FIELD MEASUREMENT RESULTS OF THE QUADRUPOLE MAGNETS FOR ATF2

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Abstract

ATF2 will be built at KEK as a test facility for the final focus system for the ILC. The specifications for the final focus system require transverse focusing of the electron beam to nearly 40 nm. The quadrupole magnets for the ATF2 magnets have to meet strict specifications on the multipole components, especially the sextupole components, in order to achieve the required small beam size. Preliminary measurement results of these magnets using a harmonic coil system will be reported in this paper.

INTRODUCTION

The Accelerator Test Facility (ATF) at KEK was built for R&D work for a future electron-positron linear collider [1]. The main goals of the ATF project are to produce, measure and control a very low emittance beam. The ATF is composed of an electron gun, a 1.5 GeV electron linac, a 1.5 GeV damping ring of 138 m circumference and an extraction line for beam diagnostics. The ATF2 project will extend the existing ATF extraction line with an ILC-type final focus system [2]. Most of the tolerances, such as the tolerances on magnetic field, jitter vibration and power supply stability, are common between the ATF2 and the ILC. ATF2 will be a very good model for the ILC final focus system and a successful commissioning of the ATF2 project will assist in the design of the ILC. The ATF2 beam line is shown in Fig. 1. The quadrupole magnets for the ATF2 extraction line are called the QEA magnets. The QEA magnets have been manufactured at IHEP in China. The basic mechanical and magnetic parameters are summarized in Table 1. Field error tolerances for the extraction quadrupole magnets are summarized in Chapter 3 in the ATF2 proposal [2]. Tolerances on the normalized sextupole amplitude to the quadrupole amplitude (B3/B2) for some of the quadrupole magnets are as tight as 0.04 % at r = 10 mm. The tolerance on the tilt is on the order of 0.1 mrad.

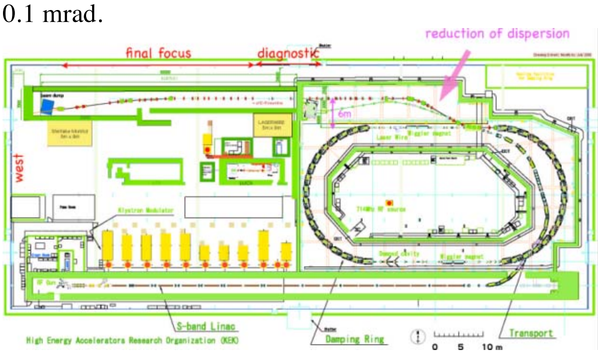

Fig.1. ATF and ATF2 layout.

Table 1

Bore diameter (mm)	32
Core length (mm)	180
# of turns per pole	48
Max. current (A)	150 or 50
Field gradient @115A (T/m)	54

MEASUREMENT SYSTEM

General

A harmonic coil system was used to measure the QEA magnets. The rod of the measurement coil, shown in Fig. 2, is made of ceramic (Alumina 99.5 %). The main and the additional bucking coils are mounted on the same frame made of Macor. Air bearings are used for smoother rotation. The number of turns and locations of the main and bucking coils are determined so that the dipole and quadrupole components are cancelled when two coils are connected in a certain configuration (bucking coil configuration). Polyurethane coated copper wire with a diameter of 0.1 mm is used for both coils. The field strength, magnetic center and the main quadrupole phase are measured by the main coil, without connecting the bucking coil (the main coil configuration). The sextupole component is evaluated by the bucking coil configuration. A coupling structure, shown in Fig. 3, is introduced in order to guarantee the relation between the coil and the encoder. When placing the magnet on the measurement system, the coil rod has to be removed from the encoder. With the coupling structure, the relative position of the coil to the encoder is expected to give good reproducibility.

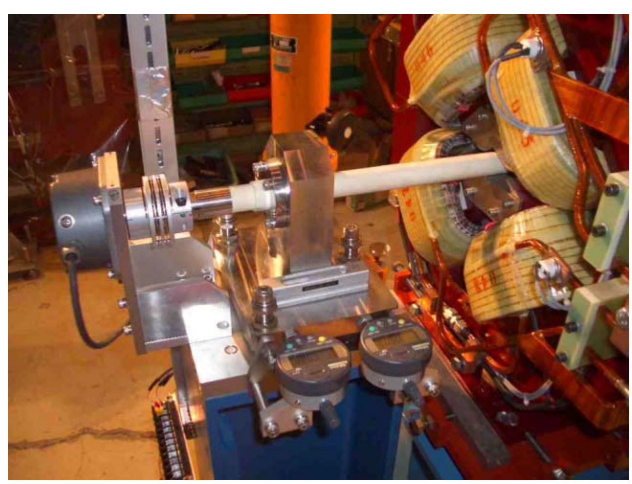

Fig.2. Harmonic coil system.

