PULSE-BY-PULSE X-RAY BEAM MONITOR EQUIPPED WITH MICROSTRIPLINE STRUCTURE

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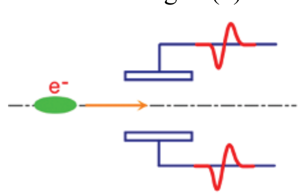
Abstract

A new pulse-by-pulse X-ray beam monitor equipped with microstripline structure had been developed. This monitor can be used for (1) a pulse intensity monitor, (2) a pulse-by-pulse X-ray beam position monitor, and (3) a pulse timing monitor. Then, we have improved the structure of the detector head in order to sophisticate the function as the pulse timing monitor. As a result, we successfully removed the ringing parts of output signal, and demonstrated that this monitor can be used as the timing monitor. We also describe a new scheme for beam diagnostics using this monitor.

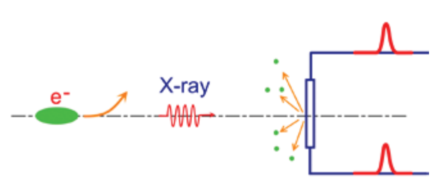
INTRODUCTION

Pulse-by-pulse measurement of X-ray beam is an important issue for the third generation light sources in order not only to stabilize X-ray beam in an experimental hutch but also to diagnose electron beam in a storage ring. However, there was a limitation in high speed response for conventional X-ray beam position monitors (XBPMs), which have metal blades as detector heads of photoemission type [1]. Therefore, we have been working on improving XBPMs by using microstripline structure for a photocathode of the detector head.

This monitor generates output signal with short and unipolar signal, so that front-end electronics can be simplified. The effort to shorten the pulse width for pick up electrodes (PUEs) has been made in other facility [2]. But PUEs intrinsically have a bipolar pulse as shown in Fig. 1 (a). On the other hand, the feature of this monitor is to produce a unipolar pulse by using the principle of the photoemission as shown in Fig. 1 (b).



(a) Bipolar signal from PUEs



(b) Unipolar signal from photocathodes

Figure 1: Two types of pulse shape.

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The detector head of the pulse-by-pulse X-ray beam monitor is equipped with the microstripline structure, which is composed of a metal line photocathode, an aluminum nitride (AlN) dielectric plate and a copper tungsten (CuW) cooling base as shown in Fig.2. Thermodynamics of the detector head is well considered against severe heat load. AlN has a high thermal conductivity and a low thermal expansion coefficient of 150 W/(m·K) and 4.6×10^{-6}/K, respectively. Similarly, those for CuW are 180 W/(m·K) and 6.5×10^{-6}/K, respectively. But, Cu does not suit for the cooling base, because it has relatively high thermal expansion coefficient (17×10^{-6}/K). The impedance of the microstripline detector head is designed to be matched to 50Ω [3]. The high voltage electrode is placed in front of the detector head in order to suppress low energy electrons emitted from the detector head, because the low energy electrons have relatively low velocity and lengthen the pulse width.

Feasibility tests have been demonstrated at the X-ray beamline of SPring-8 in terms of (1) pulse intensity monitor, (2) pulse-by-pulse X-ray beam position monitor, and (3) the pulse-timing monitor [4]. The half width at half maximum (FWHM) of the output signal was about 200 psec.

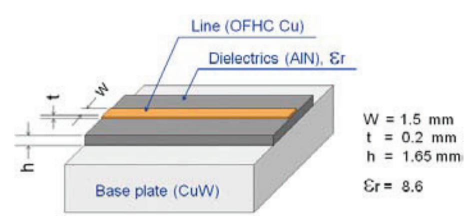


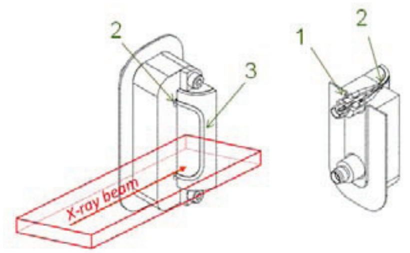
Figure 2: The basic structure of the detector head with a microstripline structure.

