TUPG06

DEVELOPMENT STATUS OF A STABLE BPM SYSTEM FOR THE SPRING-8 UPGRADE

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SPring-8 Upgrade Project [1]

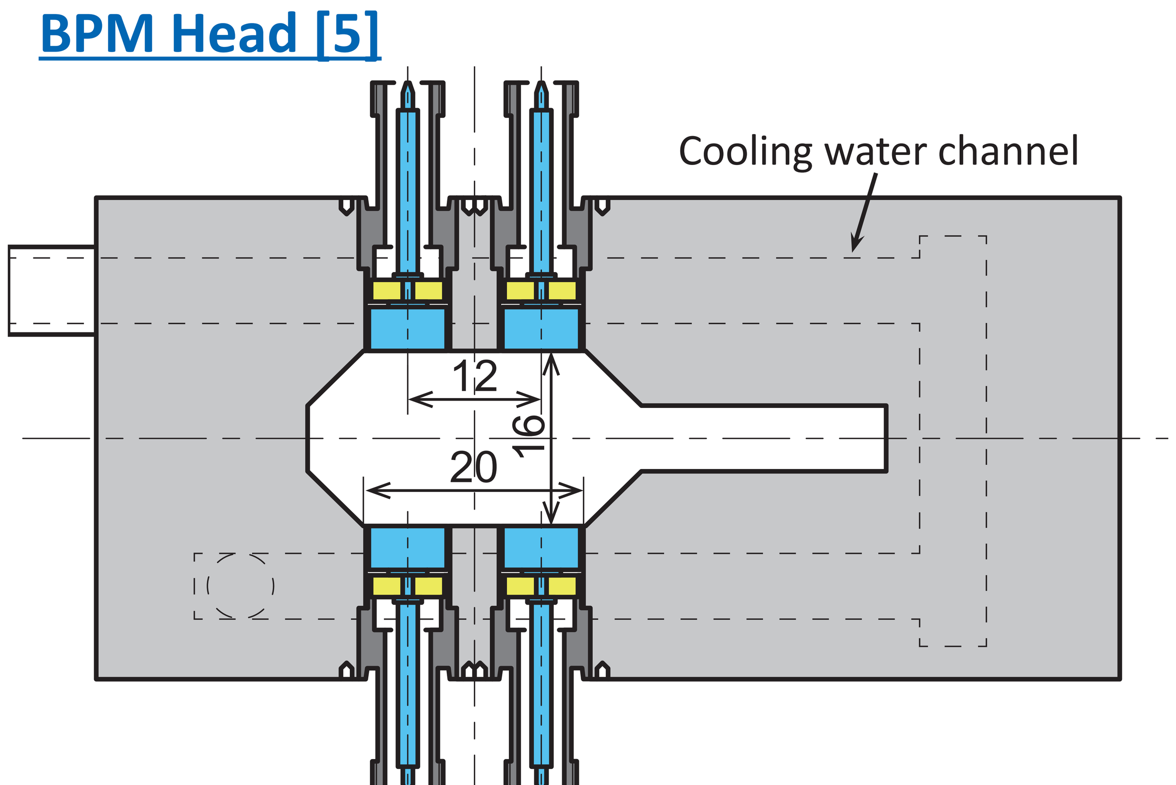
- Lattice: 5-bend Achromat (5BA)
- Natural Emittance: 140 pm rad (bare lattice)
  100 pm rad (with radiation damping of IDs)
- X-ray Brilliance: more than 1 orders of magnitude higher than the present SPring-8
- Breakthroughs of X-ray optical systems, such as Direct nano-focusing scheme [2].

