FIELD MEASUREMENTS OF NEW MAGNETS FOR THE PF-AR UPGRADE PROJECT

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Abstract

For the PF-AR upgrade project, four quadrupole and five sextupole magnets are fabricated to avoid the interference with the synchrotron radiation beam lines. In addition, vertical steering magnets are designed to ensure space for the vacuum system, and a number of magnets increase from 44 to 79 to obtain further orbit stabilization. The field measurements of the new magnets are carried out using the rotating coils. The results are presented in this paper.

1 INTRODUCTION

The PF-AR (Photon Factory Advanced Ring for pulse X-rays) was originally constructed as a booster synchrotron for the TRISTAN e^+e^- collider. Parasitic usage of synchrotron radiation started in 1986, and the ring was normally operated at beam energies of 5.0 - 6.5 GeV. Along with a construction of KEK B-factory, the PF-AR was converted to a dedicated light source in 1998.

The upgrading project started in March 2001. The goal of the project is to achieve longer beam lifetime, higher beam current, further orbit stabilization and to create more beam lines.

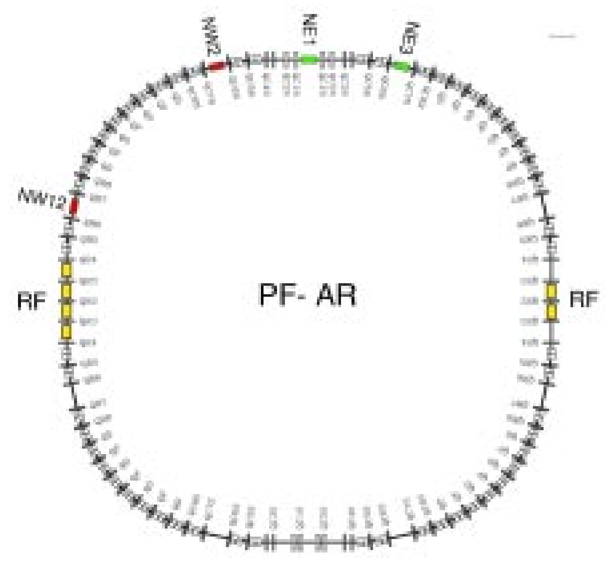

Figure 1: The lattice configuration of the PF-AR. The NE1 and NE3 indicate the existing insertion devices, and NW2 and NW12 indicate new ones.

2 MAGNET DESIGN

In the upgrading project, the lattice configuration of the PF-AR shown in Fig. 1 does not change. The vacuum and monitor system are mainly improved. The material of the duct is changed from aluminum alloy to OFHC (Oxygen Free High Conductivity) copper in order to ensure a high heat load and to reduce the radiation damage of the accelerator components. In addition, the ducts are designed to be equipped at the required pumping speeds. Then, BPM electrodes are newly designed and mounted using vacuum flanges on the copper ducts. In the magnet system, all existing bending magnets, most of quadrupole and sextupole magnets, and their power supplies are to be reused. These are elaborately maintained by exchanging with new parts as possible. Only four quadrupole and five sextupole magnets are newly fabricated to avoid interference with new synchrotron radiation beam lines. Then, the magnets are replaced with the existing magnets. Photographs of the magnets are shown in Figs. 2-4 and the parameters are listed in Table 1.

The quadrupole magnets are designed to create the space for the vacuum duct of the beam line inside the magnet, and to realize the field gradient of 20 T/m (at maximum) and the

