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DESIGN AND PERFORMANCE OF A TPS DC SEPTUM MAGNET

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Abstract

To decrease the loading on an AC septum magnet, a DC septum magnet was fabricated and applied to the extraction system of the booster ring at Taiwan Photon Source (TPS). The minimal gap is 16.44 mm; the core length is 800 mm and the pole width is 45 mm. The maximum peak field of the DC septum magnet is designed to be 0.95 T at 12 kA with 24-turn coils. The maximum bending angle of the electron beam passing through the septum magnet is 75.5 mrad. Because the electron beam would be perturbed by the leakage field from the septum magnet, shielding between the septum magnet and the booster ring is an important issue for the operation of the beam. Here we report the shielding method with two materials of the DC septum magnet, and discuss the field mapping and shielding from the leakage field.

INTRODUCTION

Taiwan Photon Source requires highly precise and stable pulsed magnets in the top-up mode. In the design of the extraction system of the booster ring, two septum magnets and one kicker magnet are used and are manufactured in TPS. If a 1.6-m AC septum magnet is in use, it must provide an angular electro-beam deflection 131 mrad for 3 GeV[1]. As the power-supply load for this AC septum is too heavy to manufacture, a DC septum magnet is designed to decrease the driving voltage and current of the power supply from the AC septum magnet. The layout of an AC septum magnet and a DC septum magnet is shown in Fig. 1. The DC septum magnet and AC septum magnet are installed at the start of the booster ring to the storage ring (BTS). To share the power load of the AC septum magnet and to fit the geometric space limit of the booster extraction section, a DC septum magnet was inserted behind the AC septum magnet. The bending angle of the septum magnet is 131 mrad during injection. The DC septum magnet is designed to share 75.5 mrad and another 55.5 mrad by the AC septum magnet. The required magnetic fields for the AC and DC septa magnets are 0.83 and 0.95 T, respectively; parameters of these magnets appear in Table 1[2]. The separate septum decreased the leakage field of the AC septum magnet that affects the booster electron beam. The electron beam is perturbed also by the leakage field from the DC septum magnet. A magnetic screen was hence designed between the DC septum magnet and the vacuum chamber of the booster ring to shield the leakage field from the DC septum. A corrector magnet compensated the residual leakage field downstream from the DC septum magnet. The magnetic field of the DC septum was simulated with TOSCA 2D and OPERA 3D software. A Hall-probe measurement system mapped the field distribution of the DC septum magnet. This paper describes the work to decrease the effect of the leakage field of the DC septum magnet on the booster electron beam.

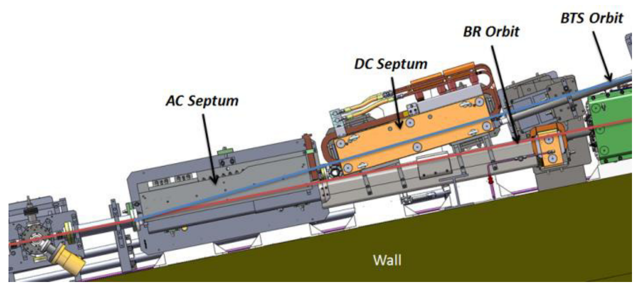

Figure 1: TPS Storage-ring Injection-system Layout. The DC septum magnet has a C-type design.

Table 1: Parameters of Booster Ring-extraction Septa

Booster-ring extraction	AC Septum	DC Septum
iron length / m	0.8	0.8
normal field / T	0.694	0.95
bending angle / mrad	55.5	75.5
magnet gap / mm	15	16.44
pole width / mm	22	45
coil conductor dimension /mm	13 x 13	13 x 13
inductance / μ H	2.85	3.47
number of turns / pole	1	12
driving voltage /kV	0.247	0.00429
current /A	8281	608

SIMULATION

We originally designed the shielding for the DC septum with an Opera 2D model and the initial pole profile shown in Fig. 2(A). The narrowest gap between the poles of the magnet and the vacuum chamber is only 14 mm, which is insufficient to install the shielding according to the initial design. The shielding decreases the leakage field and concurrently maintains the field homogeneity of the DC septum magnet in the BTS orbit. An asymmetric pole shape was designed so that the DC septum magnet could be offset 4 mm to be distant from the BR orbit.

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To simulate the new pole profile shown in Fig. 2(B), the gap would be increased to 18 mm and the normal field (B_y) kept at 0.95 T and homogeneity ($\Delta B/B$)< 0.5 % in the region of good field (G.F.R.) +/-10 mm. Figure 3 displays the simulation model of the DC septum. Figure 4 displays that the homogeneity ($\Delta B/B$) of the simulation is better than 0.5 % within the G.F.R. To improve the field quality at the transition region in the main field, shims are designed. With iron and μ-metal (NETIC S3-6[3]) used in shielding, simulations were performed to estimate the emittance growth in the DC septum magnet for these designs.

