MAGNET SUBSYSTEM OF HLS II*

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Abstract

To improve the performance of the Hefei Light Source (HLS), in particular to get higher brilliance synchrotron radiation and increase the number of straight section insertion devices, NSRL is now upgrading HLS to HLS II. Most of the magnets had to be replaced in this project. To measure the magnets, set of the magnetic measurement equipment in NSRL are also re-built. New magnets are sample measured, the discreteness and uniformity of integrated magnetic field all meet the requirements. Piecewise fitting and electron tracking of bending magnets for injector and beam transport line were performed and the results showed that the electron trajectory fitted the physical design well.

INTRODUCTION

An upgrade project for the Hefei Light Source (HLS) will be finished soon [1]. The major purpose of the upgrade is to get more straight sections for insertion devices and obtain higher brilliance synchrotron radiation. The whole project is divided into two parts: storage ring part and injector part, while the latter also contains a beam transport line. The new storage ring's circumference is the same as that of the current one, but the focusing structure is different. For the upgrade project, the new ring will be installed on the current ground settlement and all of the magnets will be reconstructed. All yokes of magnets in this paper are made of J23-50 silicon steel laminations. Coils with high current (87A or higher) are water cooled.

The storage ring lattice [2], which has a double bend achromatic structure with four periods, comprises 8 dipoles, 32 quadrupoles and 32 combined function sextupoles. There're 6 dipoles and 25 quadrupoles installed in the injector and beam transport line. The magnetic field of all the magnets have been calculated using POISSON codes [3] and Opera-3d codes [4]. The steadier new magnet point measurement system can achieve higher measure speed and lower noise, so the measure results are reliable. Sample measurement were performed to examine the quality of magnets. Based on the magnet measurement results, computer simulation is performed to track the motion of electron in injector dipoles.

MAGNETS FOR STORAGE RING PART

Considering theoretical minimum beam emittance and number of straight section, separate function DBA was adopted as the standard cell of ring, instead of TBA used in the former HLS. Figure 1 shows the magnets layout of HLS II storage ring. Similar to many light sources, the length of straight section in the arc was increased to install undulators.

Magnet field quality is strict for the new storage ring of the HLS. For the dipoles, quadrupoles and sextupoles, the systematic and random tolerances for the harmonic contents in the good field regions need to be of the order of 10^{-4}. The dipole and quadrupole magnets were chamfered at the ends to meet the integrated field quality specifications, and the size of the chamfers were determined according to the magnetic measurement results of the prototypes [5].

One of the major improvement is the optimization of the multipurpose combined function magnet, which consists of three magnets: skew quadrupole, horizontal dipole and vertical dipole, with the main sextupole magnet. This type of magnet is the first one that has been designed and used in China.

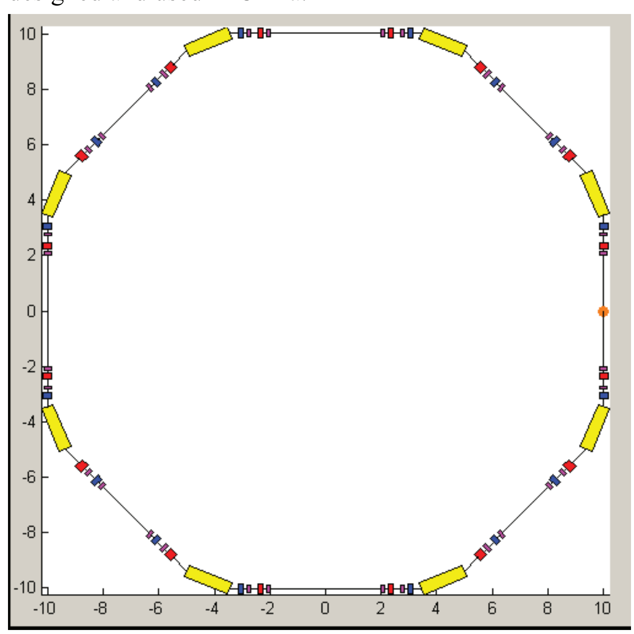

Figure 1: Magnets layout of HLS II storage ring.

MAGNETS FOR INJECTOR PART

The main improvement of the injector part is the implementation of full-energy injection, which is very important to the general performance of HLS II.