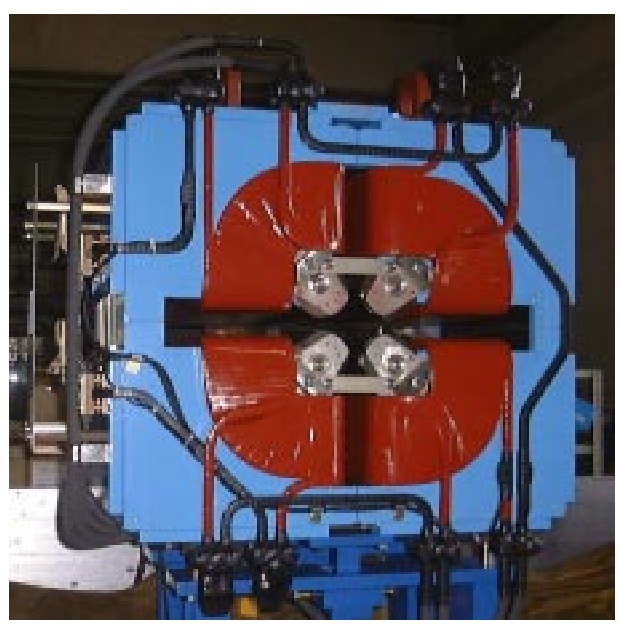

Figure 2: Photographs of the new quadrupole magnet.

Table 1: Parameters of the new magnets

	Quadrupole	Sextupole /Aux. coil	Vertical steering
Gap or Bore diameter [mm]	80	92	200
Core length [mm]	500	276	192/170
Max strength [T, T/m, T/m^2]	20	250	0.05
Turns /pole	11	32/183	864/928
Max current [A]	1340	100/10	10
Resistance [mΩ]	7.8	110/1800	1180/1100
Water flow [l/min]	9.4	0.7/not use	not use
Total weight [kg]	2630	430	115

Figure 3: Photographs of the new sextupole magnet installed in the ring.

Figure 4: Photographs of the vertical steering magnet installed in the straight section.

same core length as the existing one.

The sextupole magnets are designed to create the space for the vacuum duct of the beam line inside the magnet and to realize the field gradient of 250 T/m^2 (at maximum). Moreover, the auxiliary coils used as the vertical steering are attached.

In the design of the vertical steering magnets, it was considered to ensure the space for the pumping port and avoid the vacuum components and beam position monitor, etc. Then, the magnets have C type yoke and maximum field strength of 0.05 T. They have two different types of core length; 192 mm for the straight sections and 170 mm for the arc sections.

3 FILED MEASUREMENT

The field measurements of these magnets were performed using a harmonic coil method [1]. In this method, the induced voltage is represented as a function of an angular position since a coil is rotated in a magnet. Then the harmonic content of the magnet is directly given as the Fourier components of the induced voltage.

In the measurement, two different set of the rotating coil probe are used: one is a radial coil set, and the other is a tangential coil [2]. The radial coil set is located in the plane of one axis, while the tangential is installed on the cylinder surface. The purpose of the radial coil is to measure a precise main field gradient and a deviation of the magnetic center from the geometric center. Figs. 5-7 show the excitation curves for the quadrupole, sextupole and vertical steering magnet, respectively. The maximum integrated field gradients for the quadrupole and the sextupole magnet were 10 T and 73 T/m, respectively. The maximum integrated field strength for the vertical steering magnet was 0.016 Tm.

On the other hand, the tangential coil is used to following end-shim correction. Since the main field components reduce with proper angles and turn numbers of the coils for the tangential coil, the higher multipole components are clearly observed. Since large higher multipole fields are

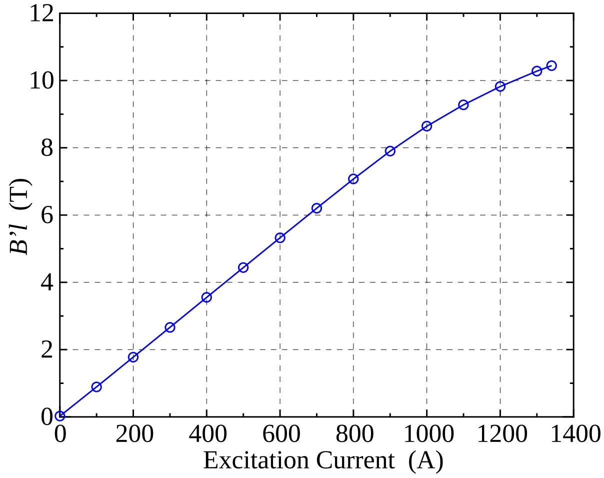

Figure 5: The excitation curve of the integrated field gradient for the quadrupole magnet.

