A Three-dimensional Magnetic Field Mapping System for Deflection Yoke of Cathode-Ray Tube

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Abstract

In this paper, we introduce an efficient three-dimensional magnetic field mapping system for a Deflection Yoke (DY) in Cathode-Ray Tube (CRT). A three-axis Hall probe mounted in a small cylindrical bar and three-stepping motors placed in a non-magnetic frame were utilized for the mapping. Prior to the mapping starts, the inner contour of DY was measured by a laser sensor to make a look-up table for inner shape of DY. Three-axis magnetic fields are then digitized by a three-dimensional Hall probe. The results of the mapping can be transformed into various output formats such as multipole harmonics of magnetic fields. Field shape in one, two and three- dimensional spaces can also be displayed. In this paper, we present the features of this mapping device and some analysis results.

Keywords : three-axis magnetic field mapping, Hall probe, laser sensor.

1. Introduction

A DY in CRT is a magnetic device which deflects electron beams to a desired point on the screen. A DY consists of vertical and horizontal coils and a ferrite core, and/or convergence coils. CRTs are required to have a wider flat screen, and a thinner depth to make them competitive to other display devices such as LCD or PDP etc.. In order to meet these requirements in CRT, a large deflection angle is an indispensable feature that can keep convergence and distortion error under the certain level. This however, will make the DY more complicated, and moreover, will take a long time to develop it.

To overcome all these conditions, it will involve intensive works such as conducting simulations on beam optics, precise magnetic field measurement, analysis, fabrication, and other experiments. Various techniques to reduce the mis-convergence, distortion, etc. have been developed to improve the DY quality [1, 2]. Some sensors to measure the field of DY were applied such as a rotating coil [3], flip coil [4] and Hall sensor. The Hall sensor has been widely used in magnetic field measurement because of its easy usage as well as its high accuracy.

We have developed a three-dimensional Hall probe mapping system for DY. In this paper we describe a system configuration and the methods of protecting Hall probe in an abnormal situation. The methods of measuring the inner contour for both round and rectangular DY type using the laser sensor are explained here as well. The mapping process and various output forms for analyzing the field are shown.

2. Measurement System

The measurement system consists of four stepping motors, PLC, gauss meter, computer, laser sensor and

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mechanical frame for supporting motors and platform mechanism for placement of the DY. The block diagram of the field mapping system is shown in Fig. 1.

