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Pulse-by-pulse X-Ray Beam Monitor equipped with Microstripline Structure

H. Aoyagi [1], S. Takahashi [1], H. Kitamura [1,2]

[1] JASRI/SPring-8, [2] RIKEN/SPring-8

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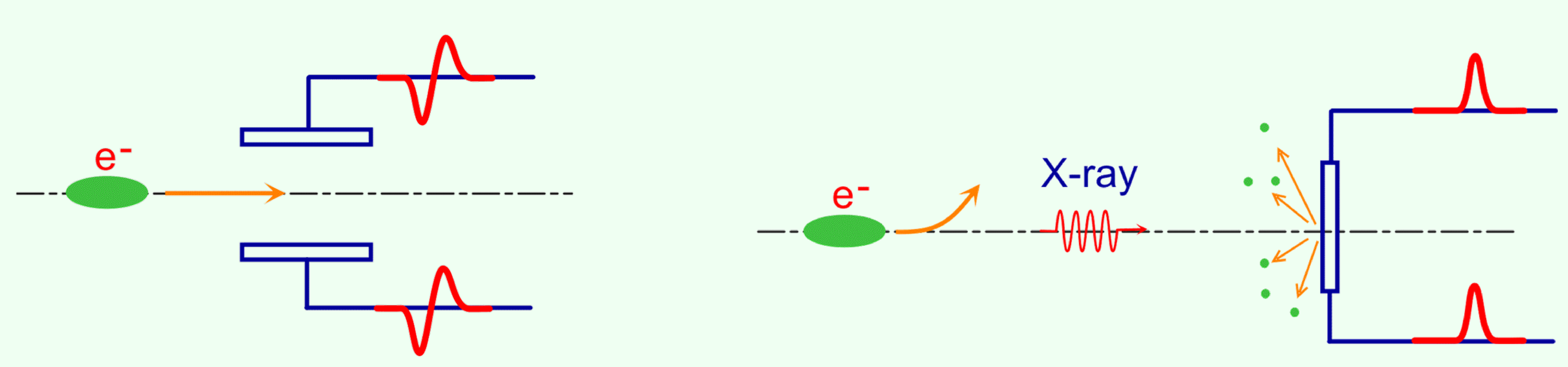
Abstract

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.

Original monitor

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. 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.

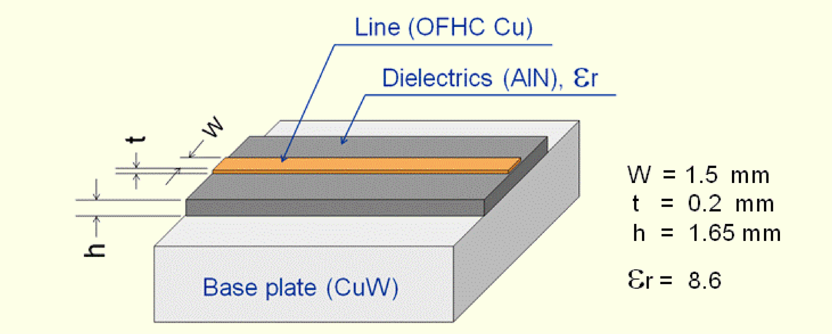
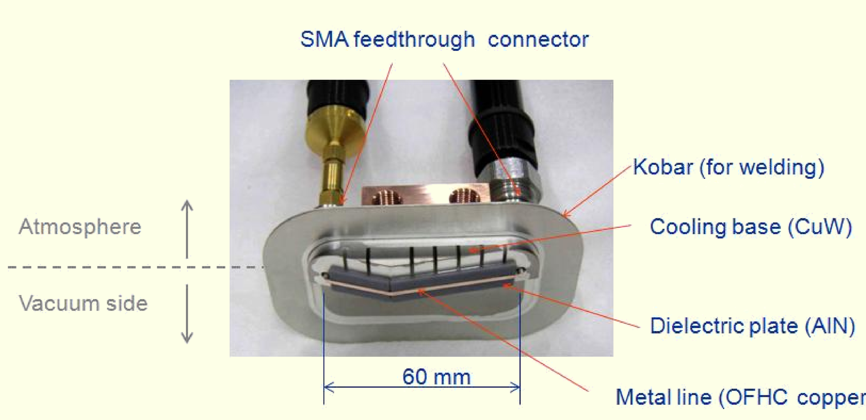


