Libera

Status of current synchrotron BPM electronics and investigations towards future BPM concepts

Peter Leban, May 17 2018

Contents

- **Current status (electronics, performance, issues)**
- **Clean turn-by-turn**
- **Pilot-tone utilization with Libera Spark ERXR**
- **Position measurement of each bucket**
- **Outlook options**

Current Libera readout electronics (ebpm)

Libera Electron | Brilliance | Brilliance+ | Spark

Current performance

	Libera Electron	Libera Brilliance	Libera Brilliance+	Libera Spark
Turn-by-turn RMS	2 µm	0.50 µm	0.40 µm	0.25 µm
Clean turn-by-turn	No	No	Yes	Yes
Longterm stability			0.2 µm p-p	< 2 µm/°C
Compensation mechanism	Switching + DSC	Switching + DSC	Switching + DSC	none
RMS performance (0-5 Hz)			~ $\frac{2nm}{\sqrt{Hz}}$	

kx=ky=10 mm

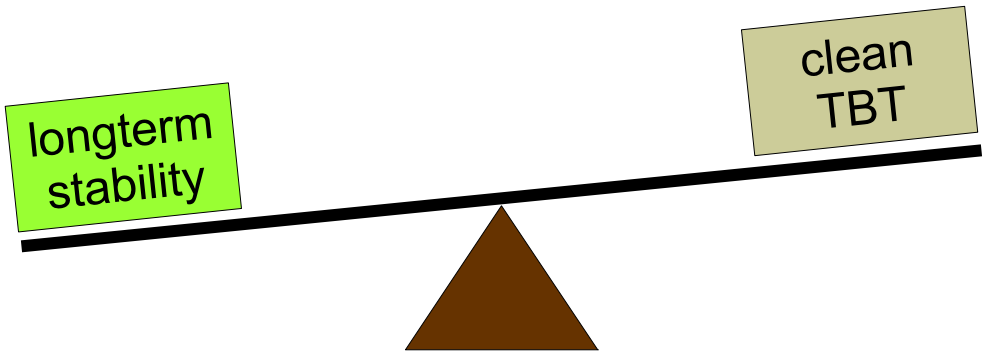
Libera

Issues with switching + DSC

No issues, however:

- **Strong 3.3 kHz component in the frequency spectra**
- **Notch filter over 3.3 kHz component spoils the fast data frequency response**
- **Clean turn-by-turn data (TDP) affected by the switching**
- **Users' requests to stream turn-by-turn data for ultra-fast orbit feedback system**

What is more important for the future readout electronics?

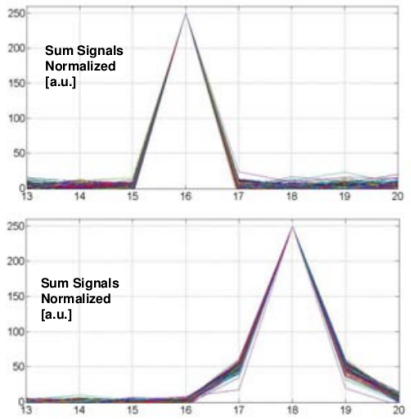


Instrumentation Technologies

Clean turn-by-turn measurements

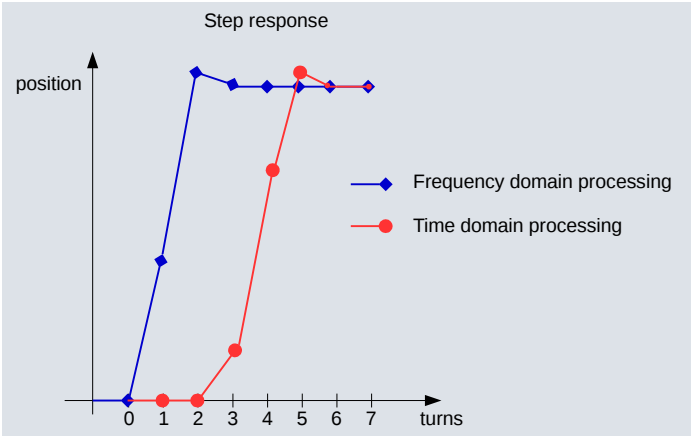
- **Turn-by-turn processing only in frequency domain causes smearing between adjacent turns (Libera Electron & Brilliance); see lower plot**
- **Workaround solution: MAF filter design with wider bandwidth; see upper plot**

