MEASUREMENT OF WIRE ALIGNMENT IN ELECTRIC SEPTUM BY USING A LASER-FOCUS DISPLACEMENT METER

Y. Arakaki, M. Tomizawa, N. Tokuda, and Y. Mori
KEK, High Energy Accelerator Research Organization
1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305-0801, Japan
S. Shibuya
Sumitomo Heavy Industries, LTD, Yato 2-1-1, Nishi-Tokyo, Tokyo 188-8585, Japan

Abstract

At an electrostatic septum used for slow extraction in a synchrotron, alignment of the septum wires is an important issues. The reason for that, with poor alignment, the wire thickness seen by the beam is effectively large, and consequently many particles hit wires and are lost. We measured alignment of wires fixed to a short test piece by using a laser-focus displacement meter. The wires, 80 μm in diameter, are aligned with a spacing of 1.25 mm over a length of 100 mm. The measured alignment error is $\pm 15\,\mu$m.

1. Introduction

The accelerator complex of the JAERI/KEK Joint Project comprises a 400MeV Linac, a 3-GeV, rapid-cycling synchrotron, and a 50-GeV synchrotron[1]. In the high intensity accelerators, beam loss cause harmful issues such as radio radio-activation and radiation damage for device. A criterion for beam loss was set to be less than 1%, which is required radiation safety[2]. At the slow extraction in 50-GeV, an electrostatic septum (ESS) will be used. Design parameters of the ESS is listed in Table 1. A beam tracking simulation for an extraction scheme using an third-order resonance predicts that was the beam loss will be ~1.0%, if the diameter of septum wires is 100 μm [3]. The beam loss occurs mainly when protons hit septum wires [4]. The wires should be therefore as thin as possible, and aligned precisely. For R&D of the ESS we fabricated a 0.7-meter-long ESS, whose cross section is shown in Fig. 1 [5]. The material of the yoke and cathode is stainless steel (SUS304), and that of the wires is tungsten-rhenium alloy (W 97%, Re 3%). The wire diameter is 80 μm, and the spacing is 1.25 mm. Through high-voltage test, we have achieved a voltage of 210 kV or higher with a wire-cathode gap of 25 mm. Prior to the R&D ESS, in order to establish the technique of fixing wires to the yoke , we made a test piece. Its specification is the same as that of the R&D ESS except that the yoke length is 100 mm. We have measured wire alignment at the test piece by using a laser-focus displacement meter. The measurement and result are described in this paper.

Table 1: Design parameters of the ESS for the 50-GeV synchrotron

Deflection angle	0.2 mrad
Electric field strength	6.8 MV/m
Cathode Voltage	170 kV
Gap (wire-cathode)	25 mm
Septum wire diameter	80 μm
Wire spacing	1.25 mm
Cathode length	1.5 m

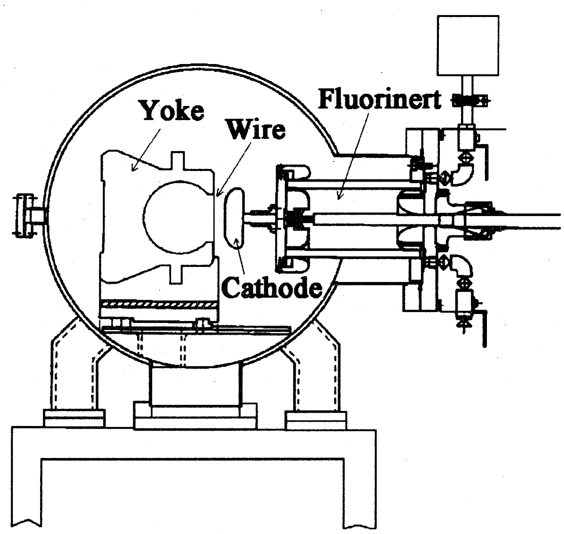

Fig. 1: The cross section of the R&D ESS.

2. A test piece for the ESS

The picture of a test piece is shown in Fig. 2. Seventy nine wires are aligned with a spacing of 1.25 mm over a length of 100 mm. Each wire is fixed to the yoke at it's upper and lower edges, where V-grooves are cut. A long wires wound spirally around the yoke so that the wire fit into the grooves; then the grooves were caulked, and the wire was cut into 79 pieces. The wire tension was 400 gf at the winding and~300 gf after fixation.

