DEVELOPMENT OF THE NON-DESTRUCTIVE BEAM POSITION MONITOR USING AMORPHOUS MAGNETIC WIRES

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Abstract

This paper describes the development of the non-destructive beam position monitor. It is very important to develop the non-destructive beam position monitor for the precision operation of accelerators. We have developed the beam position monitor using amorphous magnetic wires. Magnetic field induced by electron beam are measured by means of one-turn pickup coils with amorphous magnetic wires. This system consists of the amorphous magnetic wires, pickup coils, monitor housing, XYΘ-stage and four channels fast response digitizing oscilloscope.

Introduction

A 35MeV S-band linear accelerator, producing a 10ps single bunched beam, has been operated since 1977 [1,2]. Many kinds of experiments have been made till now. It is very important to adjust the beam position for the experiments, such as plasma lens effect[3], plasma wakefield acceleration[4], free electron laser[5], magnetic pulse compression[6], and so on. For the adjustment of beam orbits, we usually use screen monitors. However, the measurement can not been made while monitoring the beam orbits, because the screen monitor intercepts the beam passage. It is necessary to develop non-destructive position monitor for simultaneous orbit monitoring.

In 1988, the beam current monitor using an amorphous magnetic core has been developed as the non-destructive type beam current monitor for measurement of the ultra-short current pulse shape[7-10]. The outputs of this beam current monitor using an amorphous magnetic core (ACM) do not depend on a transverse beam position, because the pickup coil winds on the whole region. However, if a pickup coil do not winds on whole region of the core, the leakage inductance can not be neglected. The leakage inductance depends on the position of the electron beam. By using this effect, a beam position monitor by using amorphous core was developed[11].

Recently, we developed a beam position monitor by using amorphous wire. It is thought that the more precision monitor can be developed by using wire than by using core, because the wire can be improved the precision of μm. To detect the magnetic field induced from electron beam with the pickup coils including an amorphous magnetic wire, it is necessary to have fast pulse response. If the response of the position sensors has not fast response, the pickup coil signals were not acquired. This paper describes the design and development of the beam position monitor for Nuclear Engineering Research Laboratory, Faculty of Engineering, University of Tokyo (NERL/UT).

Beam Position Monitor

The pulse magnetic field can be produced by the pulse current as follows:

$$B0(t)=\mu I(t) / 2\pi R.$$

where R is diameter of the beam duct, I(t) is wire current and μ is permeability.

The pulse fields Bn at each of the pickup coil locations are given by,

$$B1=B0(1+2\rho COS\theta),\ B2=B0(1+2\rho SIN\theta),$$
$$B3=B0(1-2\rho COS\theta),\ B4=B0(1-2\rho SIN\theta),$$

where $\rho= r / R$, r is displacement of the wire, R is diameter of the beam duct, I(t) is wire current and the displaced wire current is at an angle θ, distance r, relative to pickup coil B1. The pickup coil including amorphous magnetic wire is self-integrating position monitor for time scales $\Delta t << L / R$. The beam displacements ΔX, ΔY are given by,

$$\Delta X= R(V1-V3) / (V1+V3),$$
$$\Delta Y= R(V2-V4) / (V2+V4),$$

Therefore, by summing and differencing the four pickup coils, the beam position is calculated.

Monitor calibration

To calibrate of the position monitor, a wire test stand was constructed. The cross section view of the beam position monitor is shown in Fig. 1. The beam position monitor is calibrated by mean of current pulse through the copper wire. The position monitor using magnetic field was measured with wire test stand both horizontal and vertical positions. The difference of the pickup voltage depends on the volume of rectangle wire and the distance from wire currents as shown in Fig. 2(a). We measured the linearity of the position monitor on a wire test stand. A linearity between the wire current and the output voltage of position monitor is shown in Fig. 2(b). Here, by moving the housing case included amorphous magnetic wires, we obtained the mapping from the magnetic field induced by the pulse current of the wire. An example of the mapping is shown in Fig. 3. The resolution of the beam position monitor is within 1mm at area of 30mm x 20mm.

