WEPP31

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Design of the Beam Diagnostic System for the New 3 GeV Light Source in Japan

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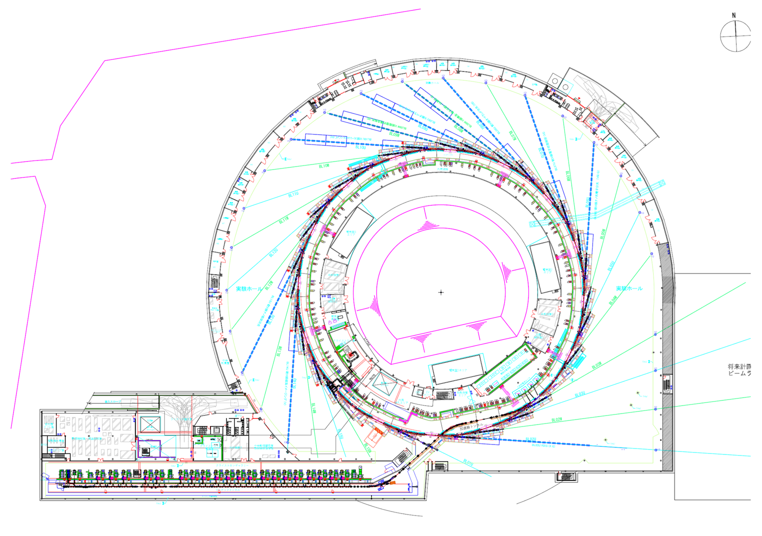
Introduction

- A new 3 GeV light source is now being constructed in Sendai, Japan.
- X-ray brilliance: more than 10^{21} photons/s/mm^2/mrad^2/0.1%BW (~1 keV)
- Natural emittance: 1.1 nm rad
- Lattice: Double double-bend achromat
- Beam current: 400 mA
- Number of cells: 16
- RF frequency: 508.76 MHz
- Circumference: 349 m
- Various beam parameters, such as the beam orbit, current, size, etc. have to be monitored precisely and stably.



N. Nishimori, T. Watanabe, and H. Tanaka, Proc. IPAC'19, pp. 1478–1481, TUPGW035.

List of Beam Diagnostic Instruments

Diagnostic instruments	Number of units
Beam Position Monitor (BPM)	112 (7/cell)
Beam Current Monitor (DCCT)	2
Stripline BPM	2
Beam Size Monitor	1
Betatron Tune Monitor	1 (in BBF)
Beam Instability Control (BBF)	1

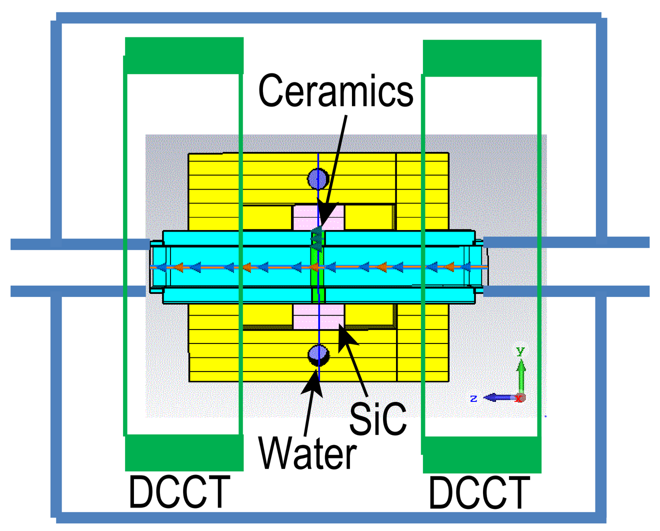
Installed in short straight sections (SSS).

- These diagnostic instruments were designed based on the SPring-8 upgrade.

