FIELD MEASUREMENT OF PEP-II LER DIPOLES AND QUADRUPOLES AT IHEP

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Abstract

The field measurement of 209 dipoles and 320 quadrupoles for PEP-II LER will be finished at IHEP in June 1997. This paper covers the details of the magnetic measurement devices developed to measure these magnets as well as the results of the measurements.

1 INTRODUCTION

Four individual measurement devices have been developed at IHEP with the aim to perform precise, fast and reliable measurement of production dipoles (63.5 mm gap height and 45 cm effective length), production quadrupoles (50 mm bore radius and 43 cm effective length) and their prototype magnets for PEP-II LER. The field properties including transfer fuction and line integral uniformity for 140 dipoles, multipole error contents and offset of magnetic center for 280 quadrupoles as well as magnet-to-magnet reproducibility have been measured by now.

2 FIELD MEASUREMENT OF DIPOLES

Two separate measurement devices were made for field measurement of dipoles.

2.1 Hall probe mapping device

It is used for mapping field distribution of prototype magnet and calibration of long coil probes. This device consists of a Digital Teslameter (DTM-141) and a positioning mechanism used to move the Hall probe in three directions, the precision of the positioning is $\pm$0.01 mm, $\pm$ 0.02 mm and $\pm$0.025 mm along x, y and z axis respectively, by means of the digital controller and servomotors. The measurement precision of magnetic field with this device is better than 2×10^{-4}.

2.2 Ramp (or step) current method

(1) Magnet-to magnet reproducibility
The measurement principle and procedure are described as follows:

- Choosing one magnet as bucking magnet(B-magnet) and another one as reference magnet(R-magnet), and others as testing magnet(T-magnet).
- Two pickup long-coil of 90cm long with about 400 turns each are connected in bucked configuration, one coil is fixed on the horizontal center plane of B- magnet and the another one into R- magnet . B-magnet and R-magnet are connected in series and powered by ramp (or step) exciting current. The relative deviation of line integral between B-magnet and R-magnet can be written as follows:

$$\frac{\triangle \int B(0) dl_{R-B}}{\int B(0) dl_R} = \frac{\int B(0) dl_R - \int B(0) dl_B}{\int B(0) dl_R} \qquad (1)$$

where $\triangle \int B(0) dl_{R-B}$ and $\int B(0) dl_R$ can be measured separately.

- In the same way, all T-magnets are measured in turn, so we can also obtain

$$\frac{\triangle \int B(0) \cdot dl_{T-B}}{\int B(0) \cdot dl_R} \qquad (2)$$

Based on above, the relative deviation of all T-magnets from the R-magnet can be calculated . In addition , the effect of remanent field can be extra added.
(2) Line integral uniformity
In practice, it is much the same way that two pickup long-coil as above are connected in bucked configuration , one coil is fixed on the horizontal center plane of B-magnet and the other one into T-magnet, B-magnet and T-magnet are connected in series and powered by ramp (or step) exciting current. When the T- magnet is moved laterally at different positions the induced signals from two pickup long-coil are fed to PDI 5025 Digital Integrater and then process data by microcomputer via RS232 and GPIB interface. The transverse distribution of line integral field can be obtained.

3 FIELD MEASUREMENT OF QUADRUPOLES

3.1 Harmonic Measurement System

The measurement system is based on the harmonic coil method. It consists of rotating long coil assembly, step motor controller and data aquisition system. While the coil assembly rotates in the aperture of the magnet, the induced voltage in coils is digitally integrated over equally spaced angular intervals by using a digital integrator. IBM computer controls the measurement procedure and performs the FFT analysis. Some of its features are as the follows :

- Measurement coil assembly is made with high bucking ratio($>$300) in order to get a high sensitivity for higher harmonics. It is wound with adequate number of turns such that the voltage signals anticipated in both configurations, unbucked and bucked, are large compared to the ambient electrical noise and insensitive to both the dipole and quadrupole components of the measured field in bucked

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configuration. The rotating coil assembly consists of a support structure made of G10 and two measurement coils, main coil (r=40 mm, r=-30 mm and N =200turns) and bucking coil (r=22.5 mm, r=-12.51 mm and N =400 turns).

• The barrel construction for the measurement coil assembly is chosen for positioning it in aperture of magnet easily and rapidly.