Fig.3. Coupling between the coil rod (left) and the encoder (right).

Measurement Reproducibility

In order to evaluate the stability of the measurement system and the reproducibility of the coupling detachment, a measurement was repeated 25 times. The measurement started ~30 minutes after the magnet was ramped up to I = 100 A. At each measurement, the harmonic coil was detached from the encoder. The measurement interval was ~5 minutes. Main quadrupole amplitude (integrated field strength) is normalized to the average value and plotted on the left side in Fig.4. The median plane angle, the tilt of the quadrupole magnet is plotted in the right side. The r.m.s. of the reproducibility of the strength and the tilt measurements are 1.2×10^{-5} and 0.01 mrad, respectively in the case where the measurement was repeated continuously.

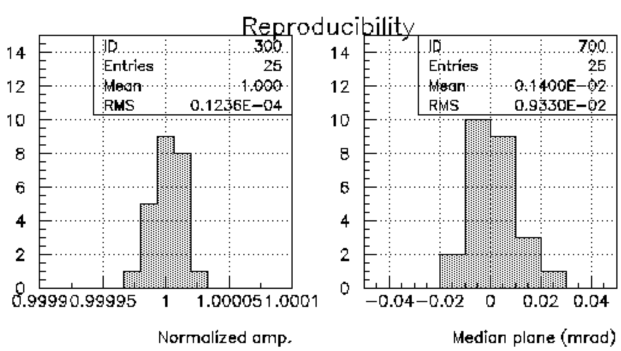

Fig. 4. Measurement reproducibility of the strength (left) and the tilt (right).

MEASUREMNT RESULTS

Twenty four QEA magnets, 13 high current magnets and 11 low current magnets, were measured in 2006. The magnets were divided into two groups, the "high current" group and the "low current" group. The "high current" magnets were allowed to ramp up to 150 A while the "low current" magnets were only up to 50 A. This requirement comes from the specification of the power supplies that will be connected to the magnets in the actual beam line. The magnets are standardized first and then ramped up to the measurement current from 0 A. In order to obtain excitation data the measurement was carried out at every 10 A step for the high current magnets and 3.33 A step for the low current magnets, respectively, with the main coil configuration. At each current, the measurement was repeated three times. The current on the power supply was monitored by DCCT all through the measurement. The temperature of the measurement hall and the cooling water were controlled within +/- 0.3 degree and +/- 0.1 degree, respectively.

Integrated Strength (B'L)

The distribution of the quadrupole strengths normalized to the average of the high current group magnets is shown in Fig. 5. It is seen that the strength varies by the order of 0.1 % among the magnets. This large spread can be explained by the thickness of the liner plates which were inserted between magnet quadrant cores in order to control the sextupole component by IHEP, as is shown in Fig. 6. Since each QEA magnet will have its own power supply, the large variation in the quadrupole strength is not a big concern.

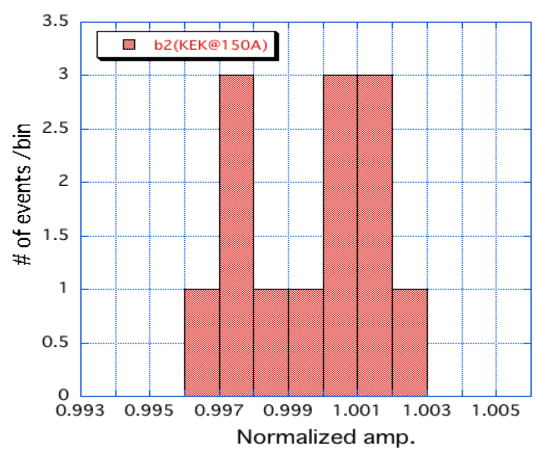

Fig. 5. B'L distribution.

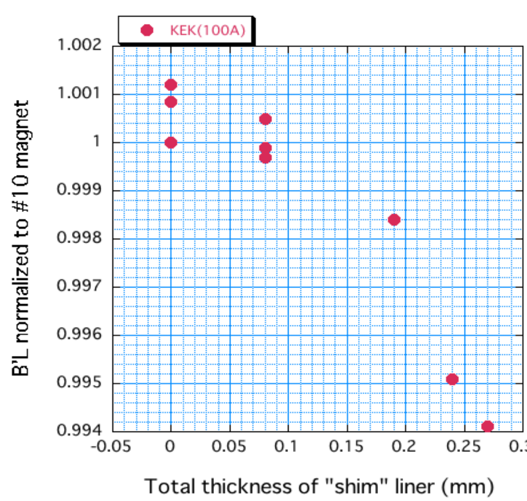

Fig.6. B'L vs. shim liner thickness.

