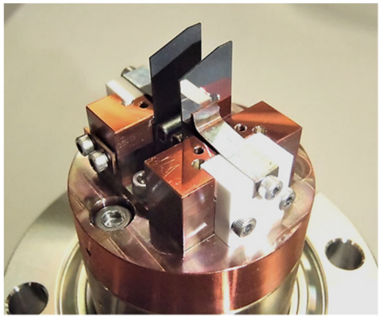
Demonstration of a Newly Developed
Pulse-by-pulse X-ray Beam Position Monitor
in SPring-8



Hideki Aoyagi, Yukito Furukawa, Sunao Takahashi, Atsuo Watanabe

Japan Synchrotron Radiation Research Institute (JASRI / SPring-8)

Contents

- Introduction
  - Motivation
  - Points to be improved in conventional XBPM
- Design and structure for a pulse-by-pulse XBPM
  - Design policy
  - Diamond heat sink, Microstripline structure
  - Evaluation with TDR (high frequency), FEM (thermal)
- Performance tests
  - Observation of waveform
  - Direct generation of position sensitive signal
  - DC mode operation
- Summary

Motivation

Features of the SPring-8 light sources

- Various Insertion devises (In-vacuum undulators, Figure-8 undulator, …)
- Top-up operation (continuous injection to provide stable flux)
- Good stability (hard ground, anti-vibration measures, auto COD correction)
- Variety of filling patterns (for time-resolved experiments)
- Bunch-by-bunch feedback (for suppressing of instability)

In order to diagnose stability of photon beam,

it is necessary to widen the band of XBPMs.

It also contributes to the diagnosis of electron beam dynamics.

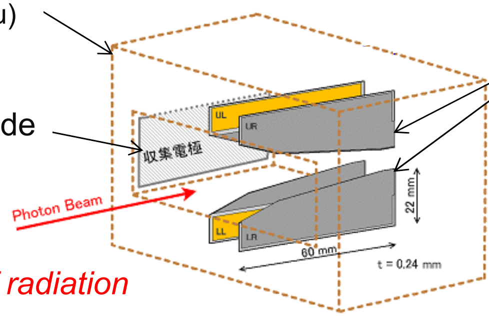
Problem in conventional XBPM

Photoemission type

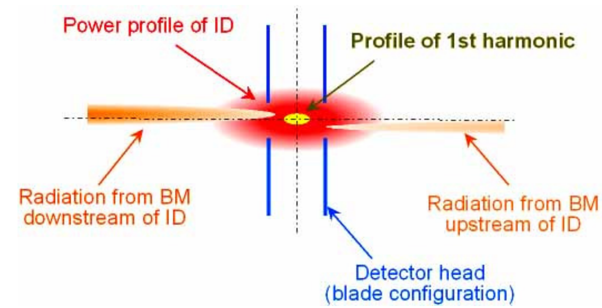
Detector head (tungsten blade)

Water-cooled holder (Cu)

Charge collecting electrode



Maximum power density of radiation is 500 kW / mrad^2 (> 1 kW / mm^2).



→ Blade shape is adopted to reduce a cross-sectional area that blocks radiation, and to increase a contact area for cooling.

It is not designed to take signal at high speed.

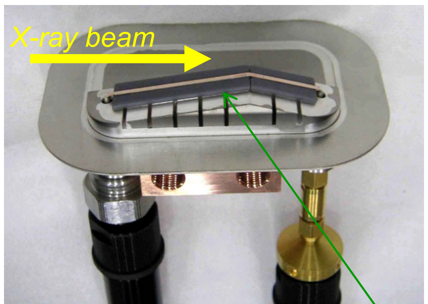
- Large detector head	Electrical capacitance C ~ 340 pF
- Long time constant	Pulse length Δt ~ 20 ns FWHM
- Impedance mismatch	Bare wires and connection in vacuum

→ We had developed a detector head equipped with microstripline structure.

Detector head equipped with microstripline structure

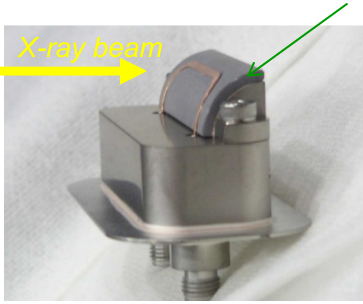
Photocathode has microstripline structure to generate unipolar pulses.

First design

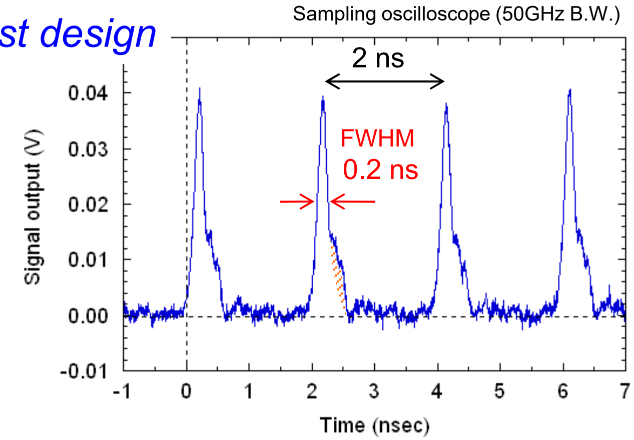


Aluminum nitride
(AlN)

