BEAM TEST PLAN OF PERMANENT MAGNET QUADRUPOLE LENS AT ATF2*

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Abstract

A prototype of a permanent magnet quadrupole lens for ILC final focus doublet is fabricated. In order to demonstrate the feasibility, it will be tested in a real beam line. Such practical experiences include its shipping, storage, handling, installation, alignment technique, and so on. Because permanent magnets cannot be switched off in contrast to electromagnets, they should be removed from beam lines when no interference is desired and the process should be quick with enough reproducibility. The magnetic center and strength stability including reproducibility are also important issues during the beam test. In order to reduce interferences with current ongoing testing items at ATF2, the magnet will be installed at a further upstream position of the ATF2 beam line. The installation and test plan will be described.

INTRODUCTION

At the interaction point of ILC, very narrow beams with beam sizes of the order of one nanometer have to collide. In order to achieve this, a strong and stable final focusing system is needed. Although the one with superconducting technology is a natural choice as the base line technology of the final focus system for ILC, the slender structure may suffer from vibrations and the transported beams may wobble. If the magnitude exceeds the controllable tolerance of feedback system, a difficult situation may arise. Permanent magnets, however, do not have any vibration source in them at the steady state. A slow drift that may come from temperature change or long term demagnetization can be compensated by the feedback system or in a periodical adjustment. Although quadrupole magnets made of permanent magnet material can be fairly strong compared with electromagnets that use iron poles and suitable for the final focus system, adjustability is desired as with optics devices during the beam tuning time.

5-RING SINGLET VARIABLE PMQ

In order to add such adjustability to a permanent magnet system, a 5-ring singlet configuration was adopted (see Fig. 1) [1,2,3]. The train of permanent magnet quadrupole rings are rotated against each other to change the global strength. When each length has an appropriate length, a coupling between x and y beam plane can be eliminated.

In order to investigate the feasibility, a prototype was fabricated. It was originally designed for ILC that has an inner bore diameter of D24mm and the extra space for the outgoing beam. In order to realize the beam test at ATF2, the inner bore is enlarged to D50mm keeping the other dimensions the same. With Neomax 48H, the PMQ can generate a field gradient of 30T/m in the D50mm bore (see Fig. 2).

Each magnet piece has 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. Only the four pole segments are pulled inward, and others are pushed outward. Thus, a special jig was prepared to assemble the magnet segments.

While it uniformly inflates the inner bore, the screws are adjusted to correct the segment positions; these screws

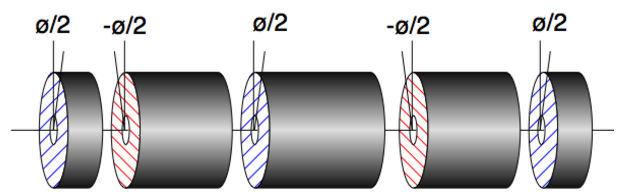
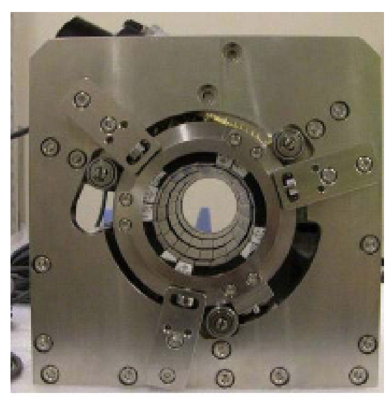


Figure 1: The 5-ring-singlet. The odd numbered rings and the even numbered rings are rotated against each other. Magnet rings with right lengths can eliminate the x-y coupling in the beam planes.



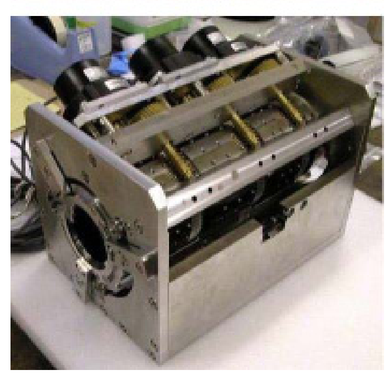


Figure 2: Variable strength PMQ with 5-ring structure.

only push the segments towards inside.

Ultrasonic motors are used to rotate the rings, so that this system can work under magnetic field from the detector magnet. The assembled unit was measured by a rotating coil system at KEK (see Fig. 3). Fig. 4 shows preliminary data of the measured integrated field gradient 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 mrad. Fig. 5 shows the magnetic center excursions as functions of the rotation angle. Although the excursion was large, three sets of measurement data showed a good reproducibility.

