PERMANENT MAGNET FINAL FOCUS DOUBLET R&D FOR ILC AT ATF2*

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Abstract

A prototype of the five-ring-singlet configuration lens proposed by R. L. Gluckstern is fabricated and under evaluation. In order to realize the beam test at ATF2, the inner bore is enlarged from its original ILC design keeping the other dimensions the same. The measured maximum integrated gradient GL is 6.8T with the total length of 25cm. When the variable range is kept between 6.5T to 1.3T, the skewing effect is less than 1millirad.

INTRODUCTION

Although the base line technology of the Final Focus Doublet for ILC is superconducting magnet, which is supposed to be conventional, the slender structure may suffer from vibration. Permanent magnets, however, do not have any vibration source in them at the steady state. The five-ring-singlet configuration proposed by R. L. Gluckstern adds 100% strength adjustability to permanent magnet quadrupole (PMQ) lens. It was originally designed for ILC that has the extra hole for the outgoing beam. In order to realize the beam test at ATF2, the inner bore is enlarged from D24mm to D50mm keeping the other dimensions the same.

THE FIVE-RING-SINGLET

The five-ring-singlet was proposed by R.L.Gluckstern [1,2,3] (see Fig. 1). The odd numbered rings and the even numbered rings are rotated against each other. The most concern in this configuration is the x-y coupling. In the linear approximation, the beam optics can be described by the transfer matrix. We need a 4x4 transfer matrix to analyze the behaviour of the coupling and the 2x2 off-diagonal sub-matrix corresponds to the x-y coupling. When we use symmetries and choose their rotation angles and lengths carefully, such components become negligible. Let the gap between magnets be 1cm, and the magnet lengths be 2, 5, 7, 5, 2 cm, respectively. The total length becomes 25cm including the four 1cm-gaps in this case.

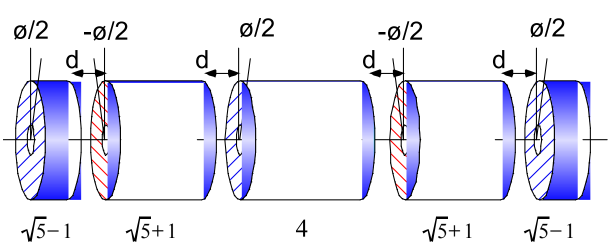

Figure 1: The five-ring-singlet. The odd numbered rings and the even numbered rings are rotated against each other. The values shown at the bottoms of the rings are concluded by R.L. Gluckstern in a case of d = 0 (the rings touch each other).

PMQ FOR ATF2

The prototype is designed so that it can be evaluated with real beams. ATF2 would be the best place for us to carry out the experiments. Table 1 shows the specifications for the final doublets for ILC and ATF2. ATF2 requires a larger bore size because of a lot of background X-rays, which should not hit the magnet. The lower beam energy in ATF2 case reduces the required field strength. Keeping the outer diameter of the magnet material 72 mm, we can enlarge the bore and still obtain the enough strength. Figure 2 compares the flux plots of both cases. The available field gradient for 50 mm bore is 30 T/m, which is twice stronger than required. The twenty-segmented configuration generates less than 10 Gauss external field at the outgoing beam region (see Figs. 3 and 4). This can be further reduced when we use a

Table 1: Specifications for QD0

Parameters at IP	ILC	ATF2
Beam Energy [GeV]	250	1.3
L* [m]	3.5-4.2	1
Bore diameter [mm]	24	50
Gradient [T/m]	142	13
Integrated Gradient [T]	312	5.9

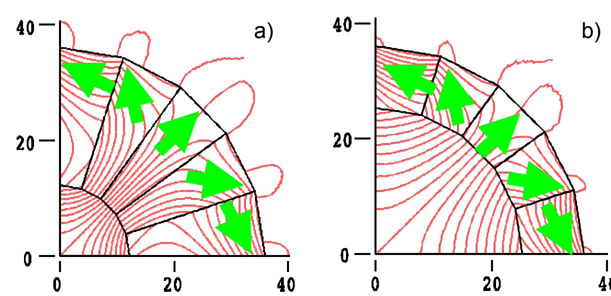

Figure 2: Segment Layouts with the outer diameters of 72 mm. a) for ILC with 22mm bore diam.. b) for ATF2 with 50mm bore diam. The field gradients are 140T/m and 30T/m, respectively.

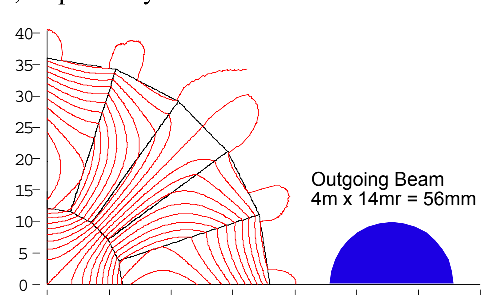

Figure 3: Outgoing beam position and the PMQ.

magnet holder made of iron. Since we do not care about the external field for ATF2 model, those of the prototype are made of SUS316.