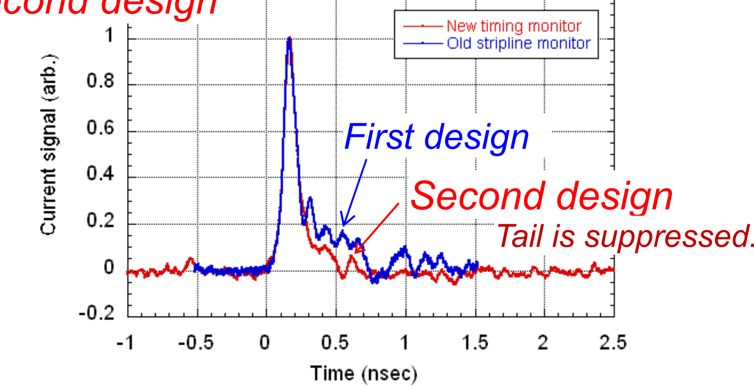
Second design



First design



Second design



However, heat resistance was not enough.

Further improvement is necessary.

(This can be used for bending magnet BLs and for a Bunch Charge Monitor or an Arrival Monitor.)

Design policy for a new pulse-by-pulse XBPM

In order to improve the heat resistance while maintaining the high frequency properties,

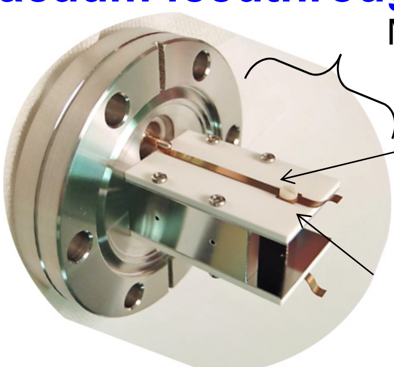
1: floating capacitance (time constant) needs to be minimized by reducing the size of the blade-shaped detector head,

2: impedance matching is necessary. (transmission line, vacuum feedthrough needs to be modified.)

We devised the detector head using diamond heat sink and microstripline structure.

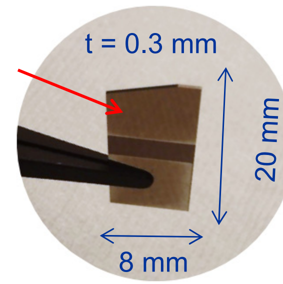
Structure of a new pulse-by-pulse XBPM

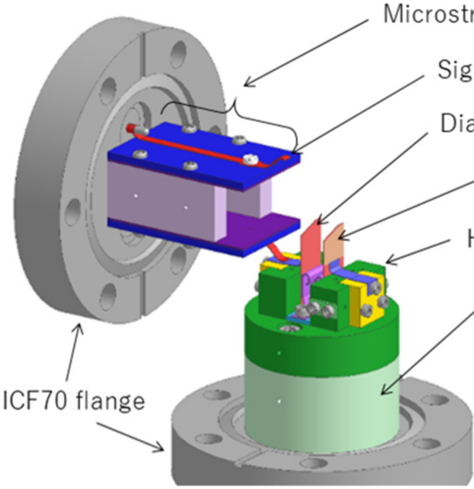
Vacuum feedthrough

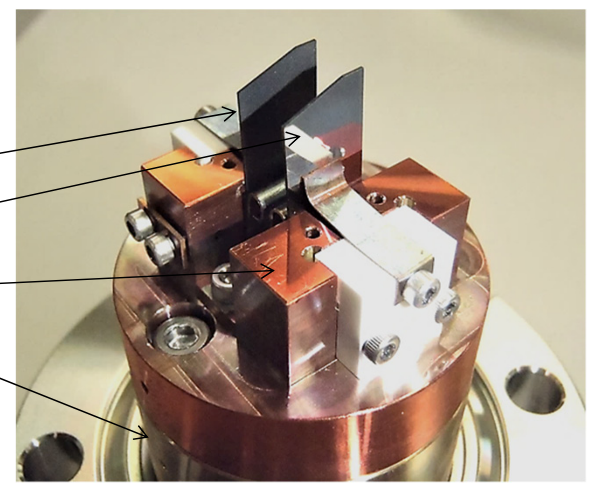


Diamond heat sink

Photocathode is on one side.



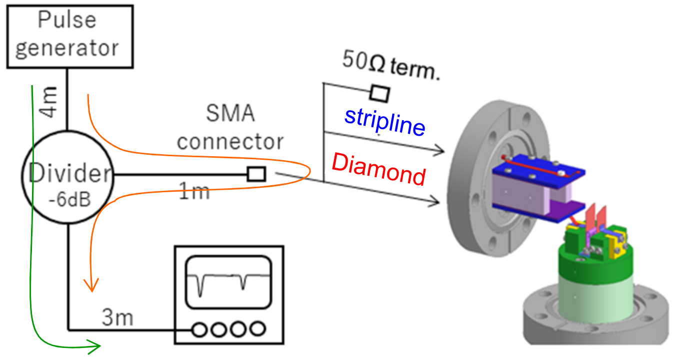


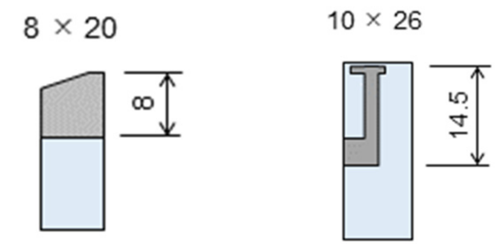


Holder and cooling base

High frequency property (off-line test)