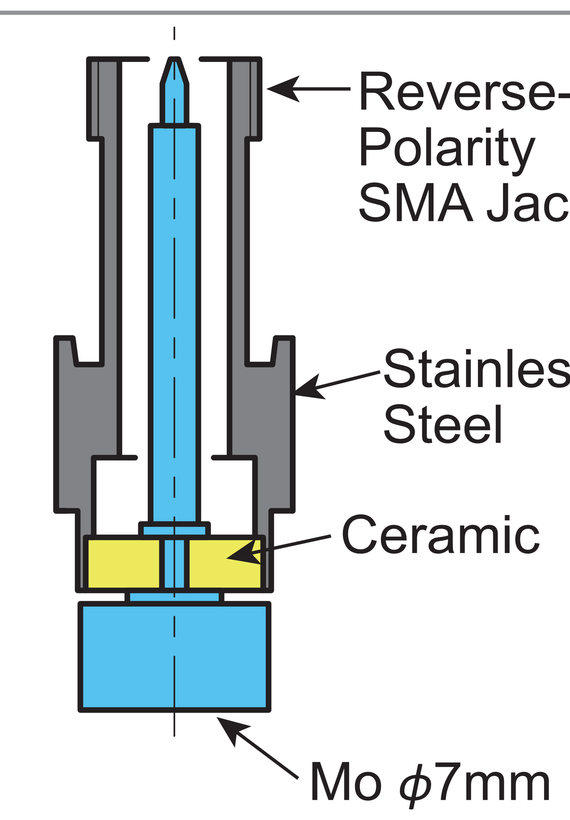
Requirements for the BPM System

COD Resolution	0.1 µm rms (100 mA, 1 kHz BW)
COD Accuracy after BBA	10 µm rms
COD Stability	5 µm max. (1 month)
Single-pass Resolution	100 µm rms (100 pC single-bunch)
Single-pass Accuracy before BBA	100 µm rms (±200 µm max.)

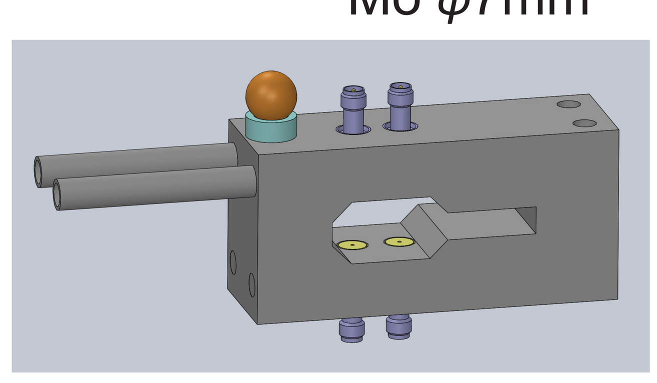
- Direct nano-focusing scheme demands that the photon axis stability should be well within the intrinsic photon divergence [3].
  → Electron beam stability: sub-µm for position and sub-µrad for direction
- COD resolution is sufficient for this demand.
  - COD stability requirement of 5 µm is challenging, although it is not sufficient for the direct nano-focusing beamline.
  - Present BPM system of SPring-8 shows some drifts of BPM data more than 10 µm [4].
- Beam position is required to be adjusted to the field center of multipole magnets within a few 10 µm.
  → Precise beam-based alignment (BBA) with 10 µm accuracy is needed.
- Single-pass resolution of 100 µm rms (100 pC) is required for first-turn steering.
- BPM electric center must be aligned to an adjacent quadrupole magnets with 100 µm rms (±200 µm maximum) accuracy to reduce an unwanted kick.

BPM Head [5]





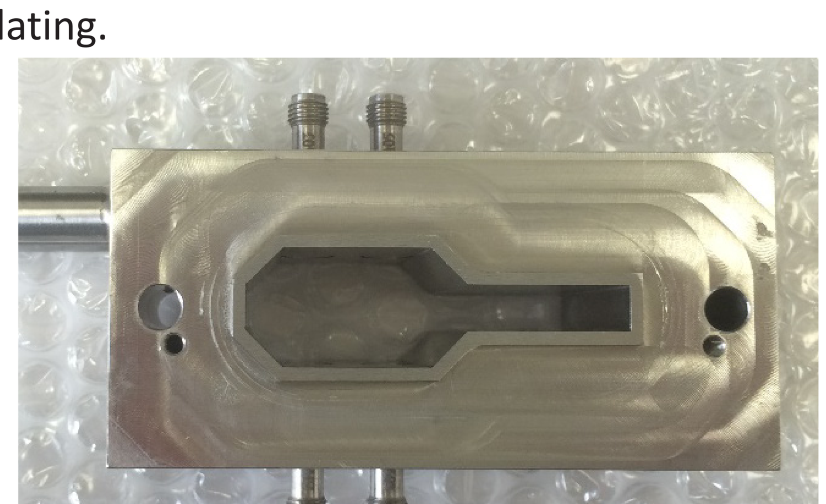
- Button diameter: 7 mm (Gap: 0.5 mm)
- Button material: Molybdenum
  - Non-magnetic material
  - High conductivity for small heat generation due to ohmic losses of trapped modes.
- Machining accuracy: a few 10 µm
  → Error on the electric center with respect to the reference plane < 50 µm rms
- Heat input: 1.1 W maximum (100 mA) for the whole BPM head [5]



Prototype

- 24 prototype electrodes were produced.
- All the electrodes passed a heat cycle test (150 ˚C) without any vacuum leaks.
- Some prototype BPM blocks by using prototype electrodes were also produced.
- Button electrodes were bonded to the block by electron beam welding (EBW).
  - Electrode was pulled out by a few 10 µm after EBW due to the shrinkage of welded part.
  - Height of the electrode was adjusted at the machining stage by considering the shrinkage.
  - Height of the electrode surface was controlled within 50 µm.
- We decided not to plate copper in the beam duct.
  - To reduce the dimension error.
  - Resistive wall impedance is sufficiently small thanks to the compactness.
    »Other vacuum chambers has inner copper plating.

