DEVELOPMENT OF STRIP-LINE TYPE BEAM POSITION MONITOR

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Abstract

In the Free Electron Laser (FEL) system at Laboratory for Electron Beam Research and Application (LEBRA) of Nihon University, the destructive fluorescence beam profile monitors were removed from the FEL beam line since the undulator permanent magnets were degraded by strong gamma and/or neutron radiation produced at the profile monitors. Thus strip-line type, non-destructive beam position monitors (BPMs) have been developed for the FEL beam line. The beam position can be deduced from the measurement of the RF power induced by the electron beam. The calibration of these BPMs has been made at the test bench in KEK. A preliminary experiment has been performed with the electron beam from the linac at LEBRA where three BPMs have been inserted at the exit of the linac, and the entrance and the exit of the undulator, respectively. Since the BPM is expected to have a high resolution of the beam position, a correlation characteristics of FEL lasing and the beam position has been investigated on the LEBRA FEL system.

1 INTRODUCTION

First lasing of FEL at LEBRA succeeded in a wavelength of 1.5μm on May 2001[1,2]. The performance of the linac has been improved for the application of the FEL experiment. Highly precise control of the electron beam orbit passing through the undulator is important for lasing FEL effectively. Therefore a non-destructive beam position monitor is required.

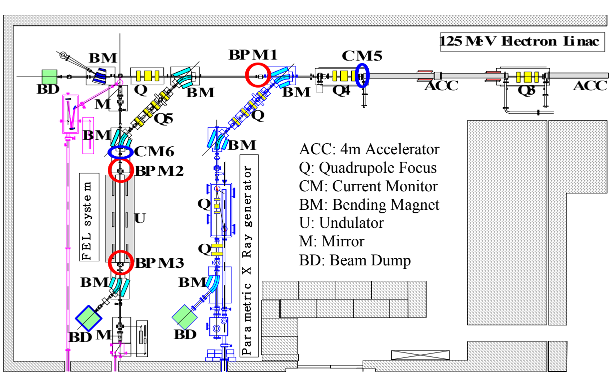

Figure 1: Installation points of the BPMs and the current monitors in the 125MeV electron linear accelerator and FEL system.

Installation points of the BPMs and the current monitors are shown in figure 1.

The structure of the BPM and calibration method are described in Chapter 2. Results of the preliminary in beam experiment are presented in Chapter 3.

2 BEAM POSITION MONITOR

2.1 Structure of BPM

The monitor geometry and a photograph are shown in figure 2 (a) and (b), respectively. The beam position can be deduced from the measurement of the RF power induced by the electron beam. The RF power is picked up by use of the electrode located in side of the vacuum pipe. The angular width of the electrode, viewed from the center position of the BPM, is 45degrees. The inner surface of the vacuum pipe and the electrode comprise a 50ohm transmission line. The length of an electrode is λ/4=26.25mm, where λ is a free-space wavelength of fundamental frequency of 2856MHz [3].