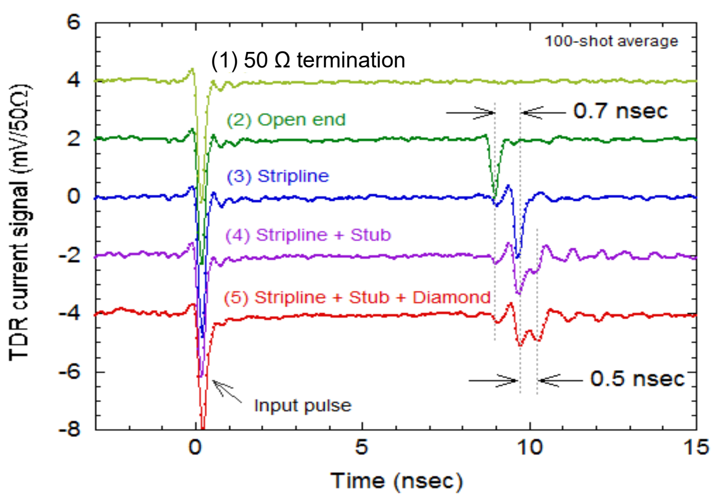
Time-domain reflectometry (TDR) by using a single input pulse

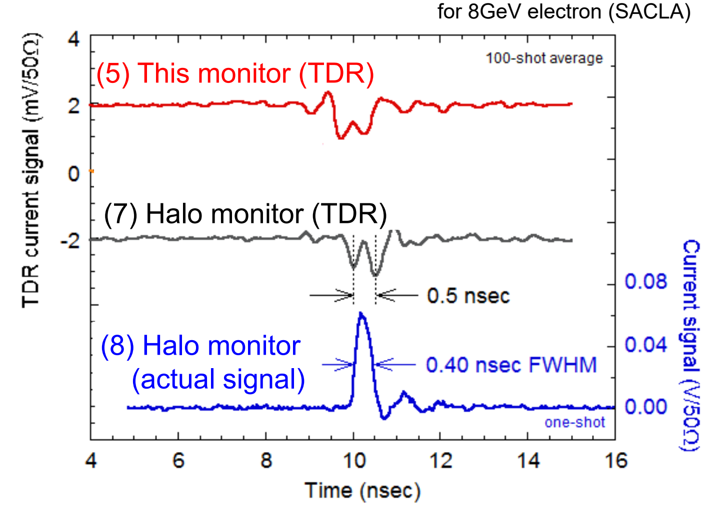




(5) This monitor

(7) Halo monitor
for 8GeV electron (SACLA)

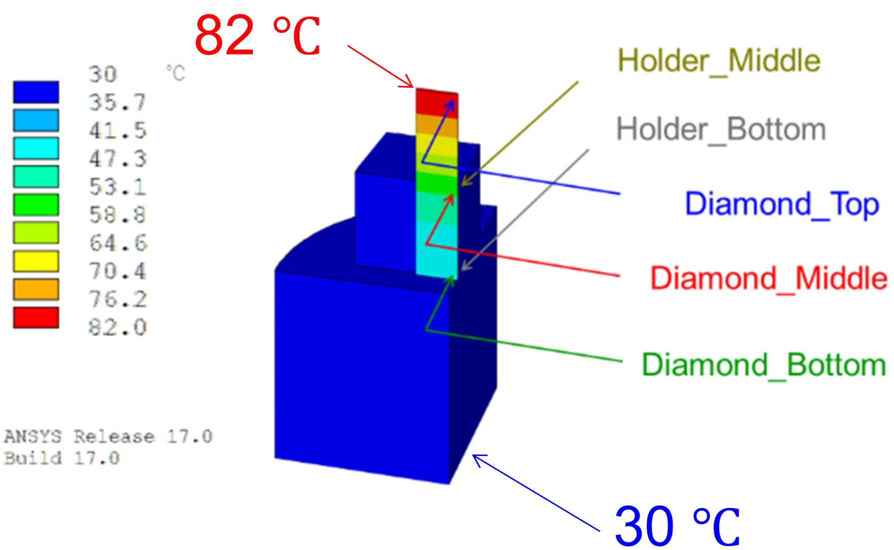




Although the peak is divided into two in TDR (7) of halo monitor, unipolar single pulse was obtained as shown in actual signal (8).
Therefore, the results of TDR (5) indicates that a unipolar single pulse can be obtained also in this monitor.

