SYNCHROTRON THAILAND CENTRAL LAB

Experience of Using Libera Spark in Siam Photon Source Storage Ring

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on behalf of
Beam Dynamics and Instrumentation Group
Accelerator Department
SLRI

17 June 2020

Siam Photon Source (SPS)

https://lightsources.org/lightsources-of-the-world/

Laboratories and offices

1.2 GeV synchrotron booster and storage ring

Siam Photon Laboratories

Siam Photon Source (SPS) is the first Thailand's synchrotron light source located in Suranaree University of Technology, Nakhon Ratchasima (~300 km from Bangkok) operated by Synchrotron Light Research Institute (SLRI).

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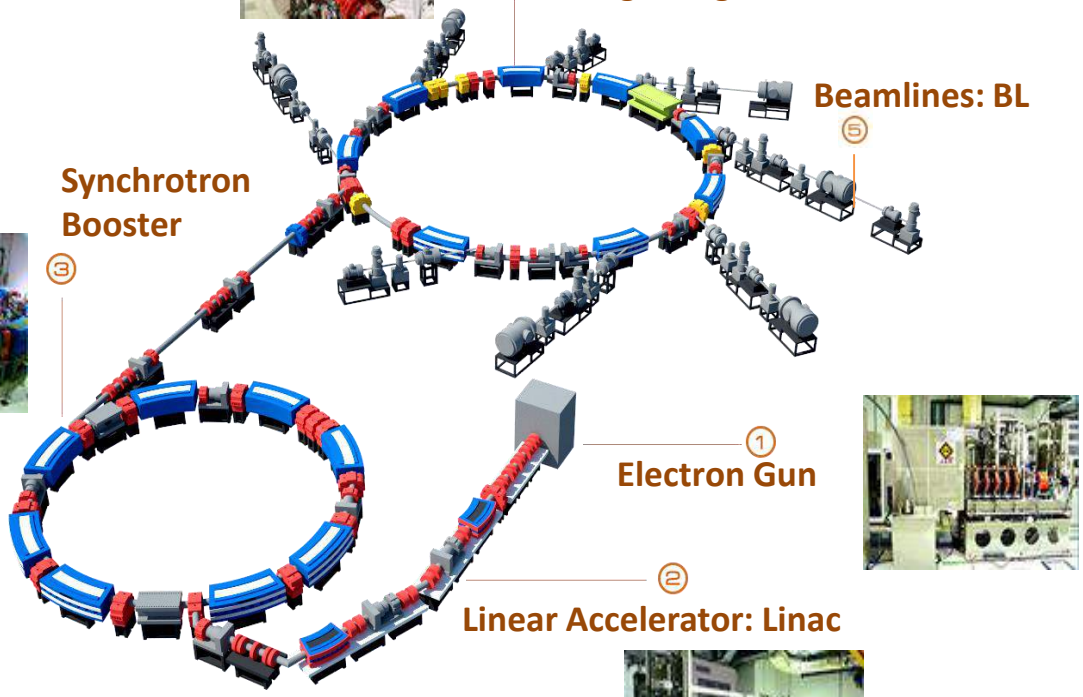
Siam Photon Source (SPS)



Electron gun	• Thermionic DC gun
Linac	• Two 20-MeV injector linacs
Accelerating structure	• Base on S-band technology
Booster synchrotron	• 1.2-GeV synchrotron booster
Storage ring circumference	• 81.3 m
Electron beam energy	• 1.2 GeV
Operation mode	• Decay mode
Maximum beam current	• 150 mA
Beam emittance	• 63 nm·rad

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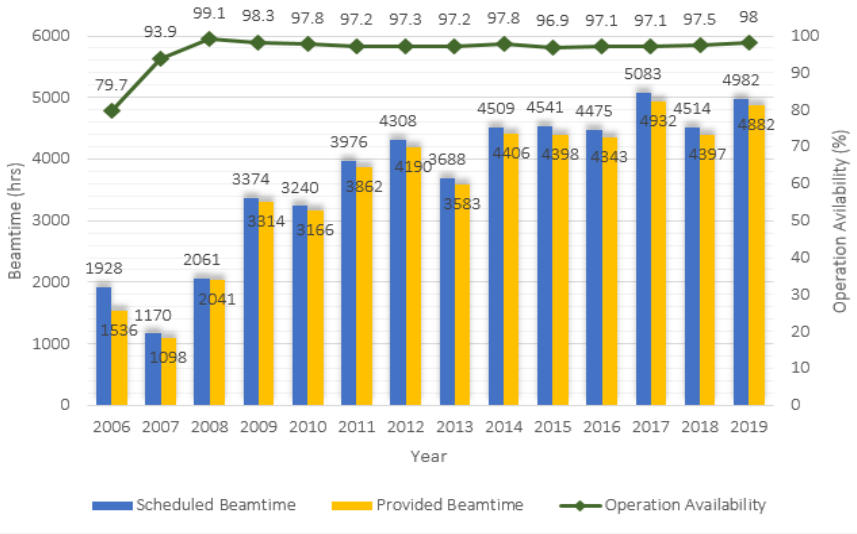
Siam Photon Source (SPS)

- Machine runs in “decay mode”
- Electron beam is injected twice a day
- Number of user beamtime per day is 23 hours (~4500 hours per year)



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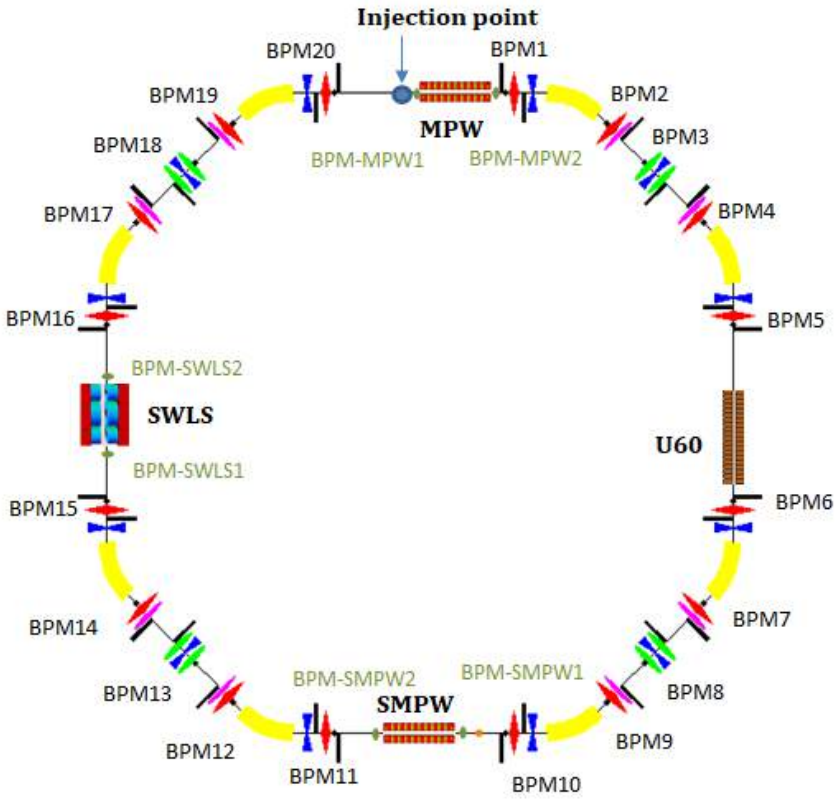
SPS BPM system

- BPM system of SPS storage ring has been based on Bergoz MX-BPM.
- Slow Orbit Feedback (SOFB) operates using moving average of slow acquisition (SA) data from Bergoz MX-BPMs

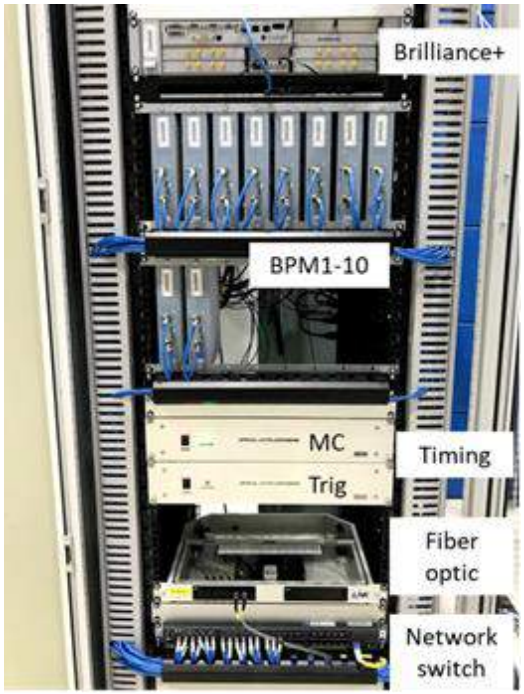


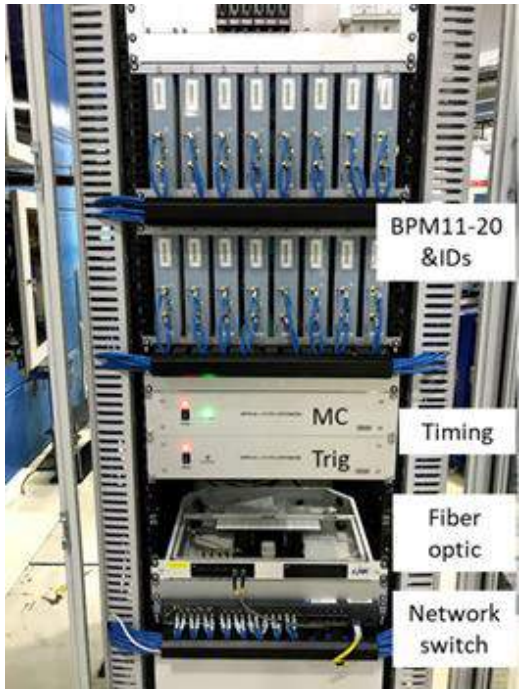
Upstream BPM	Location	Downstream BPM
BPM20, BPM-MPW1	MPW	BPM-MPW2, BPM01
BPM01	BM1	BPM02, BPM03
BPM04	BM2	BPM05
BPM05	U60	BPM06
BPM06	BM3	BPM07, BPM08
BPM09	BM4	BPM10
BPM10, BPM-SMPW1	SMPW	BPM-SMPW2, BPM11
BPM11	BM5	BPM12, BPM13
BPM14	BM6	BPM15
BPM15, BPM-SWLS1	SWLS	BPM-SWLS2, BPM16
BPM16	BM7	BPM17, BPM18
BPM19	BM8	BPM20

BPMs adjacent to IDs are normally not included in orbit control system.