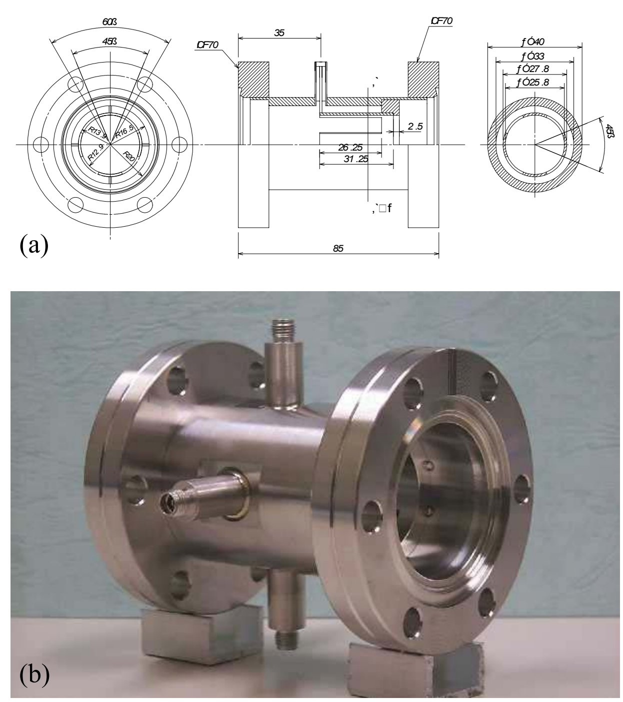

Figure 2: Geometrical drawing (a) and photograph (b) of the Stripline-type Beam Position Monitor.

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2.2 Measuring Method of Beam Position

A signal from each electrode of the BPM is inputted into a RF detector (Agilent Technologies, 423B, 0.01-12.4GHz) through RF coaxial cable (RG-55/U) of 12m long. The detected voltage waveform is measured by means of an oscilloscope, as shown in figure 3.

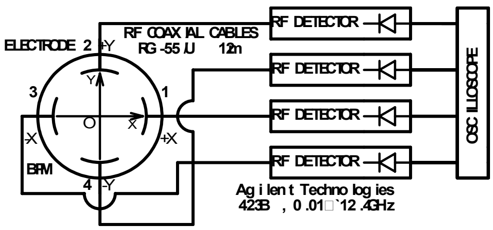

Figure 3: Measuring method.

Measured voltage is converted to RF power. Horizontal (X) and vertical (Y) beam position are represented by map functions up to sixth-order polynomial, as follows;

$$X = \sum_{i,j=0}^{6} k_{xij} \left(\frac{\Delta_x}{\Sigma_x}\right)^i \left(\frac{\Delta_y}{\Sigma_y}\right)^j , \qquad (1)$$

$$Y = \sum_{i,j=0}^{6} k_{yij} \left(\frac{\Delta_x}{\Sigma_x}\right)^i \left(\frac{\Delta_y}{\Sigma_y}\right)^j . \qquad (2)$$

Here,

$$\Delta_x = \sqrt{P_1} - \sqrt{P_3}\, , \Sigma_x = \sqrt{P_1} + \sqrt{P_3}\, , \qquad (3)$$

$$\Delta_y = \sqrt{P_2} - \sqrt{P_4}\, , \Sigma_y = \sqrt{P_2} + \sqrt{P_4}\, , \qquad (4)$$

where k_{xij} and k_{yij} (i, j=0-6) are the coefficients of the map functions [4,5]; P_1 and P_3 (P_2 and P_4) are the horizontal (vertical)-pickup RF power including cable attenuation.

The monitor has been calibrated by means of a thin wire to simulate an electron beam. The microwave of fundamental frequency transmits through the thin wire. The coefficients of the map functions were chosen so that the difference between the position of the wire and the calculated one from the map function is less than 50μm within a mapping region of a radius of 5mm from the center of a BPM.

3 THE CHANGES OF BEAM POSITIONS DURING A BEAM PULSE

3.1 Measurement Results

The beam position was deduced at FEL not lasing and at lasing. The accelerator was operated on a beam energy of 86.8MeV, pulse duration of 20μs and repetition rate of 2 Hz.

Wave patterns detected by electrodes in each BPM are shown in the figure 4, and wave patterns of the beam currents and IR detector are shown in figure 5. The installation point of the BPMs and the current monitors are shown in figure 1. In figure 4 (a-2) and (a-3) we can see that a beam position change from the electrode of –X side to +X side during the pulse duration time. On the other hand, in figure 4 (a-1), (b-1), (b-2) and (b-3) in each BPM, the signal from each electrode is similarity.

