EFFECT OF MECHANICAL VIBRATIONS ON BEAM STABILITY

B. Roche, ESRF

OUTLINE

Part I: effect of absorbers cooling on beam stability

Part II: vacuum chamber vibrations

Part III: estimation of quadrupole’s vibrations contribution to beam’s position fluctuations

Part IV: plans for an “open source” bunch-by-bunch feedback front-end

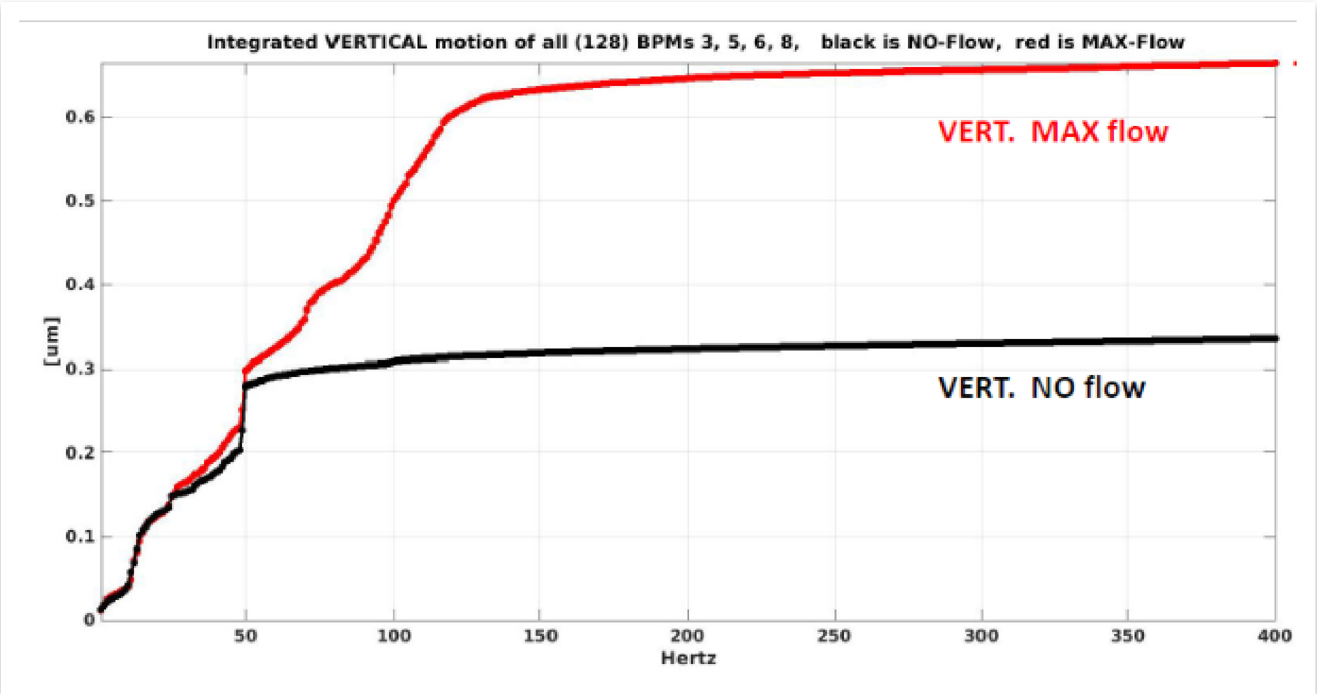
Part I: effect of absorbers cooling on beam stability

The effect of absorbers' water cooling has been measured in 2021:

Absorbers water cooling has been stopped for this test (magnets cooling was still present).

