COMMISSIONING OF THE CAVITY BPM FOR THE FERMI@ELETTRA FEL PROJECT

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Abstract

The Cavity Beam Position Monitor (BPM) is a fundamental beam diagnostic device that allows the measurement of the electron beam trajectory in a non-destructively way, with the micron resolution. Ten cavity BPM systems have been installed along the undulators chain in the FERMI@Elettra FEL1 project. In this paper we discuss the installation, commissioning and performance of these cavity BPM systems. We have carried out preliminary operations during a pre-beam period, such as alignment and fine tuning of the RF vacuum cavities. During the commissioning each BPM has been calibrated by mechanically moving the support on which the BPM is mounted. We have estimated the single shot resolution in presence of beam jitter by reading the beam position synchronously over many electron bunches, from three or more BPMs. Subsequently the algorithms have been improved, and the results are here described, together with a first resolution assessment.

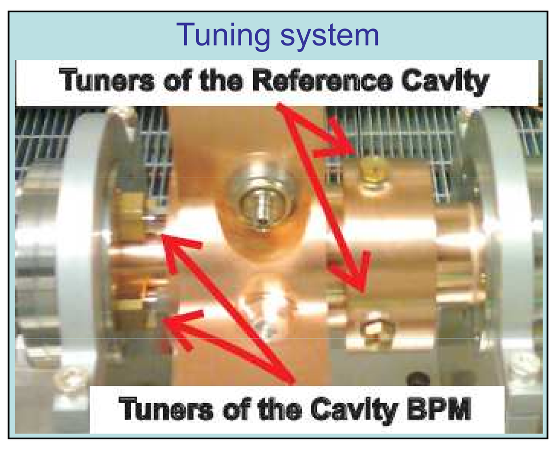
Outline

- Realization
- Workbench measurements
- Installation and tuning
- Calibration
- Resolution measurements

Realization [1]

Parts of the Cavity BPM before brazing

Tuning system



Realized with:
- Turner (Tolerance: 10μm)
- Wire-EDM (Tolerance: 10μm)

Expected resonant frequencies

Reference Cavity	Cavity BPM
6495 MHz	6505 MHz

Tuners type

	Reference Cavity	Cavity BPM
Type	Radial	Longitudinal
Δf max	+20 MHz	-4 MHz

Workbench measurements

Inspection of all the cavities, with the network analizer, to check:
- Resonant frequency
- Crosstalking

Table 1: Resonant frequencies of the Reference Cavity

Resonant frequencies of the Reference Cavity $[MHz]$			
BPM#*	Before Brazing	After Brazing	Δf
1	6495.7	6499.4	3.7
2	6494.0	6500.3	6.3
3	6496.8	6501.0	4.2
5	6495.7	6503.9	8.2
6	6496.5	6485.6	-10.9**
7	6496.8	6503.1	6.3
8	6497.0	6489.6	-7.4**
9	6494.8	6500.4	5.6
10	6497.5	6501.7	4.2
11	6498.2	6505.1	6.9
12	6500.0	6498.6	-1.4
13	6491.4	6487.7	-3.7**
14	6487.7	6482.9	-4.8**

*This is the manufacturing number
**Rectified cavities

Table 2: Resonant frequencies of the Cavity BPM

Resonant frequencies of the Cavity BPM $[MHz]$			
BPM#*	B.B.**	A.B.**, Pol. H	A.B.**, Pol. V
1	6506.7	6502.8	6502.3
2	6509.8	6502.5	6502.6
3	6506.5	6503.7	6503.3
5	6508.2	6503.8	6504.2
6	6508.8	6504.5	6504.6
7	6505.6	6503.9	6504.4
8	6507.3	6504.0	6504.0
9	6507.3	6505.3	6505.0
10	6509.3	6503.1	6503.7
11	6507.9	6504.4	6505.0
12	6510.3	6505.8	6505.6
13	6501.1	6503.2	6503.1
14	6501.1	6501.4	6501.0

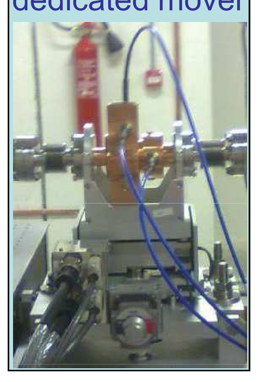
*This is the manufacturing number
**B.B.= Before Brazing, A.B. = After Brazing