Thermal Finite Element Analysis

Evaluation of maximum temperature of diamond heat sink



1/4 model for FEM and the result

Conditions of analysis

Thermal conductance

Diamond 1,500 W/(m·K)

Copper 400 W/(m·K)

Thermal contact conductance

Diamond/Copper : 10^4 W/(m²·K)

Total input power:

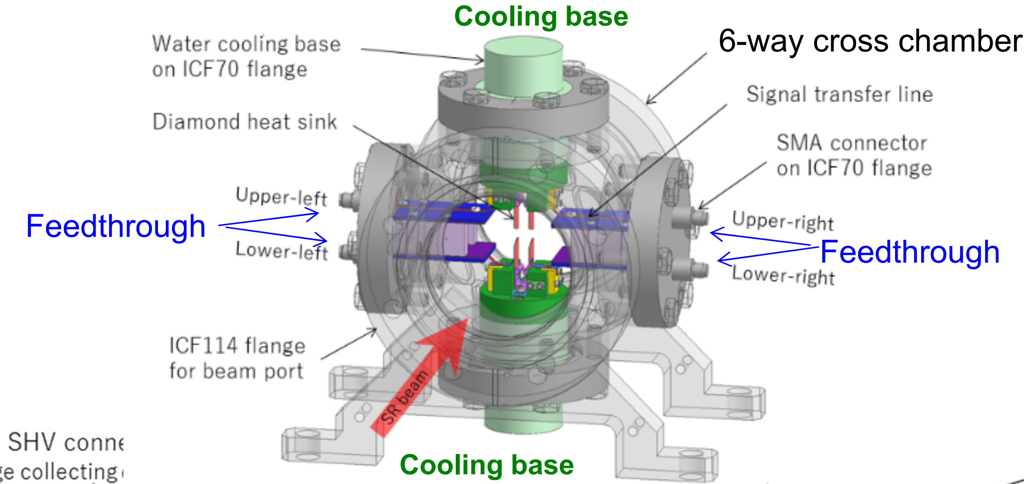
10 W on tip (1×8×0.3 mm) of heat sink

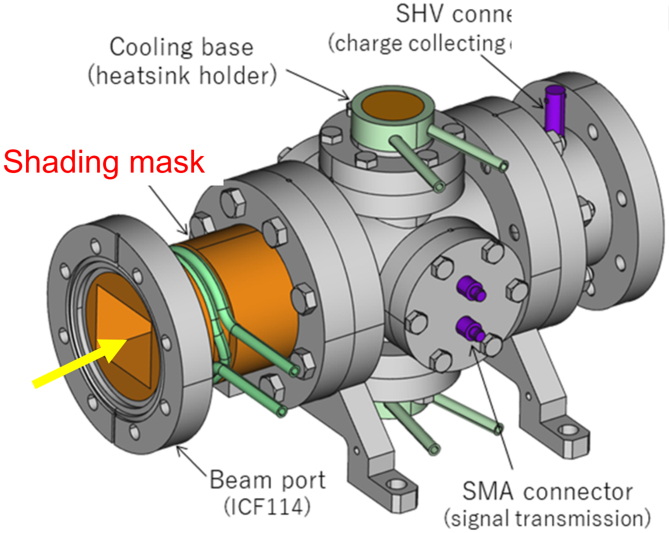
Homoiothermal condition:

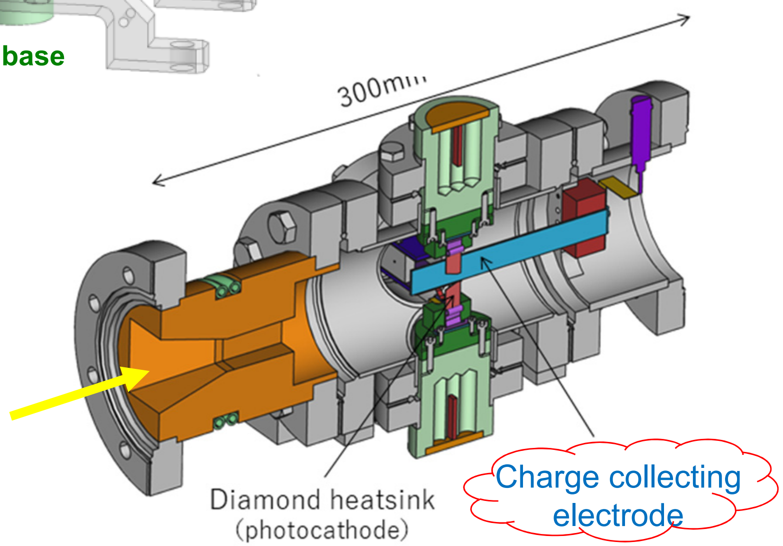
30 ℃ on bottom of the cooling base

Assuming representative values, the temperature rise is suppressed to around 50 ℃.