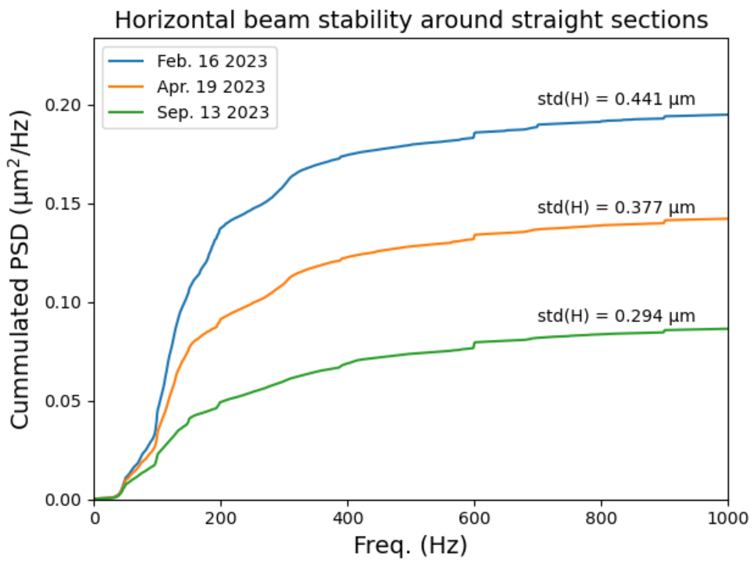
A small current was injected in the storage ring (~ 5 mA) and the stability of this beam has been measured, and compared to nominal conditions

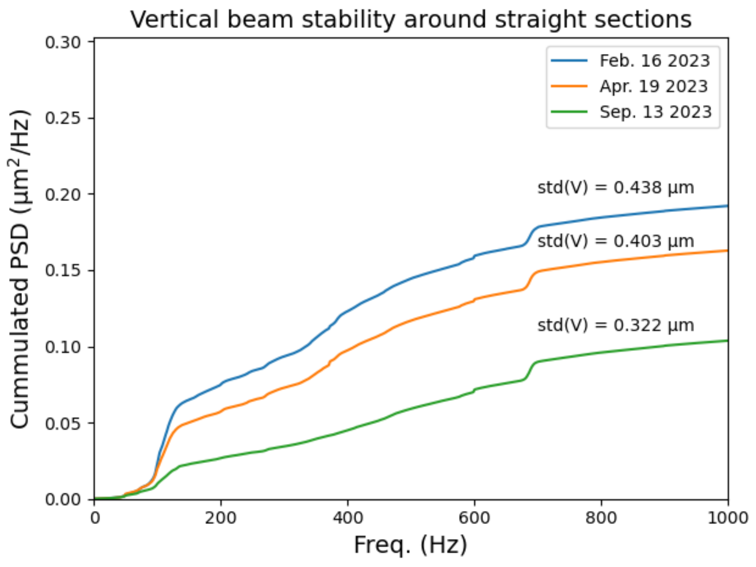
→ stopping water cooling reduces by a factor 2 beam vibrations in vertical plane.



Stopping water cooling reduces by a factor 2 e-beam vertical vibrations.
(presented at ASD Day 2022, K. Scheidt)

ABSORBERS' WATER COOLING FLOW REDUCTION: BEAM STABILITY IMPROVEMENT





Before March shutdown: all cells had their cooling at max. flow rate (**blue curve**)
During March shutdown: 8 cells had their flow reduced (**orange curve**)
After summer shutdown: all cells are running with reduced flow (**green curve**)

In 2023 we reduced water flow in the absorbers.

