Beam Stability in the MAX IV 3 GeV storage ring

Jonas Breunlin on behalf of the MAX IV team

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MAX IV

Outline

- Introduction: MAX IV Stability Task Force
- Mechanical vibration & floor stability
- Electron beam stability in the 3 GeV ring
- Photon beam stability and X-ray BPMs

Introduction: Stability Task Force

“The MAX IV STF is a **multi-disciplinary** and **cross-divisional** task force

and is working towards the **goal** of **delivering stable photon beams**.”

Active areas (examples)

- Design phase and construction of buildings, MAX IV accelerators, beamlines, …
  - STF coordinated by Brian N. Jensen until 2019
- Improvement of operational routines for user beam delivery
- Contact to beamlines for various situation of ‘unstable beam’
  - STF coordinator as a contact person
- Measurement / monitoring of stability related properties
  - Mechanical
  - Electrical
  - Photon and electron beam
- Development of such diagnostics
- …

MAX IV … we've started on a green field.

City developments around MAX IV pose vibration risks, already in their construction phase.

In varying stages in their planning process:

- Sience village and residential areas
- E22 Highway exits
- Speed bumps (in combination with heavy traffic)
- High speed train to Stockholm
- MAX IV SXL, a Soft X-ray FEL ←
- …

- Existing structures
- Planned structures
- Planned speed bumps
- Tram

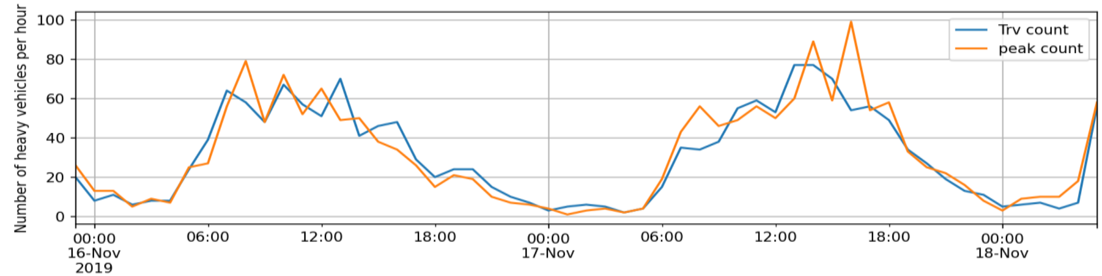
Lunds Kommun, Strukturplan Brunnshög 2020-12-16 (modified)

We need to maintain our initial floor stability goal: max 20-30 nm RMS above 1 Hz.
Tasks typical for laboratory construction phase are still ongoing!

Ground vibration from road traffic

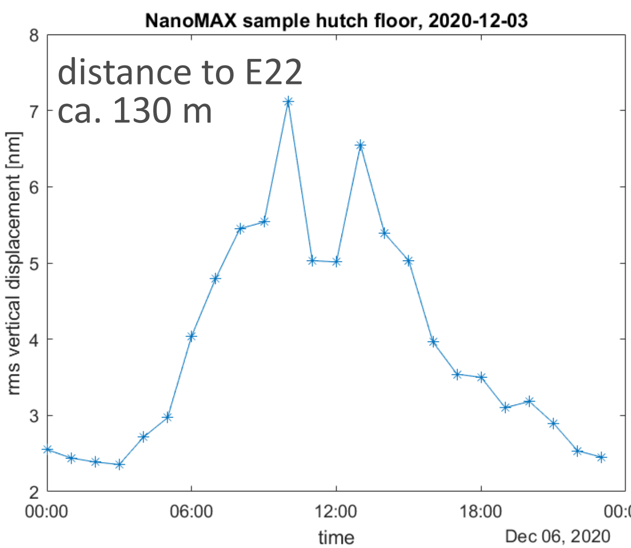
blue trace: heavy vehicle count by Swedish authorities on E22

