THE FABRICATION AND MEASUREMENT OF THE NEW INSERTION DEVICES OF HEFEI LIGHT SOURCE

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Abstract

To meet the requirements of users for higher brilliance and good transverse coherence VUV and soft X-ray synchrotron radiation, Hefei Light Source(HLS) is being upgraded. After upgrade HLS will have smaller beam emittance and install more new insertion devices. The new insertion devices include one elliptically polarizing undulator with 104 mm period, one in-vacuum undulator with 40mm period, one wiggler with 152mm period and one quasi-periodic undulator based on a new scheme proposed by us. In this paper the fabrication and the results of the magnetic field measurements of the new insertion devices are reported.

INTRODUCTION

Hefei Light Source (HLS) of National Synchrotron Radiation Laboratory (NSRL) is a dedicated second generation light source. In order to meet the increasing requirements of synchrotron radiation users for higher brilliance and good transverse coherence VUV and soft X-ray synchrotron radiation, an upgrade project of Hefei light source is undergoing. The Magnet Lattice focusing structure of the storage ring will be changed from 4 TBA to 4 DBA cells. The emittance of storage ring will be reduced from 166nm.rad to 36nm.rad. The number of straight section will be increased from the current four with 3.36meter long to eight, in which the four straight sections are with available length of 3.4meter, and the other four shorter straight sections are with available length of 1.7meter. Except one longer straight section for injection system and one shorter straight section for RF system, there are six straight sections available for insertion devices. The existing insertion devices at HLS include an undulator and a superconductor wiggler will be used continually.

In the upgrade project, four insertion devices will be built[1], including one in-vacuum undulator, one elliptically polarizing undulator (EPU), one quasi-periodic undulator (QPU) and one wiggler. The in-vacuum undulator and the EPU are fabricated by Shanghai Application Physics Institute and the wiggler and QPU are fabricated by Institute of High Energy Physics in Beijing.

For the out vacuum undulator, the beam requires transverse space(±38 mm) × (± 10mm) at straight section, so the effective straight section vacuum chamber gap is ± 10mm. Consider the vacuum chamber wall thickness of 3 ~ 4mm, and deformation error, the minimum magnetic pole gap is taken as 30mm; For the in vacuum undulator, considering the impact on the beam lifetime of gas scattering and Touschek effect, the minimum pole gap is taken as 10mm. The general requirements of the magnetic fields are given according the beam physic and shown in Table 1.

Now all the four insertion devices are completed and measured.

IN-VACUUM UNDULATOR

The in-vacuum undulator is for the Soft X-ray lithography beam-line user. The energy range of photon required is 20-200ev, the user also hope can have fairly flux at 600ev. Therefore the harmonic radiation must be used.

The total length 1691 mm of the vacuum chamber includes both ends of the bore 8 angular CF100 standard interface flanges, bellows, and high-frequency shielding and water cooling and other auxiliary structural elements.

Table 1: The general requirements of the magnetic fields

	IVU 40 $\lvert x \rvert \leq \pm 12$mm	EPU104 $\lvert x \rvert \leq \pm 12$mm	WG156 $\lvert x \rvert \leq \pm 20$mm	QPU88 $\lvert x \rvert$ ±14mm
Peak field error	⩽0.5%	⩽0.5%	⩽0.5%	
Phase error (°)	⩽3	⩽5 (*l. p.*)	⩽6	
Field integral (Gs*cm)	<100	<100	<100	<100
Second Field integral (Gs*cm^2)	<20000	<20000	<20000	<20000
Quadrupole (Gs)	<50	<100	<50	<50
Sextupole (Gs/cm)	<100	<150	<100	<100
Octupole (Gs/cm^2)	<100	<200	<100	<100

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The vacuum chamber use stainless steel, SS304 with wall thickness of 4mm. The inner diameter of the vacuum chamber is 345mm, which is larger than conventional knife-edge flange, so DN345-step flange with silver gasket ring is adapted at both ends. On the chamber 33 flange port were designed to meet a variety of needs.

The undulator is hybrid type. Taking into account the requirements of the vacuum baking, the Sm_2Co_{17} permanent magnetic material with high Curie temperature is choose, its remanence is 1.13T, intrinsic coercivity is 22kOe. The length of the magnetic structure is 1278mm. The optimized permanent magnetsize is 14.4mm in thickness, 40mm in height and 74mm in width. The size of magnetic pole is 5.6mm in thickness, 31mm in height and 43 mm in width. The apex angle of each chamfered for easy mounting and reducing the demagnetizing field of the permanent magnet inside the permanent magnet.

The ends the magnetic field designed by using two-dimensional Poisson to minimize the second integral of the magnetic field. The thickness of the end poles is 2.8mm, the thickness of the two magnets at ends were 12.8mm and 6.0mm, the interval of the end magnetic pole and the two end magnets is 5.4mm. The "Magic Fingers" is placed at both ends of the magnet.