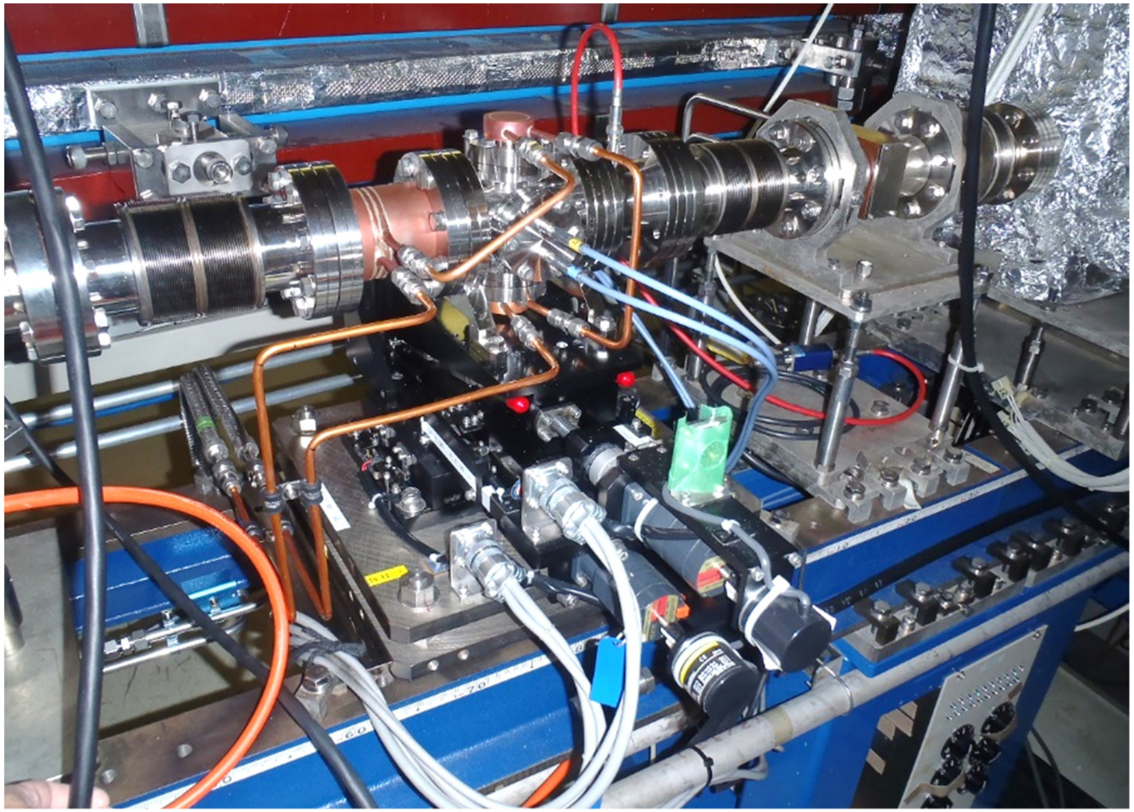
Structure of a monitor body







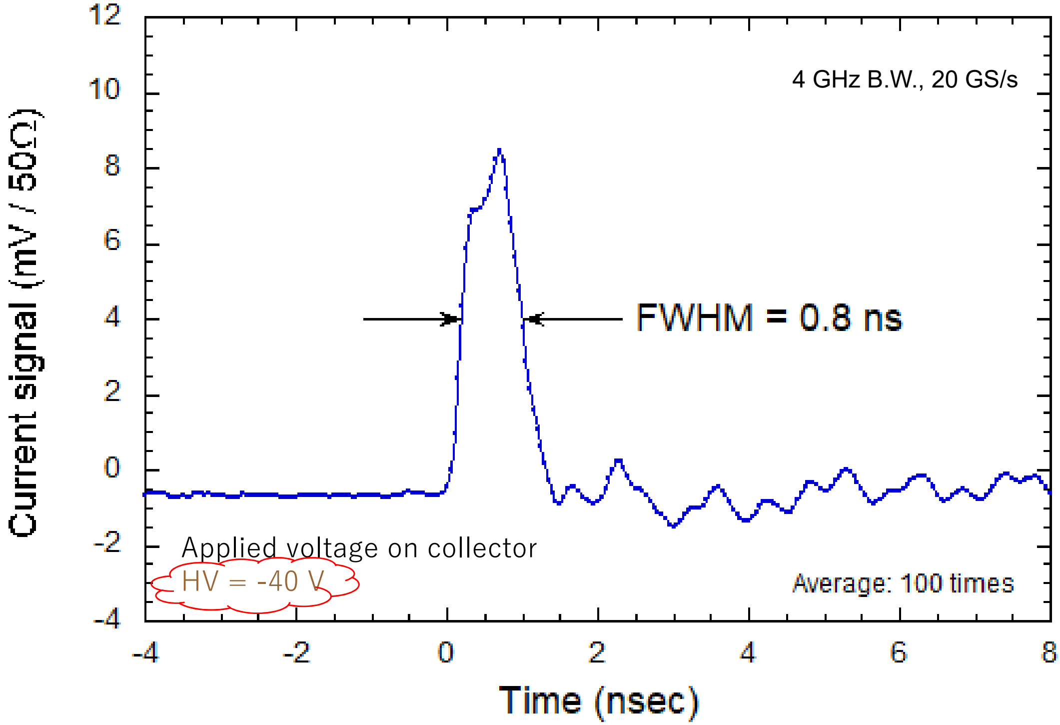
Installed at a bending magnet BL (SPring-8 BL02B1)

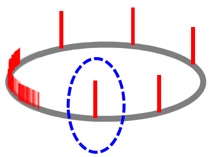


Performance Tests

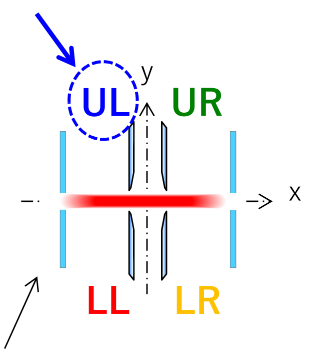
Pulse mode: Waveform observation

Observation of an isolated bunch of "1/7 filling + 5 bunches"





