Analysis of the Bunch Position Monitoring in Long Bunch Trains at FLASH.

Nicoleta Baboi, Bastian Lorbeer (DESY, Hamburg)

Abstract

Multi-bunch beams are routinely being accelerated at the FLASH Free Electron Laser at DESY, Hamburg. More than hundred Beam Position Monitors (BPMs) measure the transverse offset of every single bunch in each train with a bunch repetition frequency of up to 1 MHz and a length of several hundreds of microseconds. Various types of monitors are being used: button, stripline and cavity BPMs, each type with several designs. The performance differs from type to type, with resolutions from one to tens of micrometers. However so far only the first bunch in the train was investigated in detail. In this paper we study every bunch along long bunch train for several BPM designs and locations. Also the dependency of the bunch resolution on the bunch offset is shown.

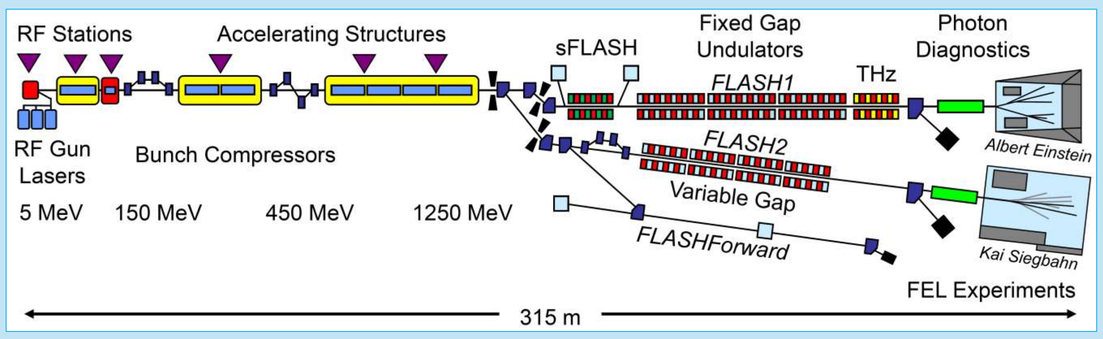
The analysis is made
- along the bunch train
- for various bunch offsets
- for button and stripline BPMs
- in the linac and FLASH1 beamline

The FLASH Free Electron Laser, DESY, Hamburg

User and test facility
The Free electron LASer in Hamburg (FLASH) produces ultra short intense XUV and soft X-ray pulses.
A photoelectric gun produces electron bunch trains with a repetition frequency of up to 1 MHz.. The TESLA superconducting accelerating technology enables the acceleration of trains of hundreds of bunches with a frequency of 10 Hz. Two bunch compressors are used to reduce the bunch length to tens to hundreds of fs. The train is split then to the two undulator beamlines, enabling multi-user operation in the two experimental halls [1].
A third beam line splits off FLASH2 and accommodates a laser-plasma experiment, FLASHForward (FLF) [ref3].

Diagnostics
Many of diagnostics monitors installed in FLASH are able to measure each single bunch in the bunch train: toroid, measuring the bunch charge, beam position monitors (BPMs), beam loss monitors. OTR and scintillator-based screen stations and wire scanners offer the transverse beam profile. Longitudinal diagnostics, such as the bunch compression monitors, beam arrival monitors, transverse deflecting structure allow the precise control of the bunch length and time synchronization, essential for many experiments.

