Activities on Beam Orbit Stabilization at BESSY II

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Roland Müller BESSY

**BESSY:** Synchrotron Radiation User Facility

**BESSY II:**
- 1.7 GeV Storage ring
- Operational User Service since `99

- 3rd generation light source

- VUV SASE FEL under Study: CDR due `03
Outline: Status

- Components
  - Diagnostics, Correctors, Set-Up
- Performance
  - Per fill, day, week, months
- Problem Areas
  - Residuals, transients
- Conclusions
Orbit Control @ BESSY

- **Basic System Parameters:**
  - 112 RF BPMs, 16 bit, 1\( \mu \text{m} \) res. (0.1s avg.)
  - 16 XBPMs, 25 SPMs, 1 TPM, 2 Pinholes
  - 64 vertical, 80+1 horizontal, 3mrad Correctors + 1Hz precision RF
  - 2 sec/orbit, 6 sec/correction cycle
  - model based response matrix
  - weighing factors 1 for RF BPM, 0 for XBPM
  - 50% significant SVD eigenvectors
The BPM Systems

1. Storage Ring - Closed Orbit
   - Accurate (1 μm)
   - Reliable
   - 1 Hz Application Update Rate

2. Storage Ring - Single Turn
   - Fast (800 ns / turn)

3. Injection system
   - Fast (5 kHz sample rate)
   - Flexible

Specialized Modes for Booster, Transfer line and Storage ring

Data collection via network handshake
**BPMs Storage Ring: Closed Orbit**

- BPMs to ADC: 16x
- VME to ADC: 7x
- EPICS: TCPIP

**Performance:**
- Dynamic range: ±10 mm
- Accuracy: ±1 μm
- Required current: 100 μA
- Update rate: 1 Hz

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**BPMs Storage Ring: Single Turn**

- 4→1 MUX: 64x
- BPM: 7x
- DAC: 8x
- EPICS: TCPIP

**Performance:**
- Dynamic range: ±16 mm
- Accuracy: ±1 mm
- Required current: <100 μA
- Update rate: 0.2 Hz
Precise Photon BPM Systems

Ver.: Staggered Pair Monitors SPM
Hor.: Transversal Position Monitors TPM
Undulator/WLS XBPM
Problem not well confined:
⇒ local vs. global scheme
⇒ feed-forward vs. drift control
⇒ orbit easier than tune/\(\beta\)-beat
Orbit Kick Compensation: Feedforward-Tables (+Offset)

Insertion Device: Superconducting Wavelength Shifter
Tune/\beta\text{-Beat Compensation:}
Storage Ring Quad Offset Terms

Quadrupole
Group Equalizer

:raw:set

:ID1:set

ID1:gap

Insertion Device Feedforward

Group D
Tune Correction

Group T
Orbit Correction Software:

Versatile, Accurate, All-In-One Working Horse

`Continuous Mode`:

1 Orbit / 2 sec

Read Orbit Calculate/Settle/Discard Read Orbit ...

1 Corr. / 6 sec
System Performance: Metrics

- **Stability**: per fill, weeks/months
  - orbit typically stabilized at 106/112 BPMs to better than 10µm/fill, 2µm fill to fill

- **Reproducibility**: spanning different user beam time slots: beam based calibration

- **Reliability**: MTBF, hardware faults, DAQ problems, controls failures: <0.5/month

- **Human Factor**: protection against faulty operation, ease of use + understanding
  - Key to problem tracking: action, data logging
1 hour example: RMS Stability

0.1 \( \mu \text{m} \) `noise`

0.3 \( \mu \text{m} \) `drift`

1 - 2 \( \mu \text{m} \) `transients`
24 hours example: Avg./RMS

Average Positions:
<0.2 µm
Stability during Start-Up Week

Per fill:
1.6 μm ver.
0.75 μm hor.

Fill to fill:
0.2 μm

2.5 μm hor. jump
Hysteresis of λ-shifter field change
Stability 2002: 6 month raw data

Steps: e.g.
Monday maintenance,
Mistakes,
Changes

User Shift:
• Recalibrated
• MD finished
Transient Perturbations

- UE56 brakes: Magnetic drives.
- Horizontal ‘spikes’ of 1-3 μm RMS.
- Complete compensation difficult.
- Discontinuous ID-feed-forward tables similar.

![Graph showing orbit stabilization with adjacent horizontal correctors and gap shift](image-url)
Step Function Changes

- Hardware repairs, modifications.
- Hysteresis
  - Field Cycle of $\lambda$-shifter: strong dipole kick compensators.
  - Minor adjustments of optics: 1D feed-forward, tune/chromaticity adjustment.
Other Uncorrected Residuals

- LHe refill of superconducting $\lambda$-shifter modifies field.
- Decay of SC eddy currents (~1h).
- Uncalibrated path length correction of $\lambda$-shifter cycles: slight beam energy changes.

Response at XBPM

Field Change during Refill

08 May, 2002

W7IT1R:rdbk

0.48

0.48

0.50

0.50

0.52

0.52

0.54

0.54
BPM Failure Detection/Repair

- MTBF: ~2 month
- Remaining malfunction hard to detect
  - E.g. exotic oscillator output level causes erroneous readings
- Beam-Based auto-calibration not yet implemented
Problem Tracking Facilities

- Comprehensive signal archive (~8000 channels): time, source-effect correlations
- Operator/Program action logging: irregularities, misunderstandings, malfunctions
Unexpected Events

- New, unexplainable orbit jumps appear: Phase analysis points to a ring segment with NO active element
- Pattern of perturbation corresponds to users time slots.

1 µm Orbit perturbation due to 1[T] user magnet switched outside (!) storage ring tunnel (3m from beam pipe).
Behind RMS: Deviations/Angles

- User magnet causes 4 µm, 1µrad peak perturbation
  - Corrected within 2 cycles.
- Obvious required counter-measures:
  - Distance, shielding, local feed-forward.
  - Inadequate: fast local ID source point feed-back.

![Graph showing beam position deviations](image-url)
Present Choice: New Location

Noise reduction not sufficient:
1 mm -> 0.3 mm RMS
50 Hz Mains Suppression

- Fast BPM signal analysed.
- Put air coil corrector at optimal position.
- Feed-forward compensation proves feasibility.
- Users don’t suffer, most detectors average with same frequency: not used.

Copy from runbook
Vibrations

Tunnel, experimental floor well characterized:

- Frequency
- Magnitude
- Critical components, major sources identified.
- Consequences for beam-line design: vibration damped BL elements.
Stability: Spectral Overview

- Diode @ experiment position
- Metric: achievable signal/noise ratio
- Dominant:
  - LHe recondensor
  - White circuit
  - Gyro mains

**Figure:** GaAs-diode signal (dB) vs. frequency (Hz)

- Difference frequency visible to orbit correction
Comparison of Sensitivities

Help to distinct accelerator beam orbit dominated effects from beam line specifics.

signal stability comparison at different ID-beamlines

GaAs-Diode signal (dB)

frequency (Hz)

Higher harmonics

(-60 dB)

(+20 dB)

-180 -170 -160 -150 -140 -130 -120 -110 -100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100

UE52SGM
U125 BUS
UE46 PGM

WLS T7

USV booster

SMU

GaAs-Diode signal (dB)

frequency (Hz)
Conclusions

- RF-BPM and XBPM diagnostic: precise, consistent, complementary.
- Growing understanding of sources and feasible countermeasures.
- Effect on experiments widely varying.
  - IR beam-line most sensitive.
- Perturbations tied to beam-line and beam orbit are of similar order.
- Improvement attempts have to consider both areas.