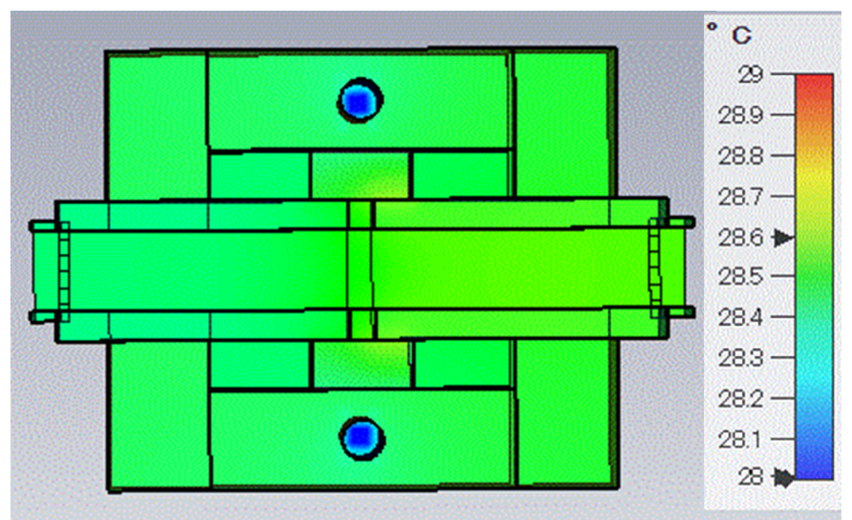
H. Maesaka et al., Proc. IPAC'16, pp. 149–151, MOPMB028.

Stored Beam Current Monitor

- Two DCCTs are integrated in the chamber for redundancy.
- Bergoz NPCT is employed.
- Noise Level: 1 µA/√Hz (±1 A full range and 10 kHz BW)
- Thermal coefficient: 5 µA/K
- Temperature rise: less than 1 K (400 mA beam)
- DCCT can measure the beam current with 1 µA precision.



DCCT Schematic



Thermal analysis result.

Beam Position Monitor

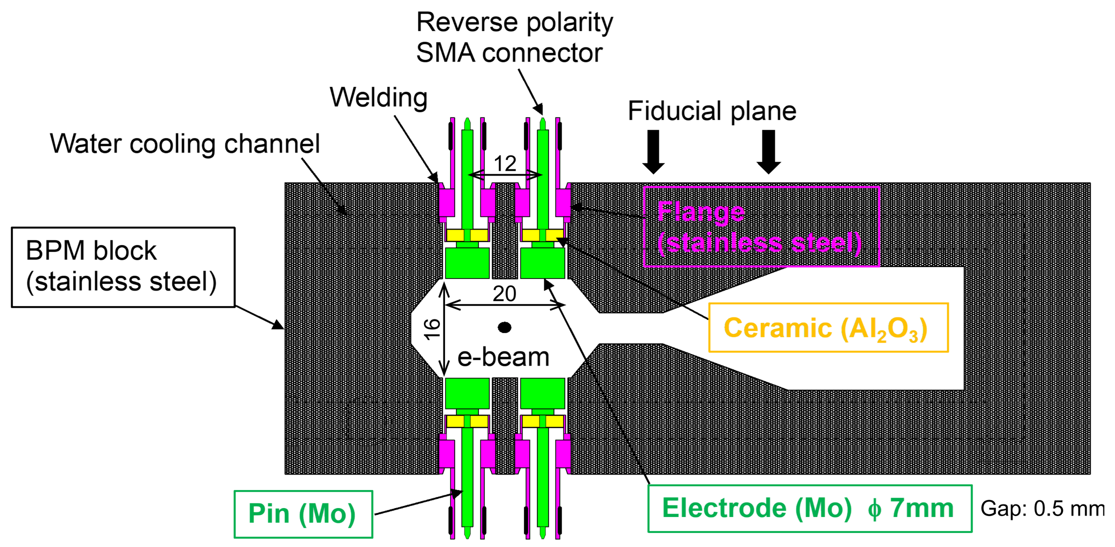
Requirements

- Single-pass (SP) resolution: 0.1 mm (100 pC) for commissioning.
- COD resolution: ~0.1 µm (100 mA)
- COD stability: 5 µm for 1 month.

Design

M. Masaki et al., Proc. IBIC'16, pp. 360–363, TUPG18.

- Button-type BPM pickups originally developed for the SPring-8 upgrade.