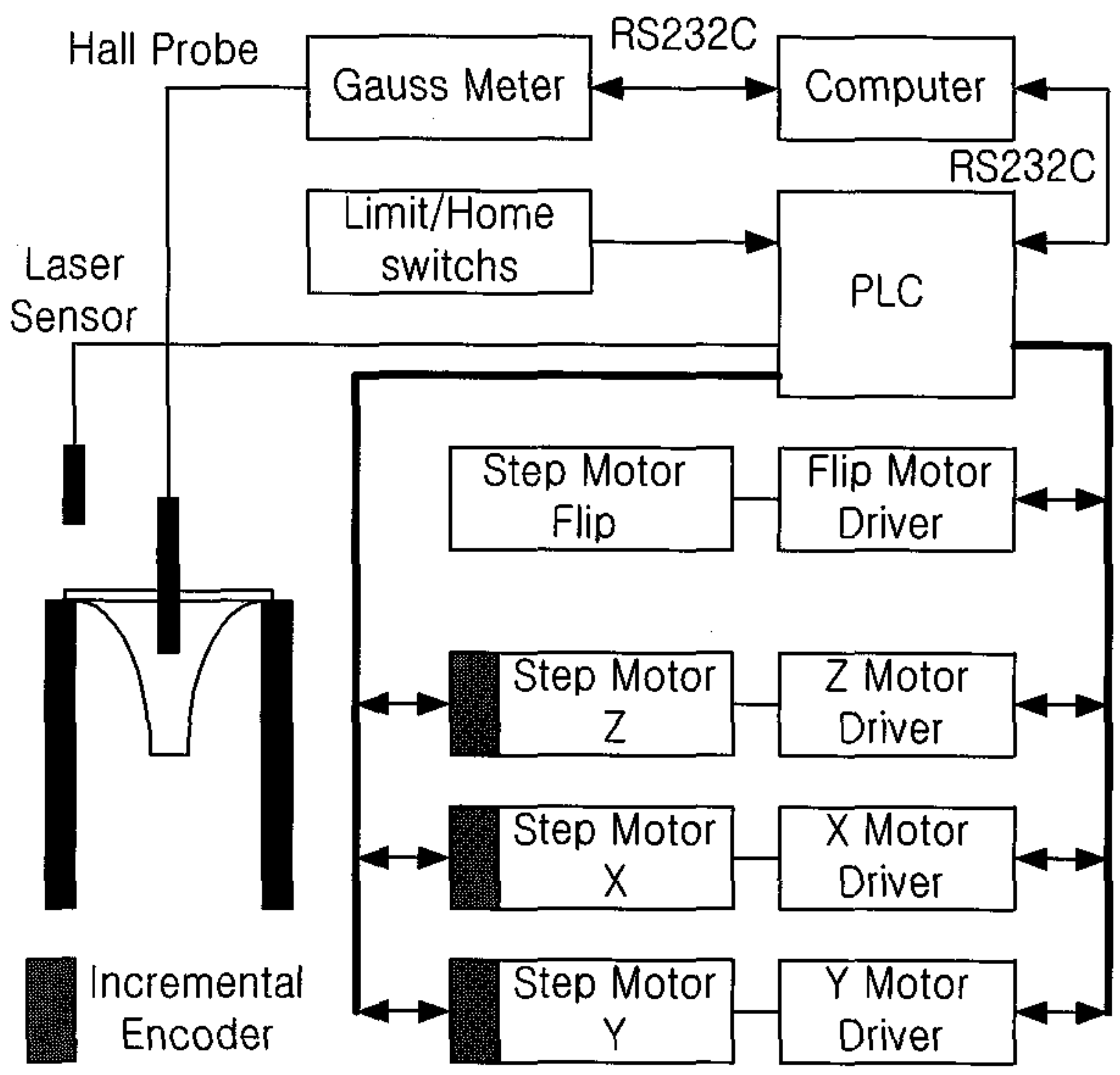

Fig. 1. Block diagram of the three-dimensional mapping system.

Three-stepping motors were used to were the Hall probe and the laser sensor to the desired positions in three-dimensional space, and the other to flip the laser sensor from 0 to 90 degrees to minimize measurement error by the laser sensor by aligning the laser beam shape parallel to the inner plane of the DY where the beam shape is similar to a tiny rectangular about 0.5 mm × 1 mm.

The platform on which the DY was laid was aligned in both the x- and y-axis using a dial gauge which was temporary placed at the Hall probe position during the alignment. The dial gauge was moved along the x-axis and then along the y-axis by the driving stepping motors. Then how much discrepancy between platform and motor axis existed was examined. The platform position was adjusted to have a good alignment with each motor axis of within 20 μm.

The model 7030 gauss meter and Series 7000 three-axis Hall probe of F.W. BELL were used. The gauss meter had an accuracy of ±0.5 % in DC mode and temperature stability ±(0.02 % of reading ± 1 count) / °C maximum. The normal active area of the Hall sensor was 1.8 mm^2.

If an instantaneous AC power failure occurred during the mapping, current position of each axis motor would be lost and physical position of each motor in PLC would be initialized to zero. This is necessary because when logical positions in computer are different from the actual position of the Hall probe, it is probable that the Hall probe will hit the inside surface of the DY to the extent of becoming damaged. In order to protect the Hall probe from such dangerous outcome, the PLC is always monitoring the AC power status. If the PLC detects a power failure, the mapping process would stop and inform the computer of the status of such power failure at the PLC.

Different counter values between incremental encoders attached to the each x-, y- and z-axis and pulses which had been fed to the stepping motor on each axis were monitored during the entire mapping period to detect any discrepancies. If its accumulated value is larger than 1 mm, the mapping process stops automatically, and this status is displayed on the monitor screen. The control program is run under Windows 2000 with menu driven method and written in visual C++.

3. Contour Measurement

To get the inner contour of DY for field mapping is one of the necessary procedures of gathering information on the space to be measured. The Hall probe should be moved inside a DY without touching the DY coil or frame to prevent it from the damage. The laser sensor LM10-250 of NAIS Co. was utilized to measure the inner contour of the DY. The LM10-250 has the measurement range of 250 mm and the linearity error of ±0.4 % in full scale. The sensor output was averaged to have minimum random fluctuation of up to 10 data sets. Its accuracy always is within ±0.1 mm. The laser sensor was installed upside-down on top of the DY. In the case of a round-type DY the laser sensor scans the depth of the DY by moving from the outer radius to the center position by 1mm step. These scan data sets were applied to solve the circular equation to get the x and y position values at a specified depth along the inner surface contour, ranging from 0 to 120 mm at a 1mm step along the the z-axis. The measured inner shape of the DY is shown Fig. 2.