TiN coating of 5um thickness for magnet blocks and poles to reduce the out gas rate and to lower friction during shimming.

In order to facilitate the magnetic field shimming, the magnet assembly use a pole plus two permanent magnet blocks with the half thickness.

The measured rms peak field error is about 0.5%, the phase error is ≤2° . The measured the field integrals are less than the design value. The normal and skew of multi-poles are also in accord with design requirements.

ELLIPTICALLY POLARIZING UNDULATOR

The elliptically polarizing undulator EPU104 is designed for the users of ARPES beam-line. The undulator is located at a straight section of 3.4meter long. The APPLE-II type variable elliptical polarizing undulator was adopted.

The total length of the undulator is 3296mm. The maximum attraction force in vertical direction is 1.6T and the maximum repulsive force is 0.7T. The maximum attraction force in horizontal direction is 1.9T, and the maximum repulsive force is 1.6T.

The size of permanent magnetic block is 32×32×26 mm. To correct the integral of the magnetic field, the "Magic Fingers" is placed at both ends of the magnet, and the correction coil is on the offside of undulator end.

The measured field integrals on the axis with phase shift at the minimum magnetic gap are given in Fig.1; the radiation phase error with the phase shift of the magnet field for different magnet gap are shown in Fig.2; the field integrals on the axis with magnetic gap at zero phase shift are given in Fig.3. The results of measurements show that the requirements of magnetic field are basically met. multi-pole component

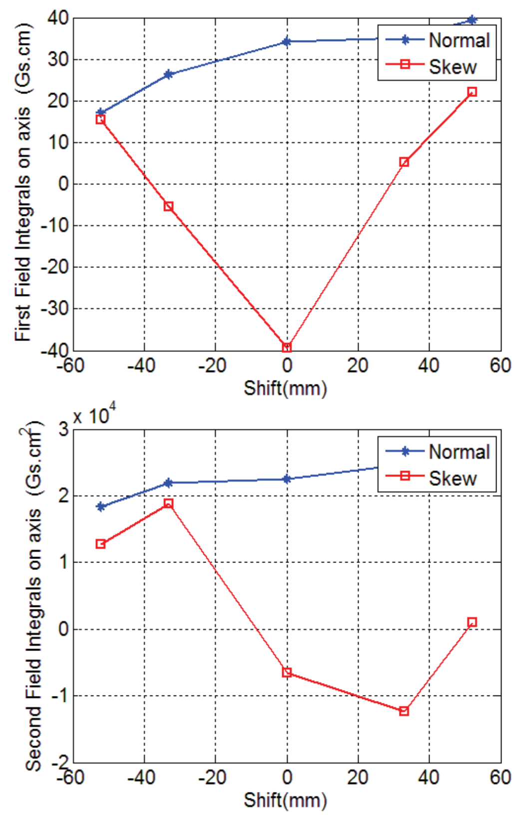

Figure 1: The field integrals with phase shift at the minimum magnetic gap

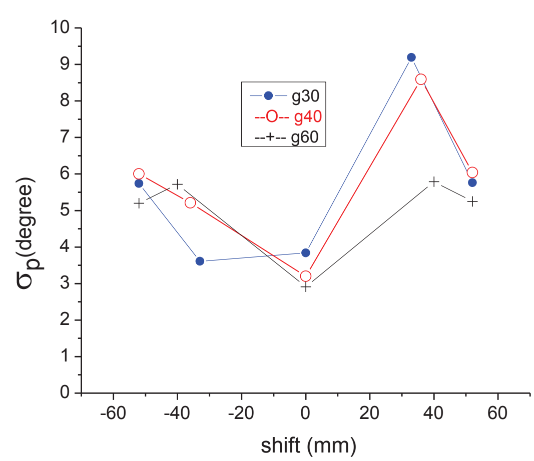

Figure 2: The radiation phase error with the magnet field phase shift for different magnet gap

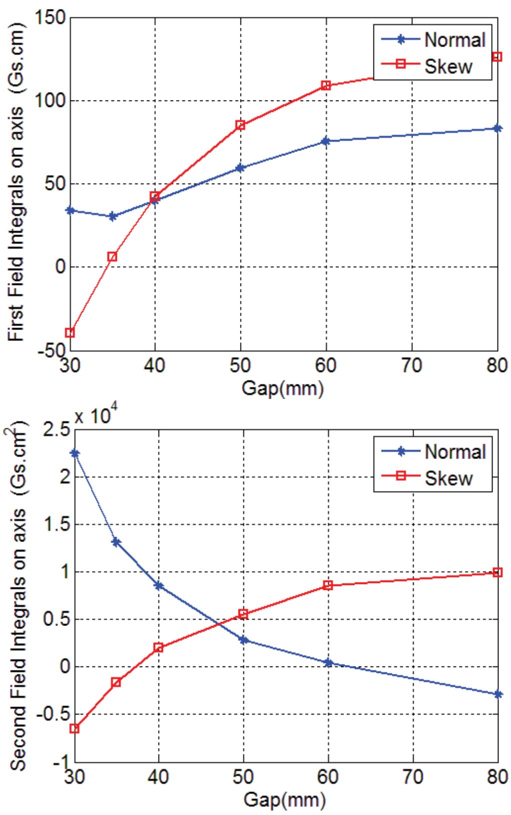

Figure 3: The integras of magnetic field with the magnet field gap (zero phase shift)