Single-bunch single turn data from Libera Brilliance



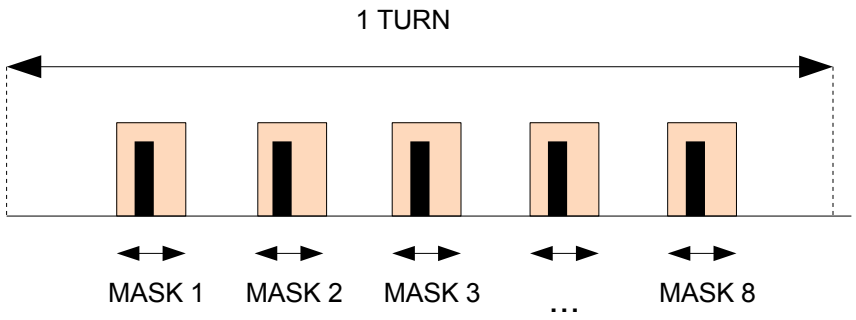
Courtesy of K.Scheidt

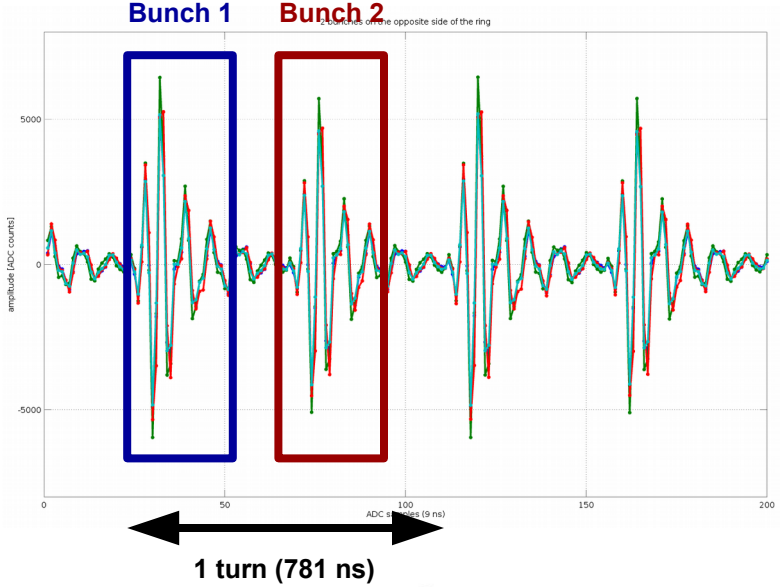
- **Clean turn-by-turn measurements available in Libera Brilliance+ and Libera Spark**
- **Switching must temporarily be disabled (for the time of data collection)**
- **Measurement bandwidth at theoretical maximum (50% of the turn-by-turn data rate) ensures 1-turn-latency on step response and no smearing between adjacent turns**



Clean turn-by-turn measurements at Spear3 (1)

- **2 bunches on opposite side of the ring**
- **Possibility to select a processing window over a bunch to follow its trajectory over turns**
- **Bunches must be separated at least 360 ns**
- **Feature not available in the software yet; proof of principle done offline**

