an AC septum to the BR. The leakage field from an AC septum is -2.56x10^{-5} T at the BR trajectory; the leakage field ratio is less than 0.1%.

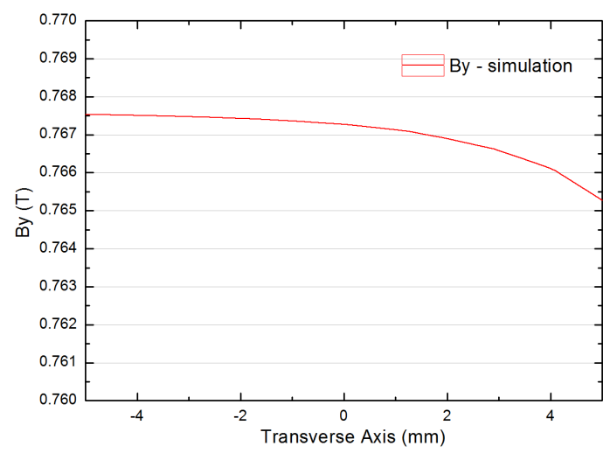

Figure 6: TOSCA simulation of an AC septum of type C.

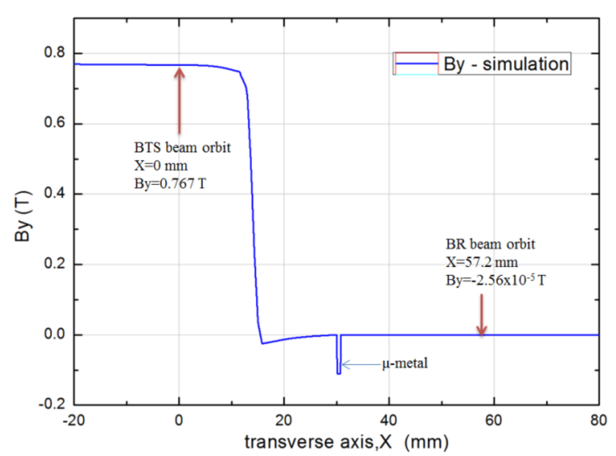

Figure 7: Field simulation of an AC septum magnet with μ-metal shielding along the transverse direction.

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FIELD PERFORMANCE OF A SEPTUM MAGNET

A Hall-probe measurement system was used to map the field strength and the leakage field of the AC septum magnet, displayed in Fig. 8(a). A long-coil system was used to measure the integral field of the AC septum, displayed in Fig. 8 (b).

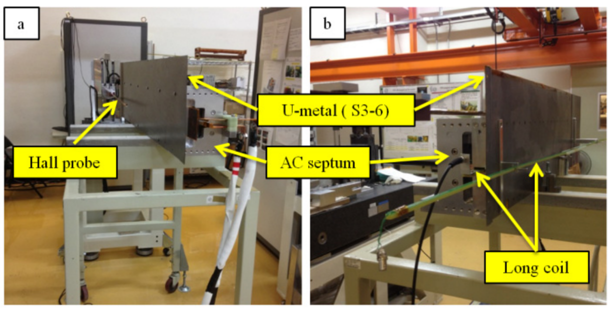

Figure 8: (a) Hall probe meassurement system; (b) long-coil meassurement system.

Figures 9 and 10 display a comparison between the simulation and the measurements. The measurement results agree with those from simulations. The field properties meet our requirements.

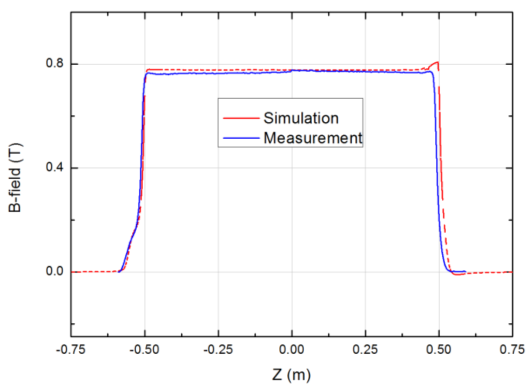

Figure 9: Simulation and measurement comparison for an AC septum magnet.

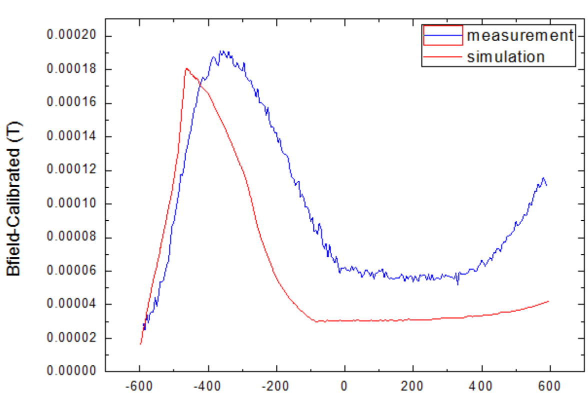

Figure 10: Simulation and measurement of the leakage field of an AC septum magnet.

Figure 11 displays a comparison of the leakage field between the AC and DC septum magnets along the direction of the electron beam. These magnets are fully installed including μ-metal shielding and type-A corrector (CA). The integral leakage field of a DC septum without corrector, DC septum with corrector 2 A charged and type C septum magnet are 332.6 G cm, 214.4 G cm and 112.2 G cm, respectively, from -700 mm to 700 mm. A DC septum magnet has a large leakage field.

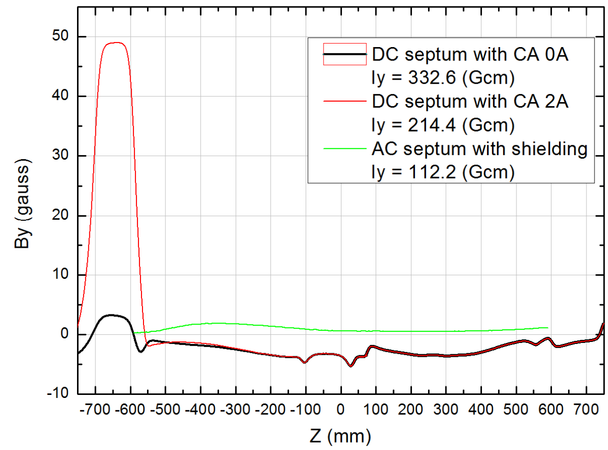

Figure 11: Comparison of the leakage fields of AC and DC septum magnets.

SUMMARY

The DC-, type-A, type-B and type-C septum magnets have been designed and measured in TPS. The results of simulations agree with the measurements. The injection efficiency was improved after the replacement of a type-C septum magnet and the realignment of BTS, because the leakage field improved. The stability and reliability of the power supply were also increased with the type-C septum magnet replacement, because of the small current setting.

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