Measuring the inner contour of a rectangular DY is more complicated than a round type DY and we have used a very sophisticated procedure to identify the inner contour of a rectangular DY which will not be described here.

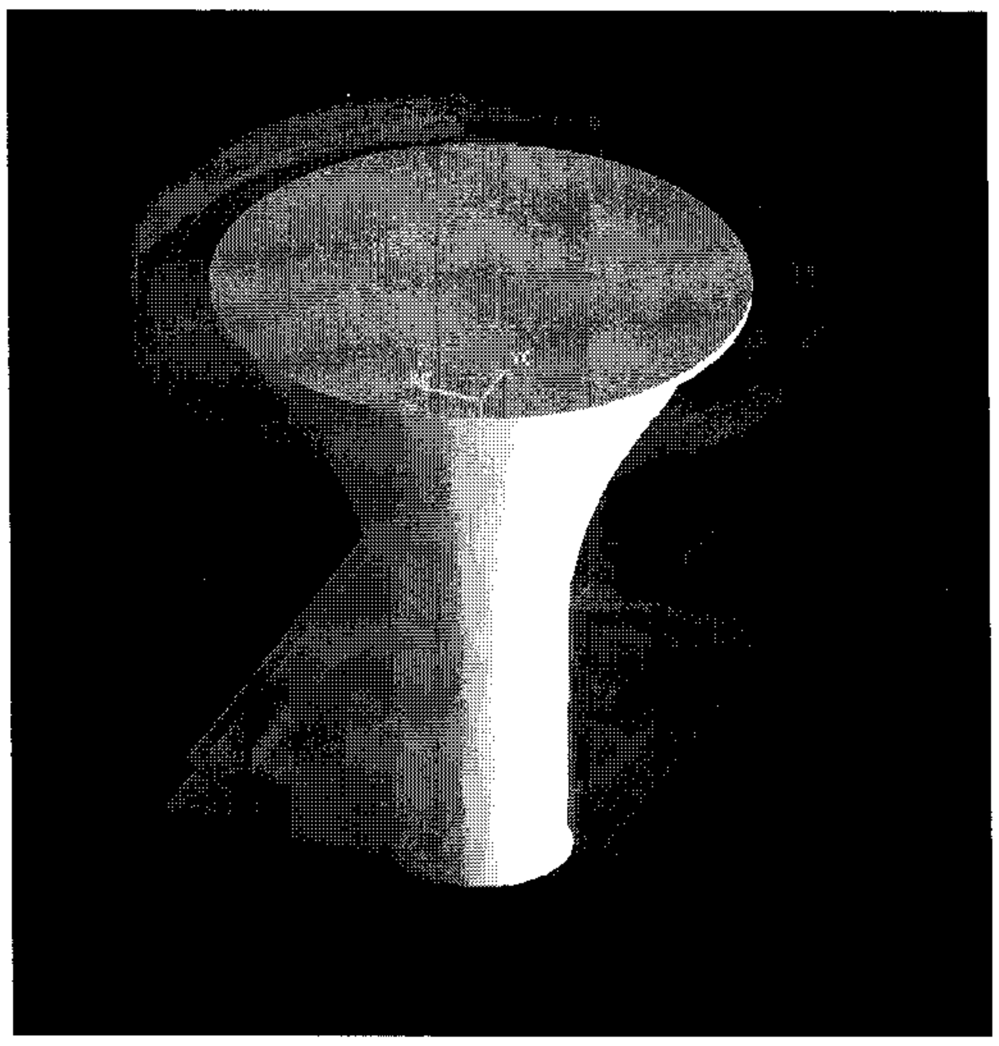

Fig. 2. Inner contour shape measured by laser sensor.

From these steps, the minimum step for mapping was fixed to 1 mm in the three-dimensional space. The Hall probe size and the safety margin were taken into account when the final table was constructed to protect the mapping system.

4. Field Mapping

At first, sample DY to be measured was placed on the platform. The DY was moved to the center position in the x-y plane using four non-magnetic steel rods, which could be moved only the inward and outward directions and tightly guided by through holes in four support-poles. Four rods were divided into two pairs, one pair was on the x-axis to adjust the DY to the y-direction, and the other was for x-direction. The z-axis alignment was dependent upon the flange thickness of the horizontal coil.