Figure 2: The basic structure of the detector head

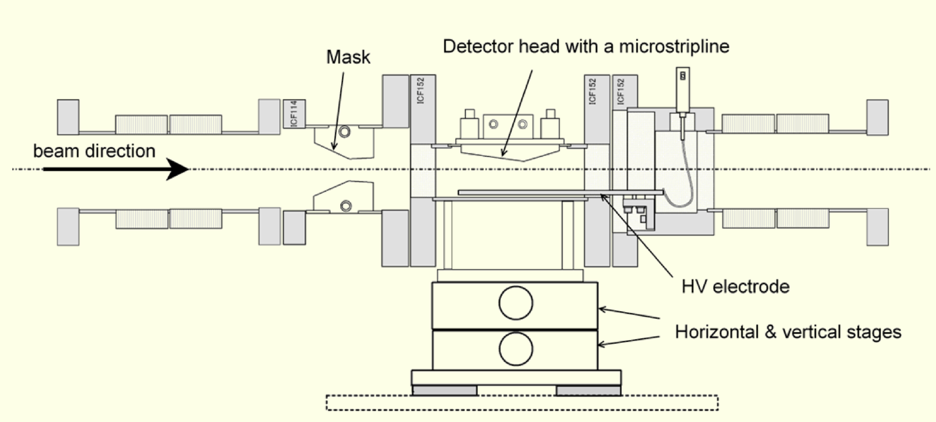
Key points for RF properties

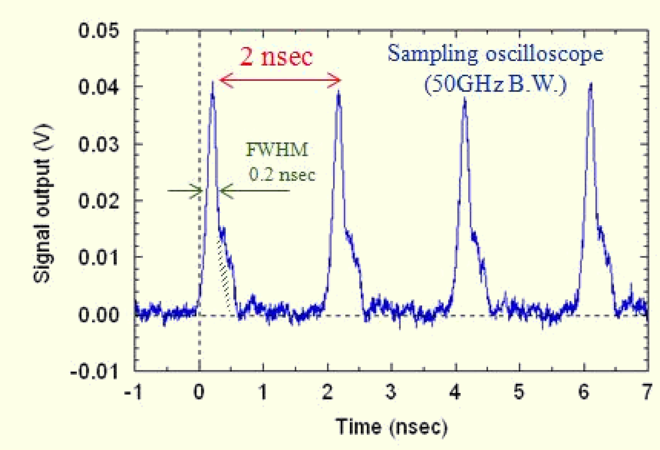
- Microstripline structure
  Impedance matching
- SMA feed through connector
  Cut-off frequency: 9 GHz → 18GHz
- 50 Ω termination of one side of strip-lines
  Elimination of reflection
- design flexibility of line width and length
  Sufficient signal for high resolution



Key points for thermal properties

- AlN for dielectric plate
  High therm. conductivity 150 W/(m·K)
  Low therm.expansion coef. 4.6×10^{-6} /°C
- CuW for cooling base
  High therm. conductivity 180 W/(m·K)
  Low therm.expansion coef. 6.5×10^{-6} /°C
  (cf : OFHC Cu 17 $\times10^{-6}$ /°C)
- Tapered photocathode
  Reduction of heat density





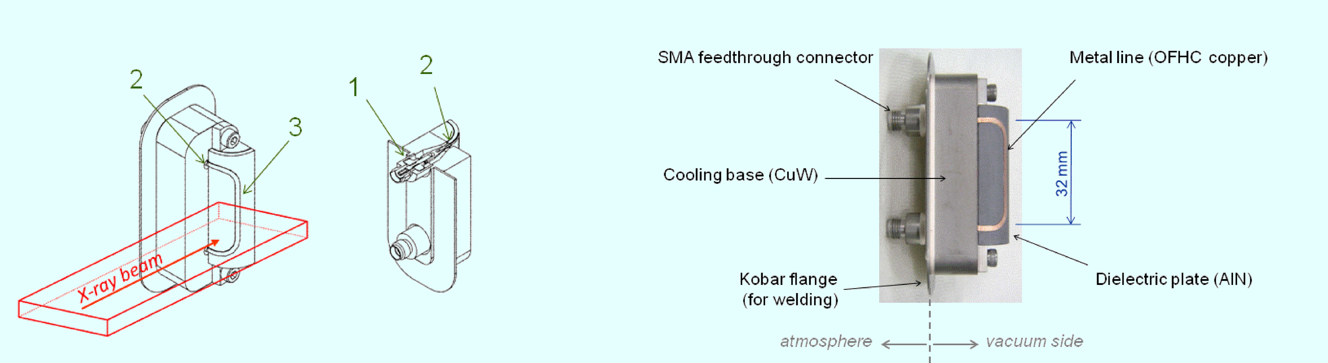
Special Design for Beam Arrival Monitor

Modification of the detector head :

(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.



