3-D CALCULATIONS AND MEASUREMENTS OF THE OPPOSITE FIELD SEPTUM MAGNET FOR THE J-PARC 50GeV RING

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Abstract

The J-PARC is a high beam intensity accelerator project. The radioactivation caused by uncontrollable beam loss is a very serious problem, especially at the injection and extraction septum magnets, because beam passes close to the septum conductor. To solve this problem, a novel, wide aperture, high strength, opposite field septum magnet[1] has been developed. The main merit of the septum magnet is the force free structure of septum conductor. 3 dimensional magnetic field calculations based on OPERA-3D have been carried out. Initial measurements of integral field and point field have been performed. The magnetic field, in the region of interest, will be presented and discussed. The calculations results are in good agreement with the measured results.

1 INTRODUCTION

Since the beam intensity of 50GeV main ring is very high, the uncontrollable beam losses must be as low as possible to decrease the residual radioactivation, which brings the challenging difficulties to the design of the injection system. To meet these tight requirements, a novel, opposite field septum magnet has been developed.

Basically, the principle of the opposite-field septum magnet system is shown in Fig.1. The magnet system consists of 2 sub-bending magnets and 1 opposite septum magnet. The length of sub-bending magnet is just half the length of septum. If these magnets are excited in series, the septum magnetic field at injection side will be increased 2 times by the sub-magnets. On the contrary, the septum magnetic field at circulating beam side will be cancelled completely.

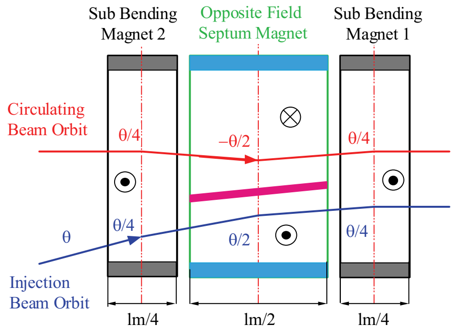

Figure 1: Principle of opposite-field septum magnet

Because the opposite magnetic field is produced at both side of the septum conductor, the electromagnetic force on the septum conductors will be cancelled, which make it easy to design their supporting structure. Even if the magnetic field is very high, the septum conductor can be made very thin. Compared with normal design septum magnet, the new one has the advantage of high field, thin septum, which can simplify the injection system design. The force free structure also makes is easy of pulse mode operation, which simplifies the cooling problems.

2 CONSTRUCTION OF MAGNET

The geometry parameters of the septum magnet system are listed in table1.

Table 1: Geometry parameters of the magnet system

		Sub Bend1	Opposite Field Septum	Sub Bend2
Pole length	mm	350	700	350
Pole gap	mm	120	120	120
Pole width	mm	374	355	272

The three dimensional model of the magnet system is shown in Fig.2, which is generated by the OPERA modules-Modeller[2]. The septum magnet is fixed, but the gap of sub-magnet can be adjusted

3 SUB-MAGNET GAP ADJUSTING

In ideal case the magnetic field at circulating side will be cancelled completely by the sub-bending magnets field. But, due to the large aperture, the end field becomes very severe and must be taken into consideration. Because the 2 sub-bending magnets have more ends, the total integral field is larger, and the magnetic field at circulating side cannot be cancelled completely, which act as leakage field. Beam tracking requires this leakage field must be less than 0.1%. To decrease this leakage field, the gap of sub-bending magnets can be adjusted, see Fig. 2.

Fig.3(a,b) shows the calculated B_y longitudinal distribution at both injection and circulating side with different sub-bending magnet gap. The ratio of integral magnetic field at the center of circulating beam B_{cir} and integral magnetic field for injection beam B_{inj} is shown in Fig.4. If the gap height is 9.35mm, the integral field at the center of circulating beam can be cancelled completely.