Magnetic Center and Median Plane

The magnetic center, Δx and ΔY, when aligned using the reference plate placed on top of the magnets are plotted in Fig. 7 for all 24 magnets. A large offset was measured, especially in the horizontal direction, x. Fig. 8 shows the distribution of the median plane when the magnet is aligned using the reference plate. Some magnets are tilted as much as 1 mrad, which is larger than the measurement system error. The offset and the median plane data must be taken into account when aligning the magnets in the beam line.

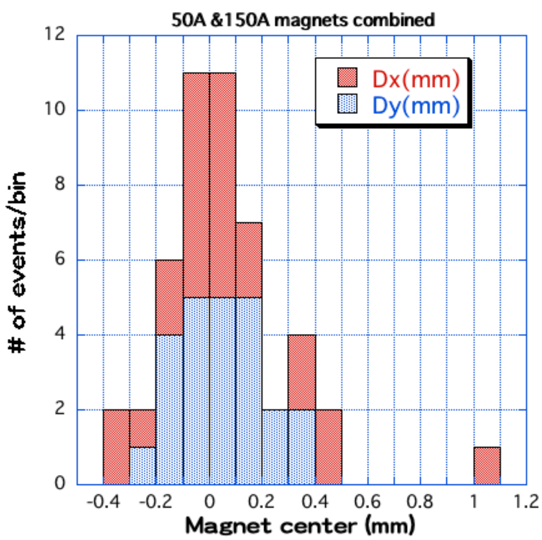

Fig. 7. Magnet center.

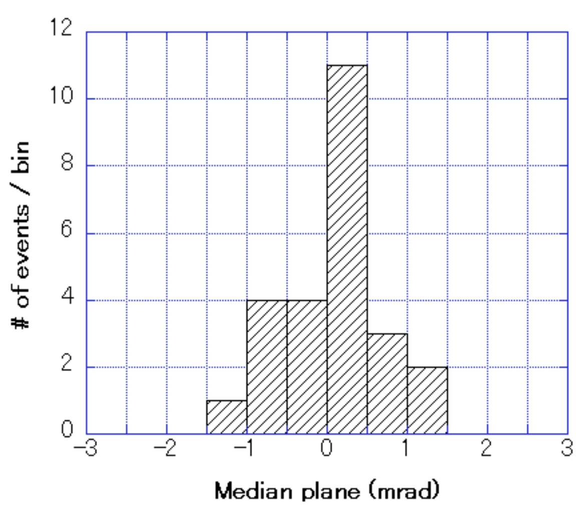

Fig. 8. Median plane distribution.

Sextupole Component

The sextupole component was measured with the bucking configuration. The magnets with shim correction, which are indicated by squares in Fig. 9. show small sextupole components. They satisfy the requirement from the optics design. Other magnets show 0.1% or larger sextupole components. Since the requirement for the sextupole component depends on the lattice position of the magnets, we can assign the magnets according to the sextupole component to a proper lattice position.

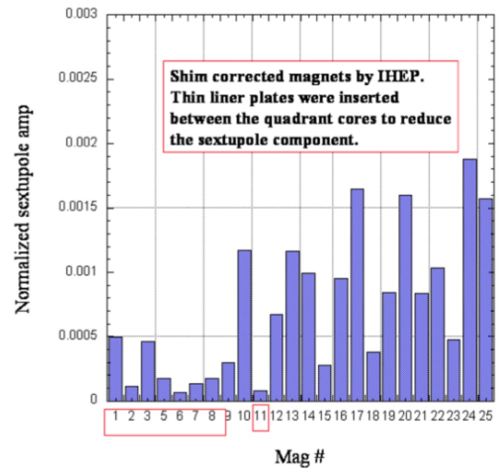

Fig. 9. Sextupole component vs magnet number.

CONCLUSIONS

The quadrupole magnets for the ATF2 extraction line have been measured at KEK using a harmonic coil system. Preliminary results from 24 QEA magnets have been presented in this report. We see a large variation in the integrated field strength, magnetic center and the median plane among the 24 magnets. The large variation of the strength is not a problem since each magnet will have its own power supply. The large offset and median plane (tilt) must be taken into account when aligning the magnets in the beamline. The reasons for the large offsets are under investigation. The sextupole components were controlled well by shim insertion performed at IHEP for some magnets. We did not require shim insertion for all of the magnets since the shimming process is time consuming.

Some more detailed analysis of the measurements will be reported somewhere else. We thank IHEP for their contributions in magnet production and measurement.

REFERENCES

[1] The ATF Group, “ATF Design and Study Report”, KEK Internal 95-4, June 1995.
[2] The ATF2 Group, “ATF2 Proposal Vol.1”,CERN-AB-2005-035, CLIC note 636, DESY 05-148, ILC-Asia-2005-22, JAI-2005-002,KEK Report 2005-2, SLAC-R-771,UT-ICEPP 0502.