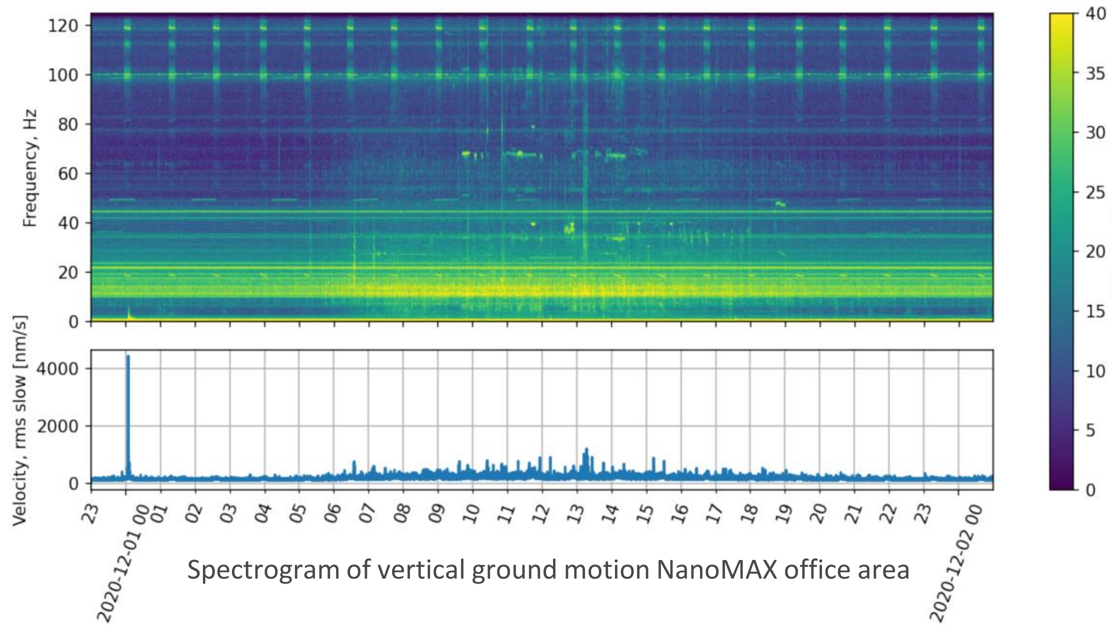
orange trace: peaks in seismometer data, 3 GeV ring experimental floor



Floor vibration levels are raised significantly during day time, and reach background levels of ca. 2nm rms during nights.
The E22 highway is a big low-frequency noise source, but levels remain well within tolerances.