Libera Spark installation and setup

- All Libera Sparks (28 units) arrived in mid 2018.
- Cables connected from BPM pickups in SPS storage ring were changed.
- Two cabinets were prepared as BPM stations outside concrete wall of the storage ring.
- 26 Libera Sparks were mounted on racks in the stations.
- Machine clock, trigger signals and network switch were connected to all instruments.
- Basic initial setups such as software update and instrument IPs were set by SLRI team.





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I-Tech on-site support

- Peter Leban arrived at SLRI for on-site support during 1-4 November 2018.
- Virtualbox image with scripts and GUI were installed.
- Hardware verification and instrument configuration were done.
  - ADC offset compensation
  - Input current range and recommended attenuation
  - Instrument temperature verification
  - Compensation of phase mismatch due to cables
  - Configuration: IP, IOC name, EPICS database, store persistent parameters, trigger delay, etc.
- (Originally) scaling coefficients and offsets from Bergoz MX-BPMs were used.
- General training related to Libera instruments was given by Peter.
- Peter is always very responsive via email discussion.

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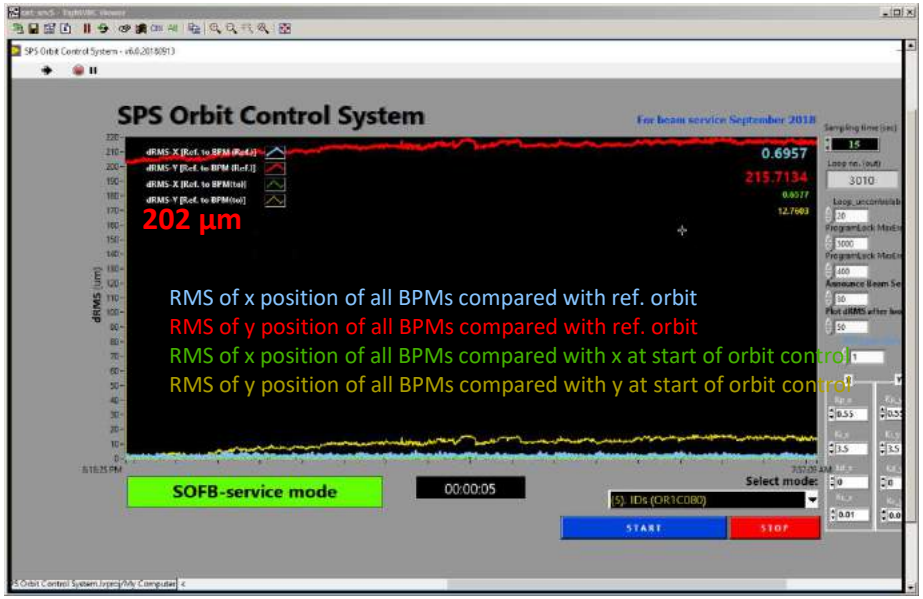
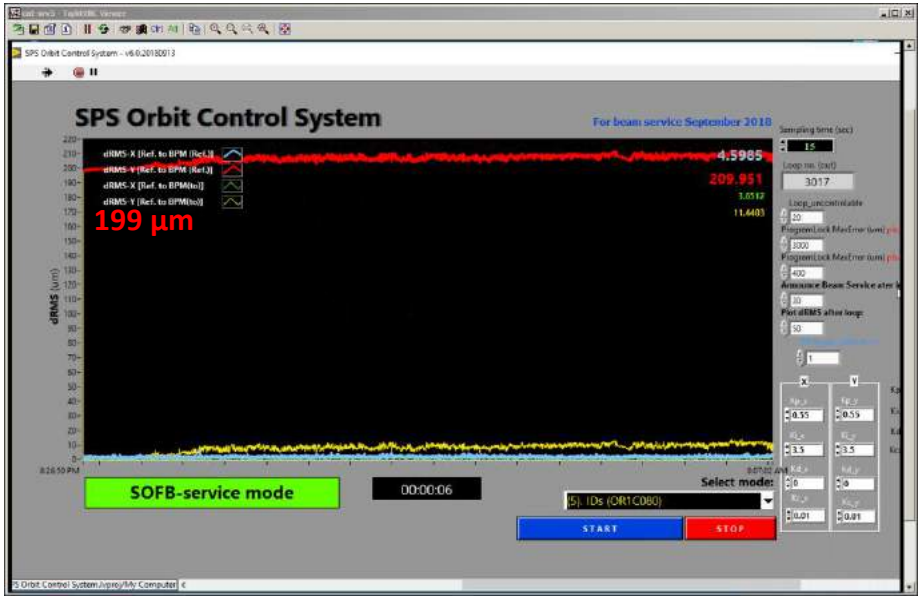
BPM system migration in February 2019

- Get orbit after Slow Orbit Feedback (SOFB)
- Swap BPM cables from Bergoz MX-BPMs to Libera Sparks
- Get new reference orbit for Libera Sparks
- Find new Orbit Response Matrix
- Scaling coefficients (Kx and Ky) and offsets were kept the same values from Bergoz MX-BPMs.

SOFB program layout and result of normal beam service using Bergoz MX-BPMs with orbit control





RMS of y position from reference orbit normally starts ~200 µm every beam service shift.

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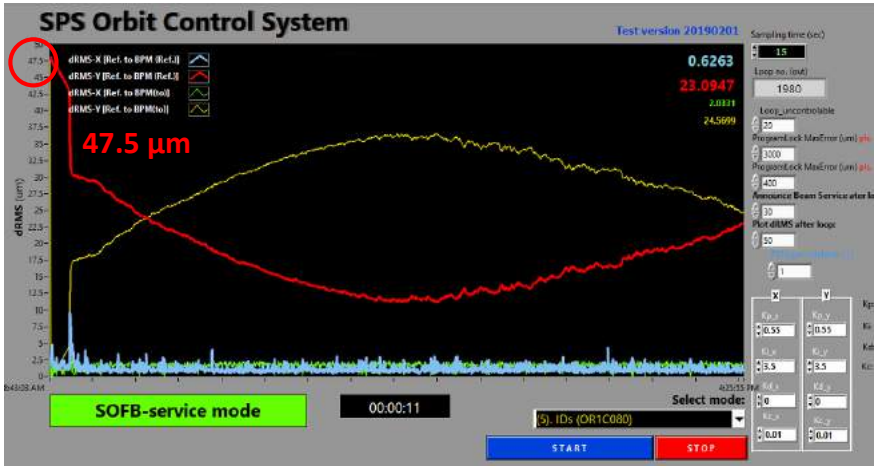
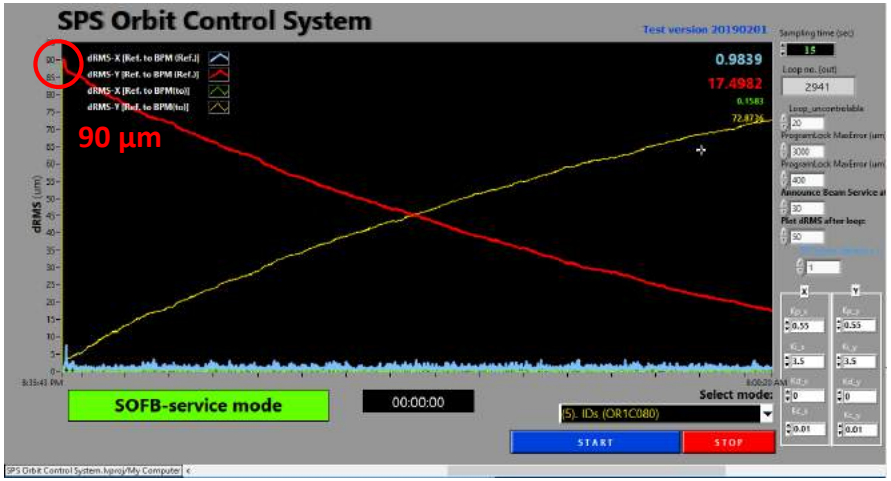
BPM system migration in February 2019

