RF system in Accelerators

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Abstract

In the accelerator physics, diagnostics of the property of the particle of photon beam is required. In this report, the overview of diagnostics instrument for particle and photon beam, such as beam position monitor, transverse deflecting cavity, streak camera, and synchrotron radiation interferometer was presented. Also, the test of the stripline beam position monitor using a wire test stand and the measurement of photon beam size using an SR interferometer were conducted in PLS-II.

INTRODUCTION

When running the accelerators, controlling the beam parameters and detecting the problem in the accelerators are necessary procedures. To do these processes, characterizing the property of the beam is required. However, the beam passes through the vacuum chamber, which is impossible to see inside. Thus, diagnostic equipments should be equipped in the accelerators. In this report, the test of the beam position monitor was conducted using a wire test stand. Also, the measurement of photon beam size using an SR interferometer was demonstrated in diagnostics beamline of PLS-II.

DIAGNOSTICS OF PARTICLE BEAM

Beam position monitor

Beam position monitor(BPM) is the diagnostic used for measuring the position of the beam by measuring the electric field or potential at certain positions.

There are several types of BPM. First, the shoe-box BPM is the device whose shape is the cube divided by diagonal cut. Shoe-box BPM first measures the electric signal from the left L and the right side of the monitor R. Then, it measures the position of the beam with the formula $x = a\frac{R-L}{L+R}$, where a is half the length of the BPM. Shoe-box BPM has good linearity and low x/y coupling. Also, it has low bandwidth. Shoe-box BPM is usually used in low energy hardron accelerators[1].

Stripline BPM measures the position by electrode strings located in a cylindrical tube. Due to the coupling between the electrodes, stripline BPM has a higher sensitivity than button BPM. In addition, it has good linearity and low x/y coupling. However, stripline BPM cannot be used in large repetition rate, and it has higher beam impedance than button BPM. Thus, stripline BPM is ususally used in linear accelerators and transfer lines.

Button BPM(See Fig. 1) are made of insulated metal plate with button electrods. Button BPM has lower sensitivity and poor linearity and low x/y coupling, but it has broader bandwidth(100MHz to 5GHz) and short bunch length. Button BPM us commonly used in storage rings.

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Figure 1: Photograph of button BPM of PAL.

Lastly, the cavity BPM consists of a pillbox cavity with two antennas. It uses dipole (typically TM_{110}) cavity modes because its driven amplitude of the mode by the beam is linearly proportional to the offset. The cavity BPM is ususally used in XFEL and collider which require high repetition and high precision at low charge.

Measurement of bunch length

In longitudinal dynamics, the bunch length of the particle bunch is an important beam parameter. In the linear accelerator, the transverse deflecting cavity is used to measure the bunch length. The deflecting cavity gives the electron bunch the time-dependent kick, rotating the electron bunch. Then, the temporal longitudinal beam parameters can be measured by measuring the spatial beam parameter on the screen.

The streak camera is a tool that can measure bunch length. It converts the temporal parameter of the beam to the spatial parameter by transmitting the time-dependent trigger signal to the electrodes inside the camera.

SR INTERFEROMETER

By analyzing the pattern made by the interferometer, the information about the photon beam can be extracted. The synchrotron radiation (SR) interferometer(see Fig. 2) is a two-dimensional interferometer that consists of quad slits, two lenses, polarizer, band pass filter, and CCD camera[1]. SR interferometer can be optimized by changing the distance between two adjecent slits, and the width of the slit.

EXPERIMENTS

Test of the stripline BPM

In this section, the test of the stripline BPM was conducted using a wire test stand (see Fig. 3). The wire test stand

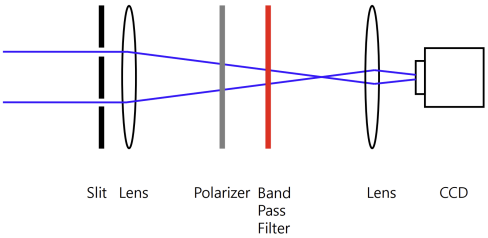

Figure 2: The layout of the SR interferometer.

measures the signal of the stripline BPM by moving the position of the wire that transmits the electric signal.