Prototype of button electrode



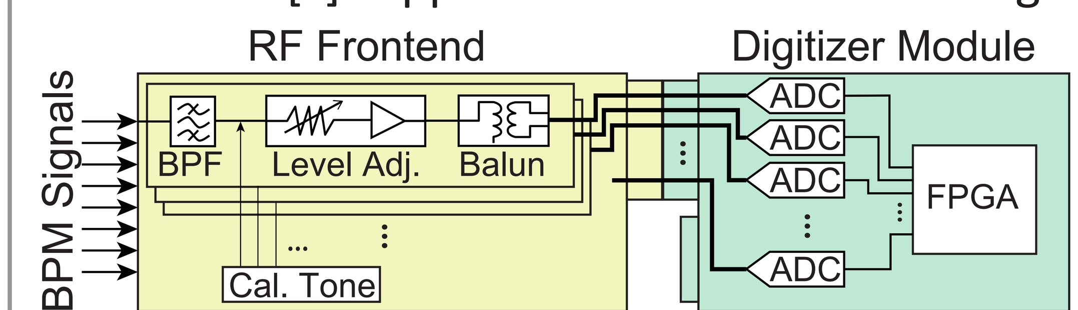
Prototype of BPM head

Support and Alignment

- BPM head is supported from the same girder as magnets and vacuum chambers.
  - Relative position between the BPM and magnets is not changed after a realignment of the girder.
- BPM head position is measured by a laser tracker survey within 50 µm rms accuracy.
- Total error on the BPM electric center: 70 µm rms ($\sqrt{50^2+50^2}$)
  - Remained margin in the alignment errror is reserved for the calibration error of the electronics etc.

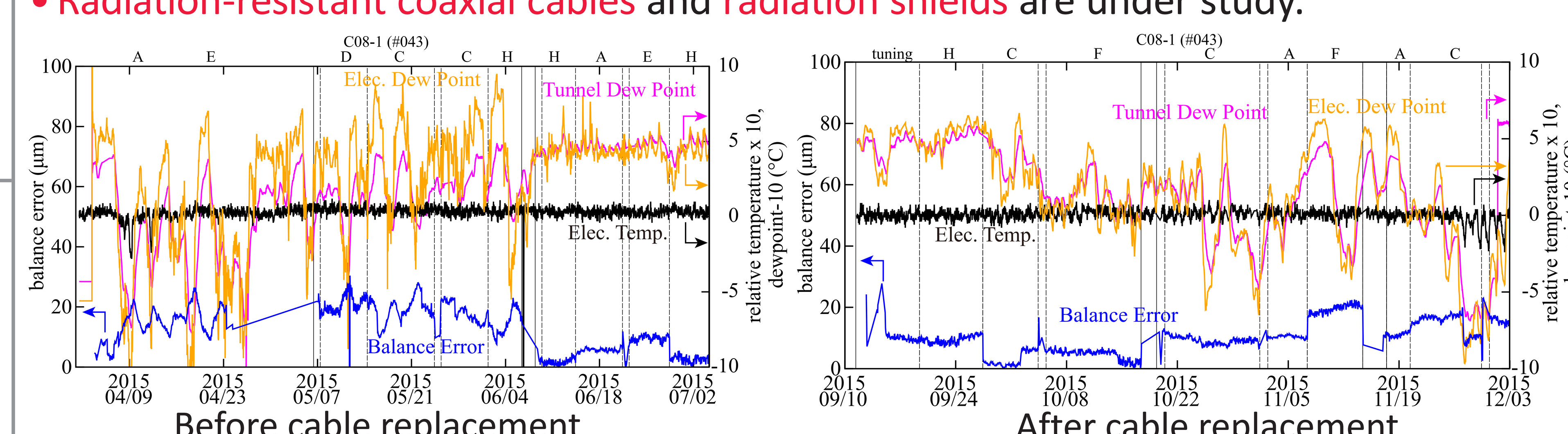
Readout Electronics

- We have two candidates for the BPM electronics:
  Original design based on MTCA.4 [6] and the new generation of Libera Brilliance+ [7]
- Most of the modules for the original design are same as the new LLRF system [8].
- Calibration tone will be used for the calibration of the original BPM electronics.
- Single-pass and COD resolutions of Libera Brilliance+ were confirmed to be sufficient.
- MADOCA [9] support is needed for the new generation of Libera Brilliance+.