Result using Libera Sparks with orbit control

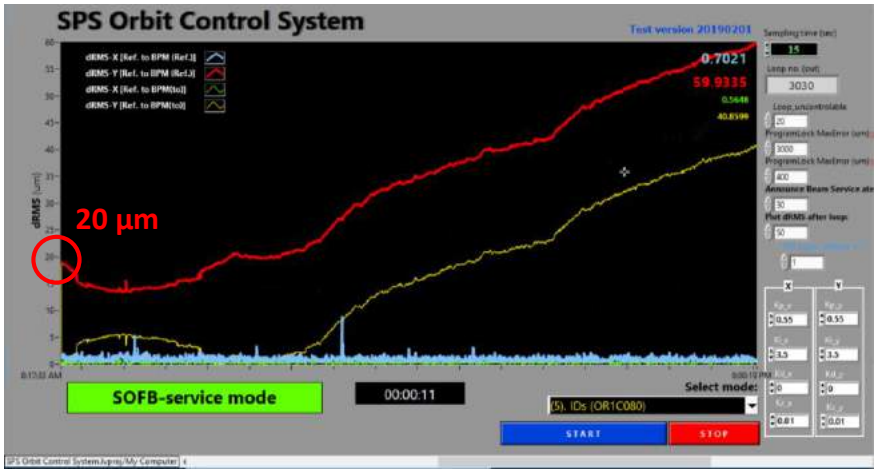
03 Feb 2019



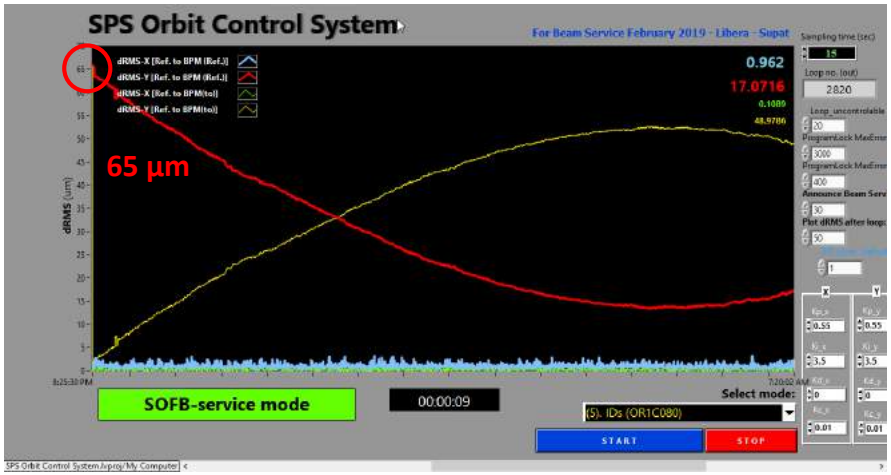
07 Feb 2019



08 Feb 2019



10 Feb 2019



- **Stable orbit control could not achieved.**
- **Poor stability of y position**

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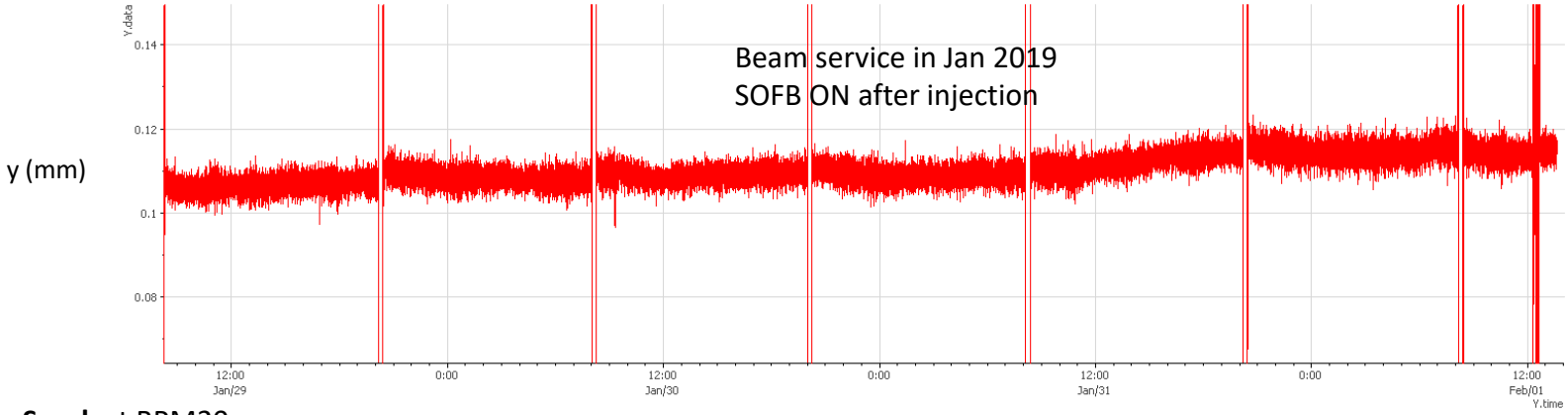
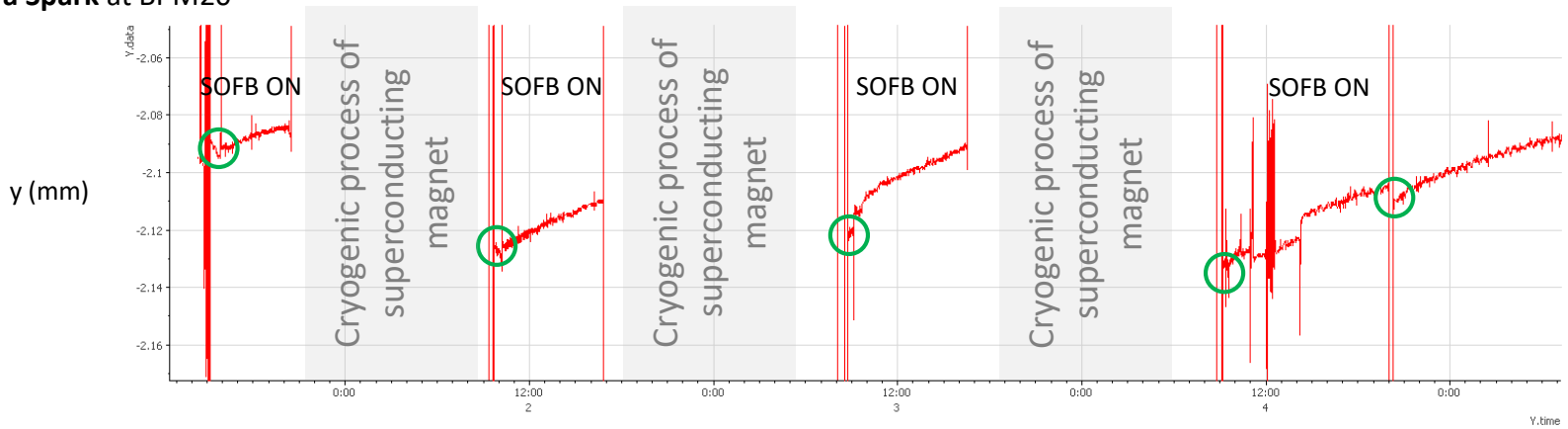
BPM system migration in February 2019

What about logged beam position?