BPMs
More than 100 BPMs of several types are installed in FLASH. Each type can be found in several geometries



Ref [2] http://flash.desy.de/

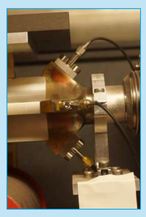
Typical parameters

Parameter	FLASH1	FLASH2
Electron beam energy	0.35 - 1.25 GeV	0.4 - 1.25 GeV
Normalised emittance at 1 nC (rms)	1.4 mm mrad	1.4 mm mrad
Energy spread	200 keV	500 keV
Electron bunch charge	0.1 - 1.2 nC	0.02 - 1 nC
Peak current	1 - 2.5 kA	1 - 2.5 kA
Electron bunches per second (typ./max)	300 / 5000	300 / 5000
Photon energy (fundamental)	24 - 295 eV	14 - 310 eV
Photon wavelength (fundamental)	51 - 4.2 nm	90 - 4 nm
Photon pulse duration (FWHM)	<30 - 200 fs	<10 - 200 fs
Peak Power (from av.)	1 - 5 GW	1 - 5 GW
Single photon pulse energy (average)	1 - 500 µJ	1 - 1000 µJ
Photons per Pulse	10^{11} – 10^{14}	10^{11} - 10^{14}

http://flash.desy.de/

BPMs in FLASH

Button BPM



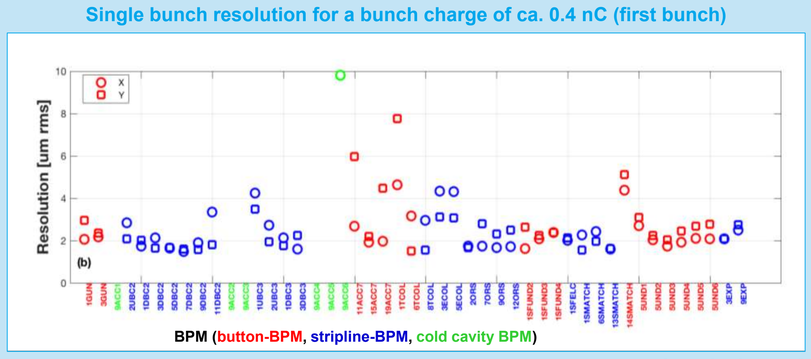
Stripline BPM

Cavity BPMs

System	Electronics Type	#	Location
Button BPMs	FLASH	39	All
Stripline BPMs	FLASH	34	All
Cavity BPMs	E-XFEL	21	FL2, FLF
Cold Cavity BPMs	TTF2	6	Linac
Magnetic BPMs	FLASH	2	FL1, FL2

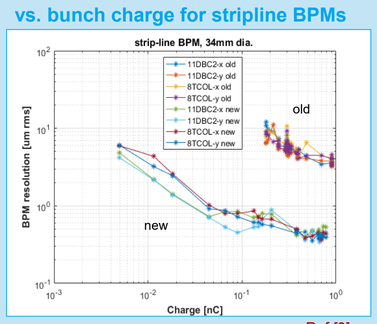
BPM Resolution

Single bunch resolution for a bunch charge of ca. 0.4 nC (first bunch)



Ref [3]

vs. bunch charge for stripline BPMs



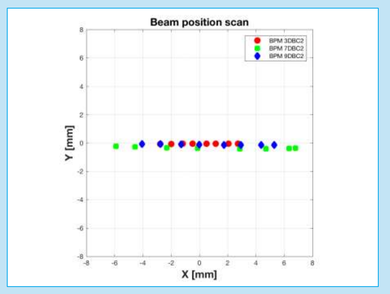
Ref [2]

Typical parameters

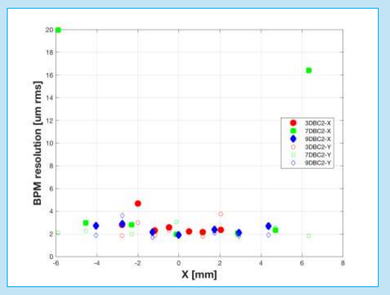
BPM-Type	q [pC]	Offset [% Diam.]	Single-bunch resolution [µm rms]
Button BPMs	20-1000	Ca. 30%	2-100
Stripline BPMs	10-1000	Ca. 30%	1-15
Cavity BPMs	10-1000	Ca. 10%	1-2
Cold Cavity BPMs	400-1500	Ca. 20%	20-100