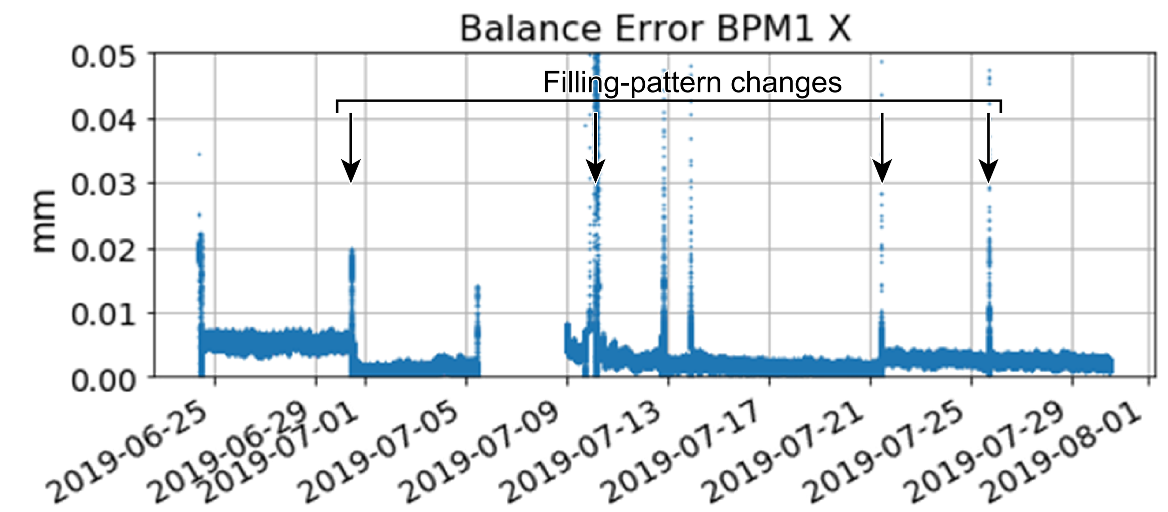


- Radiation resistive cables near the BPM block. (SiO_2 or PEEK semirigid)
- MTCA.4 electronics H. Maesaka et al., Proc. IBIC'19, pp. 471–474, WEBO03.
  - COD data: 10 Hz, 10 kHz, and 859 kHz (turn-by-turn)
  - SP process in parallel with COD.

Basic Performance

H. Maesaka et al., Proc. IBIC'18, pp. 204–207, TUOC04.
T. Fujita et al., Proc. IBIC'15, pp. 359–363, TUPB020.

- Basic performance of the BPM system was evaluated in SPring-8.
- SP resolution: 0.02 mm (0.13 nC)
- COD resolution: 0.4 µm (30 mA, 10 kHz data)
- BPM stability: 5 µm for more than 1 month.
  - Balance error was used for the stability evaluation.
  - Balance error: the maximum difference among the 4 values from the 3-electrode BPM calculation process.