The average value of crosstalking is -51,1 dB

Installation and tuning

Ten Cavity BPMs have been installed in the undulator hall in the FEL 1 section of the FERMI@Elettra project
→ Each C-BPM has a mover

Cavity BPM with dedicated mover



Mover characteristics:
Mover range: ± 0.8 mm
Encoder Resolution: 1 μm

The cavities have been tuned, the following table reports the resonant frequencies

Table 3: Tuning of the Cavity BPM

	Resonant Frequencies $[MHz]$			$\Delta f\ [MHz]$		
#*	R. Cav.	BPM H.	BPM V.	H.-V.	H.-R.	V.-R.
1	6503.03	6503.42	6503.03	0.39	0.39	0.00
2	6507.35	6507.58	6507.68	-0.10	0.23	0.33
3	6507.19	6507.77	6507.39	0.38	0.58	0.20
4	6504.60	6504.66	6504.70	-0.04	0.06	0.10
5	6503.58	6503.69	6503.63	0.06	0.11	0.05
6	6504.27	6504.04	6504.11	-0.07	-0.23	-0.16
7	6504.78	6504.94	6505.04	-0.10	0.16	0.26
8	6503.98	6503.89	6504.11	-0.22	-0.09	0.13
9	6505.64	6505.71	6505.67	0.04	0.07	0.03
10	6502.52	6502.56	6502.53	0.03	0.04	0.01

'H.' is the Horizontal polarization of the BPM
'V.' is the Vertical polarization of the BPM
'R.' is resonance frequency of the Reference Cavity
*This is the installation number

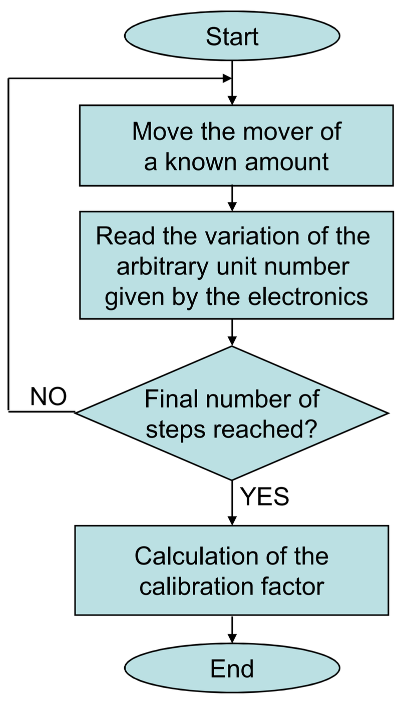
→ With the Tuners is possible to keep the difference between the two frequencies less than 100KHz

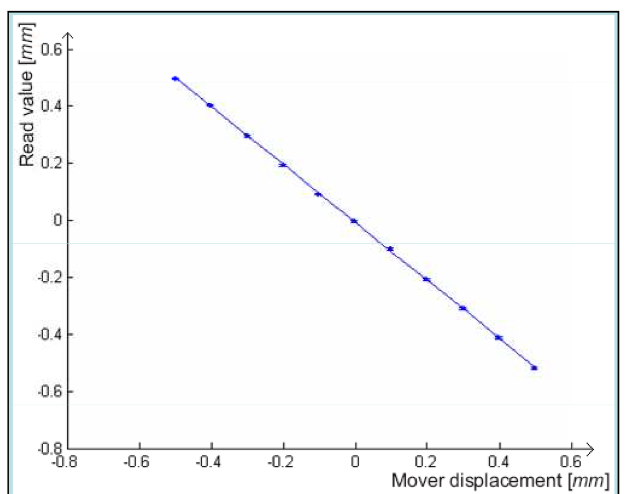
Calibration [2]

Aim: estimate the multiplying constant '*k*' that converts the arbitrary unit number generated by the electronics into the real value (expressed in *mm*)

Real time mode: the data acquisition system has the feature to acquire all the data of a single bunch in "Real Time" mode, with the bunch number

Calibration algorithm





Result of the calibration, tolerance: 10%

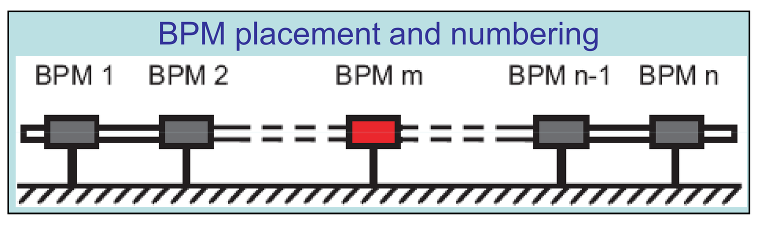
The calibration factor has been calculated by averaging 160 acquisitions.