There're two kinds of dipoles designed for injector part. Two 4°dipoles and the other two 22.5°dipoles are used to deflect and transport the beam from the electron source to injection position, where two other 22.5° dipoles are used to form an injection bump system and raise up the beam

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from underground to the entrance of storage ring. Quadrupoles and focusing coils are used to improve the quality of injected beam. Figure 2 shows a sketch of HLS II injector part.

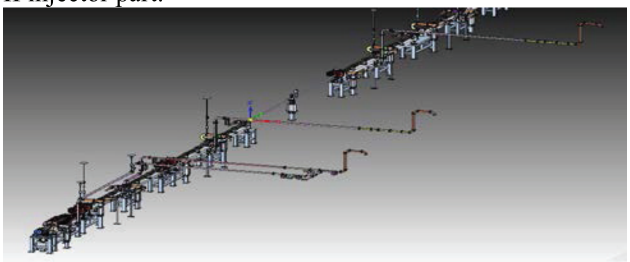

Figure 2: Layout of HLS II injector and transport line.

MAGNET MEASUREMENTS

Magnetic measurement system of HLS II consists of two parts. Point measurement with Hall probe is used to get the basic features of magnets and give a normalization standard, while measurement method with translating and rotating coils are used to suppress noise so as to analyse the high order components and detail characteristics of the magnetic field.

To meet the requirements, a new precision platform showed in figure 3 is built for point measurement. The speed of measurement increased from 0.1 meter/minute to 2.5 meter/minute, while the movement precision can be 1 μm. Meanwhile, the Hall probes installed in the point measurement system are upgrade to new ultra-low noise ones and get 20 times better precision. Figure 4 shows the effect of new Hall probe, the noise peak is limited to 0.035 Gauss.

Figure 3: Magnetic field point measurement platform.

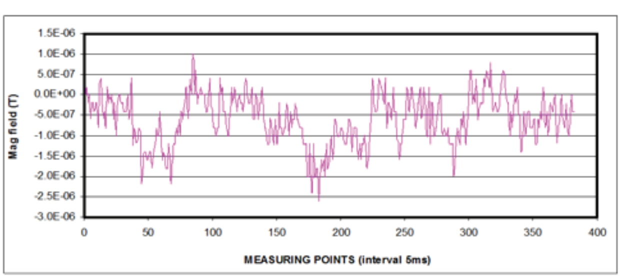

Figure 4: Effect of new 2D Hall probe.

Several sample measurements were performed using the new magnetic measurement system as acceptance inspection for storage ring magnets. Since the manufacturer of the injector dipoles is short of magnetic measurement equipment, all injector dipoles were measured by NSRL as overall acceptance inspection. Figures below shows several results as an example.

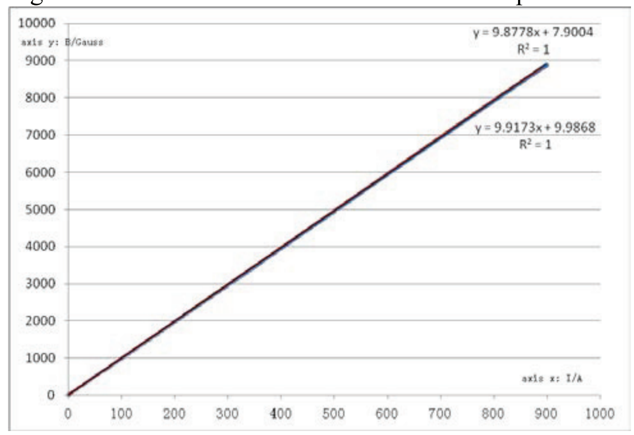

Figure 5: Excitation curve of 4° dipole 001.

Figure 5 shows two excitation curves of one 4° dipole used in injector part, given by point measurement system. It is clear that the two curves matched very well. The magnets work under the saturation region.

Figure 6 shows the integrated magnetic field and it's uniformity of the dipole. As it is shown, the uniformity is better than 2‰ in a good field region of ±17.5mm, meets the requirements

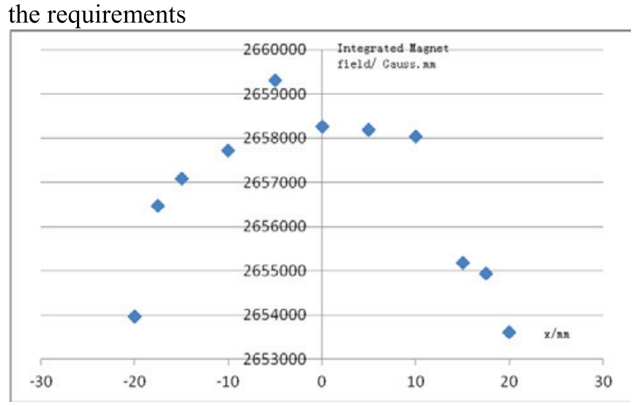

Figure 6: Integrated magnetic field of 4° dipole 001.