Effect: reduction of beam position fluctuations by

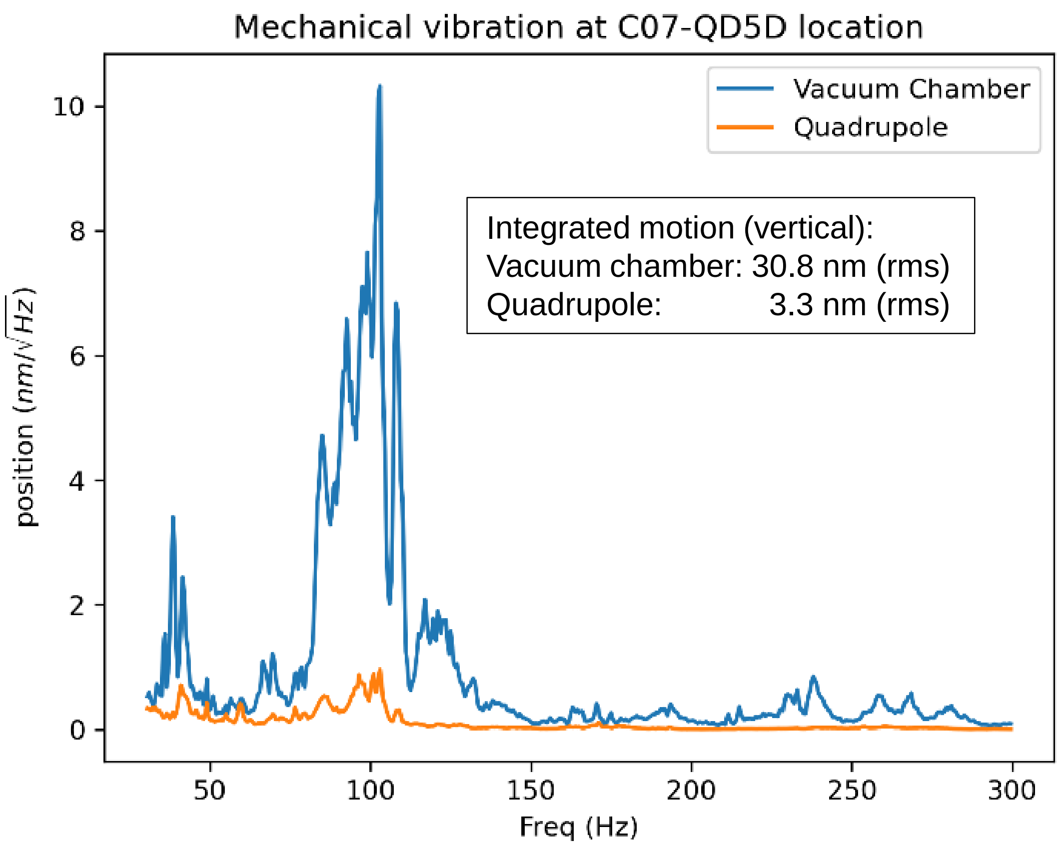
- 33 % in horizontal
- 26 % in vertical

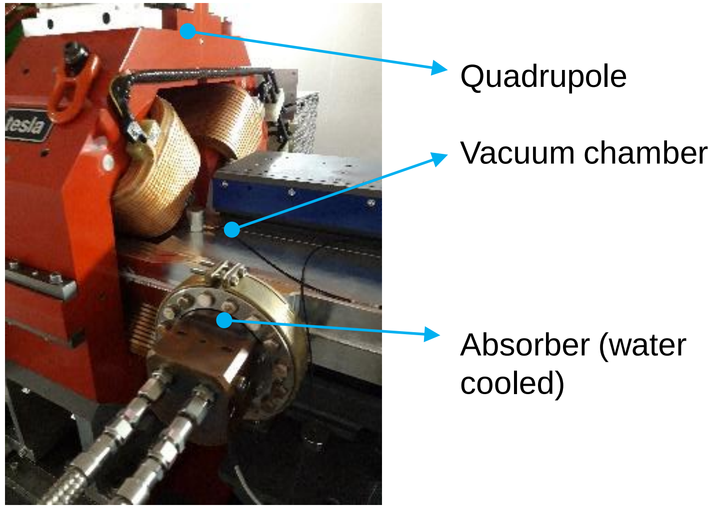
Internal reference: STORM report - 21/09/2023

Part II: vacuum chamber vibrations

STORM report - 28/03/2024

VACUUM CHAMBER VIBRATIONS MEASUREMENTS





Mechanical vibrations measurements (Jan. 2024) Comparison between the quadrupole and the vacuum chamber vibrations at the same location (C07-QD5D).