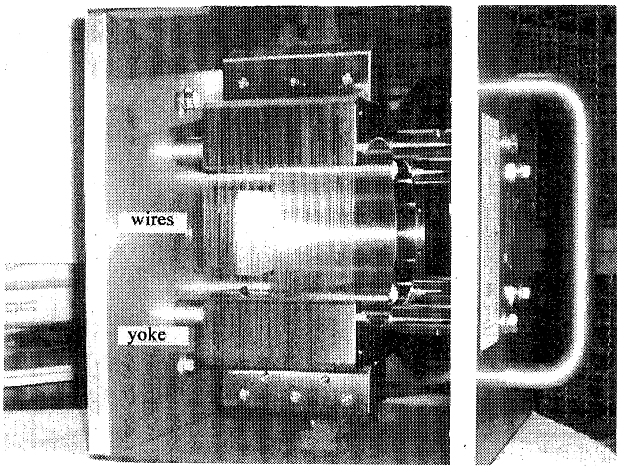

Fig 2 : Picture of the test piece.

3. Laser Focus Displacement Meter

Laser technique has been used to examine the surface profile on the material in many fields, such as surface science, medical science. We applied this technique to measure the alignment of the wires. Figure 3 shows the principle of the measurement. Semiconductor laser is used as light source, the laser passes through two half mirrors, a collimating lens, and an objective lens, then is focused onto the object. The laser reflected by the first half mirror enters a pin hole, and detected by an optical sensor. The objective lens is moved mechanically by the tuning fork. An LT-8010/8020 (KEYENCE) is used as laser head. The spot diameter is 2 μm. In this method, the distance to the object can be measured by detecting the position of lens when the laser is focused. Light other than the laser may enter the optical sensor, this light should be taken as a noise. The regulation of the light magnitude is set to eliminate the noise.

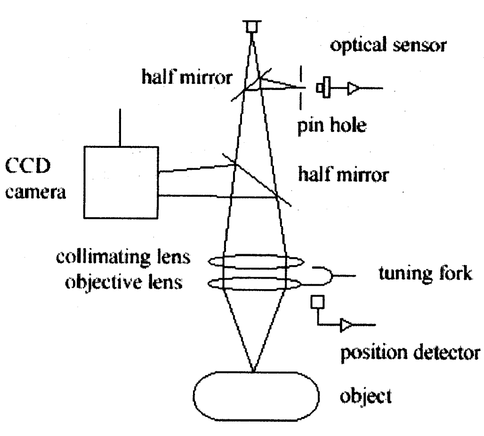

Fig. 3: Principle of a laser-focus displacement meter.

4. Configuration of System

A programmable 3D-mover was used to move the laser head. View of wire surface photographed with a CCD camera on the monochrome display. The set up for the measurement is shown in Fig. 4. The information of the laser-head position is obtained from an output of controller through an ADC board. The data processing is carried out by an personal computer.

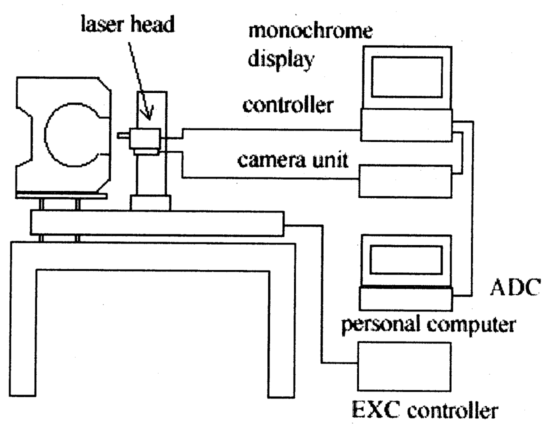

Fig. 4: Set-up for measuring the wire alignment.

5. Measurement

The laser head is run by 3D-mover with the speed of 0.1 mm/s along the beam axis. The resolution of the ADC board is set to be 0.5 μm/digit. The distance between laser head and the wire must be kept to be 5 mm$\pm$0.3 mm. The resolution of displacement in depth is 0.1 μm. The averaging number is set to be 16.

The displacement data of the wires is taken every 46 ms. Figure 5 shows the surface of a wire, where x and y axes indicates the direction in depth and the scanning direction, respectively. To evaluate the wire alignment, the top point on the surface of each wire must be recognized. A software which can calculate the top position of each wire is written in the Visual Basic. This program is useful when a large number of wires are aligned.

As shown in Fig. 6, a regular pattern is observed (some points with large x values indicate wires). This should be trace of the cutting on a fraise. Since the period of the pattern is 170 μm, and the wire diameter is 80 μm, wires may fall into grooves. This will make the wire alignment worse.

