FIELD OPTIMIZATION ALGORITHM FOR VARIOUS VARIABLY POLARIZATION UNDULATOR WITH CHANGING PHASE

C.S. Hwang, Shuting Yeh, C.H. Chang, T.C. Fan, J.R. Chen
Synchrotron Radiation Research Center, Hsinchu Science-Based Industrial Park, Hsinchu, Taiwan

Abstract

The "Apple-II" type structure of the EPU device concept can be used to switch polarization from horizontal linear, to right/left circular and elliptical, to vertical linear, to linear at 45^o and 135^o. Therefore, in this work, we develop a field optimization skill and algorithm to optimize the field quality at various variably polarization operation modes. Such an optimization algorithm includes the crucial parameters which must not only be sorted of the magnet blocks but also be shimmed on each pole. This optimization algorithm can correct and modify the field error, first integral field strength, optical phase error, trajectories, and multipole field distribution as soon as possible. For reducing the time consumption in the shimming process, the shimming method is automatically completed by a shimming code. Consequently, the magnetic field and photon spectrum quality is less sensitive to the phase position in the different polarization mode.

1 INTRODUCTION

The most obvious means of generating helically polarized radiation in recent years is by means of the helical field. Various electromagnets and permanent magnets have been proposed as well as combinations made of the electromagnet and permanent magnet designs to create the circular or helical magnetic field [1-4]. Most helical insertion devices strive for high efficiency via the phase change undulator with pure magnet arrangement. This differs from the gap change of the insertion device. As for the EPU magnet, the "Apple-II" type structure is conventionally used worldwide. This EPU magnet can be used to switch polarization from horizontal linear, to right/left circular and elliptical, to vertical linear, to linear at 45^o and 135^o. Therefore, the phasing method also differs according to the various polarization mode[5].

In light of above circumstances, the magnet sorting and shimming technique must be developed to maintain the same quality of field and spectrum in different phasing methods for various polarization light. The magnetization block is divided into two varieties, V-type (magnetization field in the vertical direction) and H-type (magnetization field in the horizontal direction). Initially, the magnetization strength of each block can be measured by the magnetic dipole moment measurement method [6] to effectively control the field strength deviation. The magnetic field strength of B_y and B_x can also be obtained by the 3-D Hall probe measurement system [7] and the integral strength of $\int B_y ds$ and $\int B_x ds$ can be obtained by the long loop coil with the dynamic measurement method [8]. These magnetic field behavior are inserted into the magnet sorting code to optimize the field distribution. Second, based on the field measurement results of the B_y, B_x, $\int B_y ds$ and $\int B_x ds$, the field deviation amount can be varied by adjusting the vertical and horizontal positions of the pole magnet and associated with the shimming technique by the iron sheet to adequately control the peak field and the integral field deviation $\Delta B_y/B_y$ ($\Delta B_x/B_x$) and $\Delta\int B_y ds/\int B_y ds$ ($\Delta\int B_x ds/\int B_x ds$) in order to be equal at each pole and half period, individually. Consequently, the optical phase error is maintained as small as possible at any phasing position.

2 FIELD OPTIMIZATION ALGORITHM

The optimization algorithm is divided into four processes to perform the active end corrective skills. The first step is the magnet blocks measurement algorithm for the magnet block sorting. The second step is based on the field measurement results of each array to adjust the vertical and horizontal position of the pole magnet individually to reduce the trajectory, multipole field and optical phase error. Third, two groups of trim magnets are used to modify the on-axis first integral and multipole component of $\int B_y ds$ and $\int B_x ds$. Finally, both end side poles and air coils are used to adjust the first integral of $\int B_y ds$ and $\int B_x ds$ to be zero at any phase and gap.