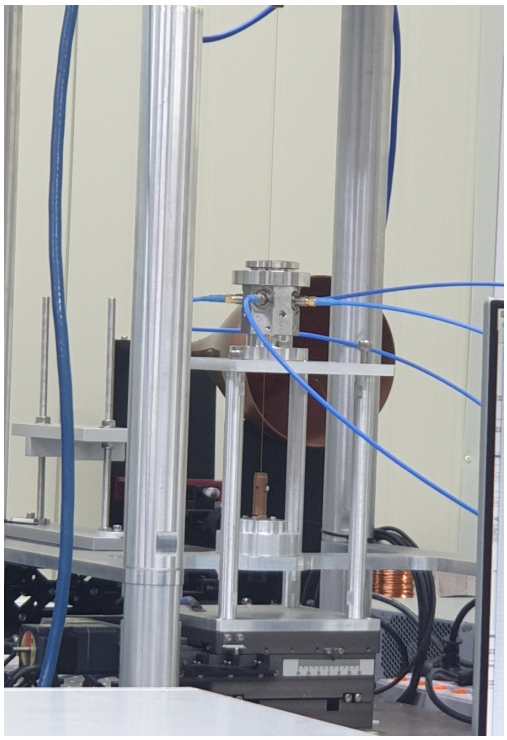

Figure 3: The photograph of wire test stand in PAL.

Figure 4 shows the result of the test of the stripline BPM. The red graph shows the trace of the position of the wire, and the white graph shows the voltage measured by BPM. By the result, we can know that the signal measured by BPM is linear to the position of the wire. When the position is more than 3mm from the center, nonlinearity is supposed to occur. However, such nonlinearity did not occur in the measurement.

SR interferometer

In this section, the interferometer patterns by different gap width of the quad slits were observed in diagnostic beamline in PLS-II(see Figure 5). During the experiment, the change of intensity of the interferometer pattern with respect to the gap width of the quad slit was observed. The horizontal slit interval was fixed as 15mm. The result of the measurements is shown in Figure 6. By the resulted 2D interferograms,

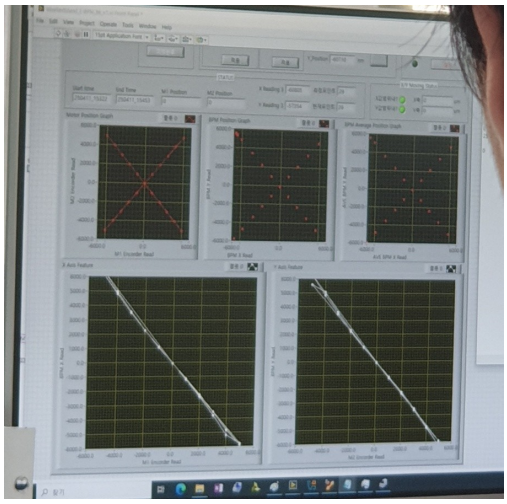

Figure 4: The result of the test of the stripline BPM.

Figure 5: (a), (b) Photographs of experimental setup for SR interferometer of diagnostic beamline in PLS-II.

fringe spacing was inversely proportional to the gap width of the slits. observed.

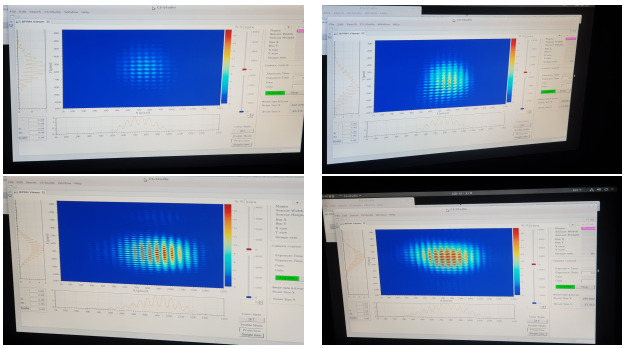

Figure 6: 2D interferogram taken by CCD camera when vertical gap width of the quad slit are (a)18mm, (b)22mm, (c)35mm, and (d)40mm respectively.

CONCLUSION

Diagnostics of beam properties is essential for the research of both particle and photon beam physics. In this report, principles and advantages/disadvantages of different types of BPM were covered. Also, the test of stripline BPM by

wire test stand was demonstrated. Lastly, the size and shape of photon beam generated by synchrotron radiation was measured by SR interferometer.

REFERENCES

[1] C. Kim, *Lecture note on PAL-XFEL diagnostics and BPM*, Division of Advanced Nuclear Engineering (DANE), POSTECH, Pohang, Korea, Apr. 2025