Plots by Gabor Felcsuti



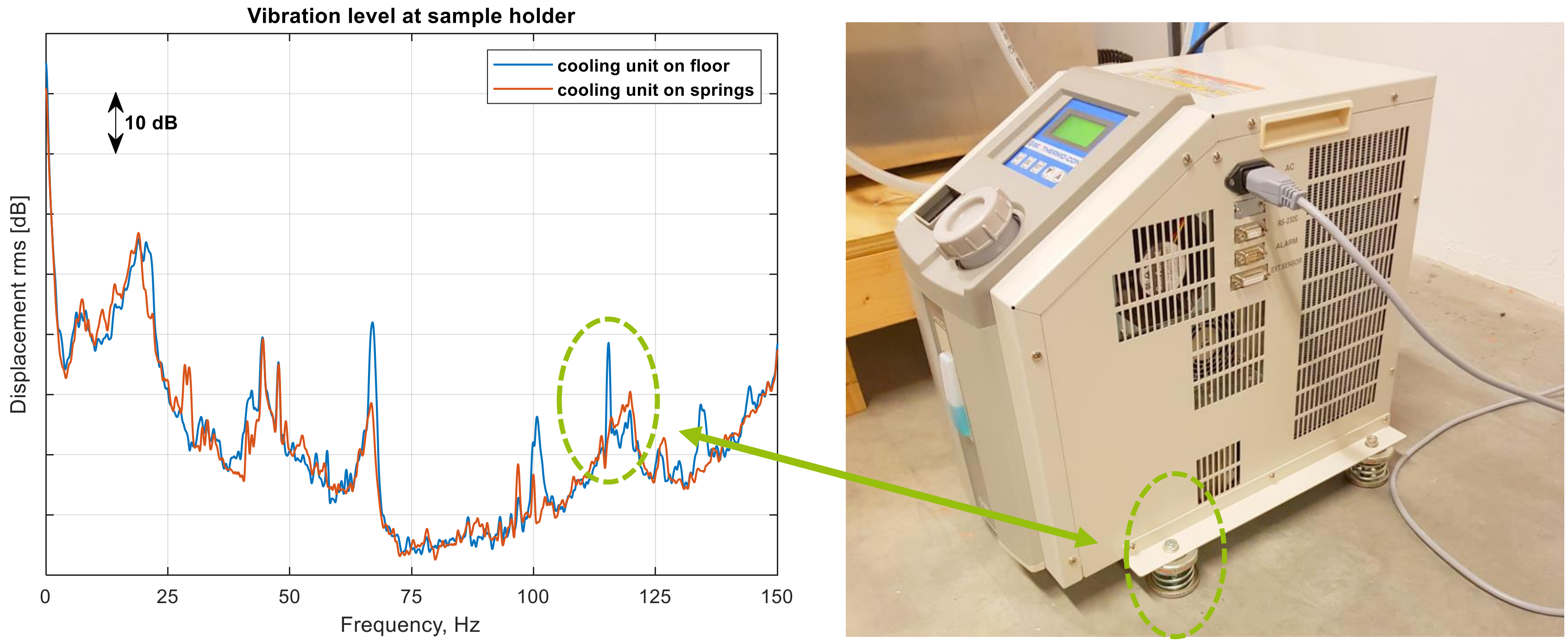


Spectrogram of vertical ground motion NanoMAX office area

Vibration isolation policies, etc…

A new cooling unit at a beamline..

… and a new peak in the vibration spectrum.



-15 dB decrease of the 115.4 Hz peak, equivalent to an rms vibration amplitude reduction of 82% at the beamline‘s sample holder. By M. Malmgren, G. Felcsuti.

Lab-internal policies regarding vibration source isolation etc. exist.
They need to be followed. Sometimes even <u>enforced</u>.

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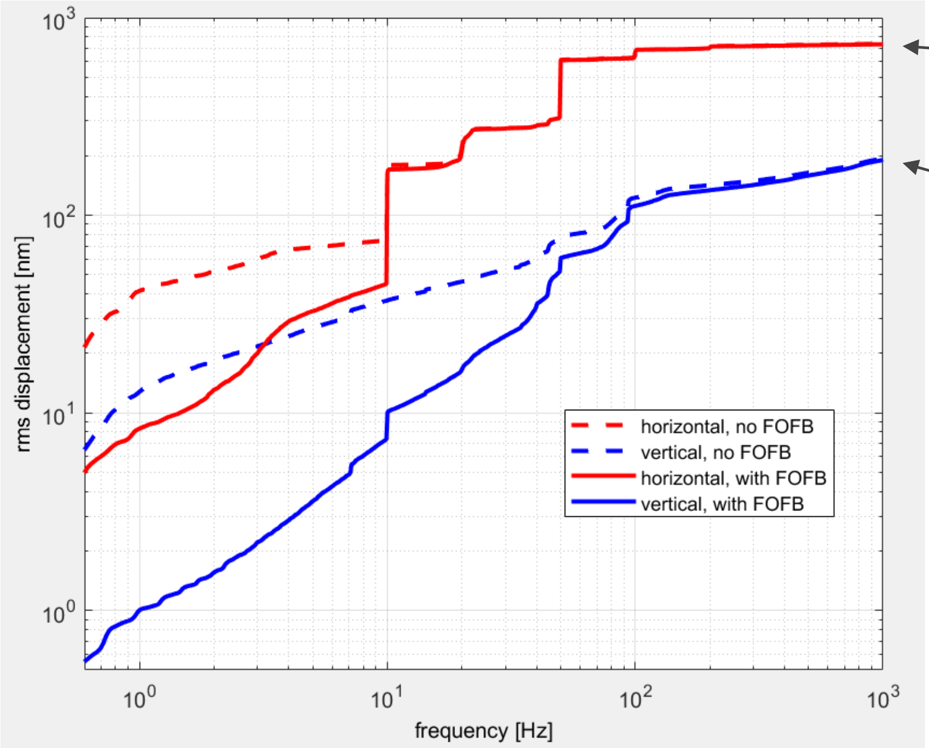
3 GeV ring electron beam stability

Beam position stability of <10 % of the beam size achievable without the Fast Orbit Feedback system (FOFB)



0.733 µm
1.3 % of the hor. beam size

0.188 µm
3.0 % of the vert. beam size

- Data taken at delivery conditions, 300 mA beam current. Slow Orbit Feedback active.
- Average rms displacement of 18 bpms, all flanking ID straights.
- Period of 8 minutes between top-up injections, no ID gap movements.