BASIC PERFORMANCE

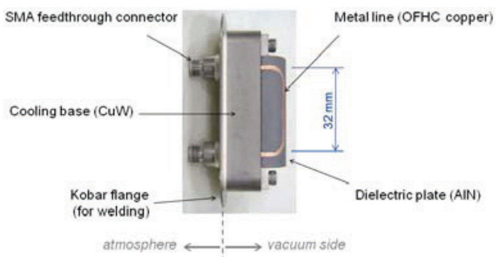
Structure of the Detector Head

The structure of the detector head has been modified as shown in Fig 3 (a): (1) The high frequency SMA feedthrough connectors, fabricated by Kyocera Corporation, have been adopted to improve the Cut-off frequency. (2) The connection of the metal lines on the SMA connectors was modified for impedance matching. (3) The strip-line as the photocathode is placed perpendicular to the beam for less sensitivity against beam position in order to suit the timing monitor and the intensity monitor.

Figure 3 (b) shows a photograph of the detector head, which was designed to be compact to prevent deformation of the pulse shape. It is mounted on the vacuum chamber by welding on the flange.



(a) Schematic view



(b) Photograph

Figure 3: Structure of the detector head.

Experimental Results

S-parameters have been measured with the network analyzer as shown in Fig. 4. Transmission coefficients (S21 and S12) give an excellent value below 10GHz, and a dip around 18GHz. Reflection coefficients (S11 and S22) show an excellent value below 4GHz. This behaviour satisfies our demand enough, because the cut-off frequency of the low attenuation cables for the monitor is about 5GHz.

The beam tests have been carried out using monochromatic X-ray beam in the experiment hatch of SPring-8 BL47XU. The signal is read from one of the SMA feed through connectors, and the other connector is terminated to avoid reflection of the signal at the open end. The unipolar pulse having the pulse width of 0.2 nsec in FWHM has been observed as shown in Fig.5. The voltage of the high voltage electrode in this measurement was set to -2000V, which is optimal value for this detector to keep the pulse width short. The cable length for signal was about 2 m, and the sampling oscilloscope was set up in the experimental hatch. The pulse width is equivalent to the original monitor, and the ringing of the tail has been removed successfully. As a result, the pile up of the adjoining pulse signal could be avoided.

The pulse width can be deformed by changing the voltage of the HV electrode. If the positive voltage is applied, the low energy electron with low velocity is emitted from the electrode with the result in spread of the pulse width. On the contrary, if the negative is applied, the low energy electron is pressed back to the detector head, and the pulse width is not affected. In order to demonstrate these behaviours, we have observed the pulse shapes by changing the applied voltage, as shown in Fig.6. The pulse width shown in Fig.6 is slightly wider than that shown in Fig.5, because the signal cables of 20m was used.

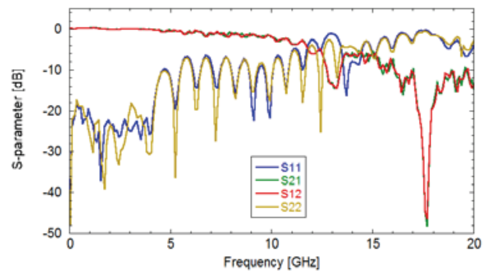


Figure 4: S-parameters of the detector head.

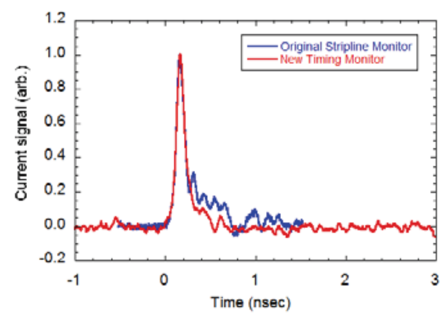


Figure 5: Improvement of the pulse shape.

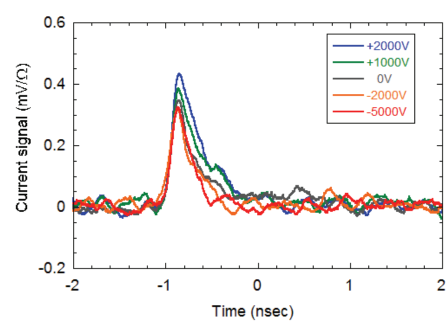


Figure 6: Pulse shapes with various high voltages.