"1/7 filling + 5 bunches" mode

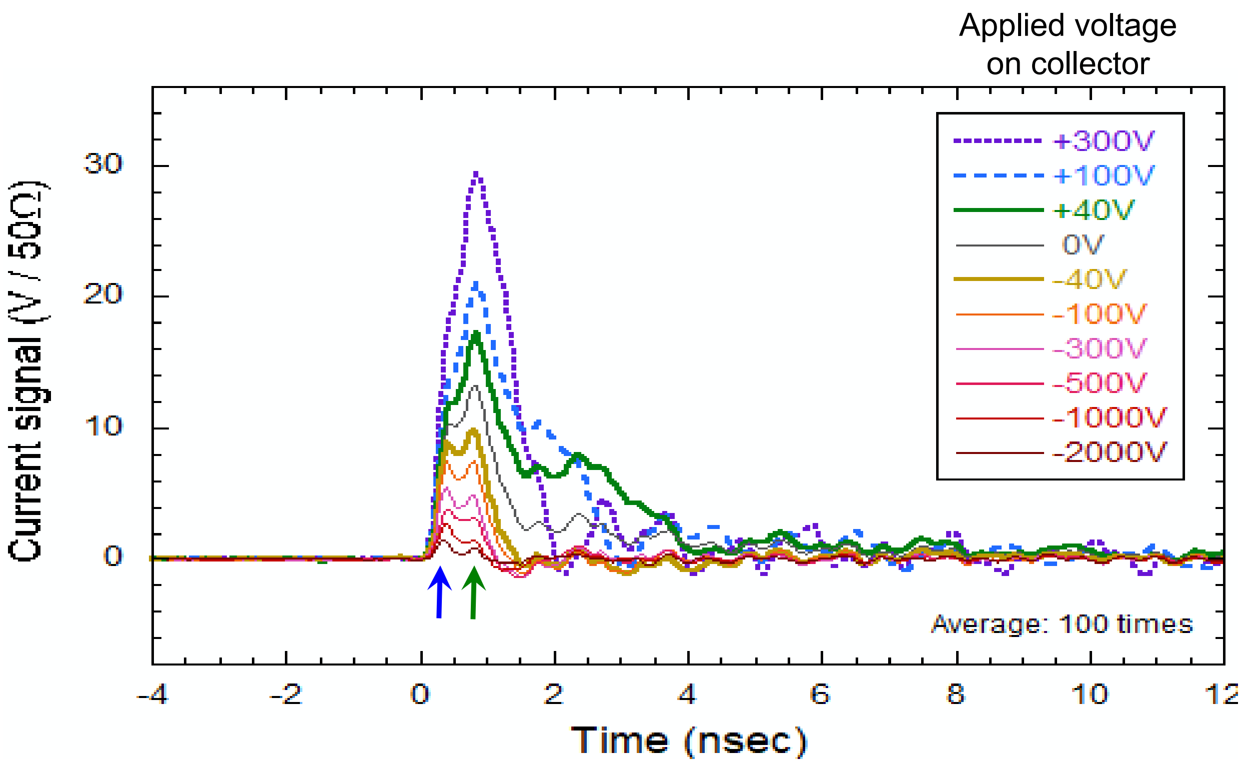


Charge collectors are placed both side of blades.

A unipolar single pulse signal of < 1 ns , which is our target, was obtained.

About double peak, this will be explain next page.

Pulse mode: Waveform shaping with collectors



1st peak: derived from photoelectron, which is high energy.

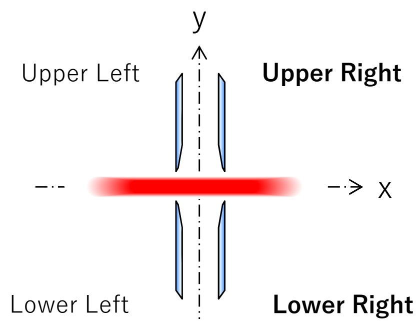
2nd peak: derived from secondary electrons (low energy).

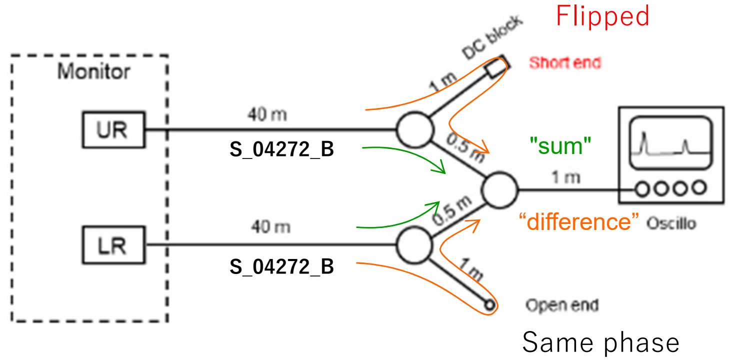
For the 2nd peak, the lower the voltage, the lower the height.