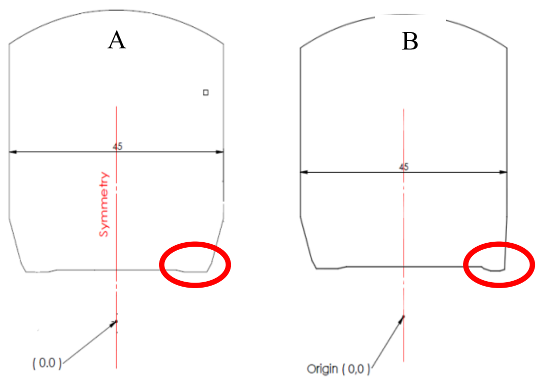

Figure 2: A is the initial pole profile, B was modified with an offset 4 mm.

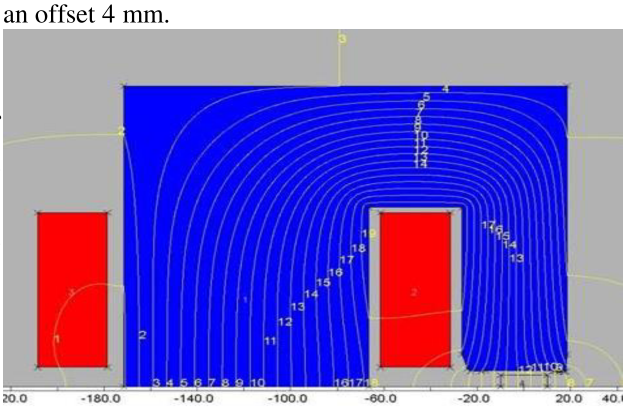

Figure 3: Profile of the DC septum magnet simulated with TOSCA 2D.

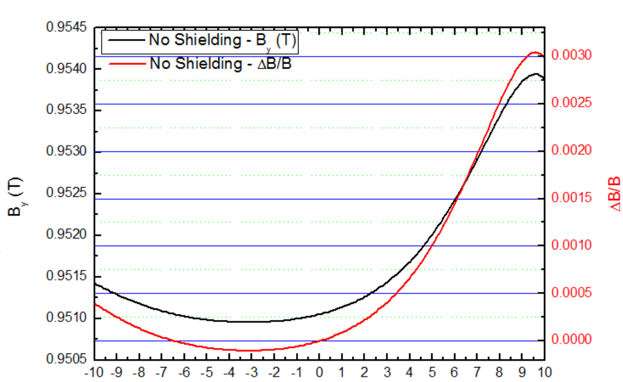

Figure 4: Normal field = 0.95 T; GFR is better than 0.5 % within ± 10 mm, simulated with TOSCA 2D.

To find the form and the size of shielding, we must consider how metal and air are distributed over the space between the pole gap and the vacuum chamber. Air can decrease the field conduction; iron increases the saturation. The air (13 mm), iron (1.9 mm) and μ-metal (three layers; NETIC S3-6) were selected with simulation. The cross section of shielding is shown in Fig. 5. To keep the leakage field via iron away from the booster orbit as far as possible and to avoid saturation, the farther side of iron had an extended thickness.

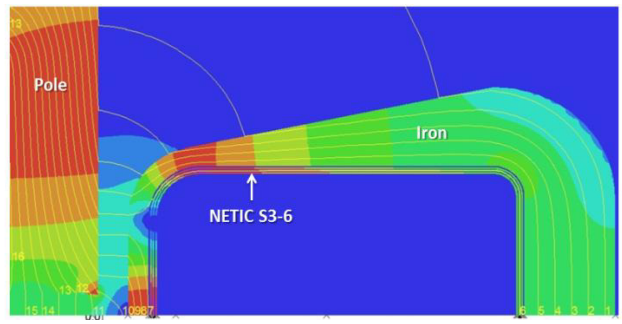

Figure 5: 2D simulation, leakage field with shielding. The shielding contains iron (2 mm) and NETIC S3-6 (0.7 mm*3).

For the longitudinal distribution of the leakage field along the center of the booster beam, the entire leakage field can be divided into two parts -- the body leakage and the end-fringe leakage. Because the shape of the vacuum chamber is complicated, the magnetic screening was divided into parts A, B and C. Figure 6 displays the positions of these parts along the longitudinal distribution from Z = 2000 mm to Z = -2000 mm. In this case, the thickness of iron is 2 mm, with three layers (thickness 0.7 mm each) of NETIC S3-6. The maximum leakage field was decreased from 700 G to 3.8 G (0.4 % of the main field) within the G.F.R.; the integral field was about 200 G cm after shielding at the center of the booster beam orbit. A corrector magnet (0.75 A) was inserted to compensate the integral field to approximately 0 G cm. The final simulation is displayed in Fig. 7.