Resolution vs. Offset

Horizontal beam position scan for stripline BPMs



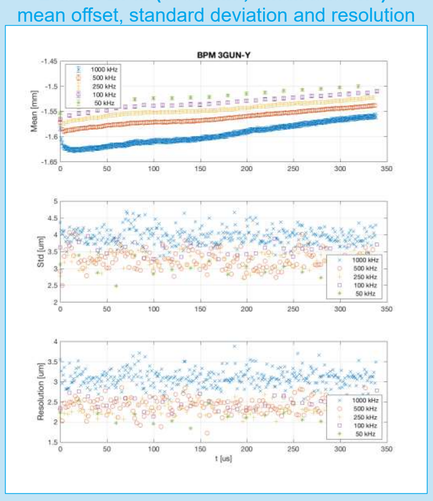
Resolution vs. beam position.



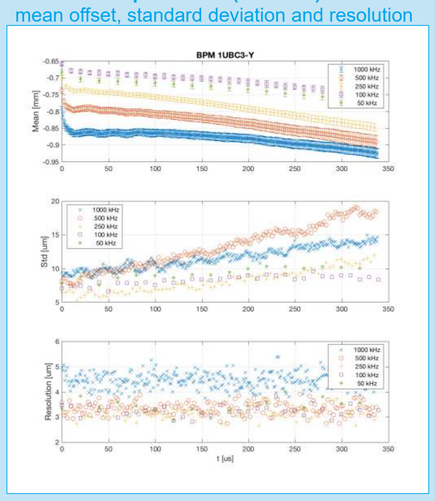
No change in the resolution within the measurement range of ca. ± 5mm.

Analysis of bunches along the bunch train for various repetition frequencies

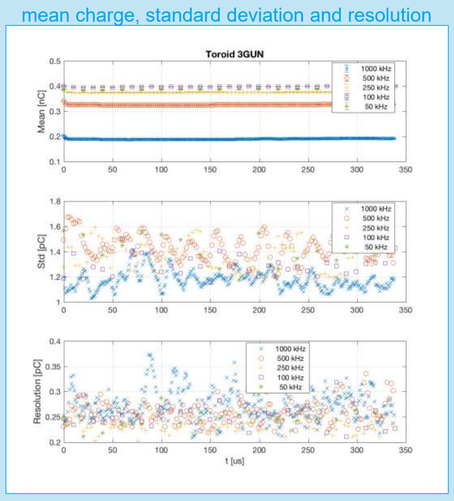
Button BPM (Ø 34 mm, small buttons):
mean offset, standard deviation and resolution



Stripline BPM (Ø 34mm):
mean offset, standard deviation and resolution



Toroid:
mean charge, standard deviation and resolution



Mean, std and resolution of BPM reading for each bunch in the train
200 bunch trains

There is a variation of the beam position along the train and also of the charge (right, upper plot)

The standard deviation increases for the stripline BPM towards the end of the train.

The difference in the resolution for different repetition frequencies is due to the different bunch charge.

Mean, std and resolution of charge reading

The charge changed when changing the bunch repertition frequency, which explains the slight change in the BPM resolution.

Summary

No dependence of the single bunch resolution has been observed along the bunch train.

Also, not significant change was observed for various bunch frequencies.

The resolution stays unchanged within the transverse measurements range of the stripline-BPMs: ca. ± 5mm.

References

[1] J. Roensch-Schulenburg et al., “FLASH - Status and Upgrades”, *FEL'19*, Hamburg, Germany, FRA03.

[2] B. Lorbeer et al., “High Resolution and Low Charge Button and Strip-Line Beam Position Monitor Electronics Upgrade at FLASH”, IPAC'18, Vancouver, Canada, p. 1923 (2018).

[3] N. Baboi et al., “Resolution Studies at Beam Position Monitors at the FLASH Facility at DESY”, in *AIP Conference Proceedings* 868, 227 (2006).

IBIC'20 International Beam Instrumentation Conference

FLASH Free-electron laser FLASH