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Overview from Light Source – Demands, Achievements, and Future Challenges

Joint ARIES Workshop on Electron and Hadron Synchrotrons, 11/13/18

Demands for BPMs

Single / Multi-turn Capability:

- Triggered high bandwidth (~Mhz) at moderate resolution (~10um)

USED FOR:

- Injection Studies, Beam Threading, Beam-Based Alignment (BBA) (without stored beam at commissioning time)
- Tune Measurement (using single or many BPMs, FFT, Naff, Model Independent Analysis (MIA))
- Average beta function measurement in quadrupoles using high precision tune measurement (tune change ~ beta function * quadrupole variation)
- Optics studies measuring phases (linear and nonlinear with the help of pinger magnets)
- Measurement of amplitude dependent tune shifts (frequency maps)
- Injection studies (oscillations of injected and stored beam)

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Demands for BPMs

High Precision Closed Orbit Capabiliy:

- Free running narrow bandwidth (a few kHz) at high resolution (~<1 um)

USED FOR:

- Closed Orbit Correction (Feedback Slow=SOFB / Fast=FOFB) / Manipulation
- Beam-Based Alignment (quadrupole/sextupole offsets to adjacent BPM)
- BPM tilt measurements with respect to adjacent correctors using closed orbit bumps
- Optics Studies (orbit response matrix, off-diagonal for coupling, optics fit with LOCO (Linear Optics from Closed Orbits) and optics correction)
- Lifetime and current measurement (using sum signal, bunch length dependence important)
- Beam size measurements (beam size dependence of button signal for large amplitudes)

Demands for BPMs

- Self calibration (pilot signal for 4-channel systems, significant for BBA constant)

- Negligible (<1 um) current dependency in Top-up operation (~mA deadband)

- Small (a few 10 um) current dependency during filling (~a few hundred mA, programmable calibration tables)

- Self diagnosis (button cross checks, intensity, variance of noise (RMS), validity flag bad/warning/good), automatic despiking for intermittent failures (→ FOFB)
- Very low failure rate (FOFB operation over weeks without interruption)
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- Bunch pattern dependence, bunch length dependence must be well known → high bandwidth CO mode (~Mhz) would allow measurement of single bunch currents → could be used for bunch pattern feedback in Top-up operation)

- Post mortem system (for beam loss analysis over a few msec before loss)
- Separate Interlock signal for insertion device protection

Demands for Photon BPMs

Many different types of photon BPMs (PBPMS):

- Blade / Diamond quadrant / Silicone carbide quadrant / residual gas PBPMs ...

- Depending on type high precision (sub um) @ a few kHz bandwidth
- Calibration complicated depending on type & ID (different photon beam profiles)

USED FOR:

- Creation of ID Feed Forward tables keeping photon beam stable during ID operation
- Integration in closed orbit feedbacks (Slow / Fast)
- Measurement of noise spectrum of the PBPM and source identification
- Localization of noise sources (who is responsible: machine or beamline)

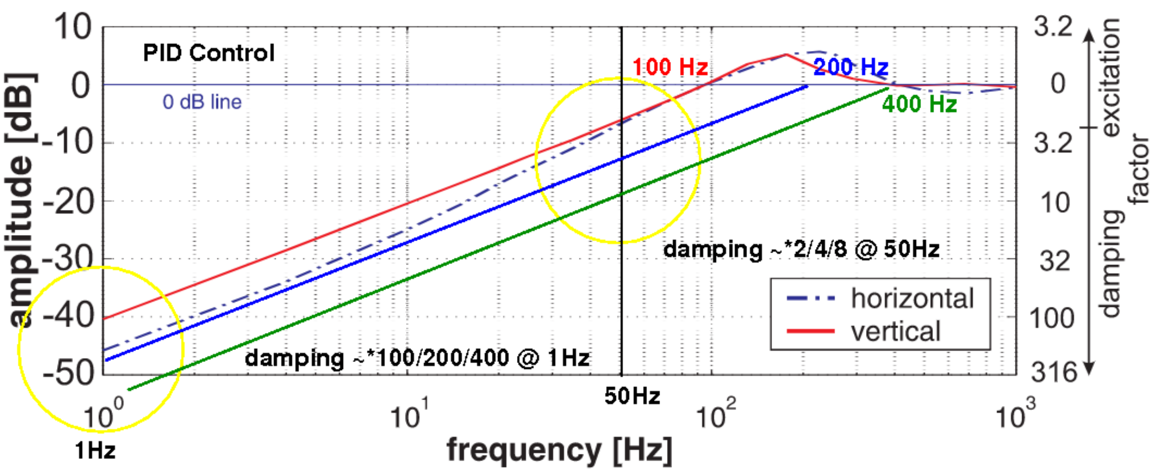
- Self diagnosis (button cross checks for quadrant PBPMs, intensity, variance of noise (RMS), validity flag bad/warning/good), automatic despiking for intermittent failures (→ FOFB)