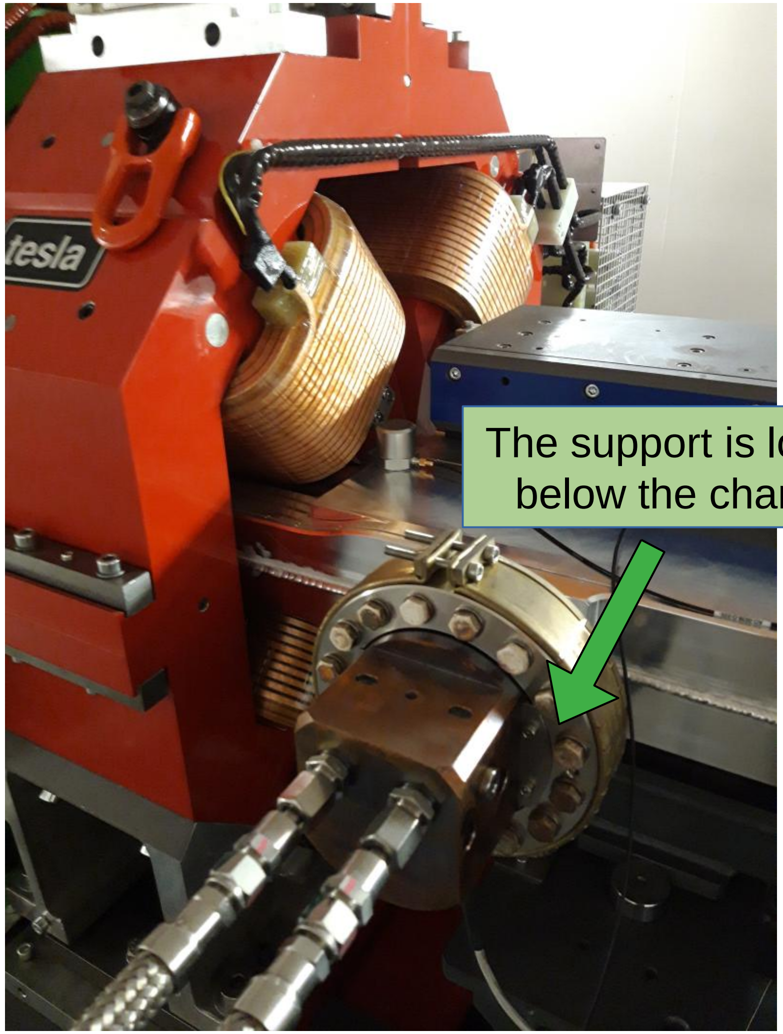
Can we improve e-beam stability by fixing vacuum chamber more rigidly? (yes)

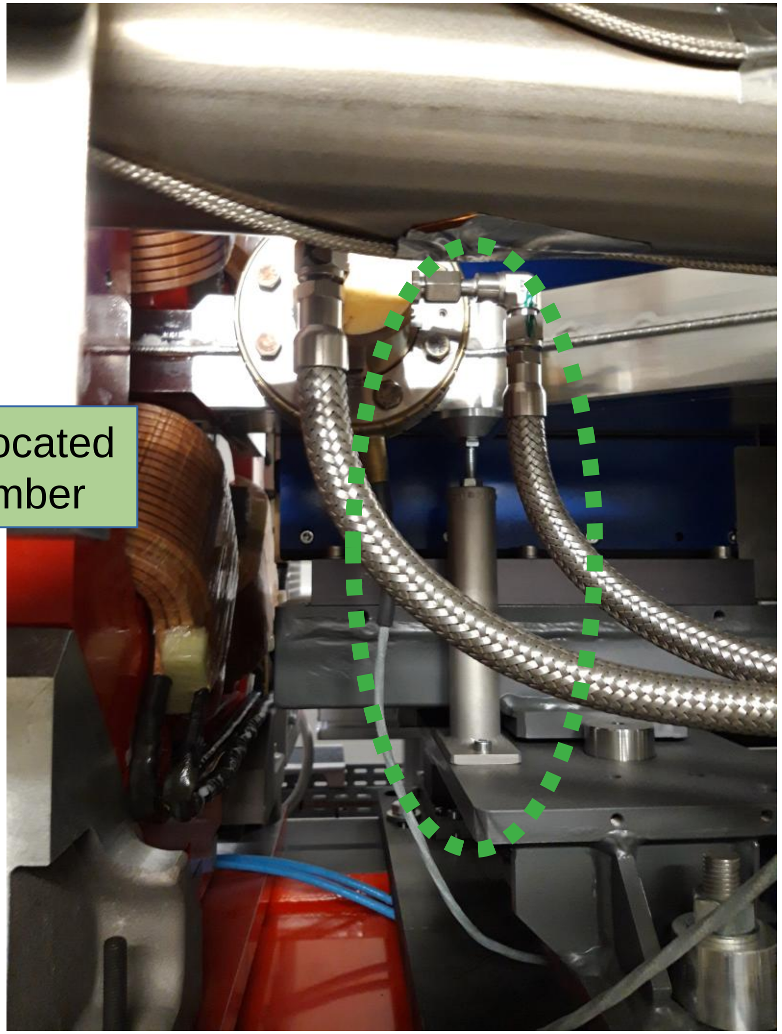
ALUMINIUM CHAMBER SUPPORTS

- There are a few supports for the aluminum chambers of the storage ring

- We are interested to see the effect of the support located almost below absorbers, next to a quadropules