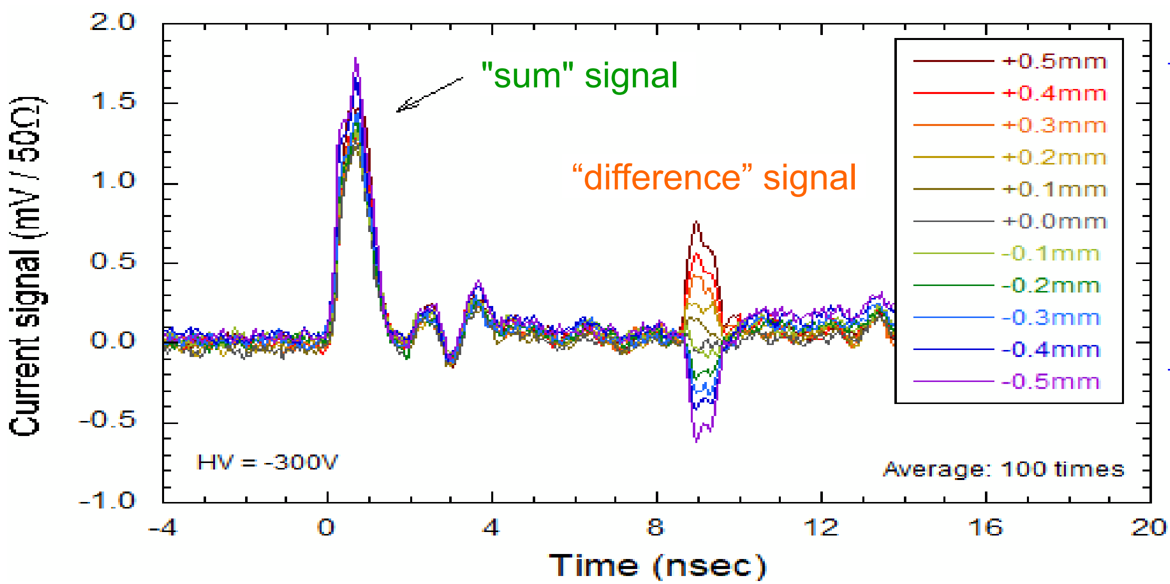
For the tail part, it seems that charges are forcibly collected by positive voltage. (HV > + 40 V)

The pulse waveform (height, length) greatly depends on polarity and the applied voltage. ---> *Controllable !!*

Pulse mode: Generation of position sensitive signal







Scan of the vertical stage in the range of ± 0.5 mm

The position sensitive signal can be generated directly by combining reflected pulses at the open end and the short end of the stub cables.

But resolution is not enough!

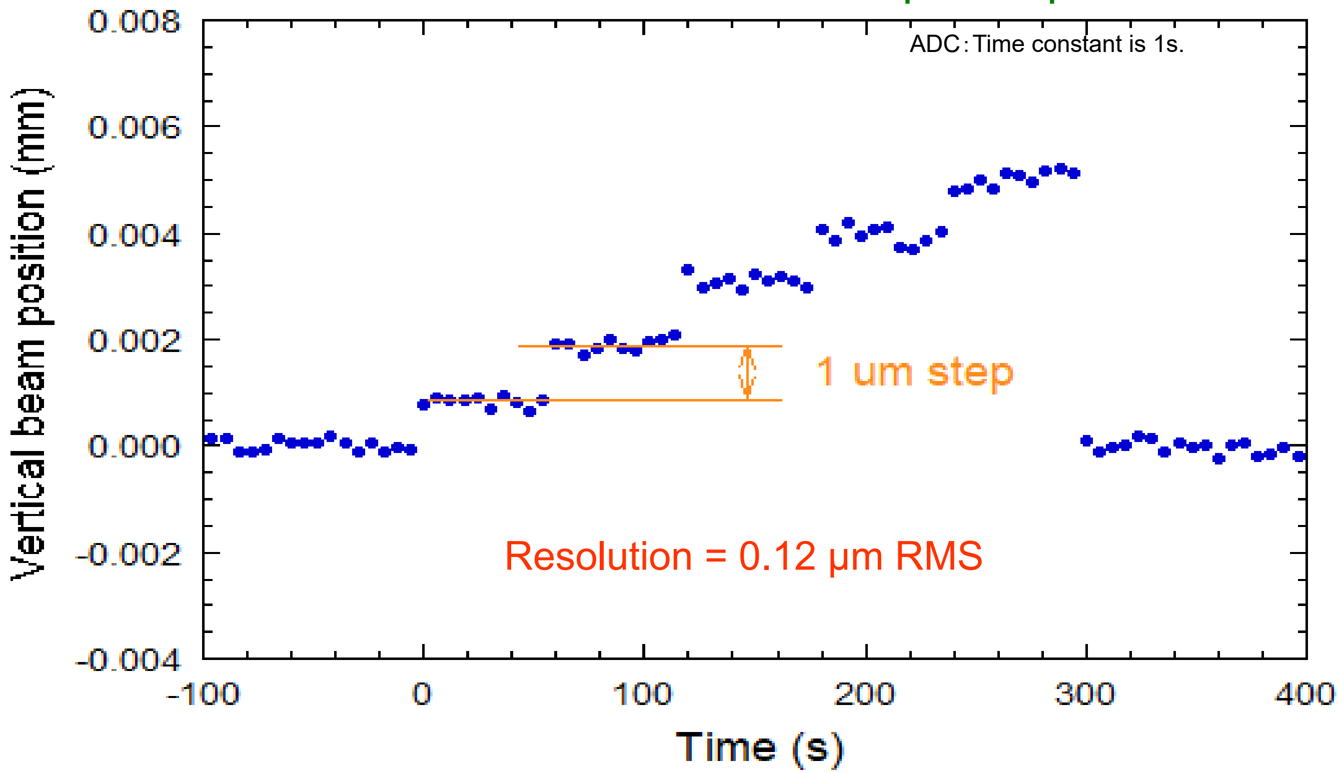
It is necessary to increase the signal amount.

