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MAGNETS AND MAGNETIC FIELD MEASUREMENTS OF HEFEI LIGHT SOURCE II *

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Abstract

The paper introduces magnets and magnetic field measurements of Hefei Light Source II. In the year 2012-2014, NSRL of USTC upgraded the HLS to HLS II. The HLS II, which was built to improve the performance of the light source, in particular to get higher brilliance of synchrotron radiation and increase the number of straight section insertion devices, is now at commissioning stage. Main purpose of this stage is to achieve full energy with high current, fine emittance and enough life time based on adjustment of magnet current, RF voltage and so on. Most of the magnets were replaced during this project. A new magnetic field measurement platform was built and used for the sampling test on new magnets. Test results showed that the discreteness and uniformity of integrated magnetic field of magnets all meet the requirements.

INTRODUCTION

An upgrade project named HLS II for the Hefei Light Source (HLS) has recently completed [1]. The HLS II has more straight sections for insertion devices and can provide synchrotron radiation with higher brilliance compared to HLS. The light source consist of 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 former one, but the focusing structure is different. The new machine was installed on the current ground settlement so all of the magnets were reconstructed. All yokes of magnets in this paper were 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 multifunctional sextupoles. This new lattice is designed to get smaller emittance and higher brilliance [3]. The method of multifunctional sextupole magnet is designed and used for the first time in China. There're 6 dipoles and 25 quadrupoles installed in the injector and beam transport line. The magnetic field of all magnets have been calculated using POISSON codes [4] and Opera-3d codes [5]. New point measurement system of magnetic field provides 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.

HLS II is now in commissioning and is expected to be put in operation before September.

DESIGN AND INSTALLMENT OF MAGNETS

Separate function DBA was adopted as the standard cell of ring, instead of TBA used in the former HLS. The storage ring contains 4 cells, each of them consists of 2 dipoles, 8 quadrupoles and 8 sextupoles. Figure 1 shows half-cell of the HLS II storage ring. Similar to many light sources, the length of straight section in the arc was increased to install undulators.

Figure 1: 1/2 cell of HLS II storage ring.

High quality of magnet field was required for the new storage ring. For the dipoles, quadrupoles and sextupoles, the systematic and random tolerances for the harmonic contents in the good field regions should 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 [6].

The multifunctional sextupole magnet consists of four magnets: three coils (a skew quadrupole, a horizontal dipole and a vertical dipole) all added on one main sextupole magnet. The dipole magnetic field can be used to correct the beam orbit distortion correction while the skew quadrupole magnetic field can be used to adjust the transversal coupling of the storage ring so as to enlarge beam profile and then increase beam life.

Two main upgrade of the injector part are applied: the implementation of full-energy injection and the top-up injection mode. There're two kinds of dipoles installed 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

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other 22.5° dipoles are used to form an injection bump and raise up the beam from underground to the entrance of storage ring. Figure 2 and 3 are pictures taken at HLS II injection point. Quadrupoles and focusing coils are used to improve the quality of injected beam.

Figure 2: Injection bump of HLS II injector.

Figure 3: Deflect and transport of beam in injector.

MEASUREMENTS AND MODIFICATION

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 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.

Several sample measurements were performed using the new magnetic measurement system as acceptance inspection for magnets. The sample contains several quadrupole magnets for the injector, several quadrupoles and sextupoles for the storage ring and all dipoles. 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 4 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 5 shows the integrated magnetic field and it's uniformity of a 22.5° dipole. As it is shown, the uniformity is better than 2 ‰ in a good field region of ±17.5mm, meets the requirements.

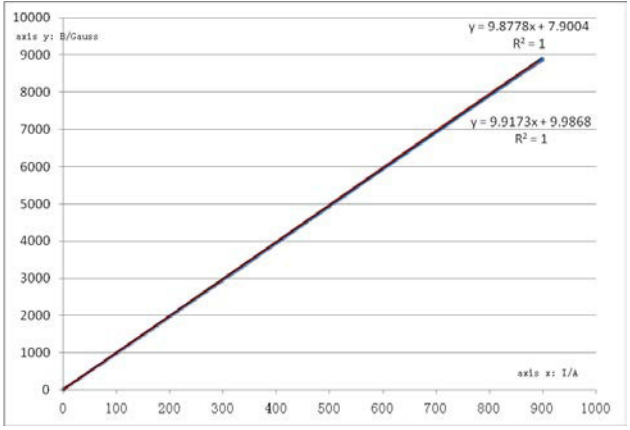

Figure 4: Excitation curve of 4° dipole 001.