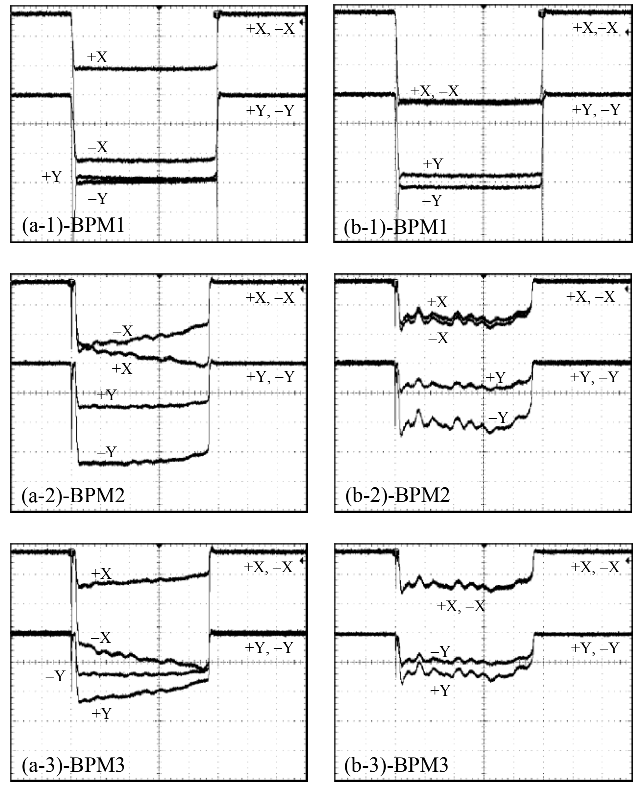

Figure 4: A detection wave pattern of each electrode on each BPM (V: 20mV/div). Horizontal scale is 4μs/div. The detected voltage was measured with an oscilloscope. (a-): at FEL not lasing, (b-): at FEL lasing.

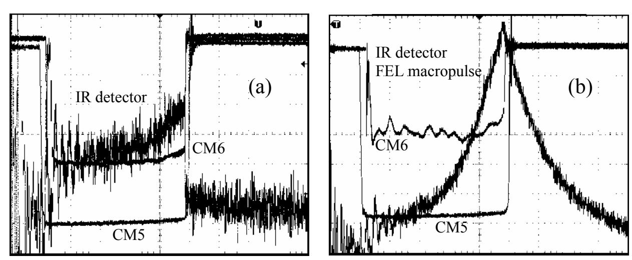

Figure 5: Wave forms of output of infrared detector (IR detector) and electron beam detected by use of current monitor. (a) at FEL not lasing, (b) at FEL lasing.
CM5: exit of the linac (20mA/div),
CM6: entrance of the undulator (20mA/div),
IR detector: (a): 2mV/div, (b): 5mV/div
Horizontal scale is 4μs/div.

3.2 Evaluation of Beam Position

The absolute beam position was deduced from measured RF power and the equations (1), (2), (3) and (4). The data taken from an oscilloscope, signal-to-noise ratio is about 1/30. This noise level is corresponding to the beam position uncertainty of 0.2mm.To reduce influence of the noise, the averages of 20 data were taken every

80ns, and signal-to-noise ratio became about 1/120. From accuracy of map-function and this ratio, a beam position includes an error of about ±0.1mm. The beam positions during a beam pulse after noise reduction processing is shown in figure 6 and figure 7.