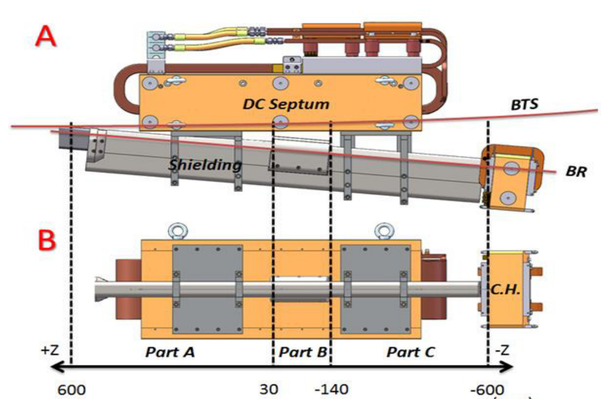

Figure 6: (A) top view), B front view. Positions of parts A, B and C and a corrector magnet (C.H.) along the z-axis.

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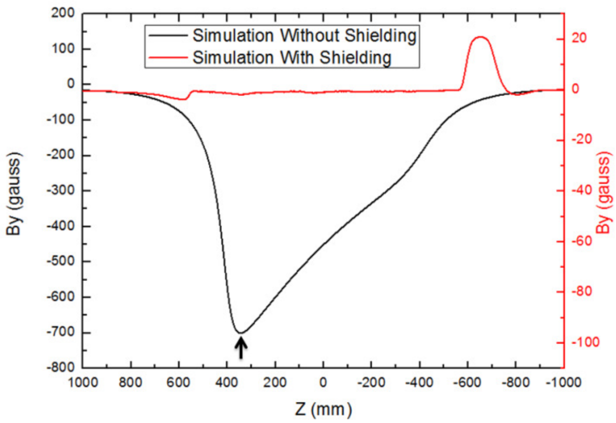

Figure 7: Leakage field with shielding and a corrector magnet, simulated with TOSCA 2D.

MEASUREMENTS

The DC septum magnets were fabricated by DANFYSIK Company. Figure 8 displays the setup of the Hall-probe system. Figure 9 displays a comparison between the measurements and the simulation of the DC septum magnet. The measurement agrees with the result of simulations. The field strength and field homogeneity ($\Delta B/B$) meet the specification requirements.

Figure 8: Layout of the Hall-probe measurement system .

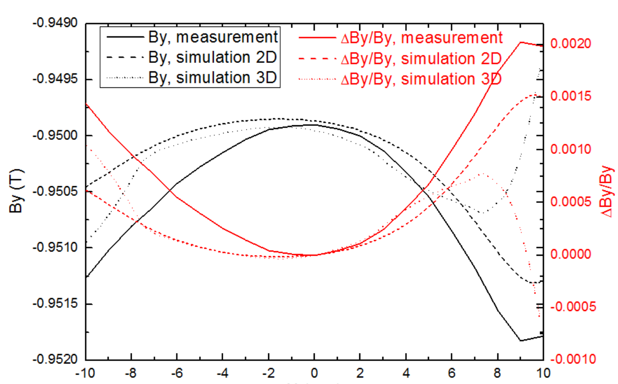

Figure 9: Measurements and simulation of the DC septum magnet.

Figure 10 displays the shielding performance of the distribution of vertical leakage field B_y along the trajectory of the electron beam. The maximum leakage field was obtained at approximately Z = -700 mm C. H. position in the simulation results; the maximum without shielding is -700 G at x = 350 mm (see figure 7, up arrow). A shielding wall added to decrease the leakage field is displayed in Fig. 10. The integral leakage field from 2000 mm to -2000 mm is 454 G cm after shielding. An extra corrector magnet installed with excitation 2 A will compensate the trajectory offset of the leakage field.

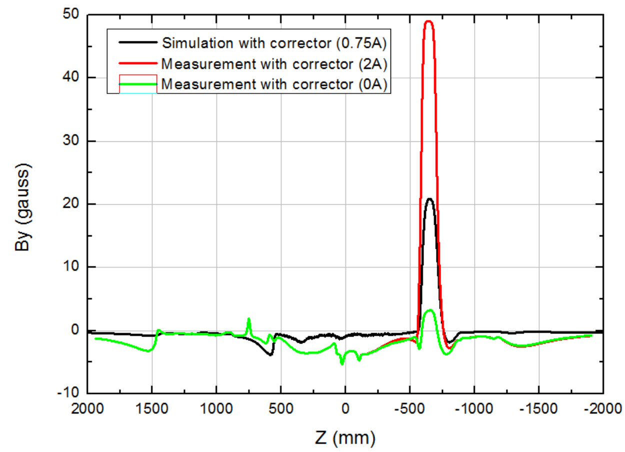

Figure 10: Longitudinal distribution of leakage field B_y along the booster beam orbit with the Hall-probe system.

SUMMARY

A DC septum magnet is effective to decrease the driving voltage and current of the power supply from the AC septum magnet, but the electron beam becomes perturbed by the leakage field from the septum magnet. The shielding would decrease the leakage field, and the trajectory offset of leakage field is compensated with a corrector magnet.

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[2] J. C. Huang et al., “Effectiveness of a shielding cabinet on the storage-ring septum magnet of Taiwan Light Source, Proceedings of IPAC’10, Kyoto, Japan, pp.1793-1995.

[3] http://www.magnetic-shield.com/