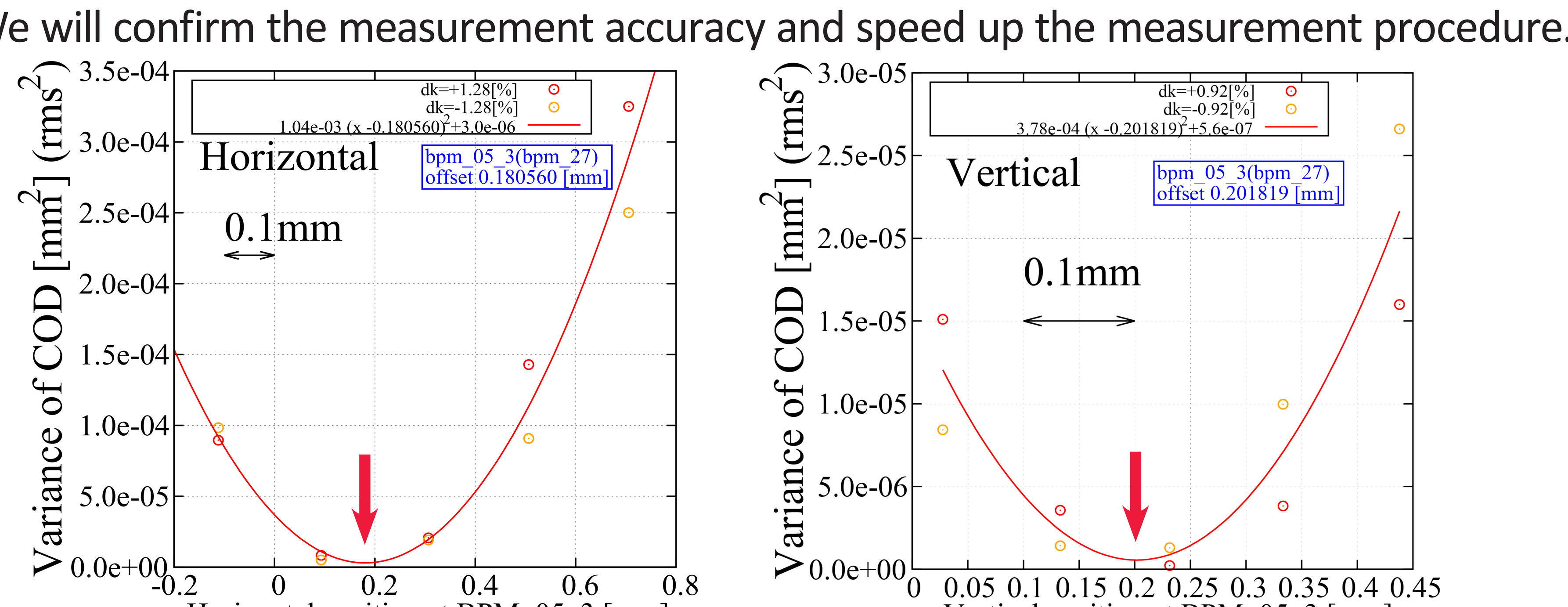
Signal Cable

- One of the most significant causes of the drift of the present BPM system:
  Radiation damage to signal cables → Humidity-dependent drift
- Balance error is defined to estimate the drift.
  - Beam position can be calculated from 3 electrodes out of 4.
  - 4 beam position values are obtained from 4 combinations of 3 electrodes.
  - Balance error is defined as the maximum difference among the 4 values.
- Humidity dependence of the charactoristic impedance was confirmed by chemical analyses.
- Replacement of the damaged cables → Humidity-dependent drift disappeared
- Radiation-resistant coaxial cables and radiation shields are under study.



Beam-based Alignment

- Beam position was shifted by generating a local bump orbit.
- Field strength of an adjacent quadrupole magnet was changed by 1%
- Reproducibility of the result was 10 µm rms.
- We will confirm the measurement accuracy and speed up the measurement procedure.



Beam Test

- Beam test setup of the new BPM system in the present SPring-8 has just installed.
- Cables and readout electronics for the up-graded SPring-8 are also evaluated in this test.
- Signal intensity, waveform, temperature rise, long-term stability will be evaluated.

Summary

- We are developing a stable and precise BPM system for the low-emittance upgrade of SPring-8.
- Requirements for the BPM are 5 µm long-term stability and 0.1 µm resolution for COD and high single-pass resolution and accuracy of 100 µm rms.
- Precise BPM electrode and block were designed with the error on the electric center < 50 µm.
- Some prototypes of the BPM head with suffi cient machining accuracy were produced.
- Candidates for the readout electronics are a MTCA.4-based system and new Libera Brilliance+.
- Radiation-hard cable and radiation shield are under study to reduce humidity-dependent drift.
- Beam-based alignment technique has been tested for precise orbit tuning within 10 µm rms.
- Beam test at the present SPring-8 will be performed.

Acknowledgment

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