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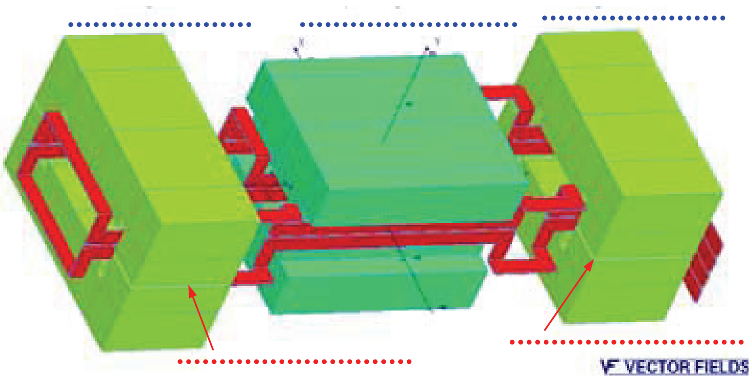
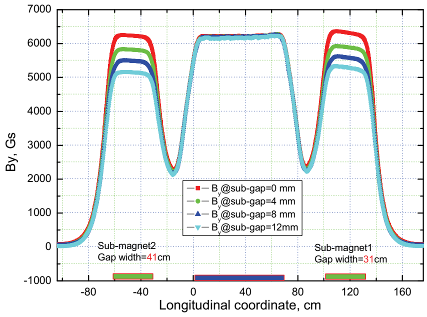


Figure 2: Layout of the septum magnet system



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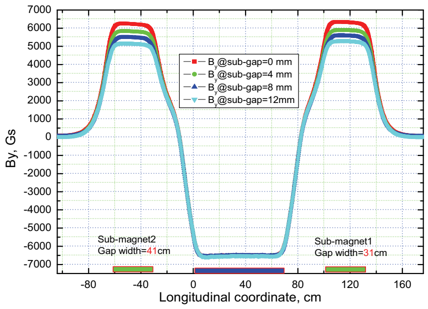


b

Figure 3: B_y distribution with different sub-bending magnet gap

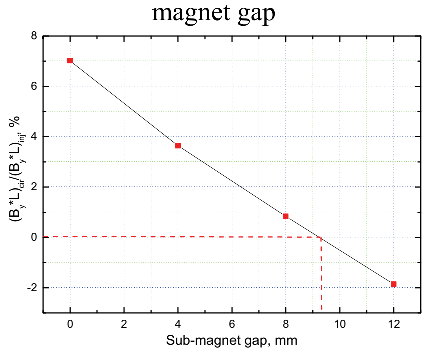


Fig.4 The ratio of integral field $(B*L)_{cir}$ and integral field $(B*L)_{inj}$

4 FIELD DISTRIBUTION

4.1 Transverse distribution

When the sub-bending magnet gap is 9.4mm, the magnetic field B_y transverse distribution at the center of each magnet is shown in Fig. 5. The field is uniformly distributed in 2 sub-bending magnet. But near the septum conductor, the field distribution isn't uniform, because the septum conductor is separated from the magnet core by the wall of vacuum chamber.

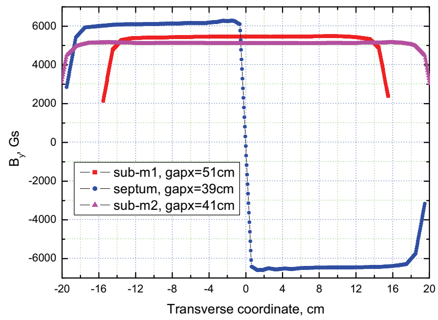
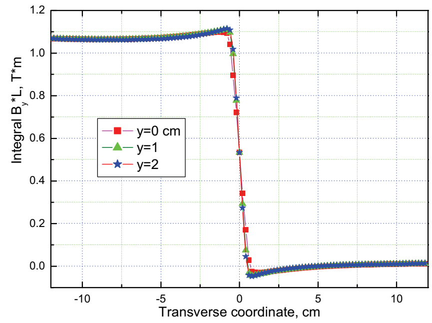


Figure 5: Transverse B_y distribution at center of magnet



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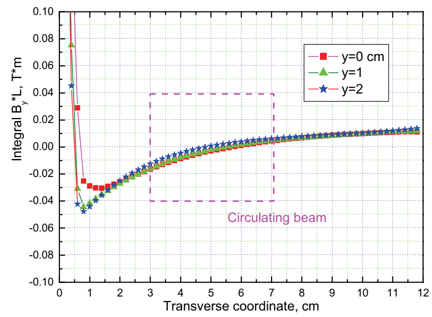

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Fig. 6(a,b) The transverse distribution of integral magnetic field

The integral field transverse distribution at different vertical plane is shown in Fig. 6(a,b). Fig. 6(b) is detailed field distribution at circulating side. It shows that, at the center of circulating beam, the integral field strength is about 0.28% of the injection side.