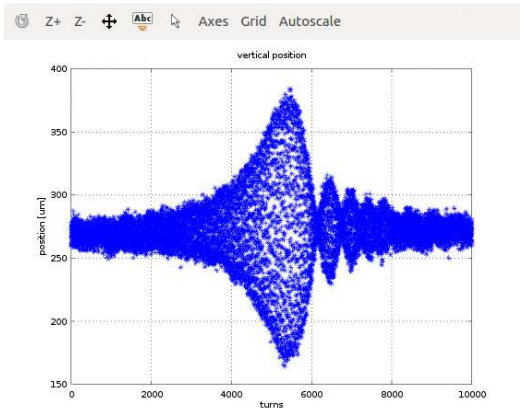




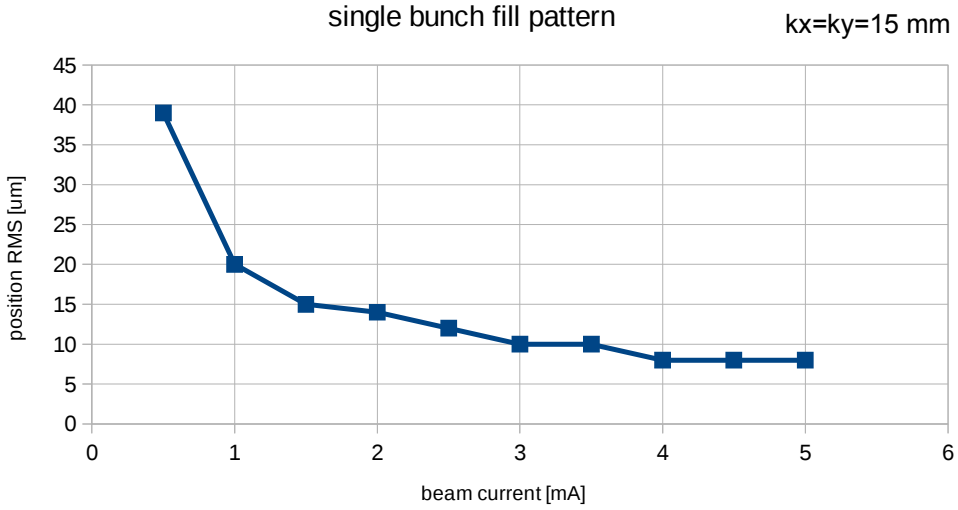
Instrumentation Technologies

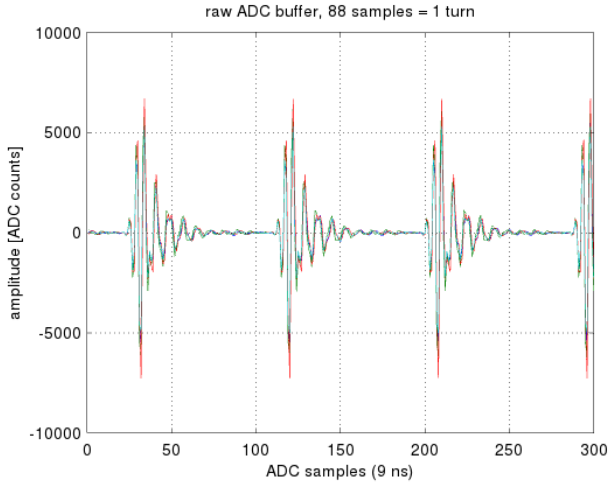
Clean turn-by-turn measurements at Spear3 (2)

- **3 mA single-bunch fill, using Dimtel's iGp12 to drive the bunch**
- **Data acquisition taken simultaneously with iGp12 and Libera Brilliance+**



Turn by turn performance with a single bunch





Longterm stability

- **Actual beam movement**
- **Drift in pickups, cables, patch panels, etc.**
- **Stability of the readout electronics**
- **Other systems that feed-back corrections to magnets**

Longterm stability

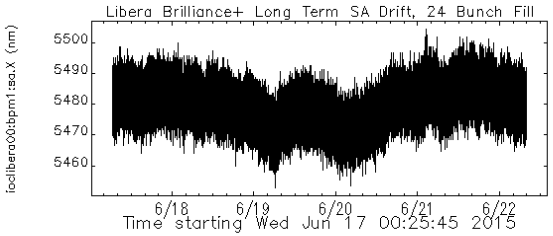
- **Actual beam movement**
- **Drift in pickups, cables, patch panels, etc.**
- **Stability of the readout electronics**
- **Other systems that feed-back corrections to magnets**