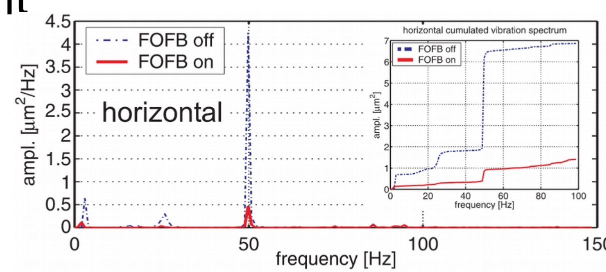
Fast Closed Orbit Feedbacks (FOFB)

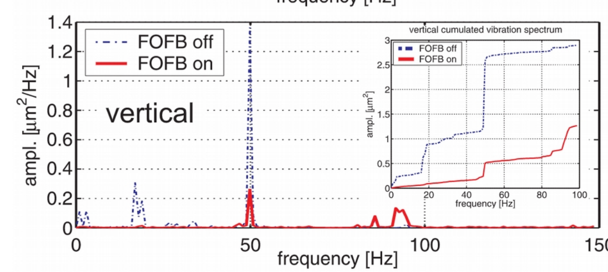
- Correction up to >100 Hz (0 dB point) → a few kHz BPM bandwidth

USED FOR:

- Suppression of all ID induced orbit distortions (~typically a few Hz, transparent ID operation)
- Suppression of residual noise (typically LS have <1um orbit stability !)
- Reference orbit manipulations for ID‘s (angle and position of e-beam in ID center, depending on the corrector/BPM response matrix → preferably each BPM has adjacent corrector → correction into integrated BPM noise <0.1 um up to 0 dB point







Demands for Fast Orbit Feedbacks (FOFBs)

- Very high availability (<1 failure / week, No FOFB = No Beam for users)
- Self diagnosis and „self repair" features (automatic re-initialization in case of faulty BPM/corrector hardware (response matrix changes) and/or BPM despiking by replacement with „virtual" BPMs based on machine model)
- Correction limitation/band to avoid FOFB induced beam losses (adaptive)
- Post mortem analysis after FOFB failure and archiving of FOFB activity
- Use of model based response matrix preferable (measured should be possible)
- Automatic adaption of used response matrix to machine optics changes
- BPM weigthing (BPMs next to ID's important) , corrector kick constraints, eigenvalue cuts for „longer range" corrections and BPM noise reduction
- Extra suppression/filters of dominant lines in noise spectrum (mains @ 50Hz)
- Feed Forwards for systematic / known distortions (ID movement, orbit bumps with known kick ratio).
- Integration of PBPMs for increased photon beam stability (→ FOFB Interface)
- Radio frequency control for pathlength corrections (energy stabilization)
- Special measurement features (Beam-Based Alignment, BPM rotation measurement with closed orbit bumps)

Demands for Fast Orbit Feedbacks (FOFBs)

- Integration of other magnets like skew quadrupoles for coupling / lifetime feedbacks or feed-forwards for systematic / known coupling changes (orbit bumps, vertical emittance control through dispersion or betatron coupling „bumps“)
- Integration of other diagnostics like beam size (emittance) monitors for fast emittance stabilization (2nd order orbit control) utilizing skew quadrupoles as actuators

➢ Most of the mentioned demands for BPMs and Fast Orbit Feedbacks (FOFBs) have been already achieved at presently operating 3rd generation light sources !

➢ Thus there are hardly any future challenges left … ;-)

Future Challenges for BPMs and FOFBs

BPMs

- Even better BPM resolution in multi-turn mode for better trajectory control and optics measurements utilizing turn-by-turn data
- Higher bandwidth for BPMs in high resolution closed orbit mode allowing ultimately to resolve single bunches (Bunch pattern feedback, bunch pattern dependency removal)

FOFBs

- Integration of more sensor types like Photon BPMs, beam size monitors (unification of interfaces necessary)
- Integration of more actuator types like skew quadrupoles for coupling and lifetime control or quadrupoles for optics control or high-order multipoles for dynamic aperture control, strip line kickers …
- Faster FOFBs (0 dB point typically <1kHz) … but ultimately FOFBs could also become multi-bunch feedbacks :-)
- Better fast Feed-Forward capabilities (most distortions are known !)
- Better filter customizations according to the given noise spectrum

- BPM and FOFB systems are demanding
- Most of the demands have been achieved
- There are of course future challenges …
- The good news is that there is NO QUANTUM STEP NECESSARY for the next LS generation to come … :-)