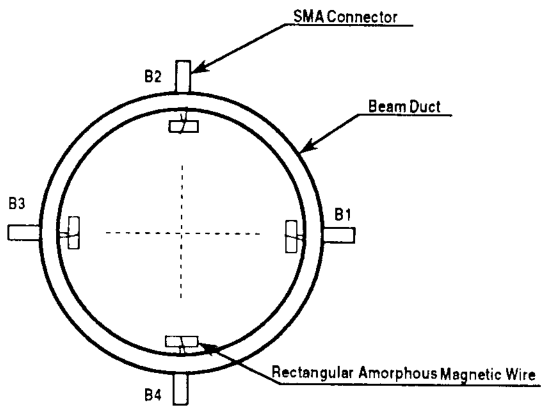

Fig. 1 Cross sectional view of the position monitor using magnetic field

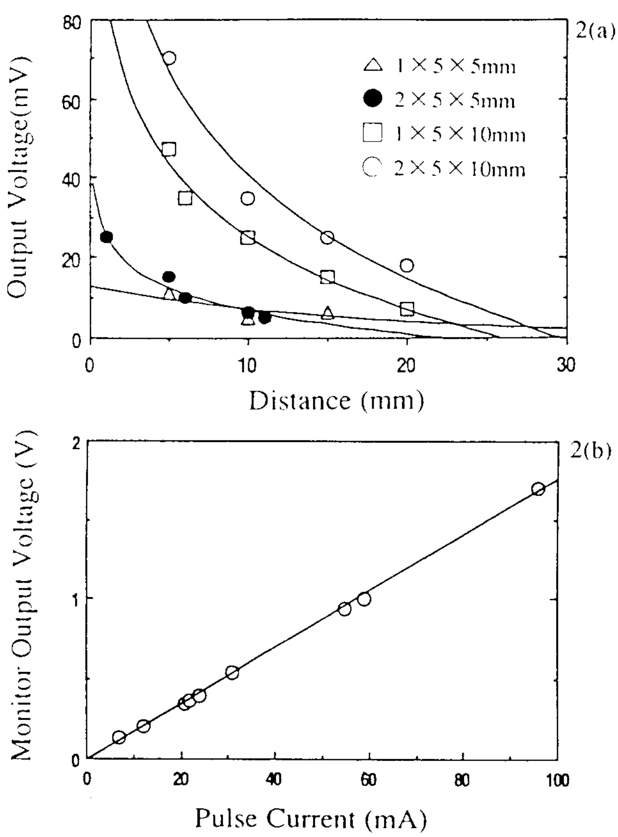

Fig. 2 Sensitivity curves including amorphous magnetic wire and linearity of output voltage versus pulse wire current

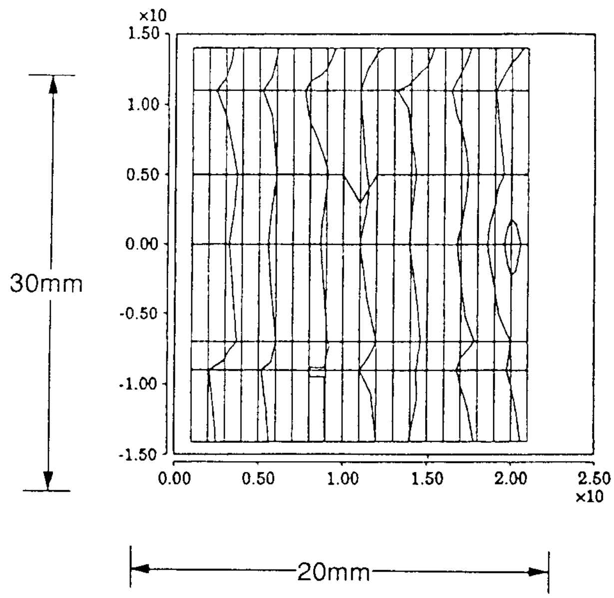

Fig. 3 A example of mapping at area of 30mm x 20mm

Results of beam test

The experiment of the position monitor was carried out using NERL/UT linear accelerator (Energy=28MeV, Pulse width = 1ns, Q= 100pC/ pulse). Preliminary experiment was performed to measure the four channels digitizing oscilloscope. The signals from pickup coils were measured at the measurement room. The semi-rigid cables (cable length 15m) were used as a signal transmission line. The beam was measured by using the digitizing oscilloscope. The beam diameter was within 3mmϕ at the exit slit of beam window. The pulse heights from each pickup coil were measured in the vertical , horizontal and Θ–stage directions using XY-stage manually. This monitor is mounted on

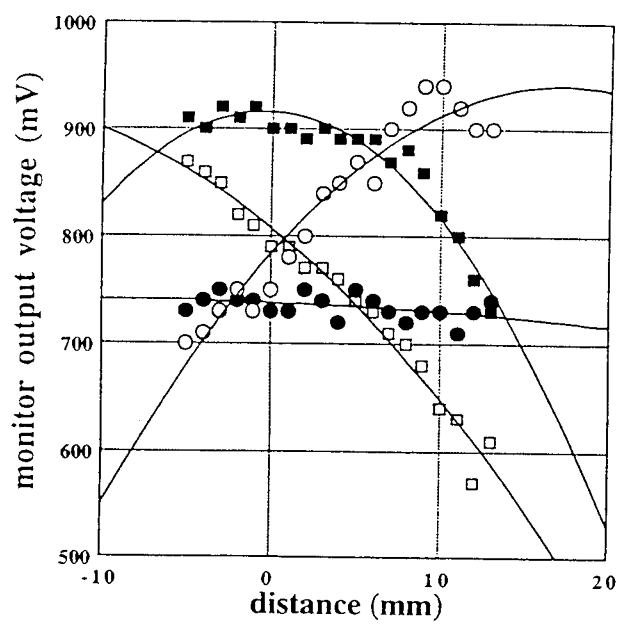

Fig. 4 The sensitivity curves of pickup coils

outside of a ceramic beam duct in the atmosphere. The beam test of this monitor carried out at the 28MeV linear accelerator. Semi-rigid cables are inserted in order to reduce the noise. Position information will be transmitted to the control room for fine tuning of the electron beam. The simplified equivalent circuit of this position monitor is transformer. Using the parameter of the transformer, the position monitor simulated by MICROCAP-3. The results of the measurements agreed with the simulation. The beam position monitor of the amorphous magnetic wires can be calculated by the ratio Δ / Σ (Difference / Sum) of the signals coming from two pairs of the pickup coils. The sensitivity curves of the pickup coils are shown in Fig. 6. Here, the output pulse height of the negative peak measured by the oscilloscope. Δ / Σ curves measured by moving the beam position monitor in the horizontal and vertical direction. Four pickup coils have good characteristics for beam position monitor. The accuracy and resolution of the beam position monitor are sufficiently to correct the orbit distortion.

Conclusions

The beam position monitor was tested using the 28MeV linear accelerator. The pulse width and peak current were about 1ns and 200mA respectively. By the experimental results, the resolution of this monitor within 1mm at area of 30mm x 20mm. The accuracy of the beam position measurement satisfies the requirement in the beam line. This monitor will helpful for adjustment maintaining a good transfer efficiency.

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