The calibration algorithm has been improved with the Waltson et al. [2] technique, that is independent of the beam jitter.

Resolution measurements [3]

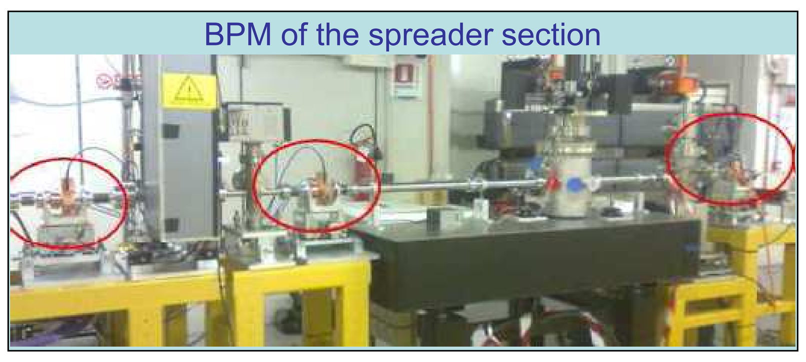
The resolution is assessed with three or more BPMs, we are interested in the resolution of the BPM '*m*'.

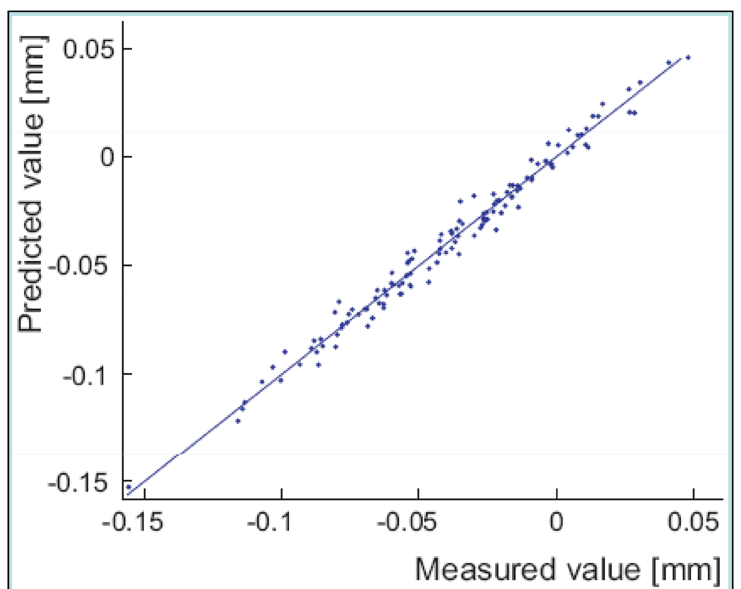
BPM placement and numbering



We used three BPMs, in the spreader section.

BPM of the spreader section





Plot of the measured-predicted value

This resolution method compares the reading of the electron beam offset measured with the BPM of interest ('m'), with the predicted value by all the other BPMs [3]. The data is acquired in real time mode, in presence of beam jitter.

$$\sigma_m = \sqrt{\frac{1}{p}\sum_{i=1}^{p}(x_{i,measured} - x_{i,predicted})^2}$$

$$BPM\ resolution = \frac{\sigma_m}{\sqrt{1^2 + (\frac{z_{12}}{z_{13}})^2 + (\frac{z_{23}}{z_{13}})^2}}$$

The resolution is nearly 4 μm, with a bunch charge of 50 pC up to 270 pC, value that has to be improved with many changes in the electronic system, that are:
1. Change the coupling transformers (the actual ones have a lower bandwidth);
2. Update μTCA power supplies with low noises one;
3. Fine tune phase delays using a remote stepper motor;
4. Add an programmable attenuator in the reference signal.

Conclusion

The Cavity BPMs have been successfully realized, installed and tuned in the undulator hall of the FEL 1 section. Many attentions have been paid to the resonant frequencies. The entire system, including the electronic and the data acquisition method, has been started-up and debugged for the first time in the last commissioning. The calibration has been performed with the movers. The first resolution measurements have been carried out with the first three BPMs in the spreader section. However, many improvements are still to be made in the electronic system.

Bibliography

[1] Cinel Strumenti Scentifici, http://www.cinel.com/.
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[5] P. Craievich et al., "Design of the cavity BPM system for FERMI@Elettra", DIPAC2007, Venice, Italy.

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