NEW SCHEME FOR BEAM DIAGNOSTIC

In the above-mentioned experiments, the reflection at the opposite end was eliminated by using the terminator. But the signals from both ends of the detector head can be utilized by connecting the signal cable instead of the terminator. One example is shown below.

Both of the pulse signals generated by the photo-emission are transmitted toward the opposite directions. If one of the edges has an open end, the pulse reflects at the end in-phase. The reflected signal advances toward the same direction as the primary signal, and it delays by a certain interval. Figure 7 gives sketches of the behaviour of the pulse transmission. As a result, the information of the X-ray beam position can be obtained, because the interval of two pulses corresponds to the position on the detector head where the X-ray beam irradiates. In addition, the centre of two pulses gives the information of the arrival time of the X-ray pulse.

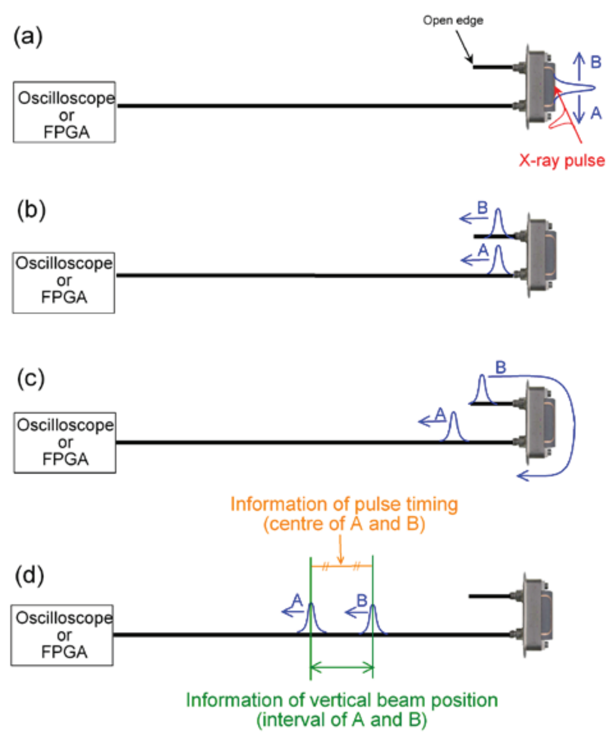


Figure 7: Sketches of the behaviour of the pulse transmission with the open end.

We have demonstrated that a double pulse can be generated as shown in Fig. 8. The polarity of each pulse can be reversed by changing an open end into a short end. We have also observed the behaviour of the interval of two pulses when the X-ray beam position was varied as shown in Fig.9. If this monitor is utilized as a beam position monitor, the positional resolution is expected to be improved by inclining the detector head to the beam axis.

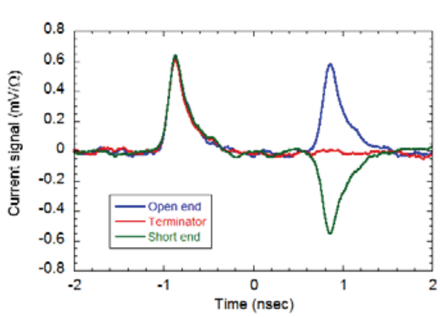


Figure 8: The reflection at the opposite terminal.

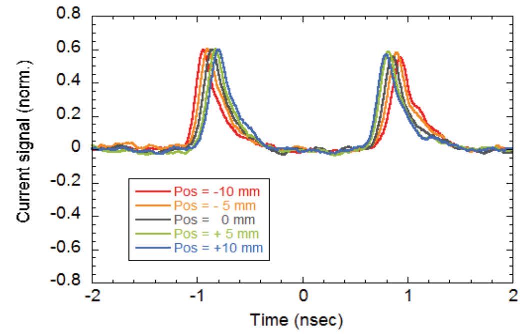


Figure 9: Position dependence of the interval of the two pulses.

SUMMARY

We have modified the detector head equipped with the microstripline structure that had been developed for the beam position monitor in order to optimize it for the timing monitor. We succeeded in removing the tail of the pulse by adopting the high frequency SMA connector. We also demonstrated that the pulse width can be controlled by changing the voltage of the high voltage electrode.

We have proposed a new scheme of beam diagnostics using this monitor. It becomes possible to get information both of the beam position from an interval of two pulses and the beam arrival time from the centre of two pulses.

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