

CONSTRUCTION OF A TEST MAGNET FOR JLC FINAL FOCUS

K. Fujii, M. Kikuchi, K. Kuno*, S. Kuroda, T. Matsui,
H. Nakayama, K. Oide, T. Tauchi and N. Yamamoto

National Laboratory For High Energy Physics(KEK),
1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305 JAPAN

*Mitsubishi Electric Corporation, Kobe Works,
Wadasaki-cho, Hyogo-ku, 625 JAPAN

Abstract

A 10 cm long test quadrupole magnet having a bore radius of 2 mm has been constructed with vanadium permendur as an R&D model for the final focus system of the future e^+e^- linear collider, JLC (Japan Linear Collider). The bore of the magnet is 4 times larger than that of presently planned final doublet. Measurements by a small Hall probe show that the quadrupole magnet produces a 700 Tesla/m field gradient in the region where the radius $<1/3$ the half aperture without any serious field deformation due to saturation effects.

Introduction

A TeV e^+e^- linear collider, JLC (Japan Linear Collider), is one of the most promising candidates for KEK's high energy accelerator following the TRISTAN e^+e^- collider [1]. Since the annihilation cross sections drop as $1/s$, where s is the squared center of mass energy, the luminosity required for the TeV collider is more than $10^{33} \text{cm}^{-2} \text{sec}^{-1}$. Therefore one of the most crucial questions to ask is whether we can realize a final focus system that focuses beams to a nano meter level.

In accordance with the present JLC parameters, design studies have been carried out for a final focus system that produces a 210 nm (H) x 1.7 nm (V) beam spot using conventional quadrupole magnets with a 1.4 Tesla pole tip field as a final doublet near the interaction point. The basic feature of the system is to use two families of sextupoles for correcting the chromaticities of the final doublet [2].

Following the conceptual design, experimental works are now under way to verify the design's feasibility within the scope of the present day technology.

In this paper we present the design, construction, and preliminary test results of our first R&D magnet.

Magnet Design

Design constraints for the final focus doublet near the interaction point are as follows: 1) The half aperture of the quadrupole is 0.5 mm with a pole tip field of 1.4 Tesla and the uniformity of gradients is better than 0.01% in the central region of $1/3$ the half aperture. 2) The outer radius of the magnet is less than 50 mm. The inner radius is determined so

as to let the $10\text{-}\sigma$ envelope of the beam go through without any disturbance from materials, and the outer radius is restricted by the detector acceptance for physics experiments.

We decided, however, to make a test magnet with a bore radius of 2 mm, since techniques at hand should be good enough to precisely measure fields in such a test model and also since the experimental verification of our field calculation for the test model should justify the extrapolation to the JLC final doublet.

To design the test quadrupole magnet, we used a computer program JMAG [3]. Prior to the detailed geometry design of the pole tip shape, we made a rough calculation with various B - H curves to select materials which can produce a 1.4 Tesla pole tip field that corresponds a field gradient of 700 Tesla/m. The gradients at the highest excitation are sensitive to the choice of material parameters. The calculation showed that the required B - H property is characterized by $B_{25} > 2.10$ Tesla and $B_{100} > 2.35$ Tesla, where B_{25} and B_{100} are magnetic flux densities at $H = 25$ Oe and $H = 100$ Oe. This means that we need a saturation magnetization higher than that of conventional soft iron. We found the condition can be satisfied by vanadium permendur (49% Fe, 49% Co, 2% V).

Using the B - H data for a sample of vanadium permendur, we optimized the shape of the pole tip to keep the uniform gradient region as wide as possible. Fig. 1 sketches the geometry of the pole tip

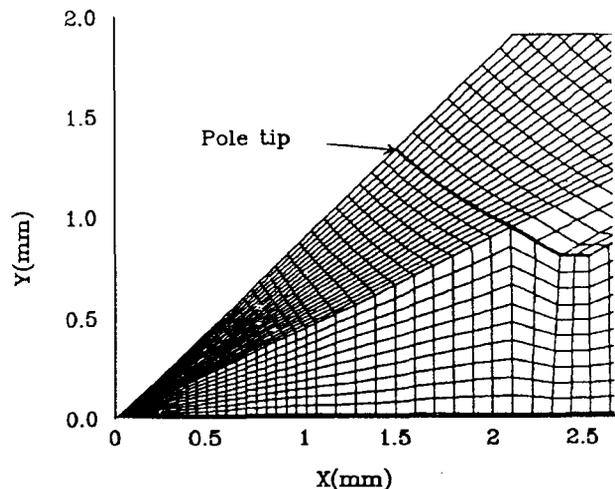


Fig. 1 Geometry of pole tip and mesh in JMAG.

together with the mesh used in the calculation. Fig. 2 shows the expected field gradient inside the magnet when we supply a current of 1500 AT. In the region $r < 1/3$ the half aperture, the uniformity is expected to be better than 0.01 %.