The Hall probe was continuously moved up or down within 4mm to keep a distance 10 mm between the flange plane of the DY and the initial position of the Hall probe. The gauss meter, including the Hall probe, had to be calibrated to zero gauss using the zero-gauss chamber. The Hall probe was moved to home positions in the x-, y- and z-axis to set all counters, encoders and driver pulses to zero.

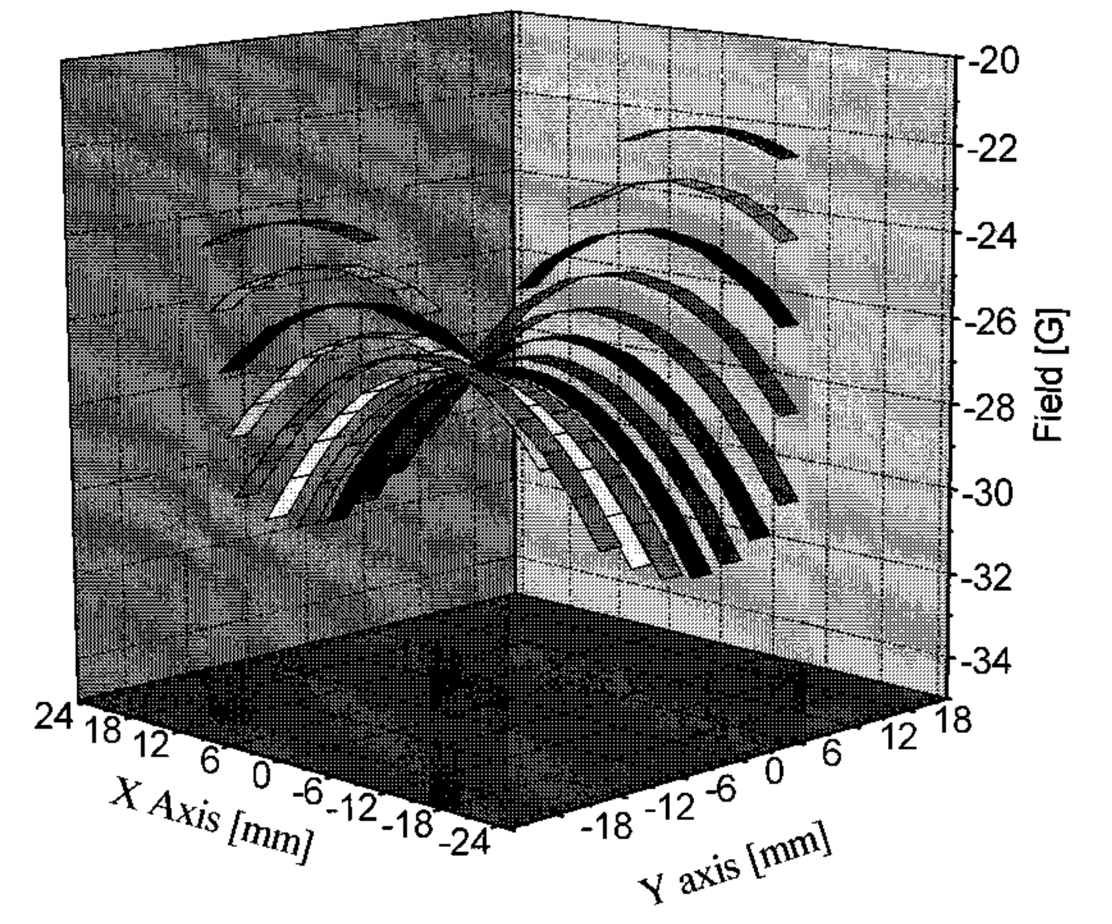

Fig. 3. Measured horizontal magnetic field at 20 mm in z-axis.