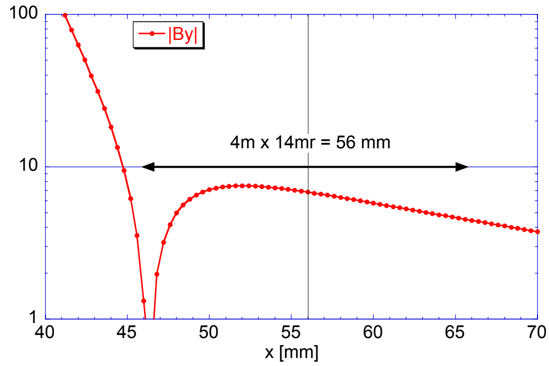

Figure 4: External field for the 20-segmented PMQ.

MAGNET ASSEMBLY

Each magnet has a measured data on the easy axis direction and strength. These data are used to select and locate the magnet segments at good positions. The magnetic force on each magnet segment depends on the segment position as shown in Fig. 5. As can be seen, only the four pole segments are pulled inside, and others are pushed outside. Thus, a special jig was prepared to assemble the magnet segments as shown in Fig. 6. While it uniformly inflates the inner bore, the screws are adjusted to correct the segment positions; these screws only push the segments towards inside. Figure 7 shows an assembled PMS ring.

Each PMQ ring is held at the outer surface of the magnet holder and rotated around it in a 5-ring-unit; the magnetic center should be measured against its outer surface. It can be measured by rotating it grabbing the holder (see Fig. 8). While a PMQ ring held in a chuck is rotated by a motor, an inserted coil picks up the field harmonics. We can check the magnetic center from the data. The magnetic center can be fine corrected by using the jig mentioned above. This correction can be repeated until it converges.

For the ILC model, which has the smaller bore size, a more sophisticated jig would be needed to correct the segment positions.

Figure 9 shows the fabricated second prototype of the magnet. Ultrasonic motors are used to rotate the rings, so that this system can work under magnetic field from the detector magnet. This still needs some modification such as adding a mover. After all the preparation, we would like to install this 22cm-length magnet replacing the original electro-magnet for the final focus quadrupole magnet.

MEASUREMENT OF ASSEMBLED MAGNET

The assembled unit was measured by a rotating coil system at KEK (see Fig. 10). Figure 11 shows a preliminary data of the measured integrated field gradient

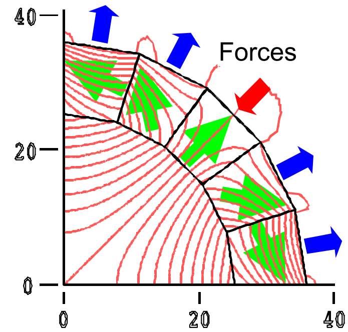

Figure 5: The magnetic forces on magnet segments. Only the segments at pole positions are attracted inside, and the others are repelled towards outside.

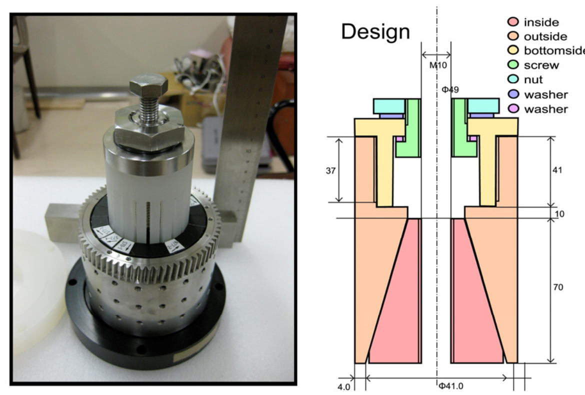

Figure 6: Special jig to fine adjust the position of the magnet segments.

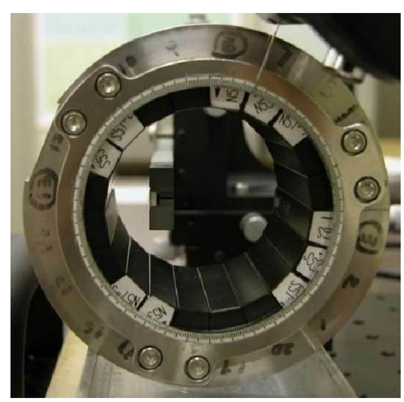

Figure 7: One out of five assembled PMQ's.

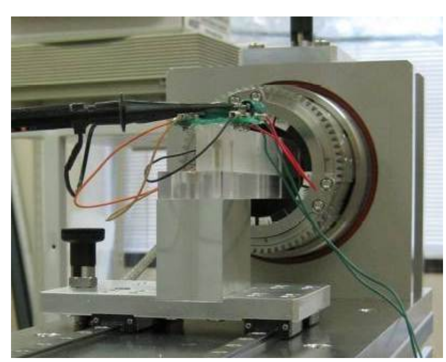

Figure 8: Magnetic center measurement.

as a function of the rotation angle. The maximum strength was 6.8 T, which is consistent with the designed value. The strength goes down to almost zero as expected.