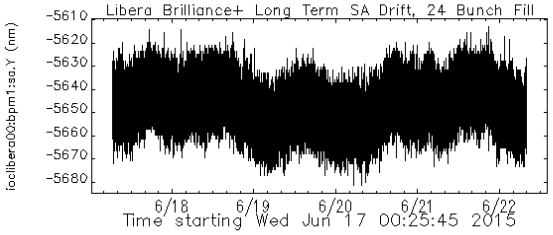
Libera Brilliance+

4 day stability

6 nm RMS horizontal

13 nm RMS vertical



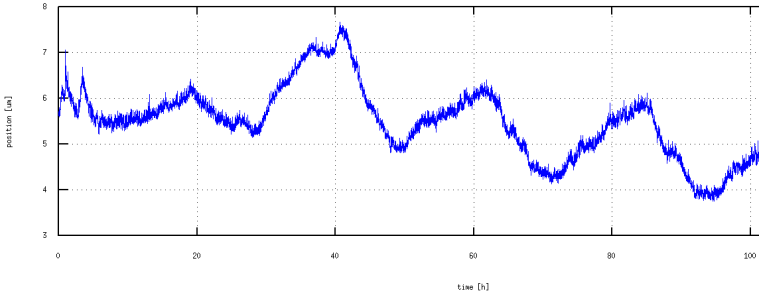


Property of Adam Brill et al, Argonne National Laboratory

Libera Spark ERXR

4 day stability

~ 1-2 µm / °C



Longterm stability

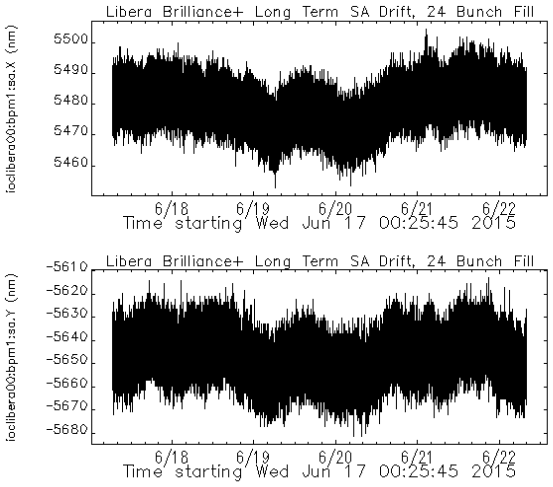
- **Actual beam movement**
- **Drift in pickups, cables, patch panels, etc.** → No compensation yet!
- **Stability of the readout electronics**
- **Other systems that feed-back corrections to magnets**