(a) Schematic view (b) Photograph

Figure 3: Structure of the detector head.

BASIC PERFORMANCE

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.

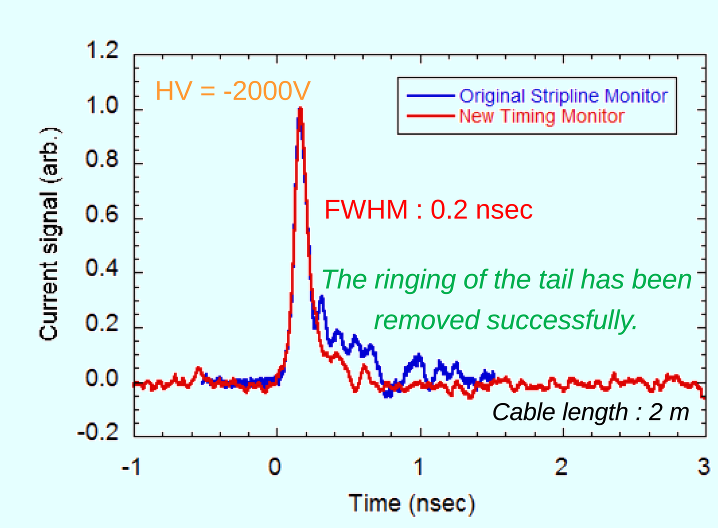


Figure 5: Improvement of the pulse shape.

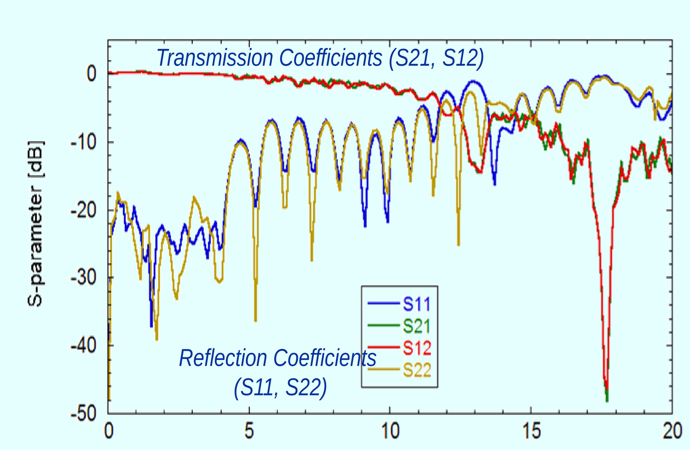


Figure 4: S-parameters of the detector head.

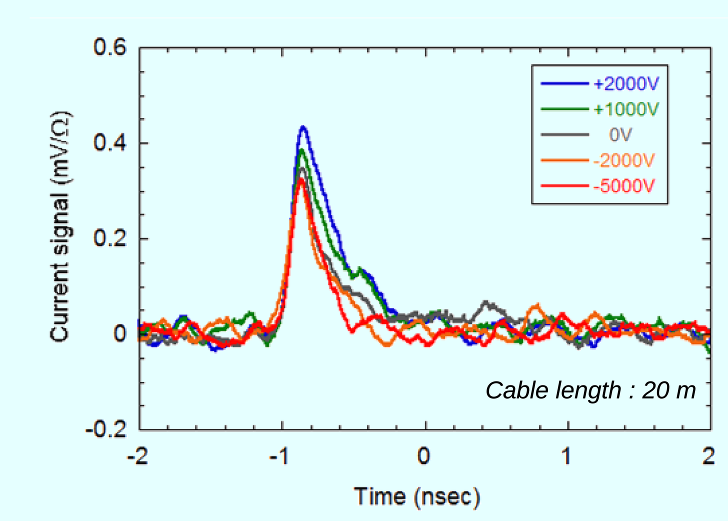


Figure 6: Pulse shapes with various high voltages.