• Higher resolution and accuracy of measurement are obtained by using a precision Digital Integrator (PDI 5025), an Angular Encoder(5VN278AZ, 14Bit) and the slow rotating long coil assembly (0.5 sec/rev).

• A switch box is used to change the coil configurations and improve the bucking ratio by the precision potentialmeters. The induced voltage signals to be collected with a permanently connected wire rather than a brush and a slip ring are drift corrected and then analyzed through FFT.

• A cycle of the measurement including data acquisition and processing can be finished automatically in only a few minutes.

3.2 Step current measurement device

The relative deviation of transfer function of the production quadrupoles from reference magnet that are excited in series by the step current is measured by using the same method as that in the dipole measurements. Instead of long-coils there are two long coil pairs to be used. It is simpler in match of the measurement coils and rapid to obtain the measurement results.

4 MEASUREMENT RESULTS OF DIPOLES

4.1 The line integral uniformity

The line integral uniformity at mid-current of 578.9 Amps for 140 dipoles is below the limit of of the central field for $-4.5\ cm \leq X \leq 4.5\ cm$. The average curves for different group A, B and C are shown in Fig. 1, and the results show that their standared deviations are less than 1×10^{-4}.

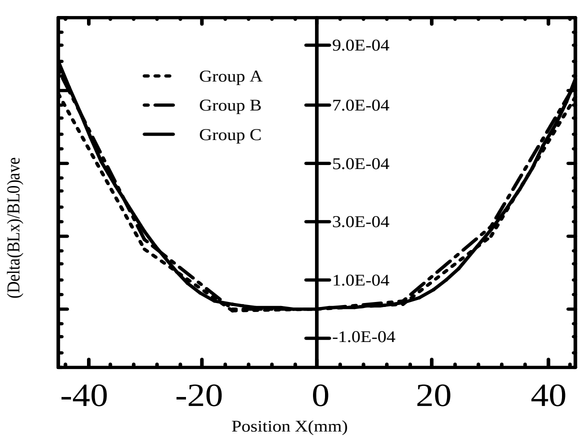

Figure 1: Average curve of field uniformity.

4.2 Magnet-to-Magnet Reproducibility

The integral field dispersion relative to the reference magnet for 140 dipoles is shown in Fig. 2, and its standard deviation is 1×10^{-4}. After shimming the magnet to magnet the reproducibility of 137 dipoles is $\leq 1 \times 10^{-3}$. The relationship between integral field and the ratio of core length to the gap height is shown in Fig. 3.

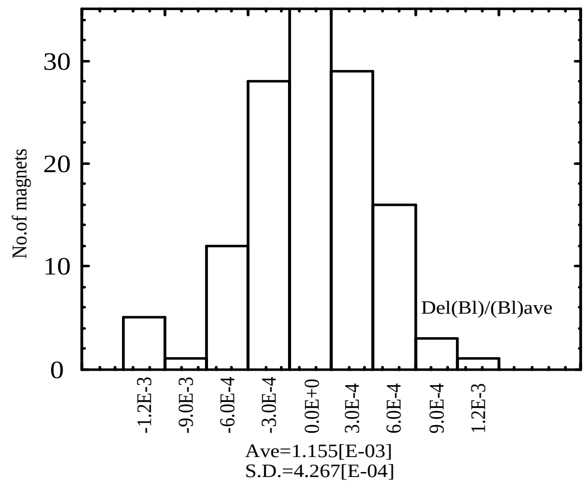

Figure 2: Integral field dipersion of 140 dipoles.

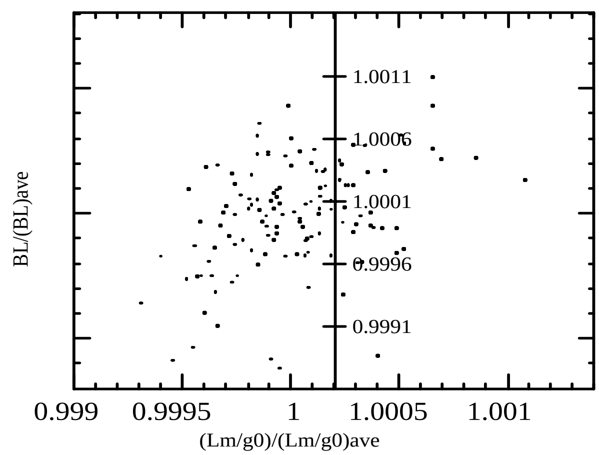

Figure 3: Integral field with core length/gap width.