2.1 Block measurement and sorting algorithm

Magnet blocks were measured by the Helmholtz coil system to adequately control the magnetization field and small angular declination from the easy axis, as well as uniformly distribute the azimuthal angles of each block. The error (standard deviation) in the mean remanent field and the angular declination is controlled approximately within 0.1% and 0.5^o by means of the sorting code. By doing so, the central peak field strength over the V-type (H-type) block at half gap (g/2) position and the end of the magnet side can be measured. Figure1 schematically

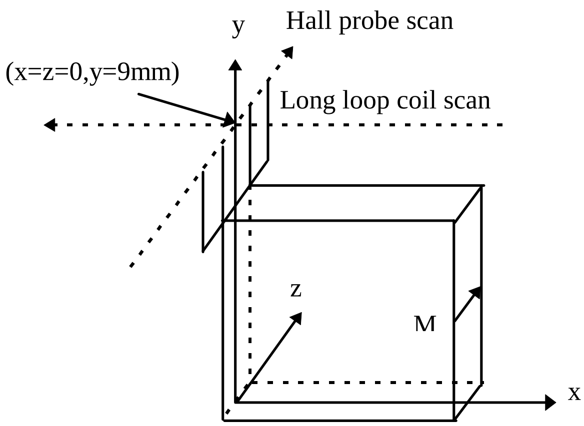

Figure 1: H-type block measurement procedure by the Hall probe and the translation long loop coil method.

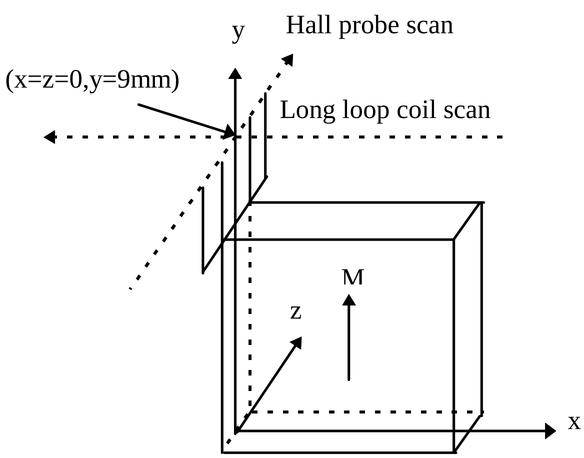

Figure 2: V-type block measurement procedure by the Hall probe and the translation long loop coil method.

depicts the block measurement in the 3-D Hall probe and long loop coil system. To measure the magnet blocks, the long loop coil is used to scan the vertical and horizontal integral field strengths in the x-y plane such that it will provide us the multipole field components ($I_y(x)$ and $I_x(x)$) and the on-axis integral field strength ($I_y(0)$ and $I_x(0)$). In addition, the 3-D Hall probe is used to scan the peak field strength of the V-type and H-type block on the on-axis, thereby providing us with the field distribution on the longitudinal position (B_y(y=9, x=20.5 mm, z) and B_x(y=9, x=20.5 mm, z)). Next, the peak field strength in V-type and H-type block are inserted into the sorting code [9] to effectively control the optical phase error and the trajectory. The data of vertical and horizontal integral field strength in the x-y plane are then measured by the long loop flip coil and inerted into the sorting code [9] to optimize the integral multipole field components. These processes provide us with the minimized field error effect of the magnet blocks.

2.2 Shimming algorithm for optical phase and trajectory at each array

After the magnet sorting and assembly of each array, the field measurement and shimming process of each array are such that in the first stage, the single array is shimmed. Then, the diagonal array of each pair and finally the entile array of the two pairs. Notably, the vertical position adjustment of the V-type block can be used to modify the horizontal and vertical field strength. In our magnet structure, the vertical position adjustment can correct the vertical (horizontal) field strength 0.7%/0.1mm (1%/0.1mm). However, this adjustment influences the field strength of the vicinity poles which are about 0.2% (0.4%). Therefore, the automatic shimming program (EPUSHIMMING code) [10] should include the effect of the vicinity poles. The 1 mm gap adjustment between the two V-type magnet blocks can only correct the vertical field strength whose amount is about 0.7%/0.1mm and, futhermore, influences the vicinity poles whose amount is about 0.2%/0.1mm. Finally, some small permanent magnets are installed in the button of pole magnet to fine tune the phase error and trajectory. The shimming program depends on this algorithm to build the automatic shimming code, referred to as EPUSHIMMING code [10].