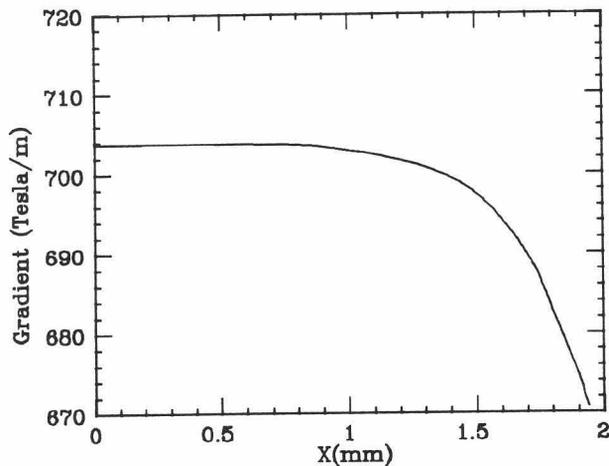


Fig. 2 Expected field gradient (1500 AT).

Construction and Testing

The quadrupole yoke was machined from a single piece block by a wire-EMD (wire electrical discharge machine) and the geometrical accuracy is better than 5 μ m. The current is supplied by five turns of water-cooled conventional hollow conductors, 6 mm ϕ (outer dia.) x 4 mm ϕ (inner dia.). The maximum excitation requires the current of 300 A corresponding to 1500 AT in total. Fig. 3 is a photograph of the magnet whose parameters are summarized in Table 1.

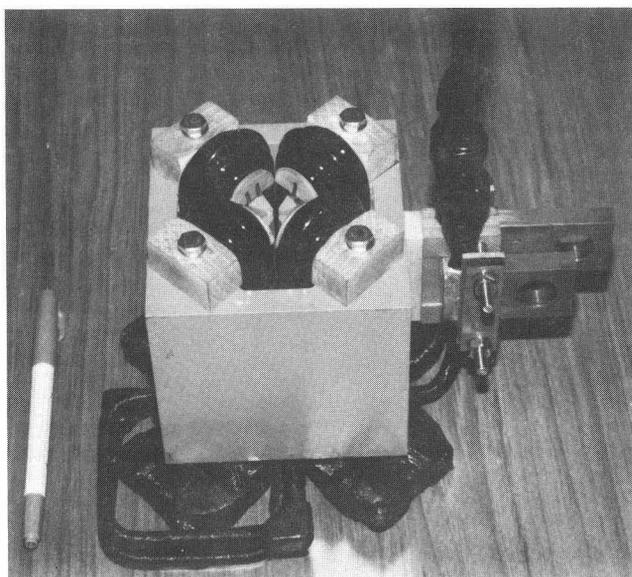


Fig. 3 Photograph of the R&D magnet.

Table 1
Parameters of The R&D Magnet

Bore diameter	4 mm ϕ
Pole length	100.5 mm
Field gradient	700 T/m
AT	1500 AT/p
Current	300 A
Resistance	7.92 m Ω
Voltage	2.4 V
Cooling water	
Flow	0.75 l/min
Pressure drop	0.34 kg/cm ²
Velocity	1 m/sec

We excited the magnet and performed preliminary measurements of the field quality using a small Hall probe (FC - 32, Siemens). The Hall generator has a 2 mm x 3 mm sensitive area and is placed in a ceramic box which has a dimension of 6 mm(W) x 12 mm(L) x 1.5 mm(H). The probe was calibrated by NMR in a dipole magnet. Coefficients of a 12th order polynomial were fitted to the data of the relationship between output voltage of the Hall probe and the field strength. The error in the calibration was estimated to be less than 0.5 Gauss.

Fig. 4 gives the excitation curve measured by the Hall probe placed at (x, y) = (0.8mm, 0.0). The results are almost consistent with the calculation and show a field gradient greater than 700 Tesla/m at the full excitation.