- There are 3 of such supports in each cell, or 96 supports in the SR





MDT DURING THE RESTART

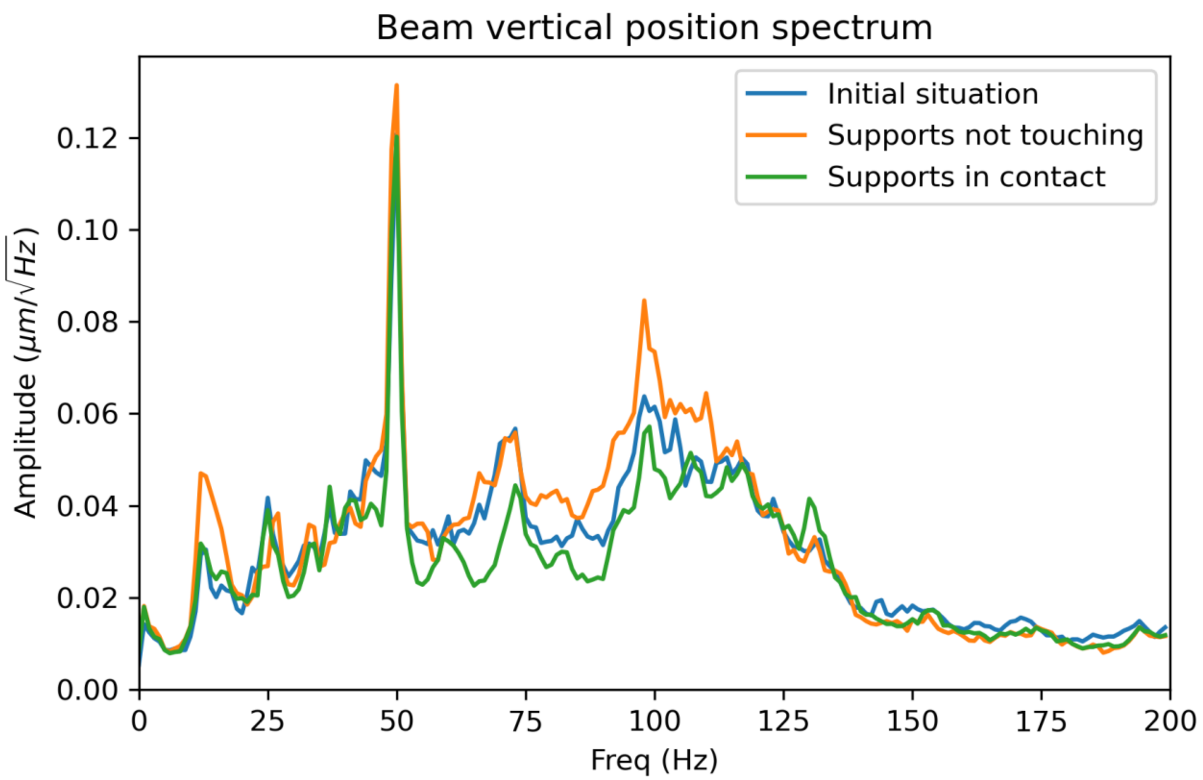
During the shutdown N. Benoist modified the position (height) of the 3 x 32 supports mentioned before.

We then measured the stability of the beam without the Fast Orbit Feedback.