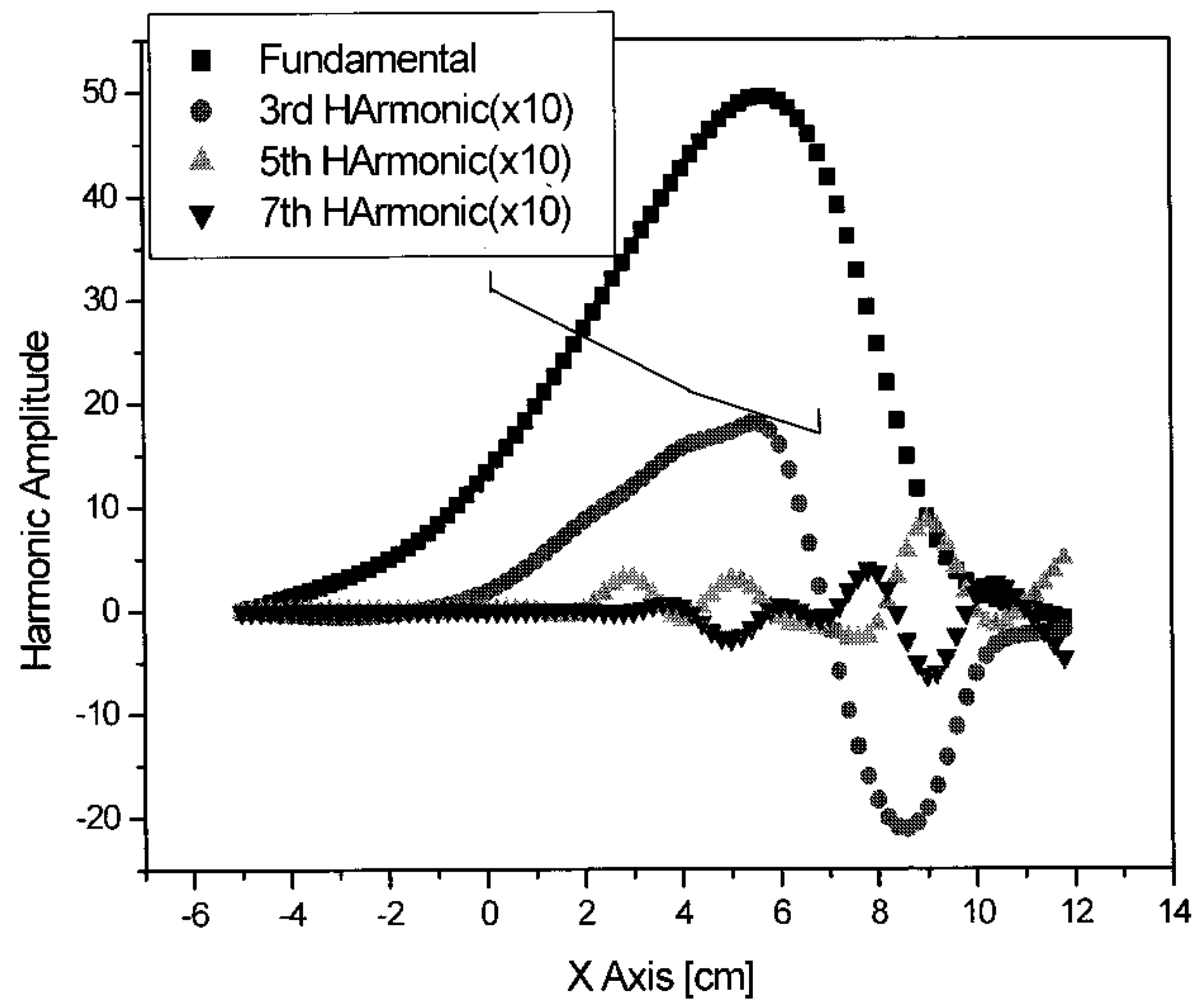

Fig. 4. Fundamental, third, fifth and seventh harmonic components of the horizontal field.

Mesh size (i.e., mapping interval) for each axis on both outside and inside of the DY were given separately to reduce the mapping time. With a given mesh size for each axis, a look-up table containing all the positions to get the magnetic field value was constructed. The range of z axis was limited from −50 mm to 120 mm. The mapping system can also measure the magnetic field in a localized region only. The x- and y-axis fields were measured at the same position. This can be done by first measuring the y field and shifting the probe by 1.1 mm, which is the distance between the two sensors. The measured field shape at 20 mm in depth is shown in Fig. 3.

The fundamental, third, fifth and seventh harmonic components of the horizontal fields at the center position along the z-axis are shown in Fig. 4. The multipole components were obtained by utilizing a polynomial fitting program. In Fig. 5, the vectorial form transformed from measured data is shown.