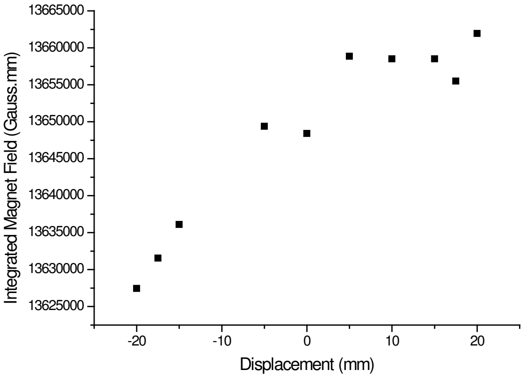

Figure 5: Magnetic field of 22.5° lay down dipole.

At the beginning, effective lengths of all dipole magnets built by IHEP factory for HLS II are 15-25mm longer than the expected value 1700mm. A reasonable guess is it's a result of the conservative model used to design the magnets. The circumference is invariable since the RF frequency is fixed, which means such large difference has to be compensated or changed. The magnets were then chamfered for the second time and the effective lengths were modified to 1697-1703mm.

SIMULATION AND COMMISSIONING

The overview of the magnetic field of the magnets can be derived based on magnet measurement results. For example, Fig. 6 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 Fig. 7. Fringing field is also described.

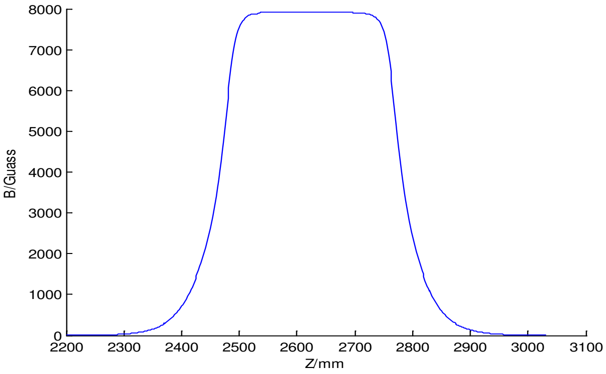

Figure 6: Piecewise fitting of 4° dipole 001.

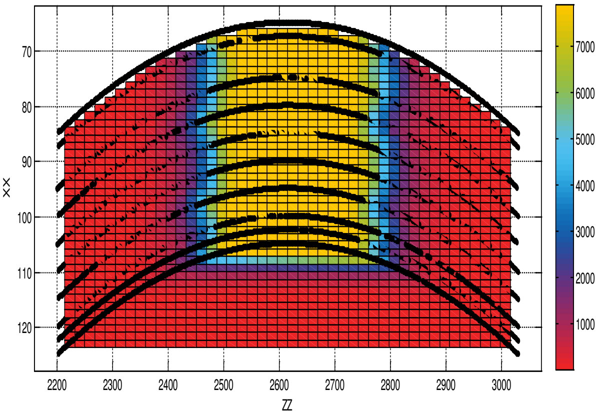

Figure 7: 2D magnetic field of 4°dipole 001.

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 Fig. 4.

HLS II is now at commissioning and beam cleaning stage [7]. Main purpose of this stage is to achieve full energy with high current, good emittance and enough life time. In commissioning, skew quadrupole coils are used to adjust the transversal coupling and enlarge beam profile. In this case, beam density is decreased, which also means beam loss is lower. The tilted beam profile is showed in Fig. 8.

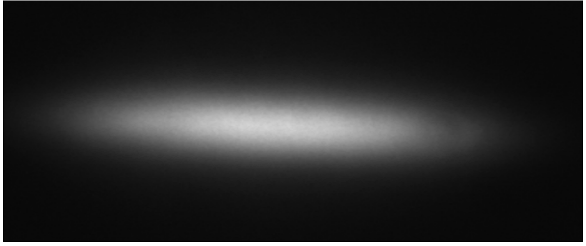

Figure 8: Beam profile with skew quadrupole coil.

SUMMARY

This paper shows the magnets and their performance 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 and the discreteness and uniformity of integrated magnetic field all meet the requirements. All installation was finished in the year 2013 while the commissioning stage began in January 2014. The new light source is expected to be put in use before this September.

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