When we set the usable range as from 1T to 6T, the variation of the quadrupole plane tilt is less than 1 m rad.

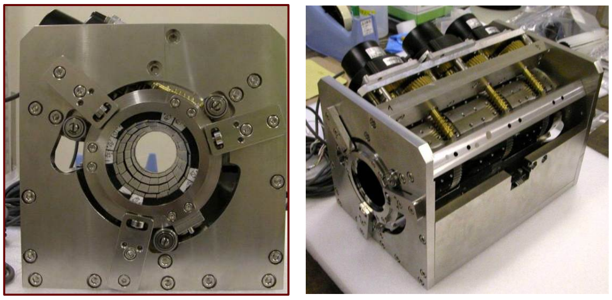

Figure 9: Fabricated five-ring-singlet quadrupole magnet. Left: A hole for the outgoing beam position is located. Right: Three ultrasonic motors drive the rings; even numbered rings are connected together and driven by the center motor.

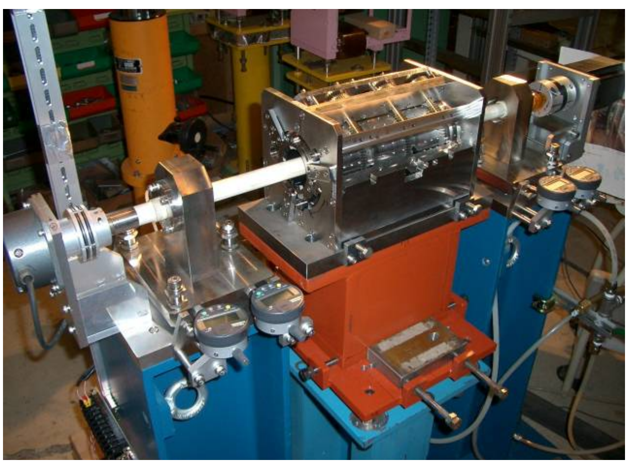

Figure 10: Rotating coils system at KEK.

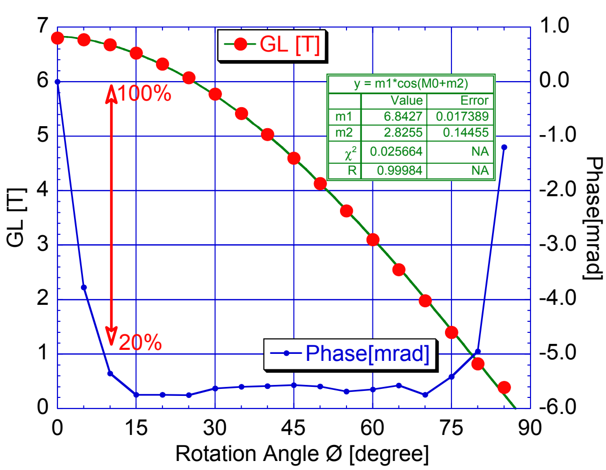

Figure 11: Integrated field gradient as a function of the rotation angle. The quadrupole plane tilt is also plotted.

Figure 12 shows the magnetic center excursions as functions of the rotation angle. There are three sets of measurement data, which showed a good reproducibility.

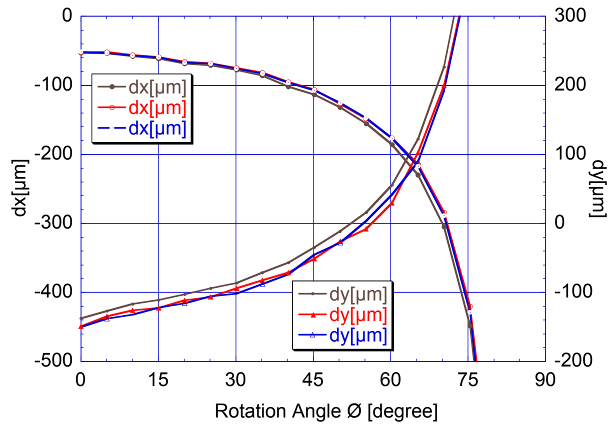

Figure 12: Magnetic center excursion as functions of the rotation angle. Three lines correspond to three runs of measurements.

DISCUSSIONS

The absolute values of the excursion would be improved by further corrections on magnetic centers of five magnet rings. We are preparing an improvement on the rotation mechanism so as to get more reproducibility and stability, which will be reported soon.

Preparation work aiming at installation of this magnet to the ATF2 beam line is going on. It needs a table with a mechanical XY mover to adjust the magnet position, and a vacuum beam pipe with a beam position monitor. Because the magnet cannot be separated like an ordinary electromagnet, the vacuum beam pipe needs a special structure whose flange should be furnished after the pipe is inserted in the magnet bore. We may tig-weld the flange afterward.

Originally, the magnet was designed as a replacement for the QD0 electromagnet. This is the reason why it has larger bore. But if we can find a good location for just an evaluation of stability and its ability, we can make the tests without a big interference with the other ATF2 tests. Thus, we are discussing about such a position.

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