Limits to short-term beam stability during beam delivery are mostly of operational nature:

- Lack of easily accessible diagnostics on critical systems
- Occasional missbehaviour of systems critical for orbit stability

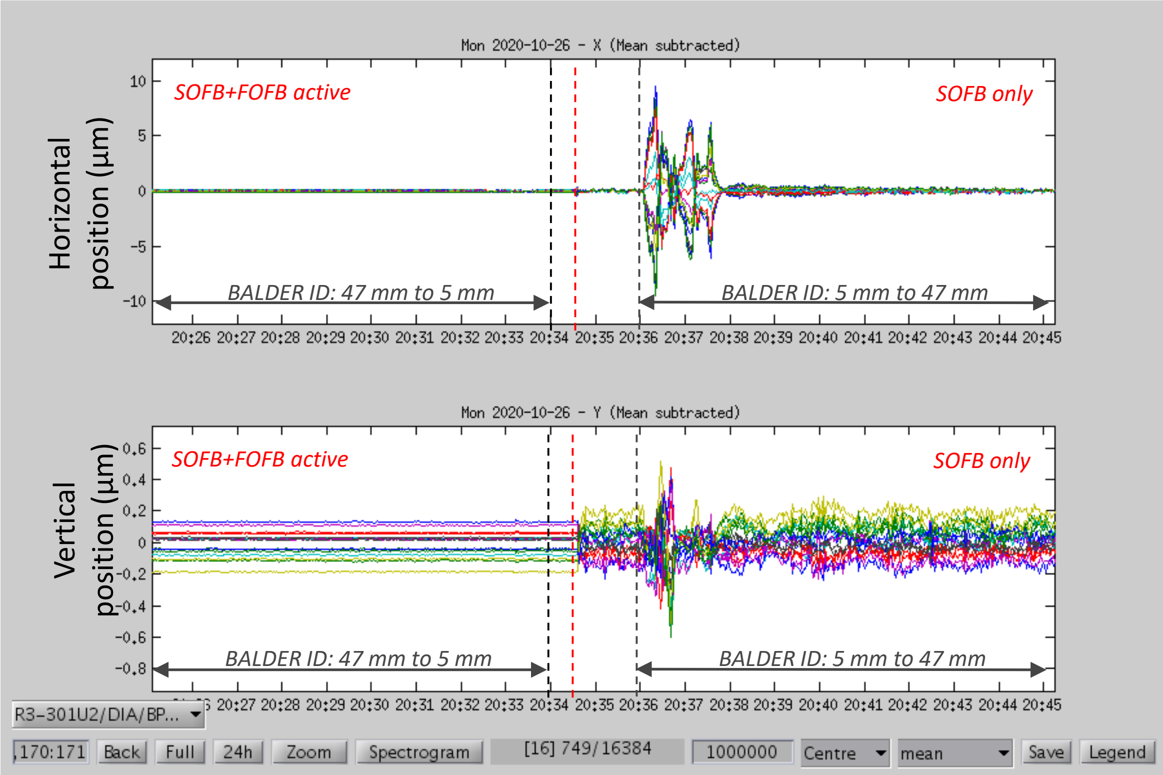
ID-induced transients

Looking at all BPMs flanking user IDs the combined SOFB+FOFB is able (even at more conservative settings with 30 Hz BW in both planes) to largely eliminate the orbit transients.

BALDER ID is an in-vacuum wiggler and has a very noticable orbit impact at low gaps.

Of note is that no fast correctors (+-10 µrad) ever exceed 10% of the strength.

NB! Plot displays highly averaged 10 kHz data (16384 samples per point).



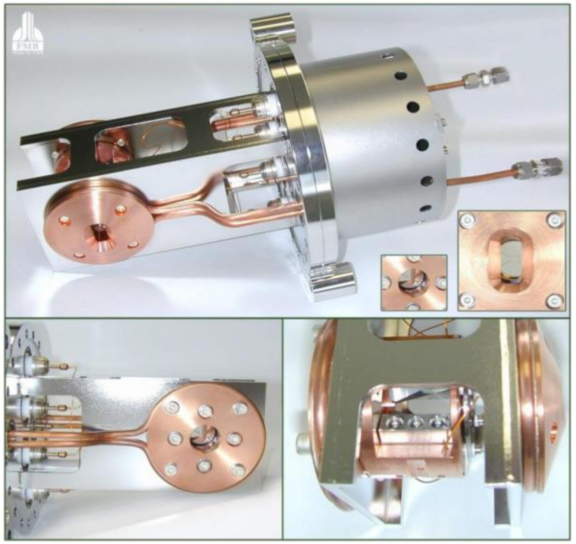
By Magnus Sjöström

Main benefit of FOFB is suppression of ID transients; orbit noise already within tolerances!