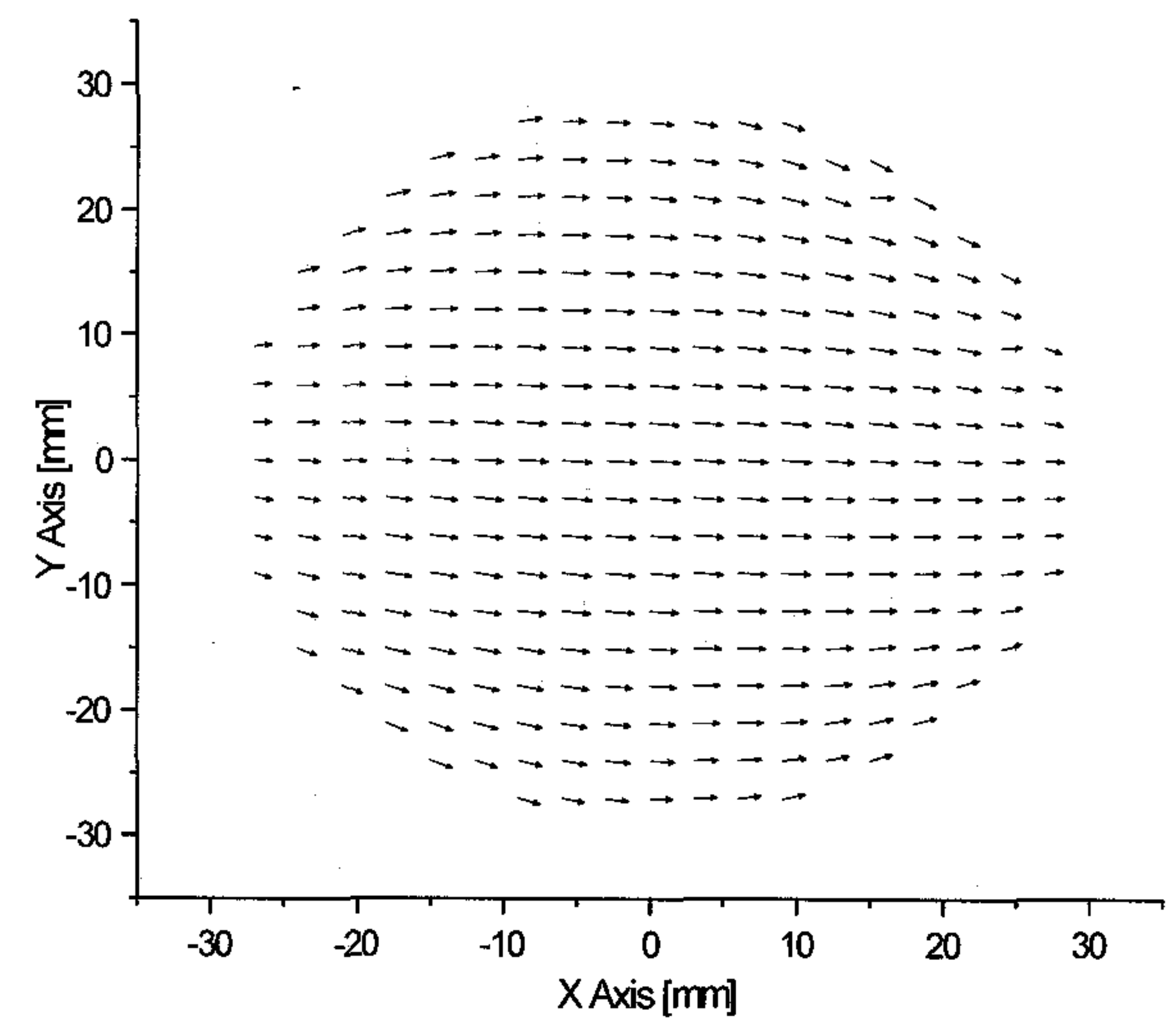

Fig. 5. Measured field data transformed to the vectorial form.

The output data could be easily manipulated to various types and can be used for multipole analysis, trajectory calculation, aberration calculation, etc.

5. Conclusions

A three-dimensional field mapping system using the Hall probe was constructed for the DY. This system has many features: (a) it is very easy to align the DY to the center position; (b) the inner contour of the DY can be measured with a laser sensor; (c) it is very safe in operation by monitoring the AC power status and encoder clocks of each axis; and (d) it is very convenient to use with Windows OS. Both the x and y components of the magnetic fields were measured at the same position, which reduced the measurement time and made the measurement more precise by eliminating the Hall probe drift with time. The output data could be easily sorted to the other formats for the purpose of modeling, simulation, drawing, and so on. We confirmed that the output data were very helpful in developing a new DY.

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