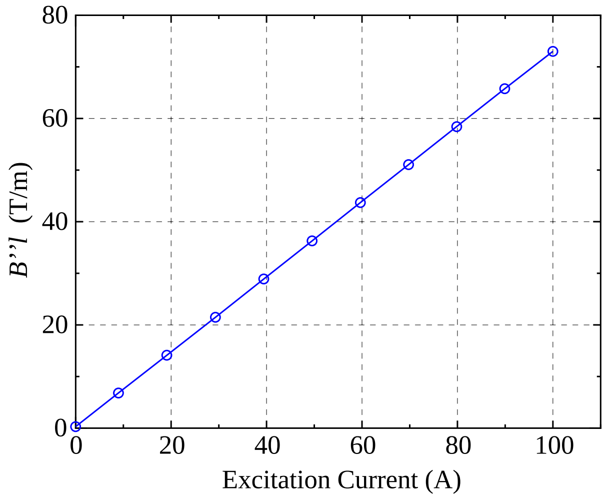

Figure 6: The excitation curve of the integrated field gradient for the sextupole magnet.

undesirable in real operation, it is hopeful to reduce them as possible. In general it is available using a proper end-shim implemented on the magnetic poles. So one of the important purposes in the field measurement is to search parameters of the end-shim. The end-shim is a pure-iron plate with various thicknesses. They are attached to both edges of the magnet poles. Fig. 8 shows a field gradient ratio of the dominant higher multipole field component to the main field for the quadrupole magnet. Data were measured at an excitation current of every 200 A step and a thickness of every 2 mm step using a tangential coil. Since the higher multipole effect depends on the thickness of the end-shim, we could determine the best thickness to reduce them: 10 mm for the quadrupole magnet. As a result the higher multipole effect was reduced less than 2×10^{-3} at a position of 36 mm from the magnetic center.

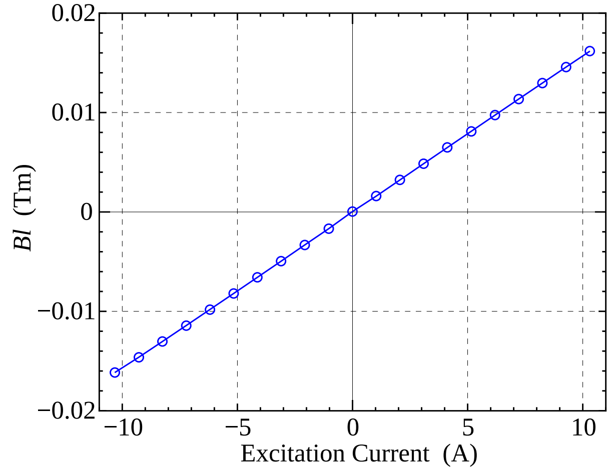

Figure 7: The excitation curve of the integrated field strength for the vertical steering magnet.

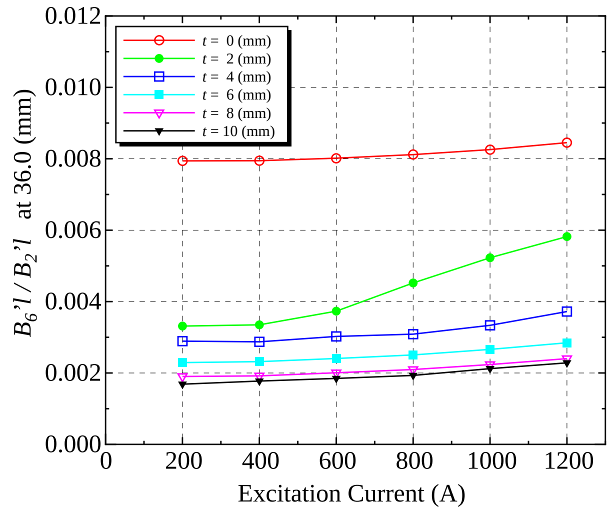

Figure 8: A field gradient ratio of the dominant higher multipole field component (dodecapole field component) to the main field for the quadrupole magnet.

4 REFERENCES

[1] L.Walckiers, “The Harmonic-Coil Method”, CERN 92-05, p.138.

[2] Y. Kobayashi *et al.*, “Magnets for the High Brilliant Configuration at the Photon Factory Storage Ring”, in *Proceedings of the 10th Symposium on Accelerator Science and Technology*, Hitachinaka, Japan, (1995) 121.