DC mode: Resolution

(Operation as a conventional XBPM)

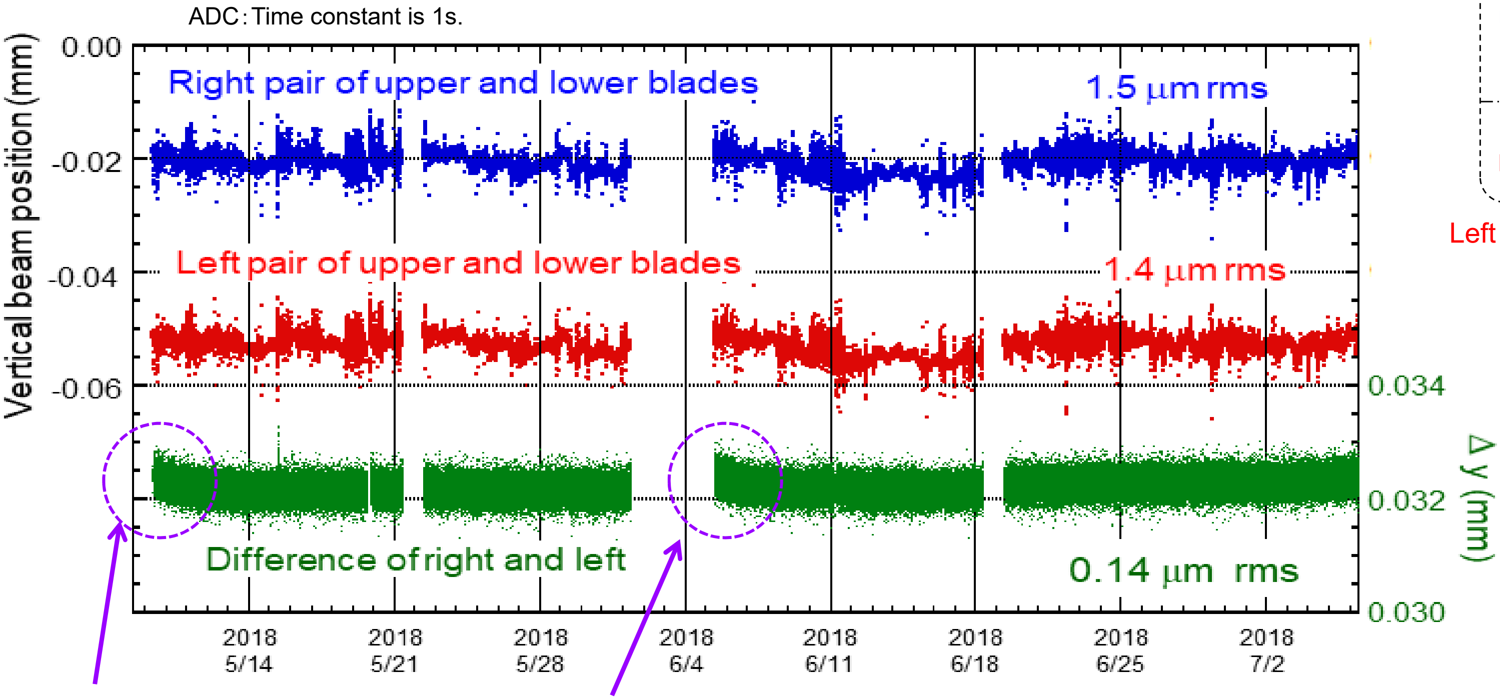
$$Y(mm) = Ay \times \frac{(UL + UR) - (LL + LR)}{UL + UR + LL + LR}$$

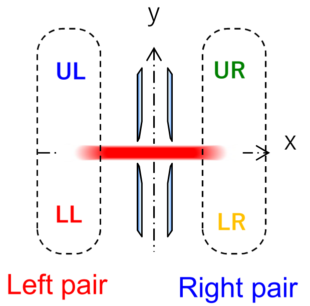
Scan measurement in 1 μm step



DC mode: Long-term Stability

Trend graph during user operation (2 months)





0.2 μm drift after shut down of several days

Stability as a conventional XBPM in DC mode is very good for 2 months.

Summary

The pulse-by-pulse XBPM has been newly designed and manufactured, and performance tests were carried out at the SPring-8 bending magnet beamline BL02B1 front end.

1. Performance in pulse mode operation

- Unipolar single pulse (0.8 ns FWHM) was obtained.
- Pulse shapes are controllable by adjusting the voltage of the collector.
- Position sensitive signal can be generated directly by combining reflected pulses.

2. Performance in DC mode operation

- Resolution of 0.12 μm RMS was obtained.
- Good long-term stability was confirmed.

<Next steps >

- Resolution needs to be improved by increasing the amount of signal.
- Signal processing system for user operation needs to be constructed.