Bergoz MX-BPM at BPM20



Libera Spark at BPM20



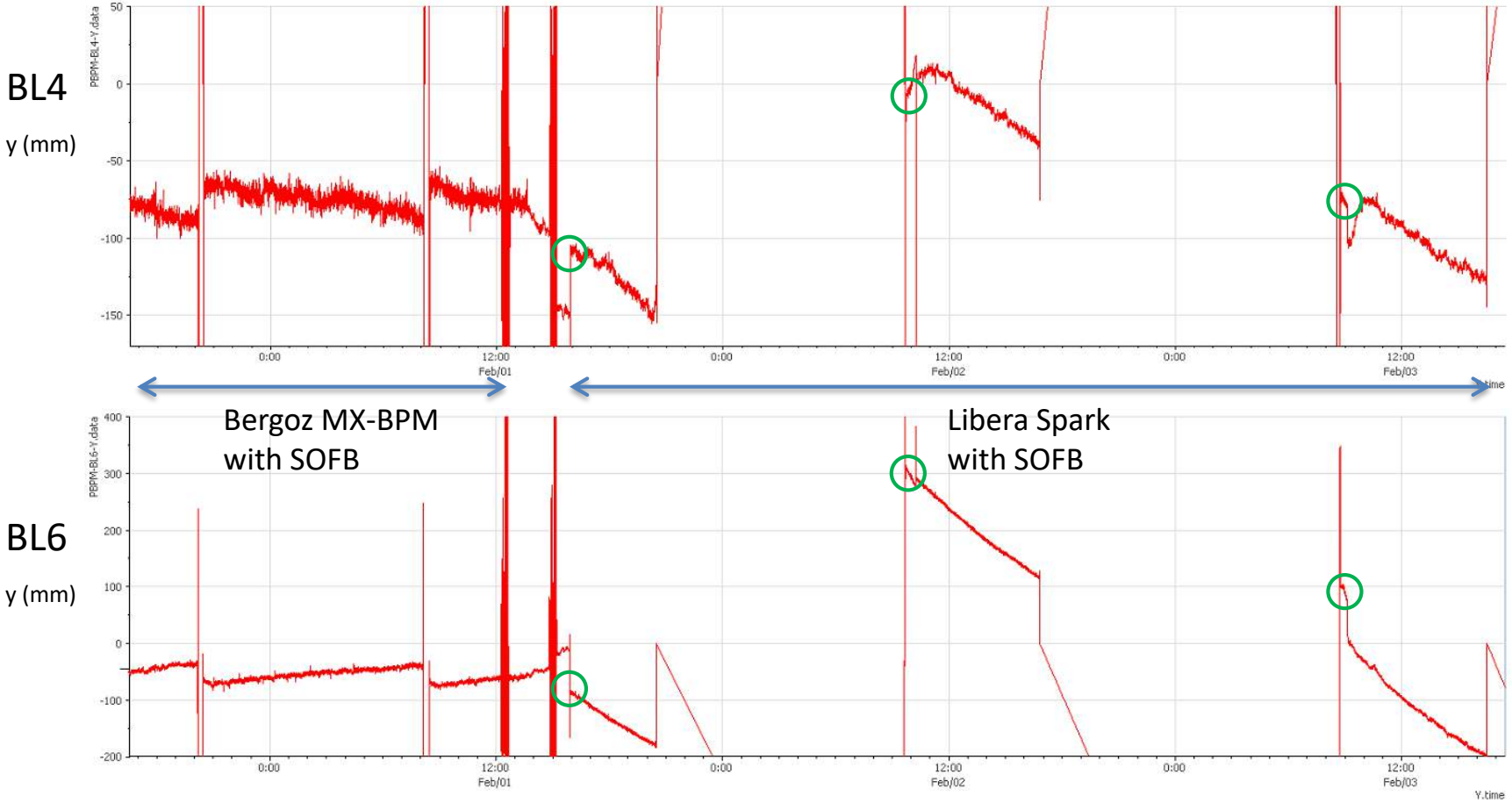
Two main problems found

1. **Offset of vertical position after initial orbit correction**
2. **Large vertical position drift in a shift**

✓ Clearly, Libera Spark has better resolution.

BPM system migration in February 2019

What can be seen by photon beam position monitors (PBPMs)?

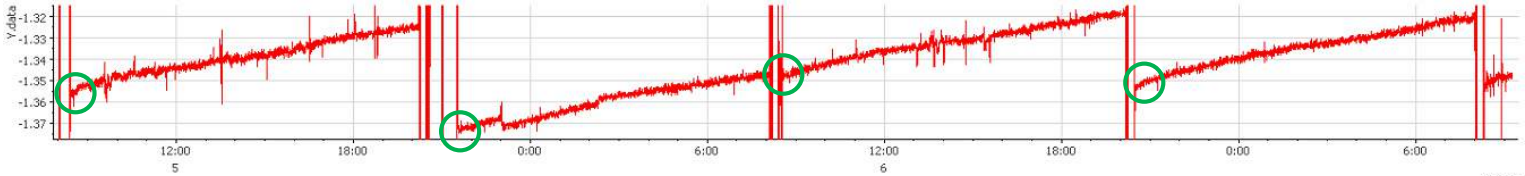


- After using Libera Spark, PBPMs saw non-repetitive pattern and larger vertical position drift when using Libera Spark with SOFB.

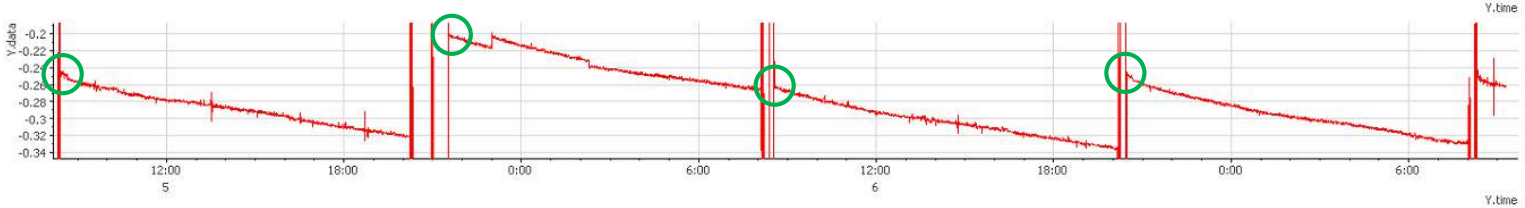
BPM system migration in February 2019

What if beam injection was done more frequently?

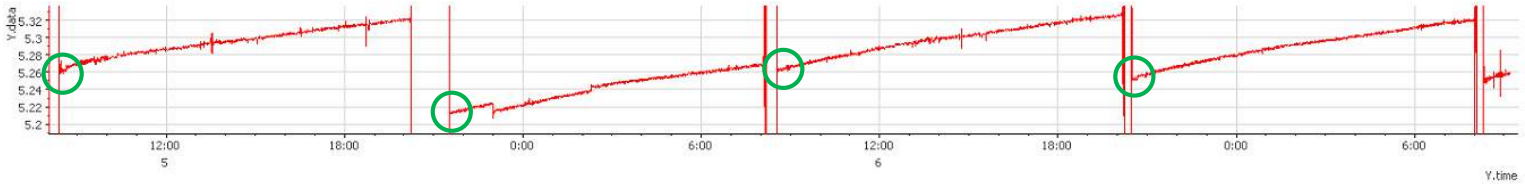
BPM01
y (mm)



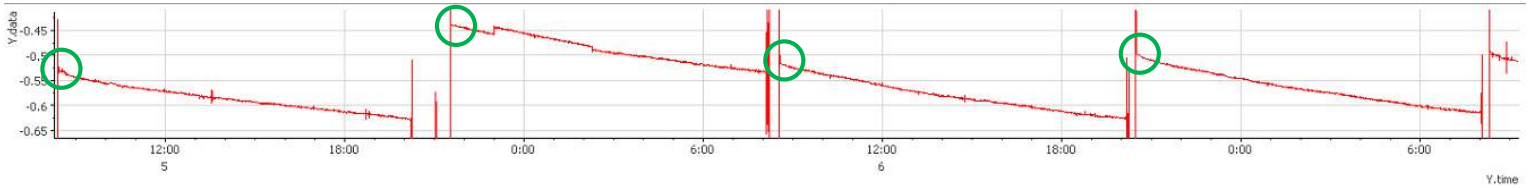
BPM02
y (mm)



BPM03
y (mm)



BPM04
y (mm)



Problems persist.

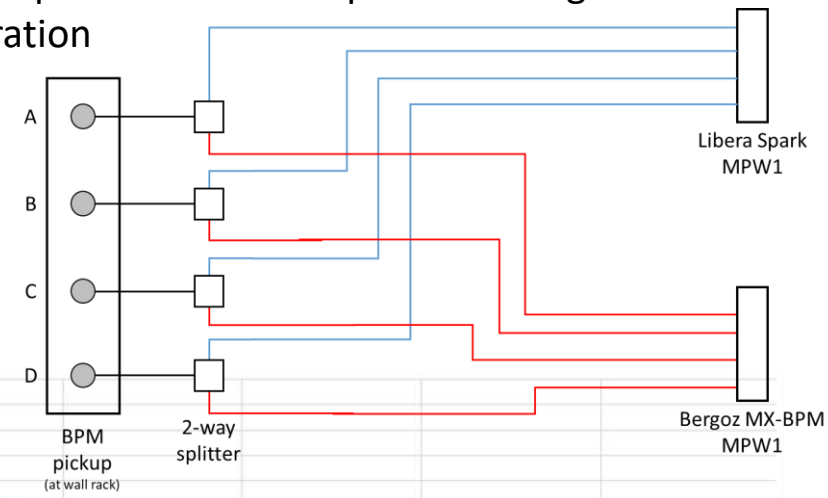
- Vertical position offset after orbit correction >10 um
- Vertical position drift >50 µm

Beamlines reported that they could not do experiments

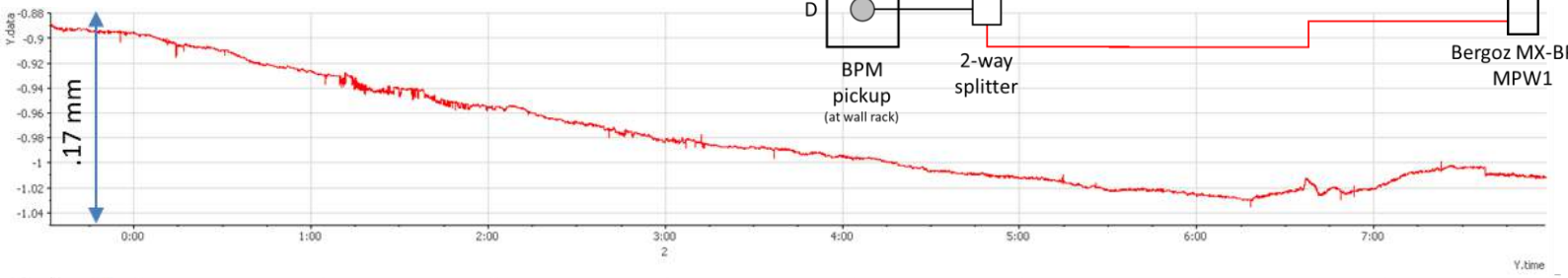
➢ We had to switch the BPM system back to based on Bergoz MX-BPMs