QUASI-PERIODIC UNDULATOR

The quasi-periodic undulator is designed for the user of Combustion and Flame beamline.

For a typical QPU, some H magnets (blocks magnetized horizontally) are retracted vertically by a value δ [2]. We propose and adopt a modified structure[3] for our QPU. We optimize the thickness (in electron moving direction) ratio of V magnets (blocks magnetized vertically) and H magnets in the current QPU, to make the third harmonic field be enhanced with the same sign to the fundamental B_{u1} [4], then the third harmonic emission are suppressed more effectively. After optimization we take the thickness ratio of V magnets and H magnets as about 1:2 .

Table2: Parameters of QPU88

Type	quasi-periodic
Periods λ_u (*mm*)	88
Number of Periods *N*	19
Gap rang (*mm*)	30~54
Peak field B_u(T)	0.62～0.26
η	$\sqrt{5}$
δ	5
H magnet(mm^3)	80×60×30
V magnets (mm^3)	80×60×14

The measured magnet field parameters have reached designed requirements. Using the measured magnet field data, the radiation spectrum are calculated with SPECTRA code [5]. The results demonstrate that the third harmonic emission are distinctly suppressed (Fig.4-5) and agree well with the design. We can see that the harmonic emission, especially the third harmonic, are significantly suppressed.

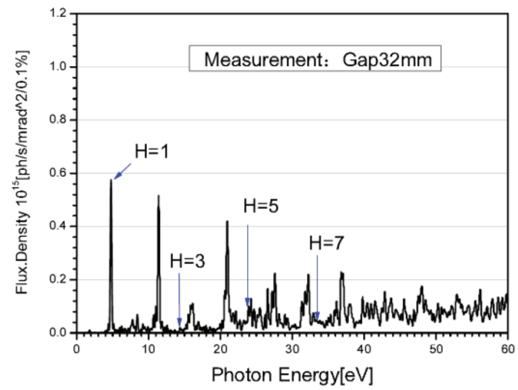

Figure 4: The angular flux of QPU88

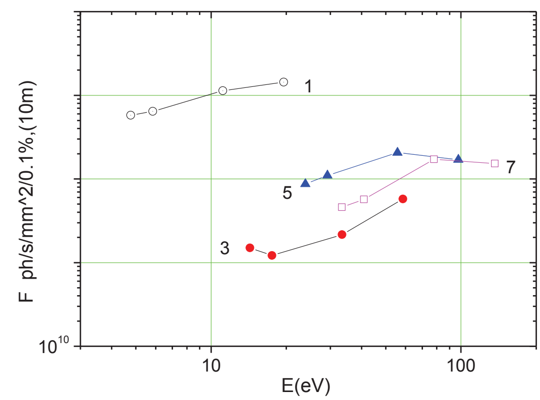

Figure 5: Flux of QPU88

WIGGLER

The wiggler is designed for the user of surface physics beam-line. The energy range of photon is 200-600ev, the maximum flux is near 520eV. Users also want the flux at 2.5Kev is as high as possible.

To increase the photon flux of high energy side, the maximized magnetic field strength is requested. For this reason, we chose the FeCoV as the pole material, its saturation field strength >2.35T and coercivity <2.4A/cm; for the permanent magnet material, the NdFeB magnet with the remanence ⩾ 1.26 T, the intrinsic coercivity ⩾ 1670 kA / m @ 20 ° C were chosen, It can provide a high field strength, and also has good resistance to radiation and the resistance to demagnetization.

Because the longer period length, the magnetic block is too large (180×162×54 mm^3) to be formed with a

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single block, it were bonded together by several magnetic blocks and with a protective layer outside. Considering the space for the shimming sheet, the minimum pole gap becomes larger. The period length had to make adjustments to ensure the magnetic field intensity. Finally taking into account the fringing fields, the real effective number of period is taken as ten.

The measured peak field is 1.44-1.2T for magnet gap 30-37mm, that is little better than the designed value. The integral and the multi-pole components of the magnetic fields also meet the design requirements.

For the four new insertion devices, three are special type ID and first time for HLS, and among them the QPU88 is a modified type QPU proposed by us. Now the four ID are completed, the results of magnetic field measurements are in accord with design requirements, and they are being installed on the ring.

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