X-ray BPMs in front-ends

XBPM heads

- Installed in all R3 beamlines in pairs:
  - xbpm1 (upstream), 11.92 m from center of ID straight
  - xbpm2 (downstream), 15.49 m from center of ID straight
- Four tungsten blades with 90° (upstream) and 60° (downstream) geometry
  - Exception xBPM heads for IVW Balder
- Two manufacturers for XBPM heads: FMB Berlin and TOYAMA
- Calibration motors with absolute encoders



Readout electronics

- Em# electrometer, a development collaboration of the ALBA synchrotron and MAXI IV
- J. Avila-Abellan et. al, ICALEPCS2017, TUAPL04
- Change electronics to Libera Photon electronics under discussion
  -> better integration into rf bpm system that is based on Libera Brilliance+

Available for measurement today: 9 pairs of xBPMs

System owner since 2021: Petr Ilinski

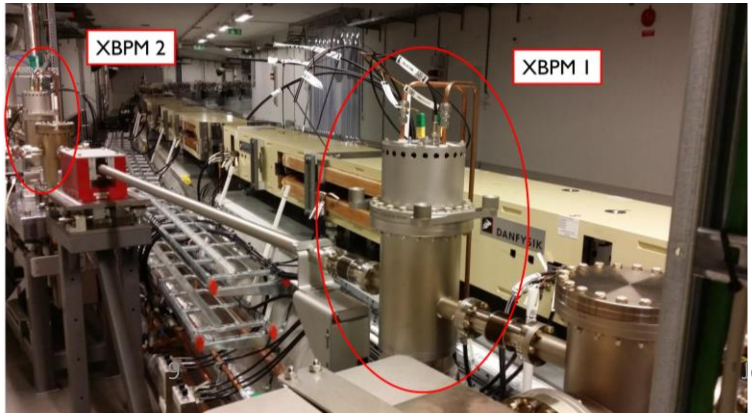


Image: J. Avila-Abellan et. al, ICALEPCS2017, TUAPL04

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X-ray BPMs, calibration & limitations

