MAGNET SORTING ALGORITHMS FOR THE SRRC EPU5.6

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Abstract

The fabrication of the full-size elliptically polarizing undulator EPU5.6 has lunched at SRRC after the prototype one has been fabricated and tested successfully. Reviewing the prototype testing, the block sorting algorithm is to be improved. In the full-size EPU5.6, we have changed the design of the magnet block shape to get a larger good-field region and better field performance in tuning the polarization. Also, before the shimming adjustment of the magnets and the end-pole correction, the magnetic field measurement results of the prototype EPU5.6 are not satisfactory as expected. We recognize the detail field distribution of each magnet block to be responsible for the phase deviation, high harmonics of the magnetic field, and multi-pole field behavior of the EPU device. The magnetic field measurement of magnet blocks for sorting has to be studied carefully. Due to the detail field concern as well as the design changing, we have to modify the sorting algorithm and measurement procedure as presented.

1 INTRODUCTION

The Synchrotron Radiation Research Center (SRRC) is constructing a 3.9-meter long elliptically polarizing undulator with period of 5.6 cm (EPU5.6). A prototype of one meter long has been fabricated and tested successfully in situ to evaluate the concept design [1]. Reviewing the prototype testing, an approach with four steps to get the field optimization of EPU5.6 is developed. The block measurement and sorting algorithm is the first one of them.[2]

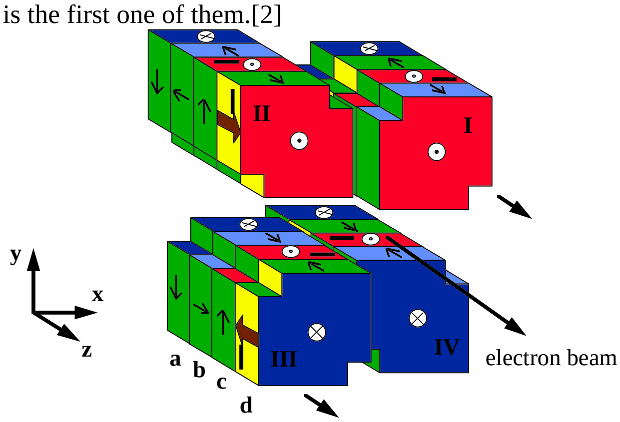


Figure 1: One period of magnets: The magnet blocks can be located at four quadrants (I, II, III and IV) and four quarter periods (a, b, c and d). The vendor marks the broad arrows showing the principal field direction and the series numbers which were indicated by small bars.

In EPU5.6 one can move each of the four magnet rows to achieve all the combination of the rows movement, and all kinds of planar- and elliptically- polarized X-rays with various energies [2]. The schematic view of one period of the magnetic structure is provided in Fig. 1. Because of the linearity of the magnets, the "row phase shift" will keep the sinusoidal fields with field phase shift. The "yaw phase shift" and "pair phase shift" also have sinusoidal fields only with the amplitude change. The terminology of these three "phase shifts" are defined in [3]. A gap adjustment mechanism supported by a drive train system can also tune the magnetic field strength.

An amount of 1412 NdFeB magnet blocks with 300 over was purchased for this prototype EPU. Due to the design of magnetic field and special symmetry of the blocks, the blocks need to be magnetized into only two types, i.e. V- and H- types, identified by the main field orientation.

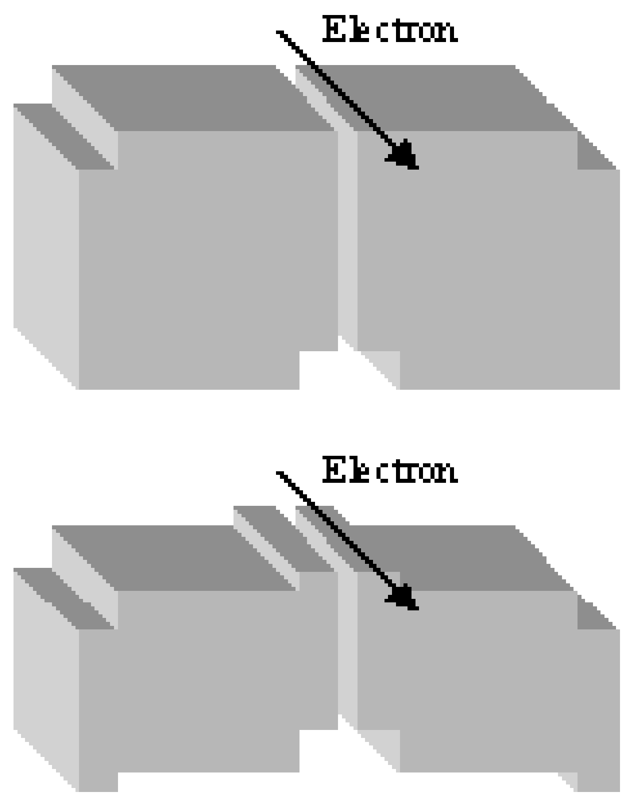


Figure 2: The prototype and new design of the magnetic blocks.