5 MEASUREMENT RESULTS OF QUADRUPOLES

5.1 Magnet Field Quality

The average values of relative multipole error contents of 150 quadrupoles with 15-turn aluminum coil at mid current of 355 A are summarized in Table 1, and their spectrogram is shown in Fig. 4. It is shown that the standard deviations of high harmonics are less than 1×10^{-4}. Systematic and random multipole error contents for 280 quadrupoles are below the limit of 1×10^{-3} and 5×10^{-4} of the fundamental field respectively.

	(Bn/B2)ave	S.D.
B1/B2	3.775E-04	1.723E-04
B2/B2	1	0
B3/B2	7.656E-05	4.48E-05
B4/B2	1.74E-04	7.61E-05
B5/B2	1.902E-05	1.08E-05
B6/B2	5.797E-04	1.86E-05
B7/B2	8.531E-06	4.72E-06
B8/B2	1.062E-05	5.6E-06
B9/B2	5.271E-06	2.89E-06
B10/B2	3.386E-04	3.91E-06
B11/B2	4.999E-06	3E-06
B12/B2	5.537E-05	7.84E-06
B13/B2	1.173E-05	7.12E-06
B14/B2	6.31E-05	9.2E-06

Table 1: Average values of spectrum of 150 quads.

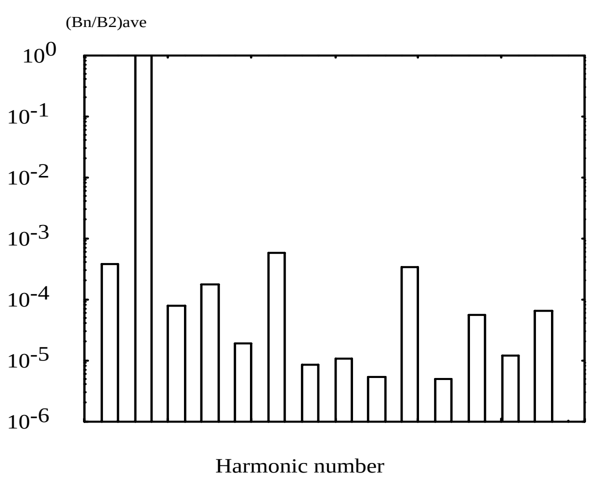

Figure 4: Spectrogram of 150 quads.

5.2 *Magnet-to-Magnet Reproducibility*

The integral field gradient dispersion of 150 quadrupoles with 15 turn aluminum coil at 355 A is shown in Fig. 5. The standard deviation is 4.12×10^{-4}.The magnet-to-magnet reproducibility of 280 quadrupoles is $\leq 1 \times 10^{-3}$.

5.3 *Displacement of Magnetic Center*

The radial displacements of magnetic center $\triangle r$ of 280 magnets are below the limlt of 0.05 mm, and their average value is 0.022 mm and the standard deviation is 0.01 mm.

6 CONCLUSION

The field performance of all magnets clearly met the specification requirement for PEP-II LER dipoles and quadrupoles except for several dipoles which are slightly out of reproducibility of 1×10^{-3}. Corrections of these magnets, shorter or longer, were made by changing the shims located at the matching surfaces in between the two half cores. The measurement results show that the relative accuracy of four sets of measurement devices is better than 2×10^{-4}.

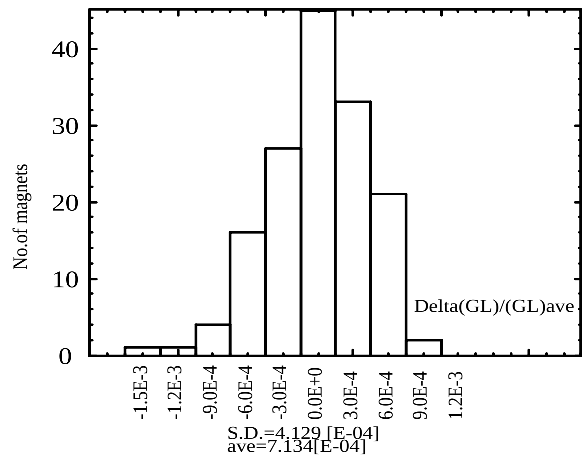

Figure 5: Integral field gradient dispersion of 150 quads.

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8 REFERENCES

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