Since each PMQ ring is mechanically positioned by rollers to its outer surface of the holder, the magnetic center has to coincide with the mechanical one. Therefore the magnetic field of each PMQ ring was measured by rotating the ring by grabbing the magnet holder, which induces a voltage on a fixed coil placed in the bore (see Fig. 6). A pulse motor drives the magnet rotation chuck and a rotary encoder monitors the rotation angle. The coil radius is 2cm and the return path is located at the rotation center. The coil voltage is amplified by a +26dB preamplifier and +20dB amplifier. The analogue signal is sampled by 24-bit ADC at 156kHz and about 800k data points are stored in a PC together with signals from a rotary encoder. The signal data is numerically manipulated and harmonic field components are scaled to those at 1cm radius. Because the raw information contains four periods, the noise level of the system can be estimated from the pedestal values that do not have harmonics number with multiples of four.

From the measurements, one magnet piece installed in the fourth ring was found to be labelled to a wrong measurement data, we replaced it with a better one and obtained a reasonable magnetic field in the bore (see Fig. 7). The other components, which have significant magnitudes, will be suppressed by further adjustments. Results of the final precise adjustment will be reported soon after the completion of series of measurements.

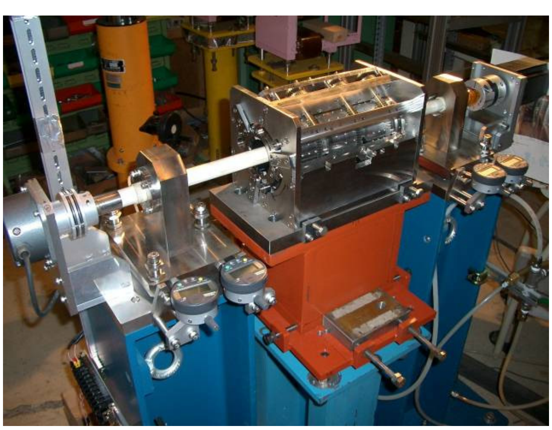


Figure 3: Rotating coil system at KEK.

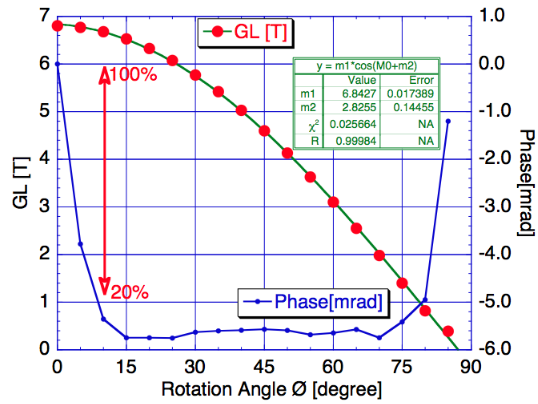


Figure 4: Integrated field gradient as a function of the rotation angle. The quadrupole plane tilt is also shown.

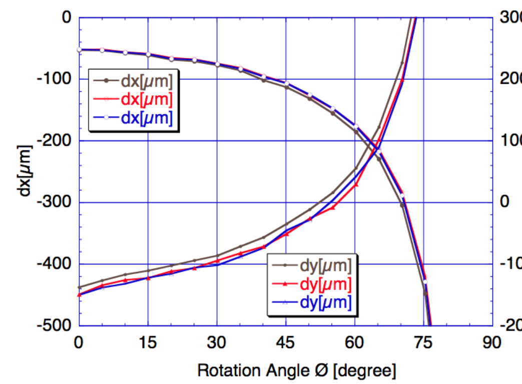


Figure 5: Magnetic center excursion as functions of the rotation angle. Three lines correspond to three runs of measurements, whose deviations are fairly small.

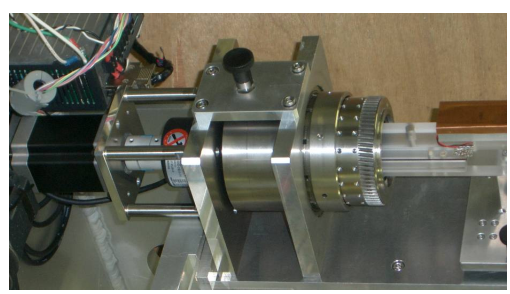


Figure 6: Each magnet is measured by rotating the ring. From left, a pulse motor, an encoder, a pillow block, a magnet rings, and a fixed coil are seen.

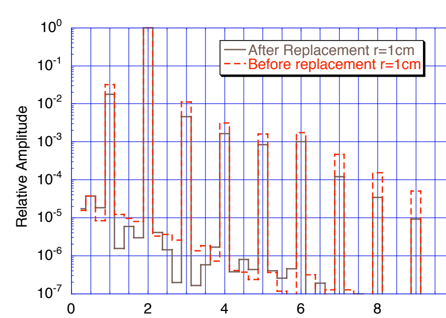


Figure 7: Field component change by replacing the bad piece in the fourth ring.