Linear calibration of the form

$$x_p = \frac{I_1 + I_2 - I_3 - I_4}{I_t} * K_x + P_x$$

$$y_p = \frac{I_1 - I_2 - I_3 + I_4}{I_t} * K_y + P_y$$

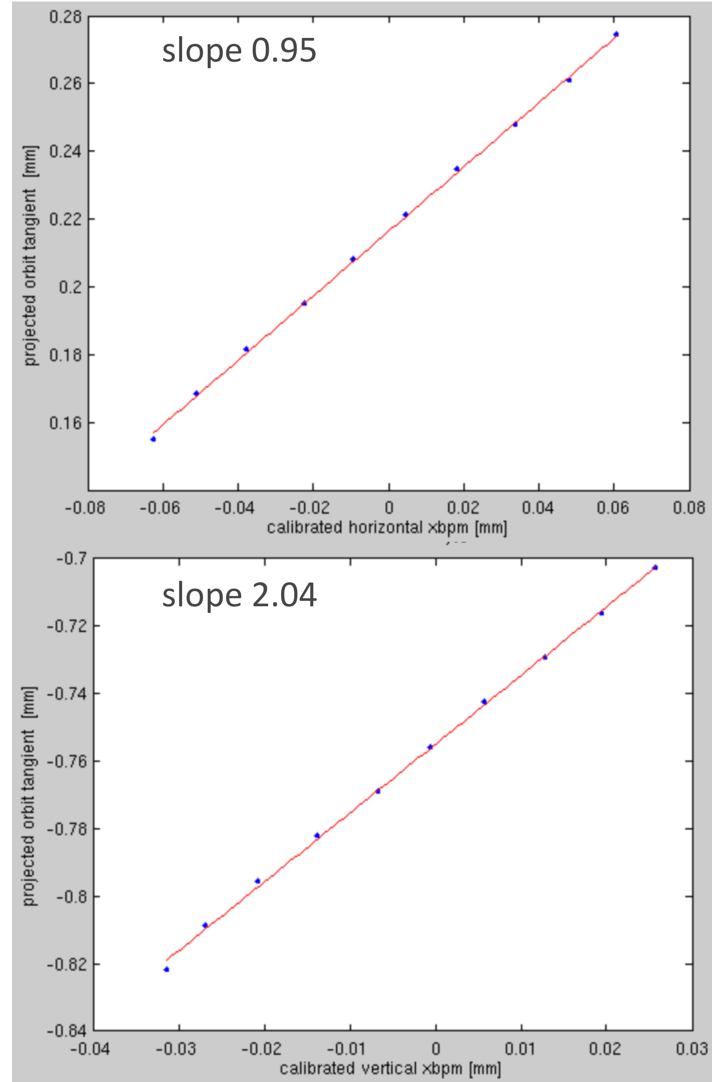
$$I_t = I_1 + I_2 + I_3 + I_4$$

Problematic dependencies of position reads on

- ID gap (and ID phase(s) in case of EPUs)
- stored beam current
- thermal effects in the FE
  - -> a challenge to be well calibrated at all times!

Apparent mismatch between electron orbit angle in an ID xbpm readings:

Relative vertical photon beam position from ID orbit bump deviates by 30% to 100% from XBPM readings.



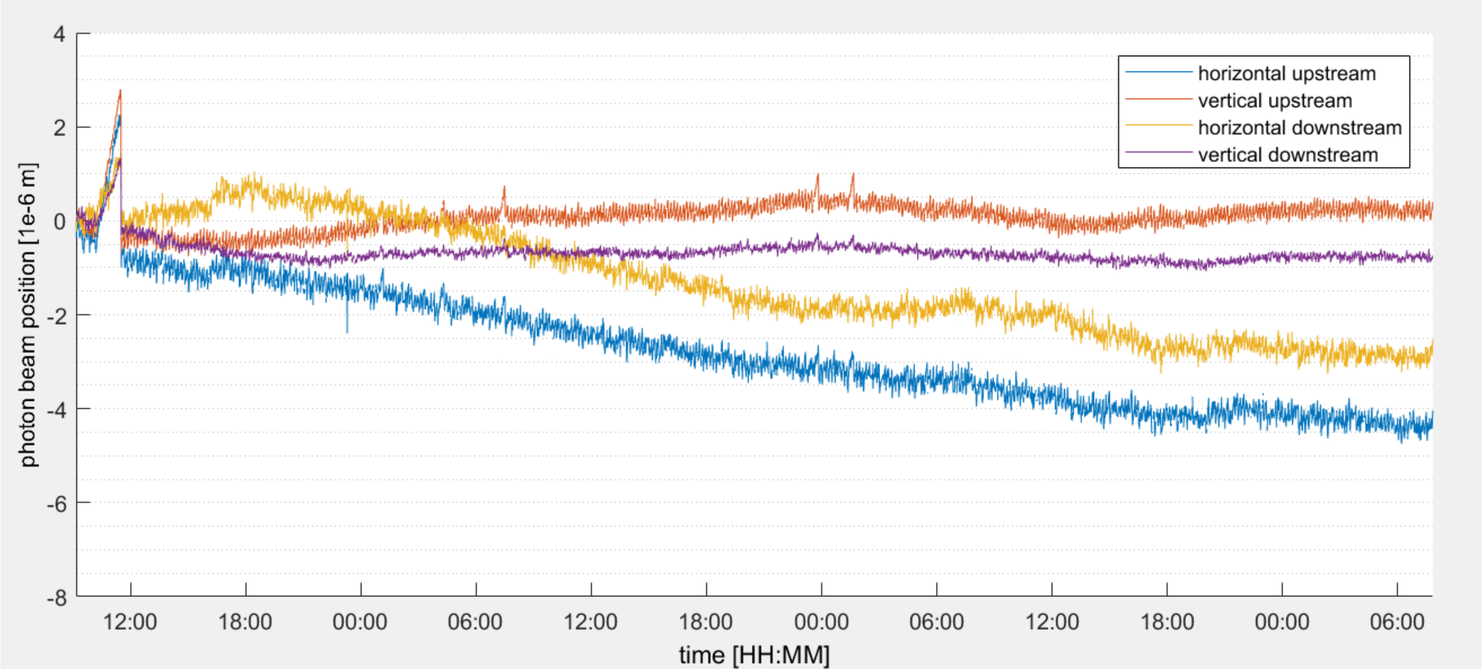
xbpm-measured vs expected photon beam position during a scan of orbit angle through an ID:

Reliable, absolute photon beam position readings in the front-ends could improve our long-term stability of beamline source points!