Formerly the cross-section of the magnet blocks was designed as a square of 40 mm x 40 mm with cutting on one pair of opposite angles on each square face for rigid clamping. During magnetic field measurement, we found that the good field region at the electron beam axis is too small and too sensitive to the relative movement of arrays of magnets. To get a larger good-field region and better field performance in tuning the polarization, the block shape has been changed into a 40 mm (width) x 31 mm (height) size with a protrusion of 0.5 mm at the edge close to beam axis. In Fig. 2, an old design and new design of one quarter of lower period are shown schematically. Fig. 3 shows a typical integral field of such new design. As a result, the symmetry of rotation in H-type blocks magnetized normal to the large face is broken. The freedom of assigning orientation and locations of any type of blocks is slightly reduced.

Figure 3. The integral field of one lower half quarter magnets. The lower graph magnifies the field scale on purpose to show the poor good-field-region. The noise-like valleys are from the trigger error of voltage integrator.

The magnetic field measurement reflects that the first integral field and multi-pole are larger than expected. The shimming adjustment of the magnets and the end-pole correction were quite time-consuming. We recognize the detail field distribution, other than the overall magnetic moment, of each magnet block to be responsible for the phase deviation, high harmonics of the magnetic field, and multi-pole field behavior of the EPU device.

To assure that the sorting is based on the reliable data-base, a field measurement with high precision and sophistical data processing are essentially.

2 PROTOTYPE EXPERIENCE

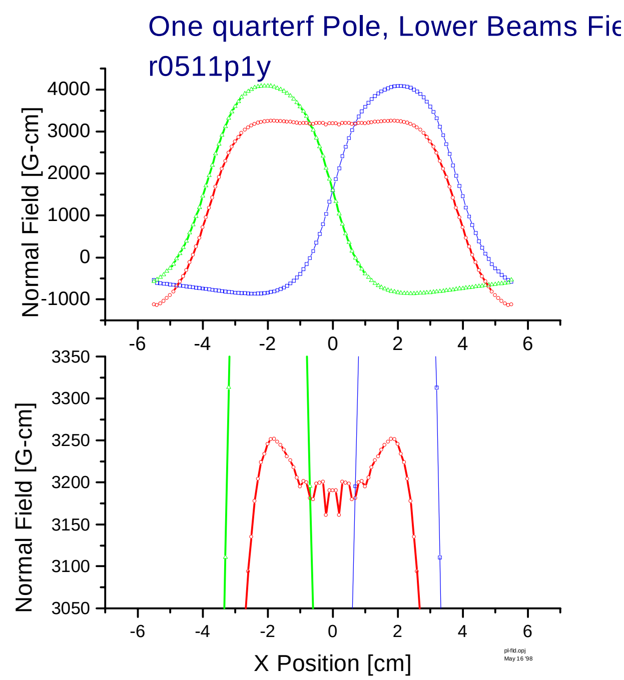
In the prototype, we sorted the magnetic moments of all blocks to minimize the total magnet moments. We thought that if we can ignore the minor moments, Mz and Mx for V-type and My and Mx for H-type (the convention of axis orientation is shown in Fig. 1), we would have a beautiful sinusoidal vertical and horizontal fields at each period of each row by calculation.

Actually the magnet moments is just a kind of total effect of each magnet block and has no direct relation with the field behavior at beam axis. The one with direct effect on the sinusoidal behavior is the real detail field distribution at beam axis.

For insertion devices with hybrid structure, the magnet sorting algorithm reducing the deviation of the average Mz of each unit cell do establish uniform pole excitation so as to get good 1st integral field to certain degree [4]. Moreover, by iterative algorithms and techniques of optimization with stimulated annealing to sort the minor components, one can effectively controlled the multi-pole field. [5,6]. In pure permanent magnet structures such as EPU 5.6, it is not the case. With an advantage of ignoring the nonlinear component, the only way one can control the quality of the magnetic field is to adjust and calculate the field distribution by utilizing the superposition of the magnet field. The first integral and second integral field is to be controlled by the point-by-point measured beam axis position field. On the other hand, sorting the real multi-pole field of each magnet block controls the multi-pole fields.