New Scheme for Beam Diagnostic

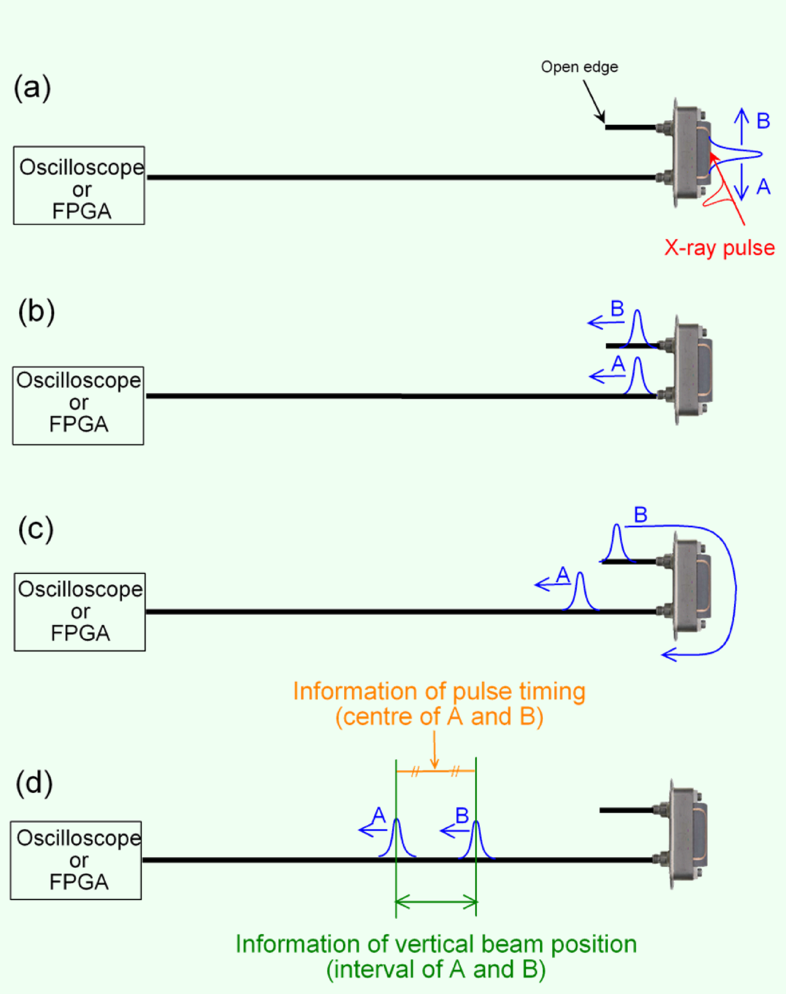


Figure 7: Sketches of the behaviour of the pulse transmission with the open end.

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.

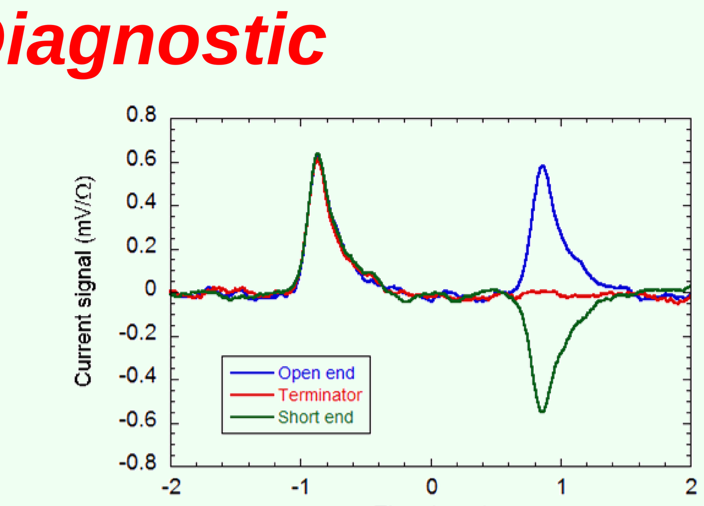


Figure 8: The reflection at the opposite terminal.

The polarity of each pulse can be reversed by changing an open end into a short end.

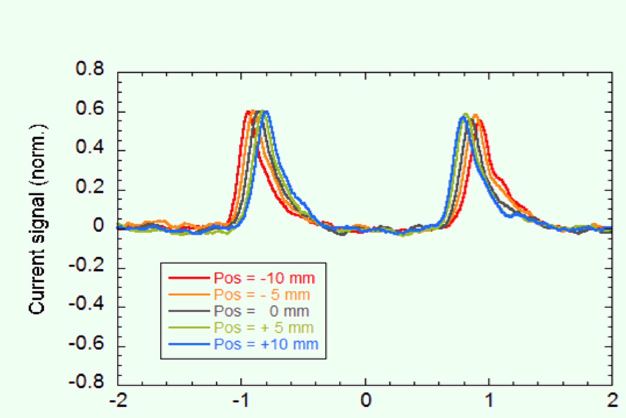


Figure 9: Position dependence of the duration of the double peaks.

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.

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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