X-ray BPMs, long-term stability

Current implementation

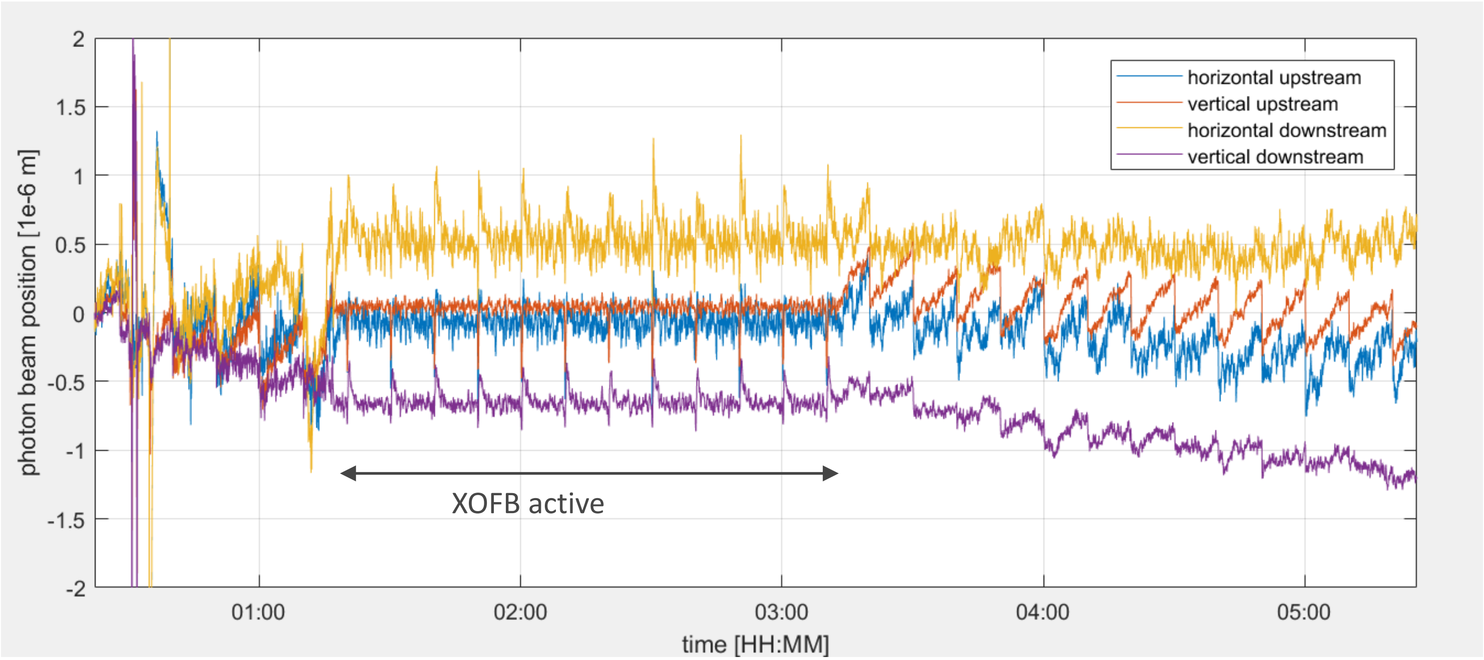
- electrometer readout rate 1 Hz
- continous archiving of beam positions
- helpful tool in tracking down stability issues reported by beamlines
- photon beam motion spectra



X-ray BPMs & orbit feedback

preliminary results!

- Test of a photon beam based orbit feedback 'XOFB'
  - correcting orbit angle and position in the ID straights
  - considering readings from upstream & downstream XBPM
  - update of the slow orbit feedback reference every 10 seconds
  - Example shown:
    - BioMAX beamline
    - Stored beam current 300 mA. Top-up injections at 10 minute intervals
    - vertically angle adjustments 0.1 µrad on top of a -78 µrad orbit bump
- Compensation of the measured photon beam position drifts
- To be tested with a (sensitive enough) scientific beamline!



Conclusions

- Efforts during design phase and construction have lead to a 3 GeV storage ring with good passive stability.
- Continuous monitoring of beam stability parameters, close communication with beamline staff quick reaction in case of trouble are becoming increasingly important.
- Maintaining a stable environment for our accelerators is an ongoing tasks, lab-internally and externally.
- Extension of (machine-owned) diagnostics to photon beam in the front-end is a must! Better understanding of our X-ray BPMs needed.

Thank you for your attention.

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