3 CONSIDERATION ON MAGNETIC FIELD MEASUREMENT

To get the multi-pole field quickly, we use a dynamic long coil measurement system with a digital voltage integrator[7]. At the beam axis position, the integral field



varies drastically, the deviation from the average field of all magnet sample is believed to be meaningful for multi-pole calculation and sorting. For simplicity, only the net contributions of each block on dipole, quadrupole and sextupole field are put into calculation. Suffered from the drift and the triggering error on positioning, an effort on recovery of the data is necessary. Fig. 4 shows an example of them.

The beam axis field is measured by a Hall probe system. Also for saving time, the on-the-fly measurement is adopted. In practice, it is infeasible to analyze and sort the magnet blocks by the contribution on the sinusoidal field or the high harmonic field due to the tremendous computer calculation. The practical approach is to sort the magnets by individual peak field of at the beam axis position. A static long coil measurement of integral field is provided to cross check the calculated integral field from Hall probe system.

Before deciding the criteria for sorting, we should have some numbers in hand. The maximum principal magnetic moment variance and inclination angles of the block are required to be (1% and 2(respectively. The vendor use a Helmholtz coil system to measure the magnetic moment with a reproducibility of 4 Gauss, which is about 0.03% of the average field.

All the above measurement will cover the Bx and By field of the upper and lower faces (P and N measurement). With the sorting of a large amount of magnets, it is evident that an average effect will diminish a part of effect from measurement error.

4 SORTING ALGORITHM

To simplify the modeling, we separate the sorting algorithm into two stages. At first stage, we try to make a reduction of first integral of field at the axis of electron beam as the following steps:

1) The V-type blocks are assigned to upper rows (I and II) alternatively from upstream to downstream in ascending order of integral field at beam axis with N-field of By direction at 1st quarter and P-field at 3rd quarter. The left ones are assigned to lower rows (III and IV) in the similar way, but from downstream to upstream, with P-field at 1st quarter and N-field at 3rd quarter this time.
2) After calculation, the H-type blocks are assigned to rows to compensate the By and Bx deviation.

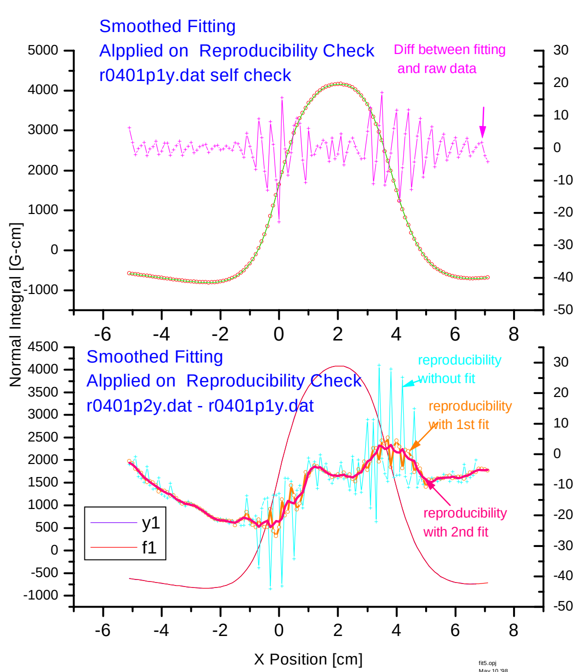


Figure 4: After fitting process, the trigger errors can be cured. From the upper graph, one can see the obvious regular trigger error due to subroutine calling. The lower graph shows that after two step fitting, the remaining reproducibility error is mainly from the drift, which can be further cured by drift fitting.

4) After all the magnets are assigned to locations and the zeroth order of field is established, the next step is to face the multi-pole problem. To see one period as a unit, we can exchange the locations or rotate the orientation of magnets in each unit. In order not to destroy the sinusoidal field obtained at the first step, some exchange and rotation are forbidden.
5) The upper rows (upper jaw) of magnets can not be interchanged with the lower rows owing to the large difference of 1st integral. The magnets of the same jaw can, since the difference is quite small according the first stage ordering.
6) In each cell, the permutation can be iterated to find an optimum of the multi-pole field without seriously affecting the beam axis field.

5 CONCLUSION

The sorting algorithm has been modified in the full-size EPU 5.6. Although there are many complicated phase shift modes in EPU, it is feasible to sort the magnets directly to reduce the error effect on the spectrum and beam dynamics.

6 REFERENCES

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