4.2 Longitudinal distribution

Fig. 7 is the B_y longitudinal distribution at the center of circulating beam in different vertical plane. The field distribution is quite uniform except at the end of magnet, which caused by the coil.

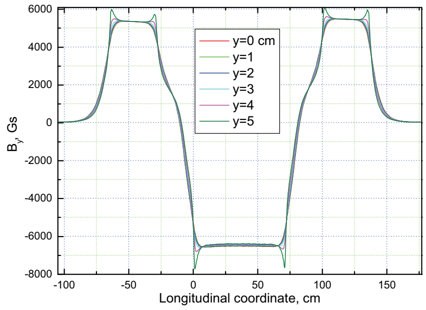

Figure 7: B_y longitudinal distr. at different vertical plane

5 INITIAL MEASUREMENTS

Fig.8 shows 2 kinds of short coil structures.

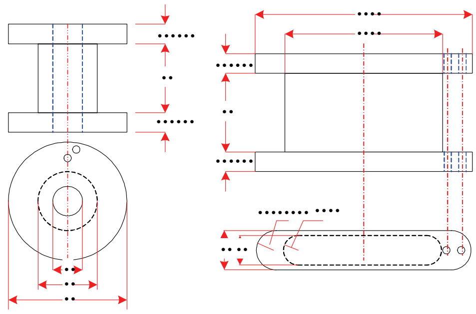

Figure 8(a,b): 2 search coils structure

The short coil can move precisely in 3 dimensional directions for point field measurement. Initially, the measurement was only performed at the circulating side of septum magnet.

5.1 Measurement of field longitudinal distribution

The B_y longitudinal distribution at the circulating beam center was measured with the circular search coil (Fig.8a). Fig. 9 is the comparison of measured data and calculation data. The calculation agrees with the measured data very well except some measured data have position error, which probably caused by the coil support. Since the longitudinal measured distance is about 2.7m, but the maximum longitudinal movable distance of the 3D shift is only 1m, so several short poles were connected to perform the measurement.

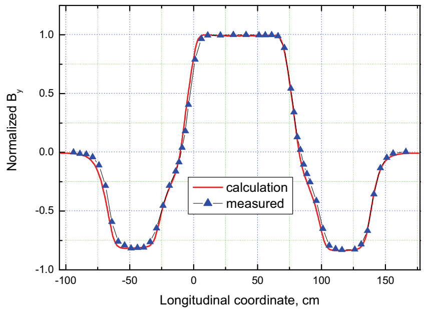

Figure 9: Comparison of measured data and calculation

5.2 Measurement of field transverse distribution

To measure the field very close the septum, a narrow search coil was used (Fig. 8b). Transverse field distribution at different longitudinal position has been measured. Fig. 10a illustrates the longitudinal position. Measurement is only performed in the region of circulating side of septum and the measured result is shown in Fig.10b.

The measured results accord with the calculations well inside septum (1) and at the end of septum magnet(2), but at the outside(3,4), there are much errors. This is because the search coil is long(10mm), and the longitudinal distribution changes abruptly, see fig. 9, so the measured data is only the longitudinal average magnetic field.

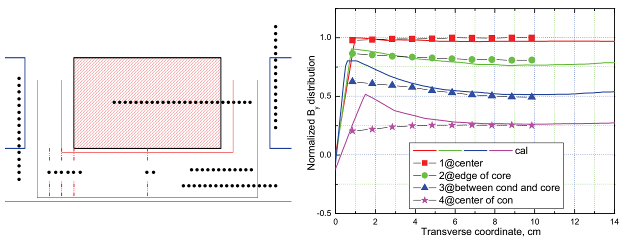

Fig.10(a,b) Measurement position and results

5.3 Integral field measurement

2 long search coils are used for the integral field measurement. One is placed at injection side as the reference, another was used to measure integral field at the position of circulating beam center. When the sub-magnet gap is 9.5mm, the integral field at circulating beam center is about 0.1% of that at the injection side.

6 CONCLUSIONS

3-D calculation is very useful for large aperture magnet design, in which end field becomes very serious. The measured data of the opposite field septum magnet conform the calculation.

REFERENCES

[1] Sakai, et. al., IEEE Trans. on Applied Supercon., Vol.12, No.1, March 2002
[2] OPERA-3D user guide