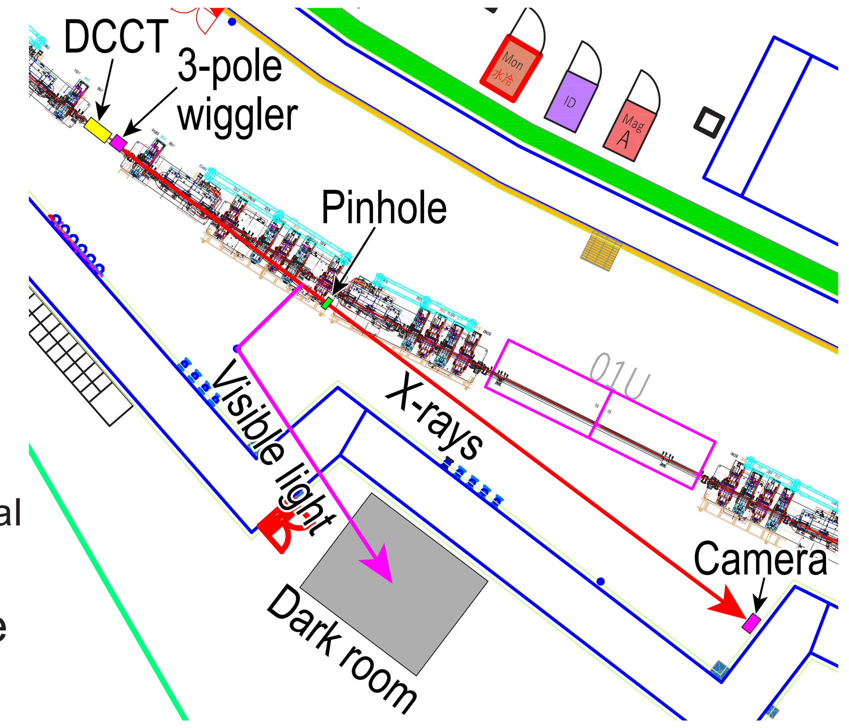
Bunch Current and Phase Monitor

- Bunch current and phase are important for top-up operation.
  - Electrons should be filled to the bunch that has the largest current deficit.
  - Injection timing should be adjusted bunch-by-bunch.
- Stripline BPM at an SSS is used.
- Readout electronics: MTCA.4 high-speed digitizer (~5 GSPS) or high-speed oscilloscope.
  - Decided in the near future.
- Bunch current is obtained from the amplitude of each bunch.
- Bunch phase is from the zero-crossing timing of the signal.

Beam Size Monitor

S. Takano, et al., Proc. IBIC'15, pp. 283–287, TUCLA02.

- Beam size monitor is needed to estimate the emittance and the x-y coupling.
- We use an X-ray pinhole camera for the size measurement.
- Light source: 3-pole wiggler in a short straight section (SSS).
- Distance from the light source to the pinhole: ~5 m.
- Distance from the pinhole to the camera: ~10m.
- Photon energy: ~50 keV
- Optimum pinhole size: 13×13 µm^2
- Optical resolution: ~4 µm.
- Beam radius at the SSS: 80 (H) × 6 (V) µm^2 std.
- Design x-y coupling ratio: 1%
- Enough resolution for emittance.
  - Emittance can be estimated from horizontal size.
- Need more precise method to measure the x-y coupling ratio better than 1%.
  - Interferometry: e.g. M Masaki, et al., PRAB 18, 042802 (2015).



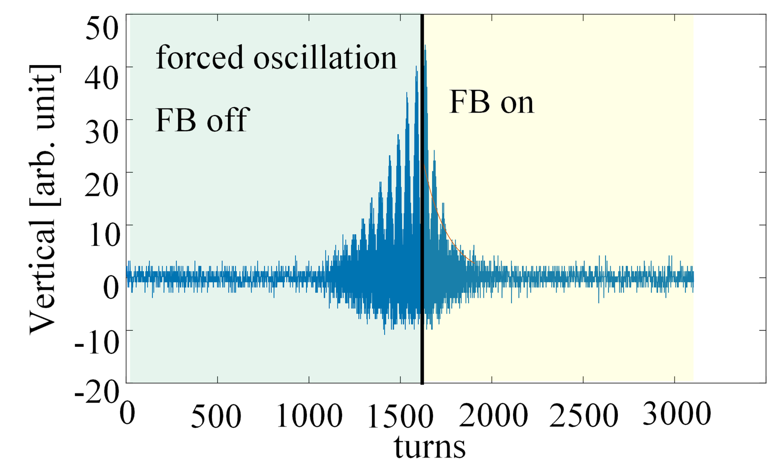
- Visible radiation from the 3-pole wiggler is also extracted to measure various parameters, such as beam size, bunch length, etc.
- Visible light is guided to a dark room outside of the accelerator tunnel.
- Detailed setup of the visible light diagnostics is still under consideration.

Beam Instability Control and Tune Monitor

- Threshold current for transverse instability: less than 100 mA
  - Due to narrow vacuum chambers.
- Suppression of beam instability is necessary.
- Betatron tune monitor is also needed for commissioning and stable operation.
- We use a bunch-by-bunch feedback system for both instability suppression and betatron tune measurement.
- Signal processor: Dimtel iGp12
- Signal pickup: Stripline BPM
- Kicker: Stripline electrodes driven by wideband power amplifiers.
- Required damping time: 0.01 ms (1 mA bunch current)
- Betatron tune function in iGp12:
  - One of the bunches is shaken by a swept sine signal.
  - Sinusoidal kick phase is locked to the resonance of the betatron oscillation.
  - Tune is obtained from a spectral notch under the BBF on.

Test results at SPring-8

- Damping time: 0.6 ms (0.5 mA bunch)
- It corresponds to 0.01 ms damping time for the new light source.
  - Differences of energy, beta function, circumference, etc. were considered.
- Tune resolution: 2×10^{-4} (swept sine), 1×10^{-5} (phase lock)



Grow-damp test result