Libera Brilliance+

4 day stability

6 nm RMS horizontal

13 nm RMS vertical

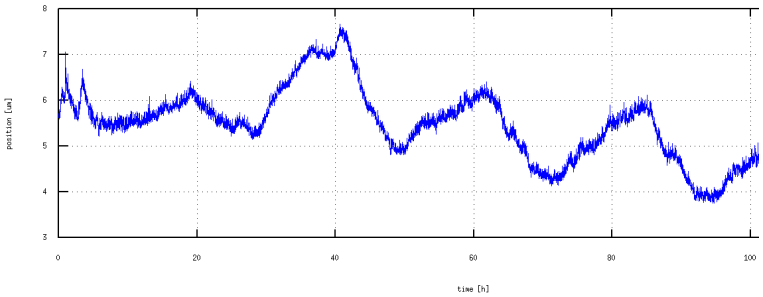


Property of Adam Brill et al, Argonne National Laboratory

Libera Spark ERXR

4 day stability

~ 1-2 µm / °C

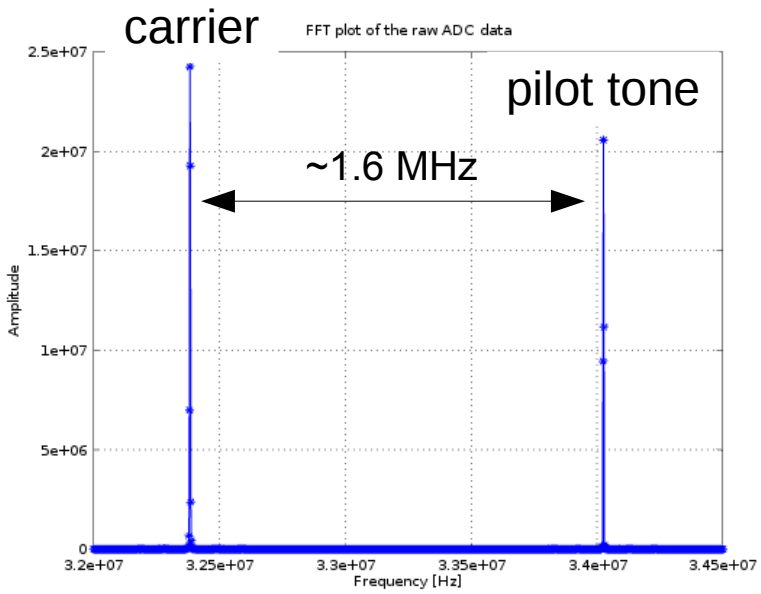


Longterm stability with pilot tone (setup)

Main goal: compensate for drifts in pickups, cables, patch panels, etc.

- Collaboration with ELETTRA
- Pilot tone injected at 501.28 MHz (~1.6 MHz away from the carrier)
- Position calculation from FFT (Octave)
- Amplitude compensation:

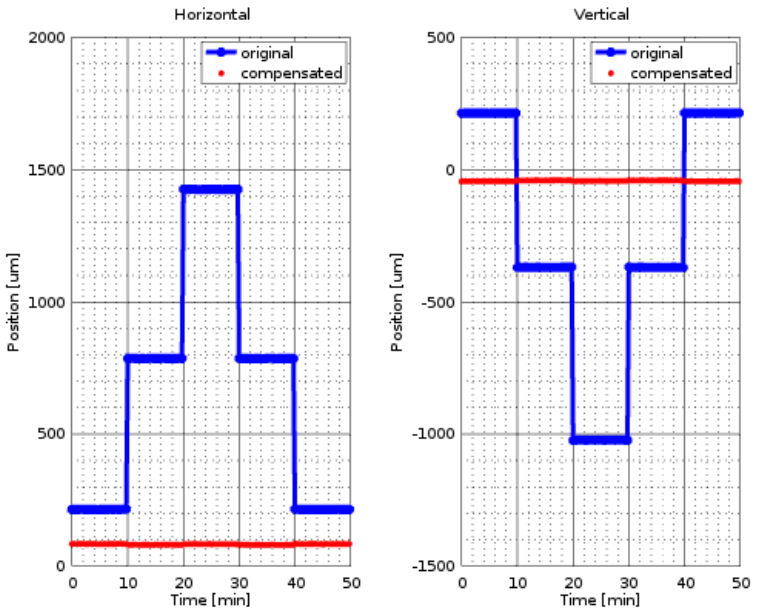
  $A_{comp} = A_{RF} / A_{PT}$

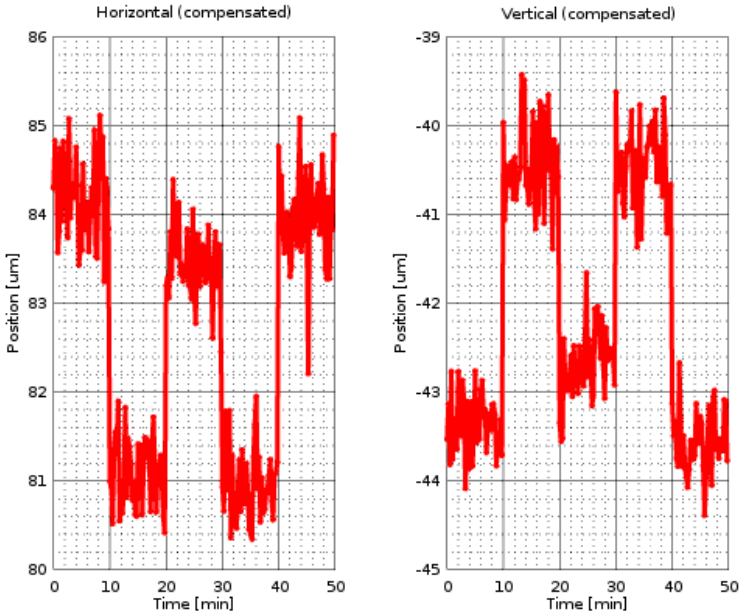


Longterm stability with pilot tone (results 1)

- Simulated cable failure (2x 1 dB attenuation change in channel D)
- Original position (peak-to-peak): ~1.2 mm
- Compensated position (peak-to-peak): ~5 µm

zoomed-in

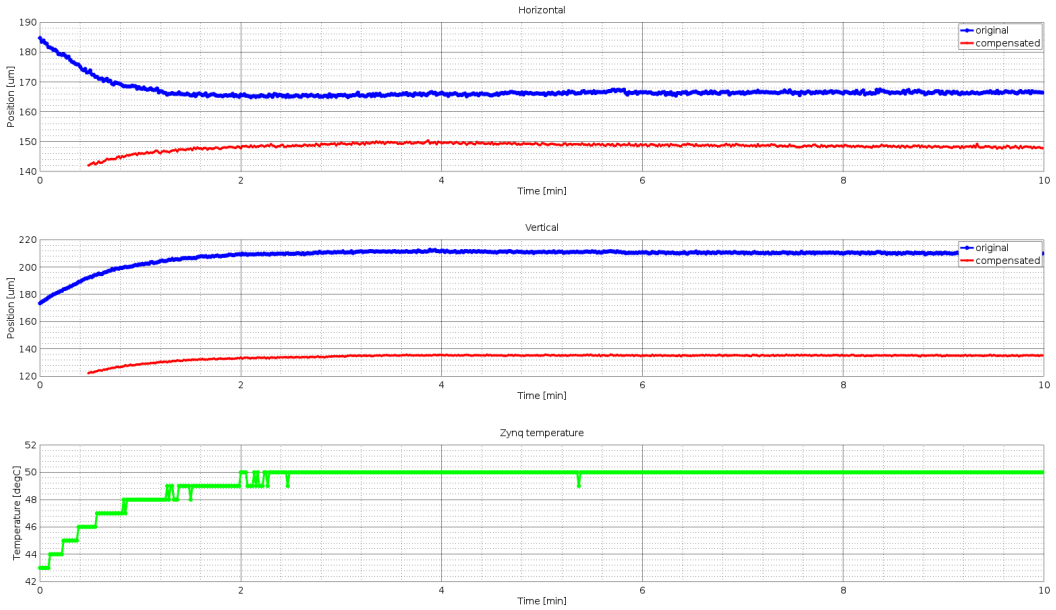




Instrumentation Technologies

Longterm stability with pilot tone (results 2)