The wire alignment is shown in Fig. 7, where z axis is parallel to the wires. The base line ($dx = 0$) is determined by method of least squares. A large displacement was detected at the wire No.79, it would be due to manufacturing error at the yoke edge. The other wires

(Nos.1-78) are aligned within ± 15 μ m. This value contains errors coming from the roughness of the yoke surface, the movement of the 3D-mover. The accuracy of the 3D-mover will be measured by using a standard straight-edge.

6. Summary

The alignment of wires in test piece ESS is measured by a laser-focus displacement meter. The data taking system has been developed. The alignment error was ± 15 μ m except for a wire at an yoke end. The same measurement will be performed by R&D ESS whose yoke was finished to a roughness of ~1 μ m.

7. Acknowledgment

We thank M. Muto for his technical advice on the 3D-mover.

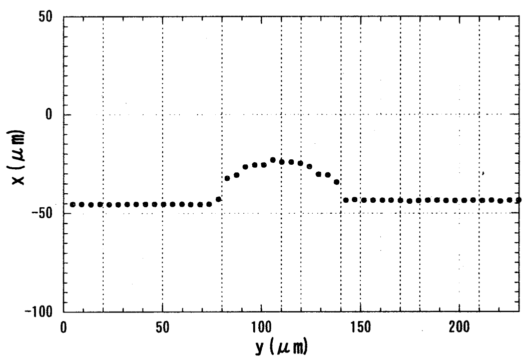

Fig. 5: Profile of a wire.

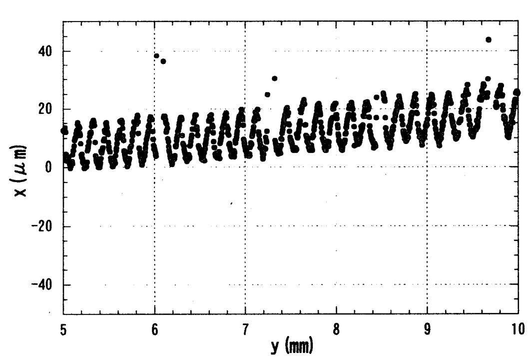

Fig. 6: Roughness on the surface of the yoke.

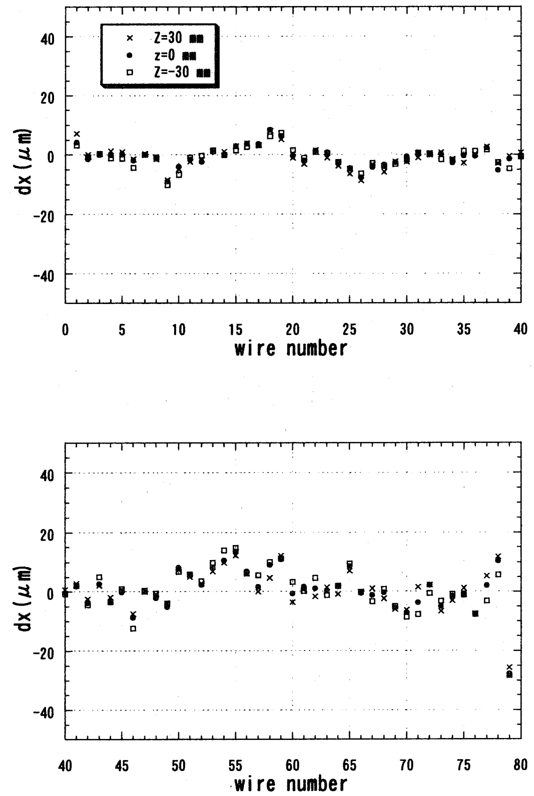

Fig. 7: Alignment error of the wires.

8. References

[1] Y. Yamazaki, "High-Intensity Proton Accelerators for the JAERI/KEK Joint Project", EPAC 2000 Proceedings.
[2] JHF Accelerator Design Report, KEK Report 97-16 (JHF-97-10), 1998.
[3] N. Tokuda, "A Design of the Slow Extraction System in the JHF 50-GeV Proton Synchrotron", Proceedings of the 11th Symposium on Accelerator Science and Technology.
[4] M. Tomizawa *et al.*, "Design of Small Beam-Loss Slow Extraction in a High Intensity 50-GeV Proton Synchrotron", EPAC2000 Proceedings.
[5] S. Shibuya *et al.*, "Development of an R&D Electric Septum for the 50-GeV Proton Synchrotron", EPAC 2000 Proceedings.