Investigation: scaling coefficients

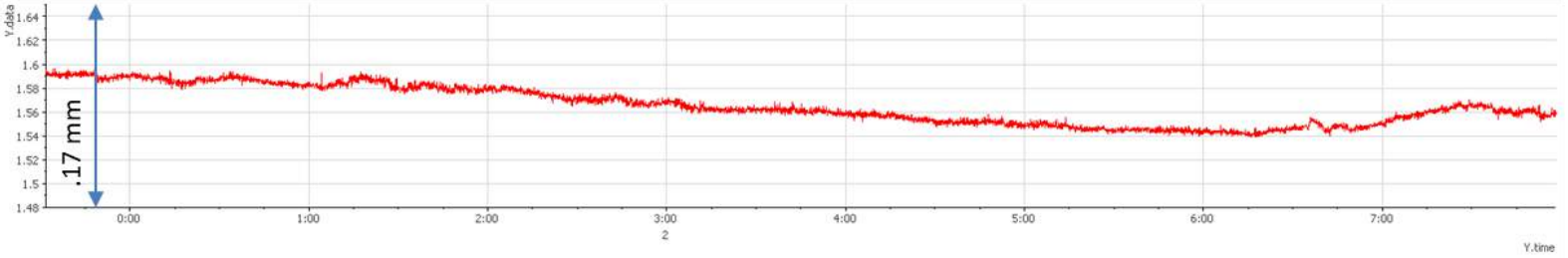
- Check beam position with SOFB OFF
- Split signal from the same BPM pickup via 2-way splitters to Libera Spark and Bergoz MX-BPM to compare beam position at the same duration



Libera Spark
MPW1
y (mm)



Bergoz MX-BPM
MPW1
y (mm)



Libera Spark has larger vertical position drift

- Confirm improper scaling coefficients (Kx, Ky)
- Beam current dependent effect

(Peter did not recommend to split signal between Libera Spark and Bergoz MX-BPM due to crosstalk that can spoil the signals.)

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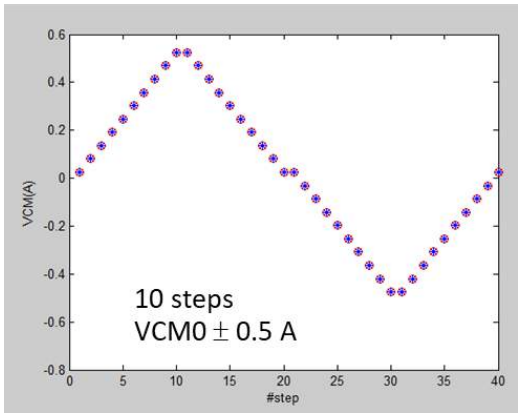
Investigation: scaling coefficients

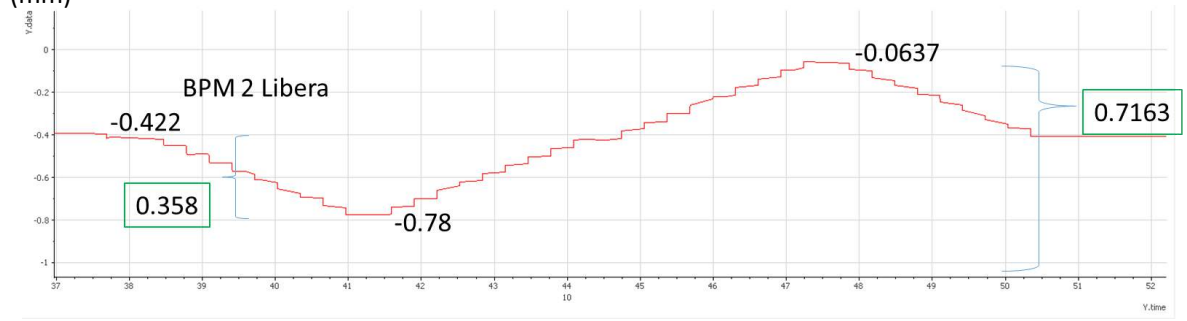
- Step changes in RF frequency, horizontal corrector magnet (HCM) and vertical corrector magnet (VCM)

Compare reading at BPM02 both cases with SOFB OFF

VCM

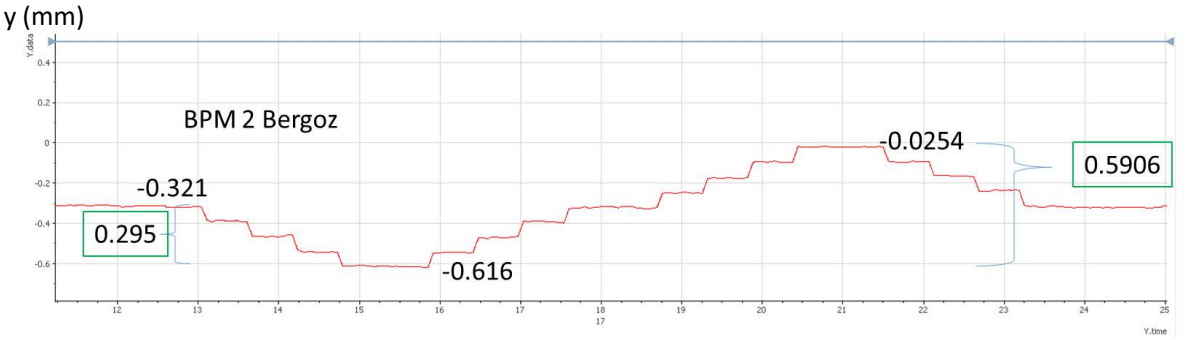


y (mm)



Data from Feb2019

y (mm)



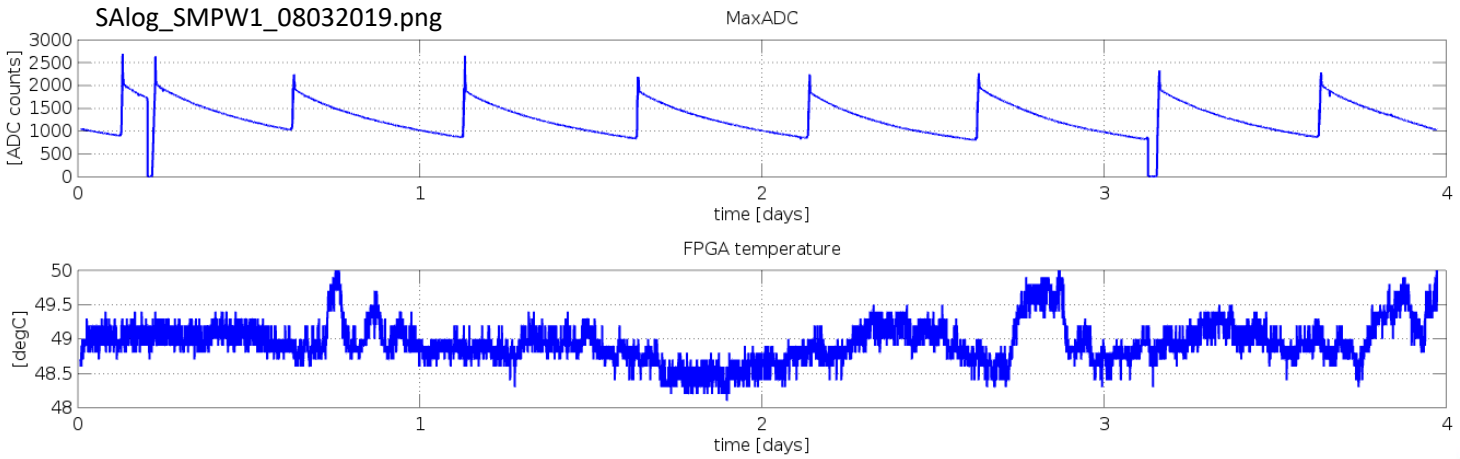
MD Apr2019

Position change of Libera Spark is about twice of Bergoz MX-BPM.

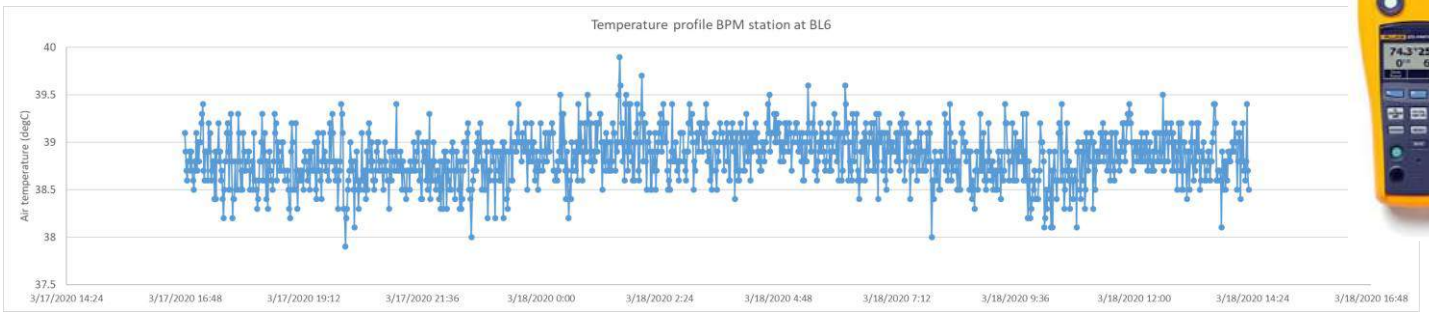
- Improper scaling coefficient Kx and Ky
- Use ratios between position change of Libera Spark and that of Bergoz MX-BPM to adjust the coefficients.