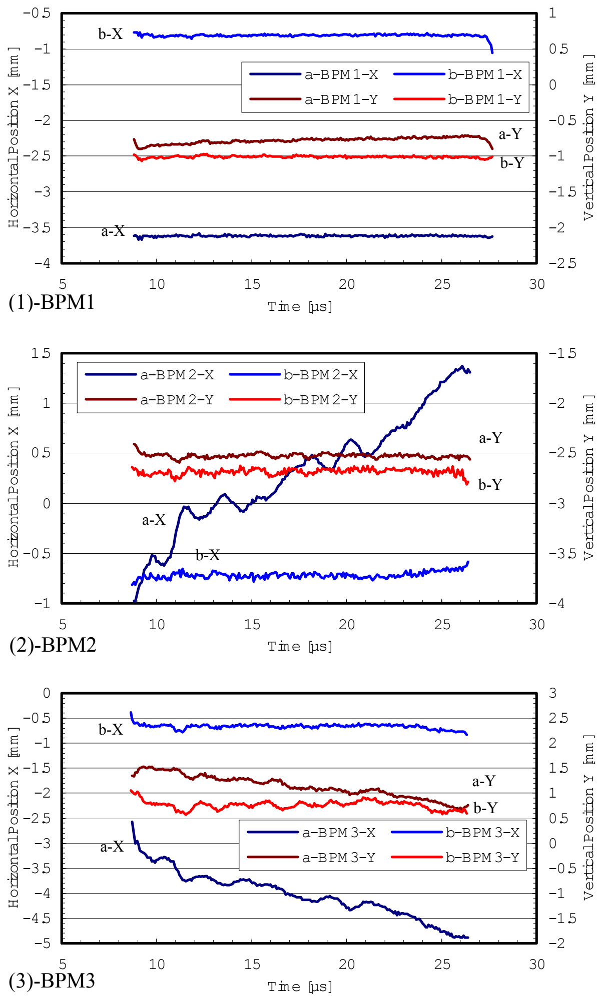

Figure 6: The changes of beam positions in a beam pulse in pulse duration of 20µs. (a-) at FEL not lasing, (b-) at FEL lasing.

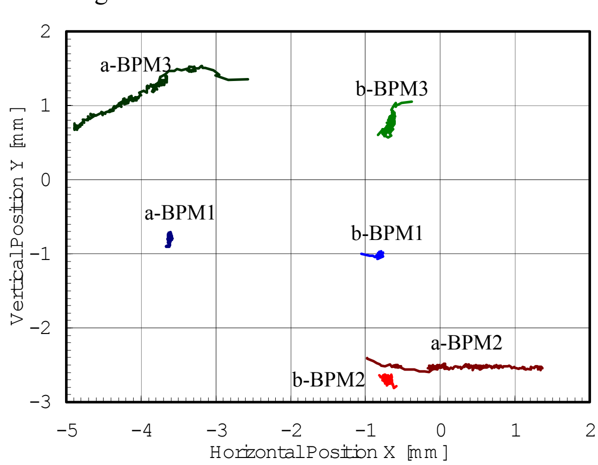

Figure 7: The changes of beam positions in a beam pulse every 80ns. (a-) at FEL not lasing, (b-) at FEL lasing.

Curves a-X and a-Y in figure 6 show the beam positions under adjustment of the linac. Vertical position at the exit of the linac (BPM1-a-Y) moves monotonously up during the pulse duration time about 0.2mm. Horizontal position is kept constant (BPM1-a-X). In the FEL beam-line, at the entrance of the undulator, horizontal position (BPM2-a-X) moves significantly over 2 mm. At the exit, horizontal position (BPM3-a-X) move same span but reverse direction. These movement of the horizontal positions caused by residual dispersion of the 90 degrees bending system.

Curves b-X and b-Y in figure 6 show the beam positions under lasing FEL. In this case, the linac and beam transport line are well tuned. Then both horizontal and vertical beam positions are kept constant. In the FEL beam line, beam positions are nearly constant during the pulse duration time without small ripple. It is considered that the shape of the beam current which is not able to be rectified is appearing.

4 CONCLUSION

Three BPMs have been inserted into the exit of the linac, and at the entrance and the exit of the undulator beam line, respectively. In this way beam position get possible to be measured, and it became very easy to synchronize the beam orbit with a light axis of the optical resonator.

As a beam position includes an error of about ±0.1mm, and it is pursued beam position, it is thought enough as position search precision because a diameter of electron beam is about 0.6 to1 mm.

The FEL was very weak poor lasing at this measurement. As a result, for lasing FEL, a beam position change during beam pulse has to be less than 0.2mm when other factors are not taken into account.

5 REFERENCES

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