TEST AT ATF2

A test in a real beam line is an important process to evaluate the feasibility of the system. Since this type of optics device is new to us, practical experiences, which includes its shipping, storage, handling, installation, alignment technique, etc., is inevitable for real applications. For that purpose, the first beam test is planned at the ATF2 beam line. Although the magnet system is designed as one of the final focus system, initial test will be carried out at the upstream position to avoid any conflictions with the other activities around the final focus area (see Fig.8). The wire position monitors can be used to measure the beam movements caused by the system during the strength change by rotating the rings. X-Y coupling is of concern also.

The magnet system will be precisely aligned and adjusted by a mover. The prepared magnet mover can also evacuate the magnet system from the beam line without vacuum break, which enable us to evaluate the real magnet center by asking the beam about its deflection. The feature should also minimize any interference in a series of the machine time schedules.

CONCLUDING REMARKS

The precise adjustments of the magnet pieces in each PMQ rings with an initially prepared jigs seems to take much longer time than expected. We are considering another design of such jigs for an efficient procedure. The magnet system is planned to be installed in the ATF2 beam line after this summer.

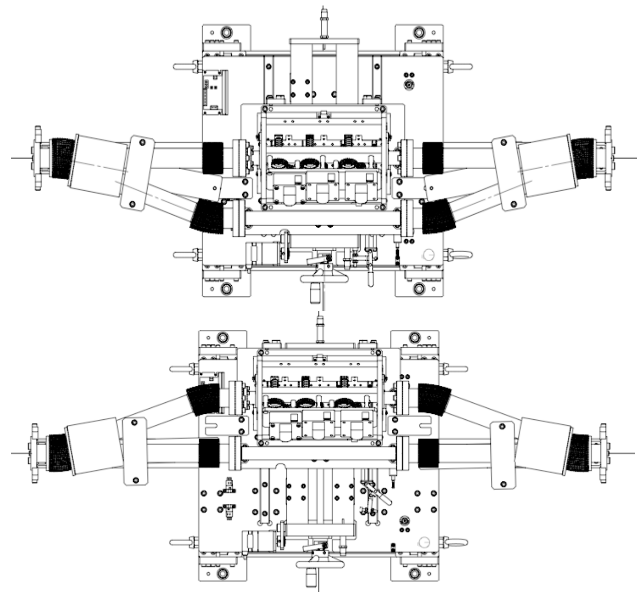


Figure 9: The magnet system can be evacuated instantly without vacuum break. Top figure shows in-line position, and bottom one shows off-line position.

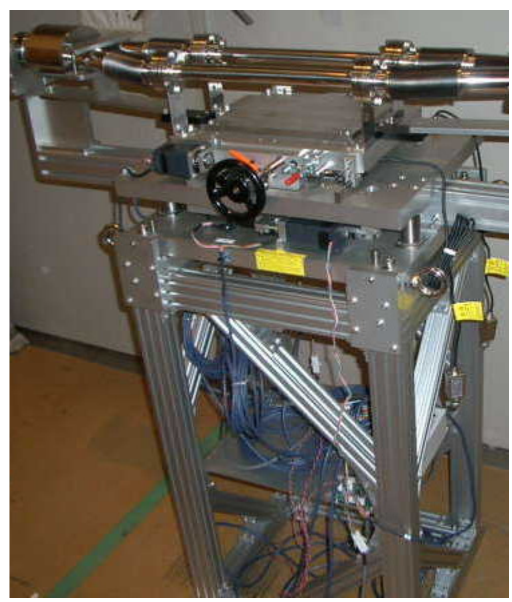


Figure 10: Fabricated magnet mover.

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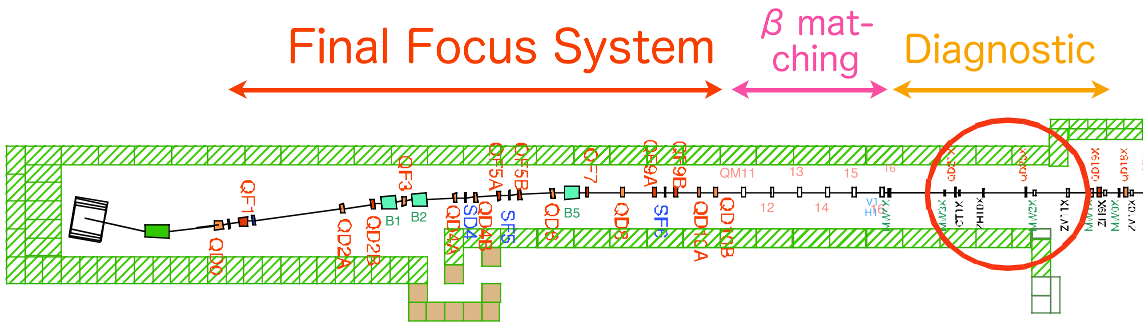

Figure 8: ATF2 beamline. The initial beam test for the PMQ system will be performed at the upstream position.