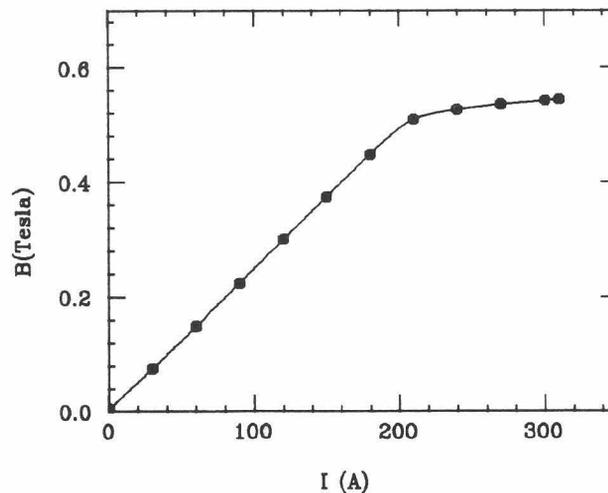


Fig. 4 Excitation curve measured by the Hall probe placed at (x, y) = (0.8mm, 0.0).

Fig. 5 plots the field strength on the median plane ($y=0.0$, $-0.8 \text{ mm} < x < 0.8 \text{ mm}$). The field gradient uniformity was confirmed to an accuracy of 1%, although the required accuracy was not achieved yet because of the positioning error of the Hall probe. Nevertheless the present results strongly supports the feasibility of constructing a 1.4 Tesla/m quadrupole magnet having a bore radius of 0.5mm.

We are now constructing a positioning device using techniques that have been developed in JLC alignment R&D [4]. The system can control the probe with an accuracy of 10 nm using piezo transducers as a drive unit and laser interferometers as a monitor unit. With this device, we expect to be able to measure the field to an accuracy of 0.01% in near future.

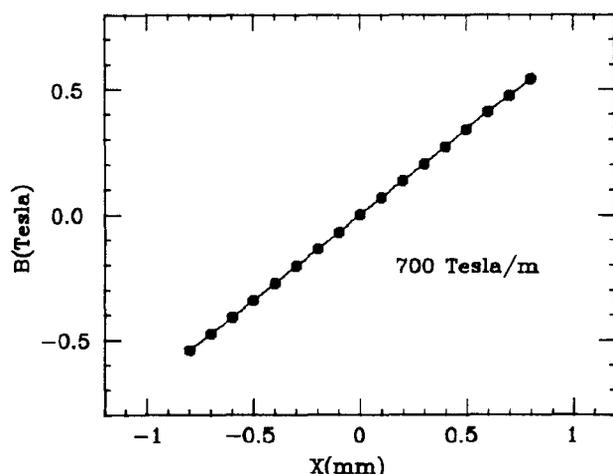


Fig. 5 Field strength on the median plane ($y=0.0$, $-0.8 \text{ mm} < x < 0.8 \text{ mm}$) at the full excitation of 700 Tesla/m.

Summary

We have constructed and tested a 10 cm long R&D quadrupole magnet, which has a bore radius of 2 mm, with vanadium permendur (49% Fe, 49% Co, 2% V). The magnet has a 4 times larger bore of the JLC final doublet. The magnet has produced a design field gradient of 700 Tesla/m without any serious field deformation due to saturation effects by using a material with high magnetization property. The results from preliminary field measurements strongly suggest the validity of the design calculation. We thus believe that the construction of the JLC final doublet is quite feasible using techniques at hand.

Acknowledgement

We would like to thank professors Y. Kimura and S. Iwata for their support and encouragement.

References

- [1] K. Takata and Y. Kimura, KEK Preprint 89 -124 (1989). S. Takeda, Particle Accelerators, Vol. 31,143-152(1990), Proc. 14th International Conf. on High Energy Accelerators, Tsukuba, Japan, 1989.
- [2] K. Oide, KEK Report 90 - 20, Proceedings of the First Workshop on Japan Linear Collider, KEK, 1989.
- [3] Developed by Japan Information Service Ltd., Tokyo, Japan.
- [4] N. Ishihara et al., Particle Accelerators, Vol. 31, 57-62(1990), Proc. 14th International Conf. on High Energy Accelerators, Tsukuba, Japan, 1989.