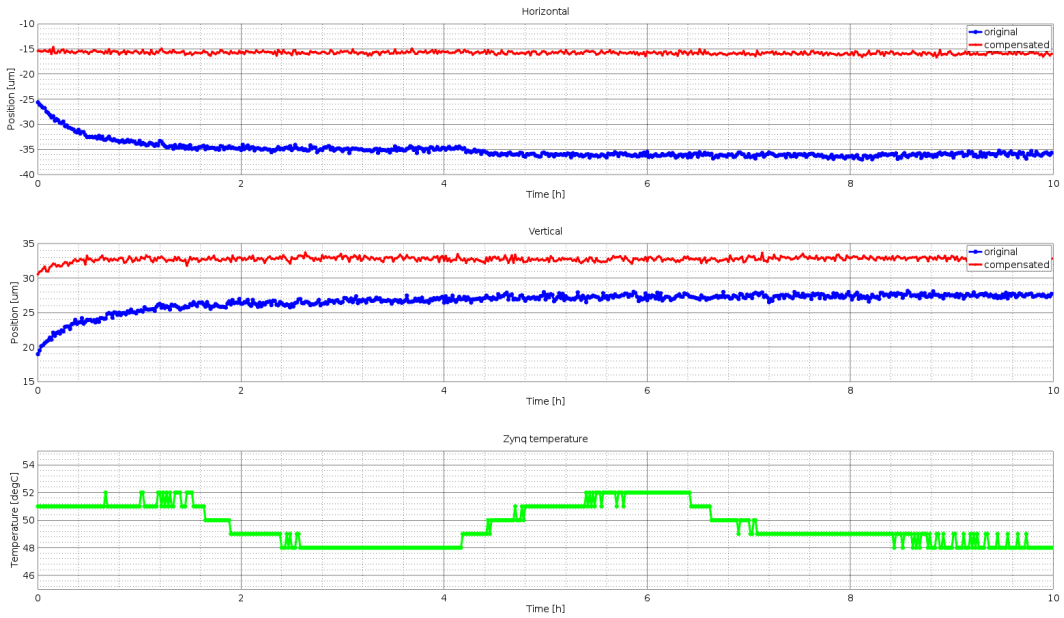
- Temperature variation in Libera Spark (from »cold start«, 10 hours)
- 7 degC temperature raise during the warm-up period
- Approximately 20-30 µm drift in X/Y directions
- Not possible to compensate better than 10-15 µm
- Drift is most probably related to SAW filters



kx=ky=20 mm;
absolute position offset
for better result
visualization

Longterm stability with pilot tone (next step)

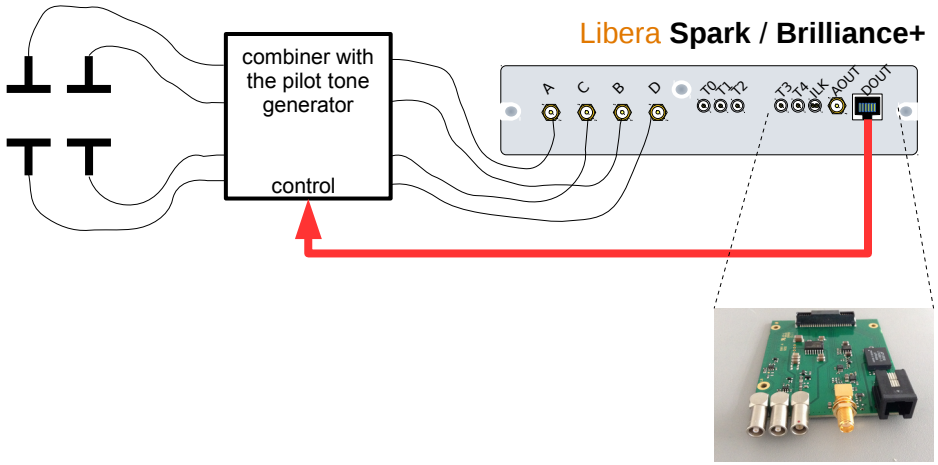
- Test with a modified Libera Spark (like an AC digitizer)
- 4-5 degC peak-to-peak temperature variation
- Drift in the warm-up period (unknown reason) but later the drift is < 1 µm
- Difficult to judge the overall stability since the pilot-tone front end was kept at quasi stable temperature



kx=ky=20 mm;
absolute position offset
for better result
visualization

Use of pilot-tone front end with Libera Spark

- Implementation of parallel turn-by-turn processing for Pilot-tone for »real time« compensation
- Clean turn-by-turn measurements <u>not possible</u> due to Pilot-tone frequency component
- Compromise: run pilot-tone with a slow period (e.g. every 1 minute)? Still affects the clean turn-by-turn data stream.