2.3 Multipole components and first integral shimming by the trim magnets

Process 2.2 has corrected the multipole components as minimum as possible for the roll-off of any pole location. However, this correction is still insufficient to maintain the integral field strength within ±50 G-cm in the range of ±10 mm. Therefore, the trim magnet arrays for the B_x and B_y are necessary to correct the integral field strength as flat as possible and maintain the multipole components within the specification. Table I lists the criteria of the EPU5.6 specification. These two trim magnet arrays can also be used to correct the integral field strength close to zero.

2.4 End side pole and air coil

Herein, the air coil is located at the both end side (upstream and downstream) of the insertion device. The air coil can produce the B_x and B_y field to maintain the integral strength at zero while in the energy tuning (change gap or phase). In particular, the upstream air coil can be used to maintain a constant optical path while the energy is tuned. The air coil structure is designed to follow the phase and gap.

Table1: The criteria specification of the SRRC EPU5.6

	Tolerance
Block dimension	40x14x31 mm^3
$\int B_x dz$ and $\int B_x dz$	±0.5 G-m
$\iint B_x dzdz'$ and $\iint B_y dzdz'$	±2.5 G-m^2
skew and normal quadrupole	50 G
skew and normal sextupole	100 G/cm
skew and normal octupole	50 G/cm^2

3 CONCLUSION

This work develops a field optimization algorithm of the block measurement procedure and the sorting algorithm. Figure 3 and 4 illustrate the field measurement of a one meter long EPU5.6 without any shimming. Figure 3 reveals the multipole field distribution along the transverse axis and Fig. 4 displays the electron orbit behavior along the longitudinal axis. The shimming is performed on t he circular polarization mode. However,

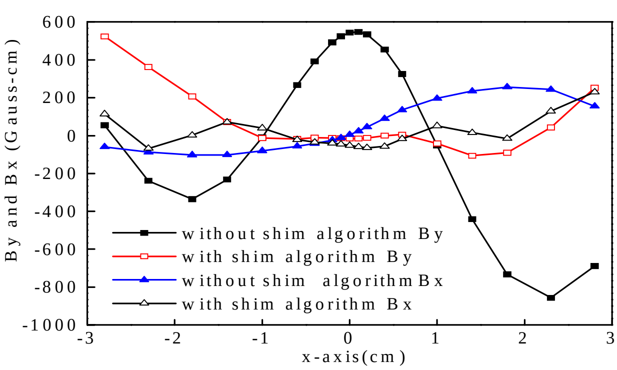

Figure 3: Multipole integral field distribution along the transverse x-axis with and without shim algorithm.

after the shimming algorithm (especially, the automatic shimming code) from 2.2 to 2.4, the field measurement results and analysis are also shown in Fig.3 and 4. Comparing the two results confirms that the field quality is improved and the quality is controlled within the specification on TABLE 1. Meanwhile, the optical phase error is improved from 53 degrees to maintain within 7 degrees.

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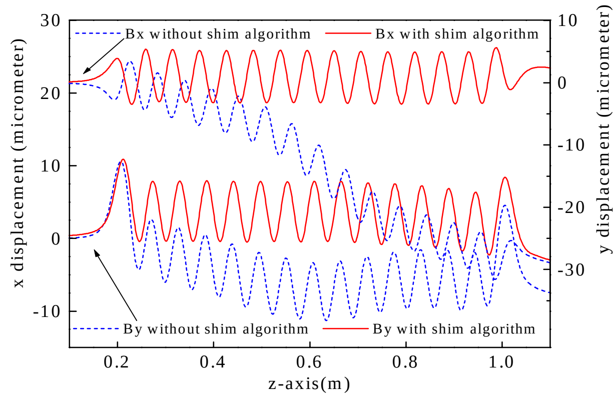

Figure 4: Electron trajectory along longitudinal z-axis with and without shim algorithm.

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