Investigation: temperature effect

- Temperature of Libera Spark FPGA board was monitored with Peter's script (logData.sh)



- Temperature inside a BPM station was monitored with an air temperature sensor



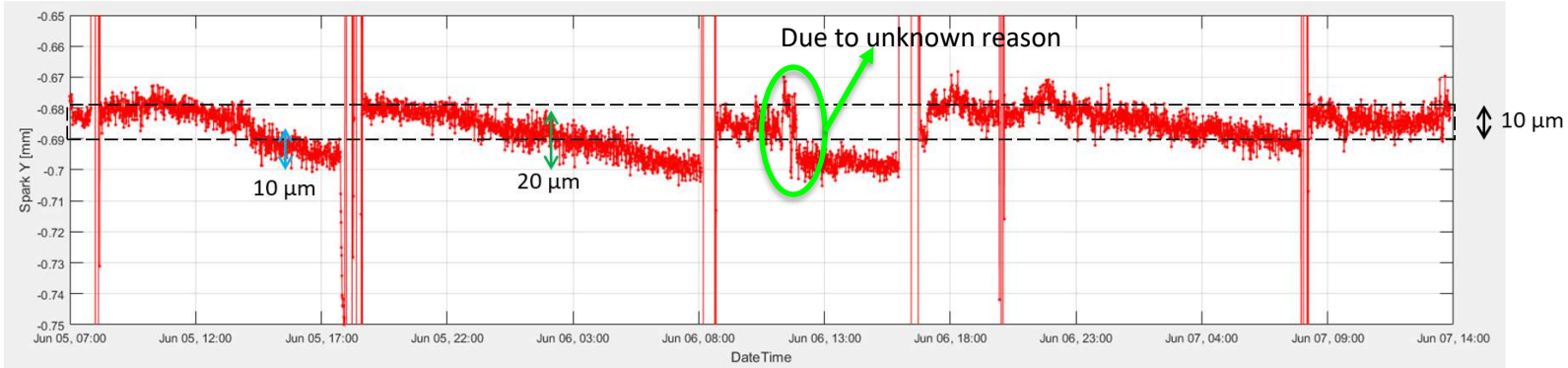
- FPGA temperature meets the specification.
- Peter commented that operating Libera Spark at 39±0.4°C is fine.
- ✓ Temperature is not the cause.

Investigation: Spark VS. Brilliance+

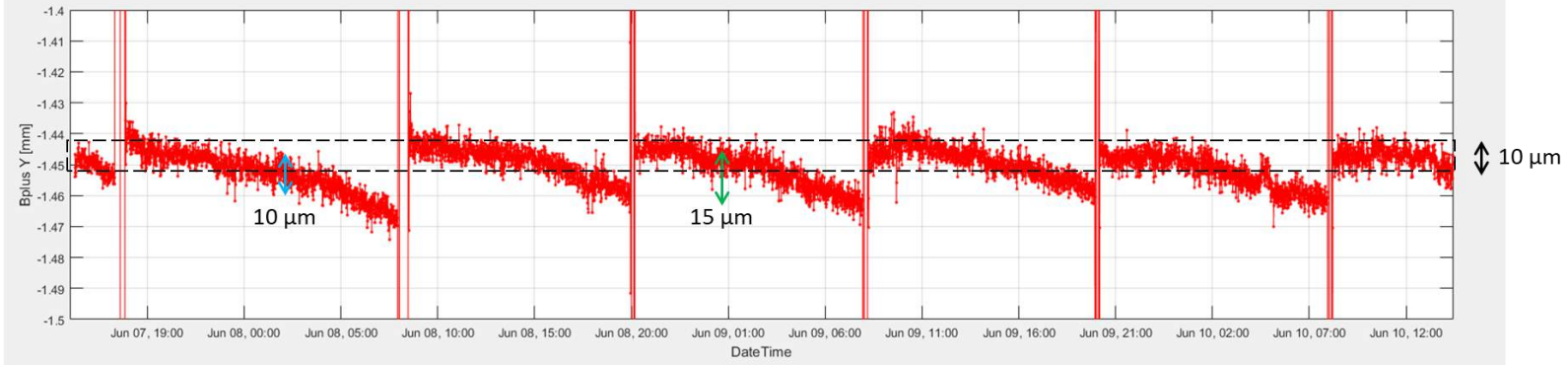
Peter suggested that Libera Brilliance+ should have better performance against current dependent effect.

➢ Compare Libera Spark with Libera Brilliance+ (data taken at different times)

Result from Spark BPM-SMPW1



Result from Brilliance+ BPM-SMPW1

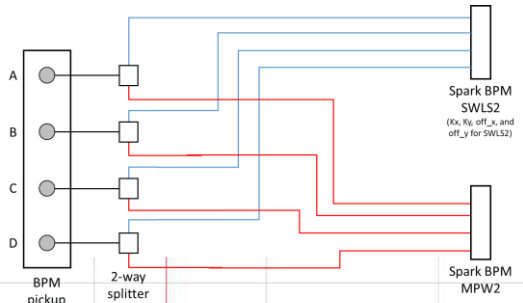


- Vertical position offset cannot be seen clearly.
- Vertical position drift in a beam service shift shows in both instruments.

Investigation: Spark VS. Spark

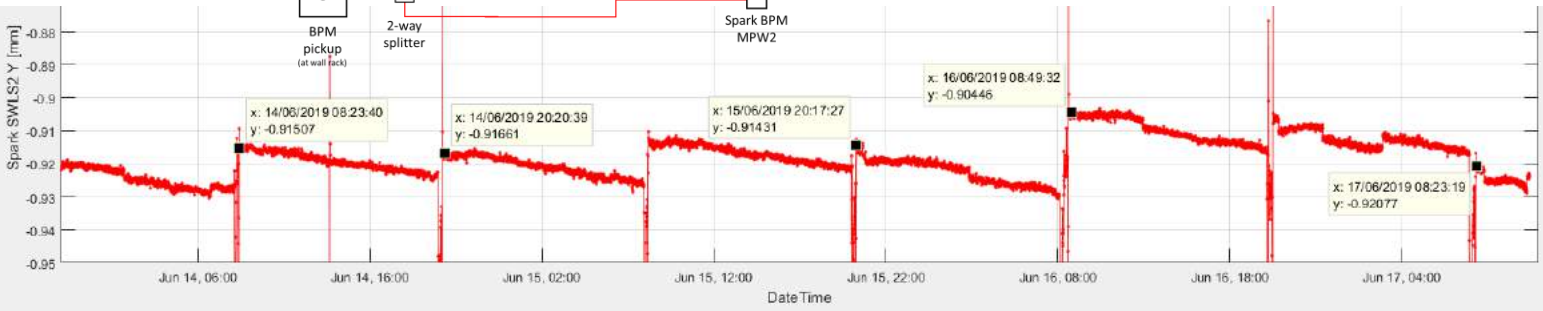
Most of the times, Libera Spark at MPW2 shows large vertical position offset.

- ➢ Split signal to two Libera Sparks to check whether position offset and position drift can be detected by both

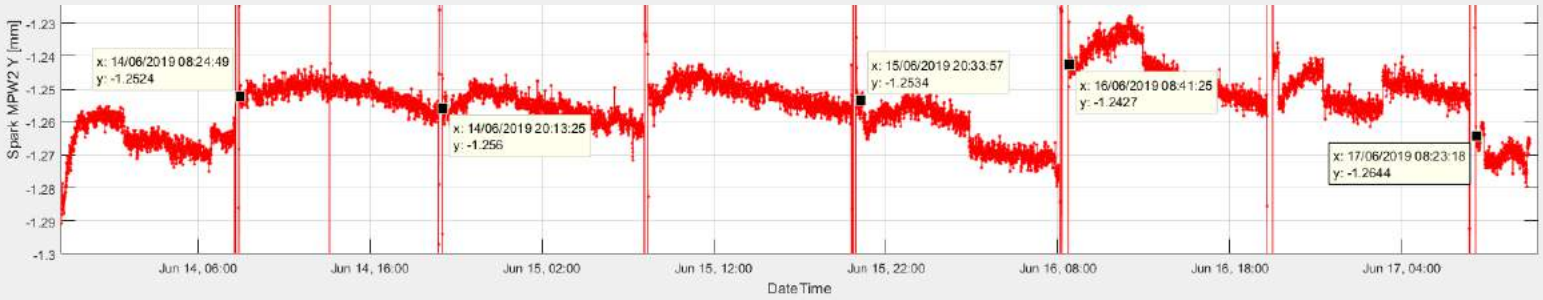


(both use their own scaling coefficients and offsets just to check tendency of read position)

Libera Spark SWLS2 y (mm)



Libera Spark MPW2 y (mm)

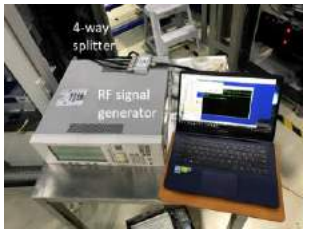


- Both Libera Sparks show position offset and position drift.
- Noisier position data suggested that scaling coefficients of MPW2 should be rechecked.