Position measurement of each bucket

- Inquiries from Pohang Light Source, Diamond Light Source and others:

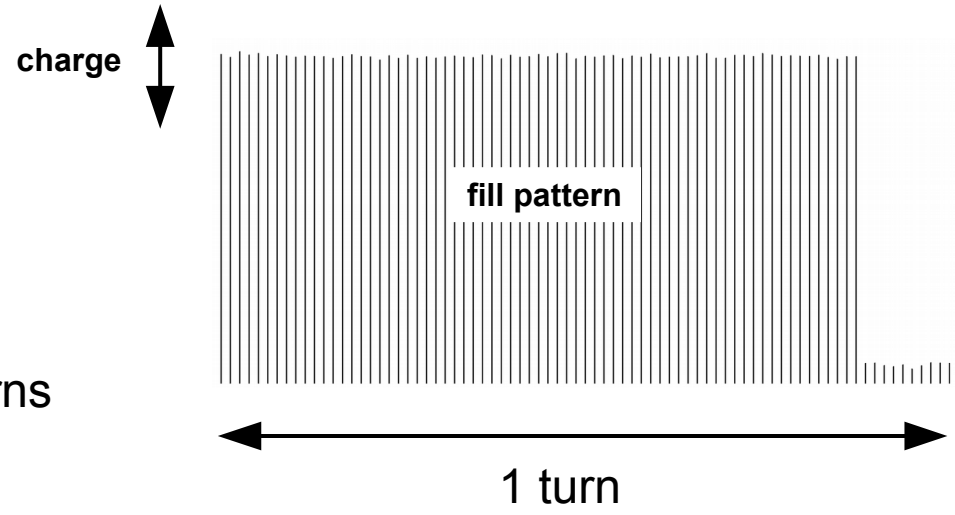
  Readout electronics capable of detecting position of each individual bunch within the filling pattern.

  Optionally, have capability to feed-back to a selected bunch within the filling pattern.
- High processing bandwidth required:
  - Sampling at 500 MS/s (direct)
  - Sampling clock locked to the RF with fine phase adjustment per channel
  - Position calculation at 500 MHz? Or calculated on-request?
- Limited A/D granularity (12 or 14 bit), limited position resolution
- Narrow bandwidth data streams (2 kHz, 5 Hz) required or not?

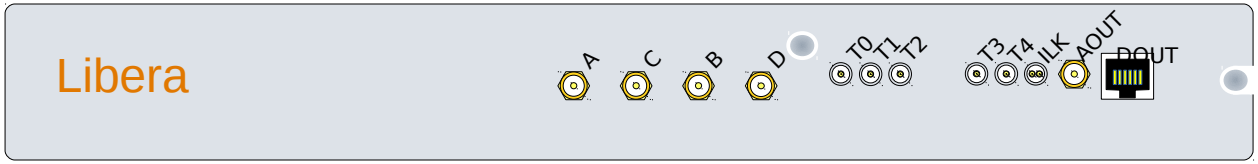
Bunch-by-bunch position and SUM data

Possible features

- Fill pattern monitor
- Charge per bunch
- Position per bunch
- Trajectory of each bunch over turns



Future options for brainstorming



- Higher sampling rate option for bunch-by-bunch readings
- Software / FPGA improvements to meet the processing requirements:
  - Bunch-by-bunch for each turn
  - Polynomial equation for position calculation
  - Position calculation with 3 amplitudes only
- Temperature stabilization within a degree C
- 10+ Gbps SFP links?
- Synchrotrons that would install such instruments?

Conclusion

- Libera provides a **clean turn-by-turn** position data
- Pilot-tone front end compatible with Libera Spark ERXR
- Higher sampling rate will introduce bunch-by-bunch position readout
- Temperature stabilization will ensure sub-micron long-term stability