SIMULATION BASED ON MEASUREMENT OF INJECTOR MAGNETS

Based on magnet measurement results, the overview of the magnetic field of the magnets can be derived. For example, figure 7 shows the piecewise fitting curve of the 4° bending magnet mentioned before. Using this fitting curve, we can see the description of the magnetic field distribution of the dipole in the whole area, showed in figure 8. Fringing field is also described.

By piecewise fitting method, the magnetic field curve is divided to several parts. In figure 7, the fringing filed can be described by part of Gaussian distribution and part of

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exponential distribution. Using several measurement track we can then describe the distribution showed in figure 8 on the whole plane.

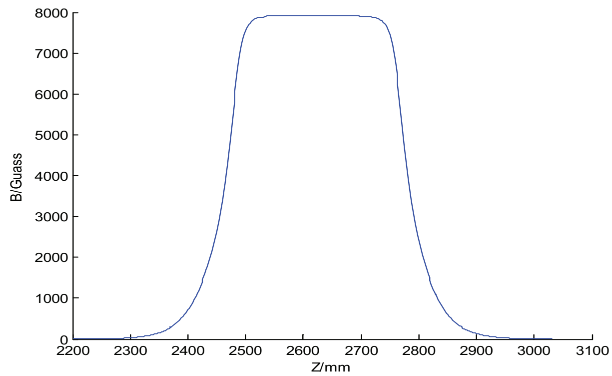

Figure 7: Piecewise fitting of 4° dipole 001.

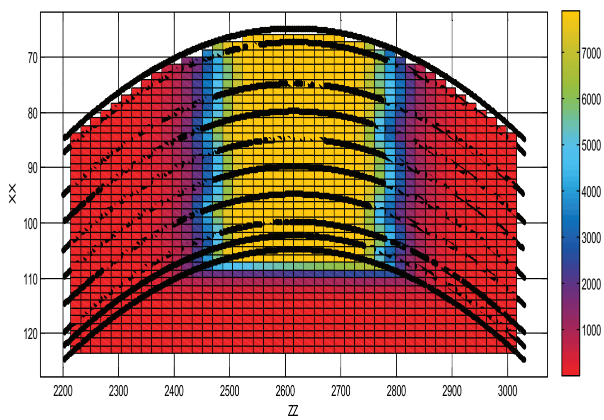

Figure 8: 2D magnetic field of 4°dipole 001.

Assuming an electron with given energy enters the magnetic field and tracking down its trajectory is a way to study the electron motion in magnets. I.e. in the dipole magnet mentioned above, after some computer simulations, it is clear that when the excitation current is 700A and the electron energy is 1 GeV, the electron will get a rotation angle of 4° while the integrated magnetic field is a match to the results got in Figure 6.

SUMMARY

In this paper, the magnet sub system for the HLSII is described. The field designs of all the magnets give a few 10^{-4} of the multipoles and the integrated field qualities will be of the order of 10^{-3}. The fabrication and acceptance inspection of all the magnets has been finished. The discreteness and uniformity of integrated magnetic field all meet the requirements while all installation will be finished in August 2013.

REFERENCES

[1] H. Zhang, W.M. Li, G.Y. Feng, et al, “The magnet design for the HLS storage ring upgrade project”, Chinese Physics C (HEP&NP), 2012, 36(1),p.91-95

[2] L. Wang, W.M. Li, G.Y. Feng, et al, “The upgrade project of Hefei Light Source (HLS)”, Proceedings of IPAC2010, p.2588-2590

[3] Poisson Superfish Code, Los Alamos National Laboratory, Los Alamos, U.S.A.

[4] OPERA-3D/TOSCA, Vector Fields Limited, Oxford, U.K

[5] C.S. Hwang, C.H. Chang, et al. Status of Magnet Design For The Accelerator Lattice of The TPS Project, Proceedingof PAC2009, Vancouver, BC, Canada: 2009

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