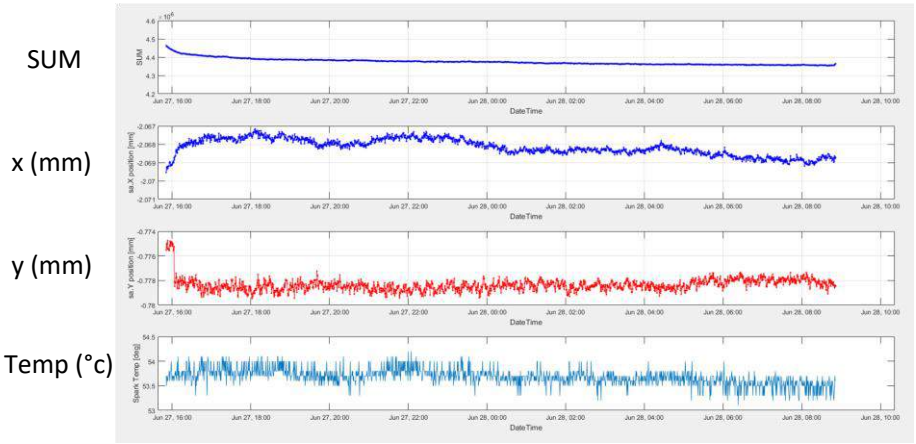
- ➢ Support that problems can be due to beam instabilities.

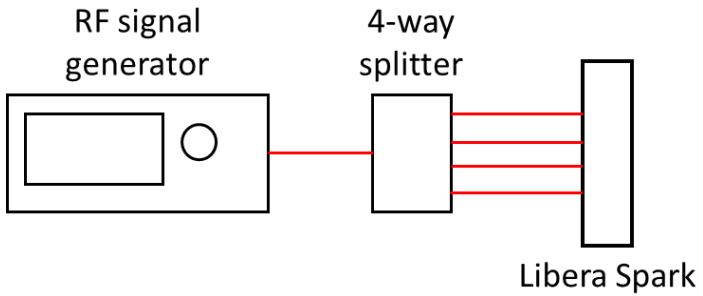
Investigation: problems come with the beam?

- Test without the beam using RF signal generator in two cases:
  - Constant power
  - Power sweep cycle (simulate the decay-mode beam)



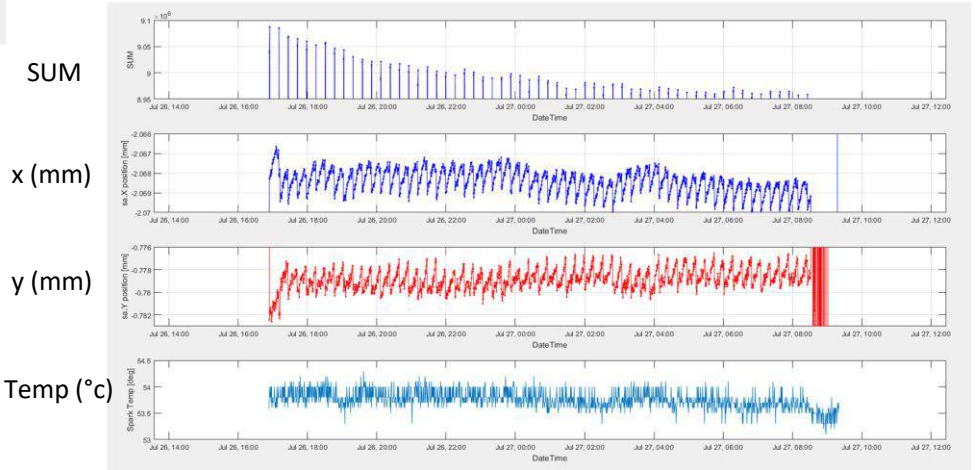
Constant RF signal to EBPM-MPW2 Att = 10 dB
118 MHz, P0 = 13.3 dBm ➔ max ADC = 1934 counts





Sweep RF signal to EBPM-MPW2 Att = 10 dB
118 MHz, P0 = 14.8 to 13.3 dBm
Step of 0.1 dBm, dwell time = 60 s

SAlog_MPW2_autoSweepP0_run5



- Vertical position drift <2 µm in both cases
- Vertical position offset <4 µm in power sweep test
- Temperature stability of Libera Spark ~0.5°C
- Overshoot of signal at the beginning of the test may be due to performance of the RF generator.

➢ One of main suspects is the beam.

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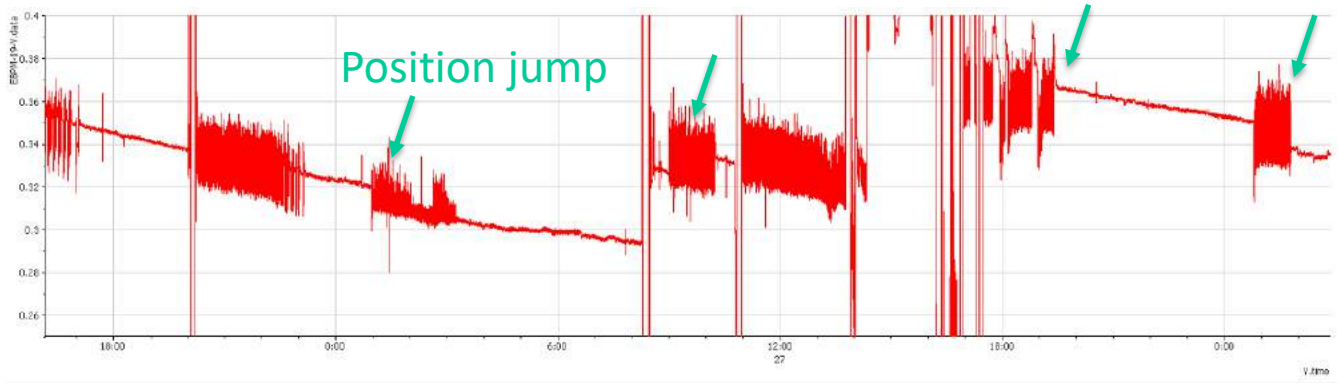
Test after machine shutdown in September 2019

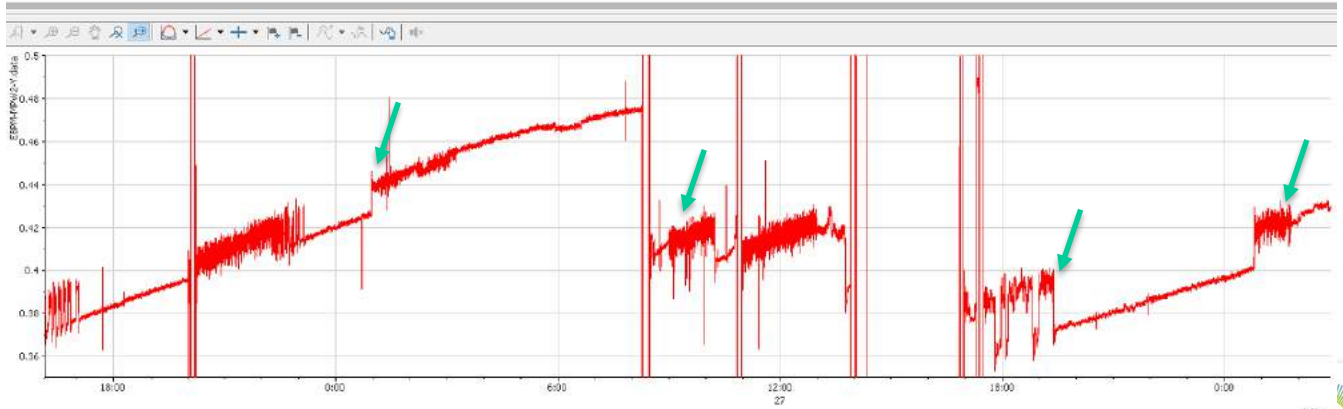
- Switch all BPM cables to Libera Sparks
- BBA
  - ➢ Update offset values
- LOCO
  - ➢ Since scaling coefficients were similar to ones adjusted previously, keep all coefficients.
- The orbit control was in a good condition until unknown noise presented randomly. It was worse due to vertical position jumps after noise disappeared.

SOFB ON

Libera Spark
BPM19
y (mm)



Libera Spark
MPW2
y (mm)



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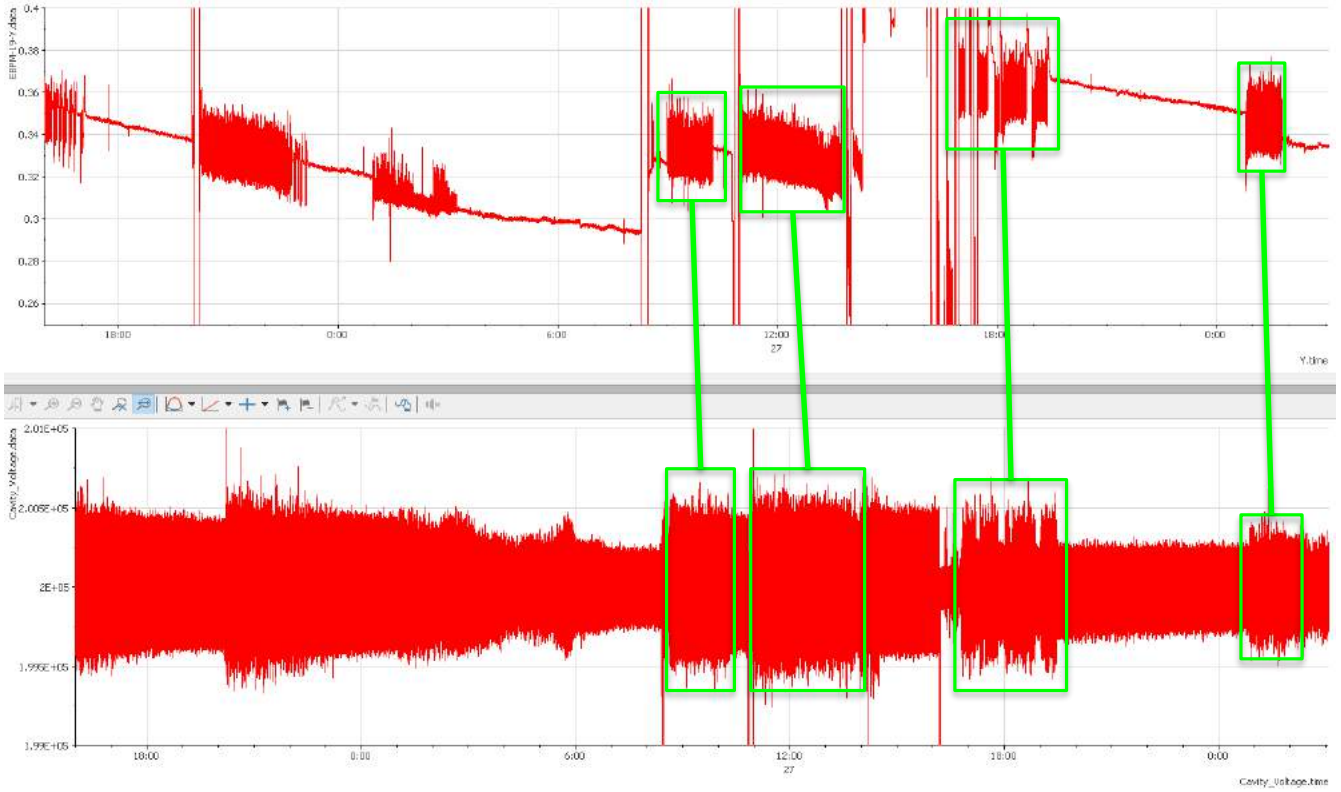
Test after machine shutdown in September 2019

- Correlation between noise seen by Libera Sparks with RF cavity voltage fluctuation was found.

Libera Spark
BPM19
y (mm)

RF cavity
voltage
(V)



❖ *Why RF fluctuation posses greater threat to vertical beam position?*

Effect of RF voltage fluctuation

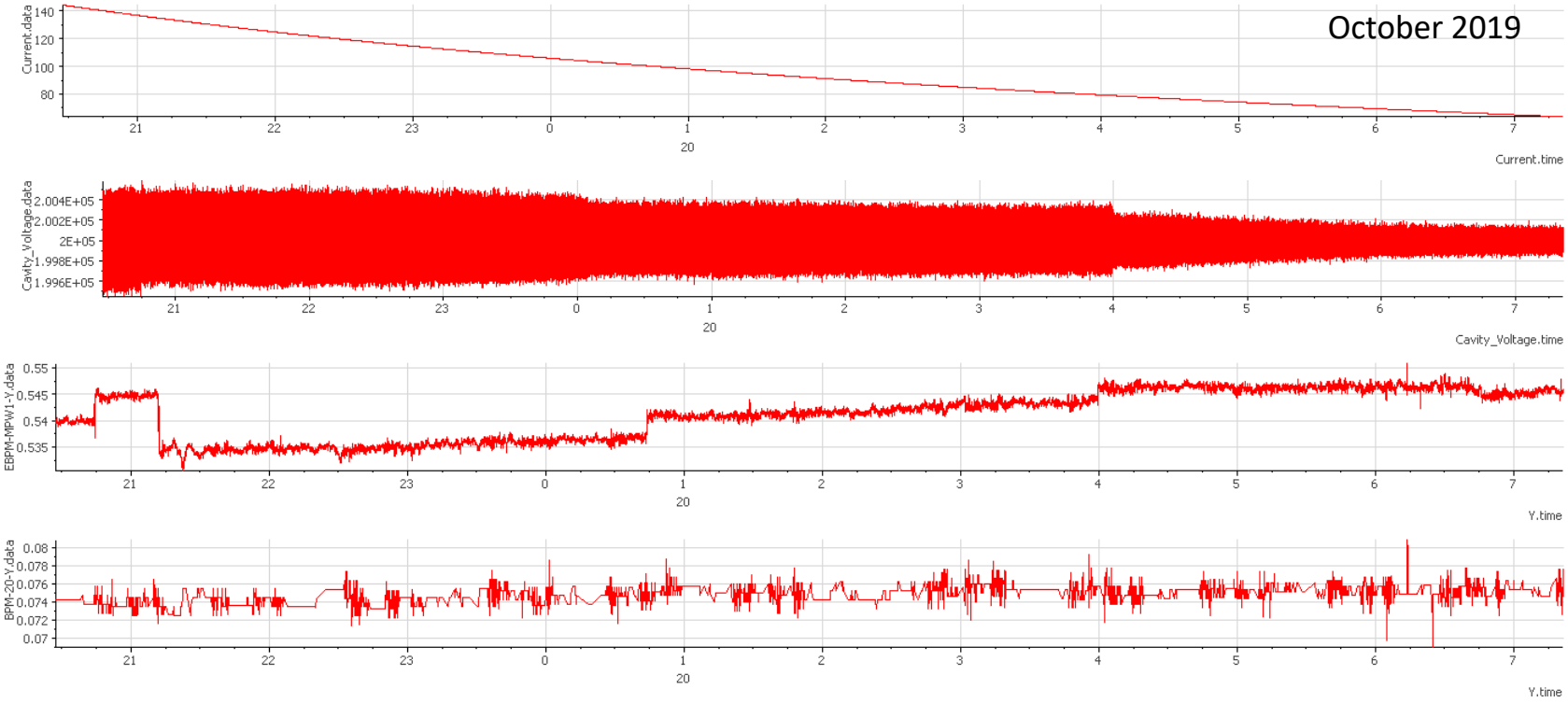
- Check logged of RF voltage and beam position from Libera Spark and Bergoz MX-BPM

Stored current (mA)

RF cavity voltage (V)

Libera Spark MPW1 Y (mm)

Bergoz MX-BPM BPM20 y (mm)



- *Why Libera Spark detects RF fluctuation but not Bergoz MX-BPM?*

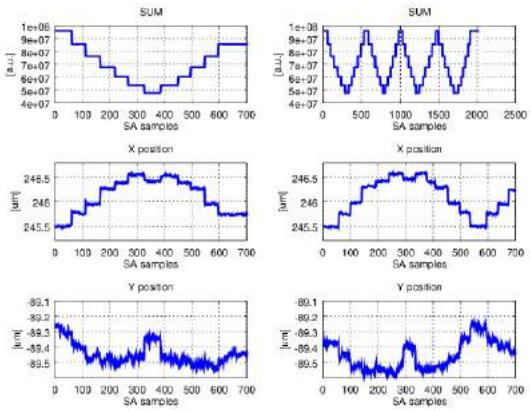
- Investigation to RF cavity voltage fluctuation has been carried on.

Recently…

- December 2019 - January 2020: two Libera Sparks were sent back to I-Tech for testing in lab.
- January - May 2020: tests were done by Peter. Several experiments suggested by us to test in lab
  - Long term test at 40°C
  - power sweep and power change to simulate decay mode in our machine
- Peter reported that stable position was found in long term test at 40°C and position offset and position drift were found <2 µm.
- June 2020: two Libera Sparks are prepared to send back.

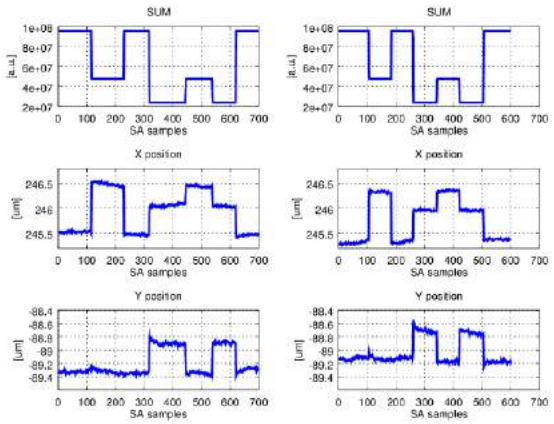
Power sweep (SN024)

- Single sweep (left) and multiple sweeps (right)
- Position change in both measurements:
  - dX = 1.1 µm
  - dY = 0.4 µm



Step power change (SN024)

- Before (left) and after (right) power cycle
- Position change:
  - dX = 1 µm
  - dY = < 0.7 µm
  - Absolute position change after power cycle
  - dX = -0.4 µm
  - dY = +0.2 µm



Ref: Peter's test report (2020_05_25_power_tests)

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Next steps

- Several tests suggested by Peter
  - Set proper SAT environment and use a 4-way splitter model (ZFSC-4-1+) to reproduce FAT on five Libera Sparks
  - Repeat power sweep and power change test
  - 24-hour long term test in our facility with temperature log
  - Split signal from each button of a BPM pickup to a Libera Spark via 4-way splitter
  - Repeat with Bergoz MX-BPM

- Plan for machine study to collect more data of running SOFB based on Libera Sparks in beam service mode. Focus on comparison between data from instruments that run SOFB.

- Investigate RF voltage fluctuation

- Check noise from master oscillator and other sources of instabilities

Thank you for your attention

Your comments and suggestions are appreciated.