We can compare 3 different situations:

- Original positions of the supports (it was a bit **random**, some supports in contact with the chamber, other not touching it)
- All the 96 supports **not touching** the chambers
- All the 96 supports **in contact** with the chambers

RESULTS



Average spectrum of all BPMs #1 and #10

Dates:
1/ 2024-01-11 21:56:07
2/ 2024-03-15 15:46:00
3/ 2024-03-22 18:00:00

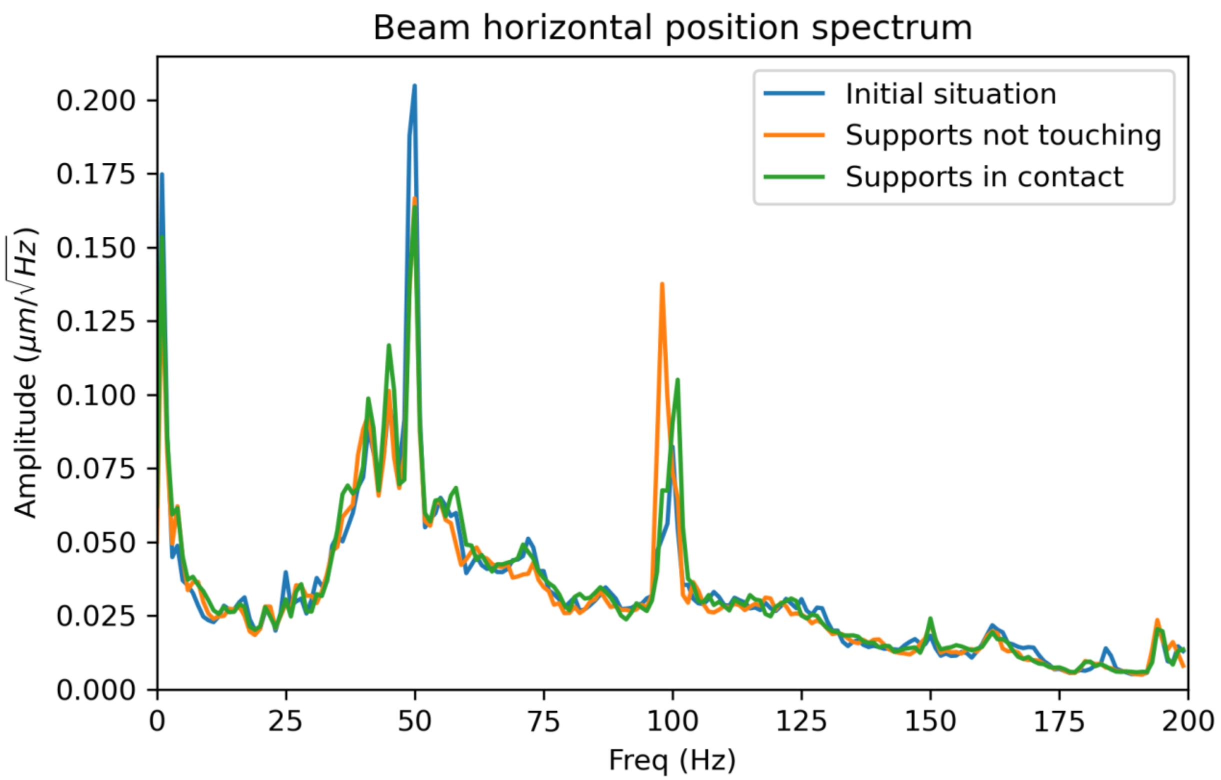
Vertical beam stability:

1/ Initial situation
(191 mA, 3*1/3 multibunch)
0.480 µm rms

2/ Supports not touching
(intermediate restart,
117 mA, 3*1/3 multibunch)
0.531 µm rms

3/ Supports in contact
(197 mA, 3*1/3 multibunch)
0.436 µm rms

RESULTS



Average spectrum of all BPMs #1 and #10

Dates:
1/ 2024-01-11 21:56:07
2/ 2024-03-15 15:46:00
3/ 2024-03-22 18:00:00

<u>Horizontal beam stability:</u>

Not very different

The small differences (< 2 %) are maybe not even related with supports' position

CONCLUSIONS

- The supports have an effect on beam stability.
- The beam is more stable when the supports are in contact with the vacuum chambers.
- We could improve vertical beam (raw) stability by 9% using the already existing supports.
- Could we improve beam stability even more with a more efficient, dedicated, solution?

Vacuum chamber mechanical vibrations can affect beam stability due to eddy currents

This has been explained and demonstrated at Spring-8:

Orbit Fluctuation of Electron Beam due to Vibration of Vacuum Chamber in Quadrupole Magnets

Sakuo MATSUI*, Masaya OISHI, Hitoshi TANAKA, Tetsuhiko YORITA, Koji TSUMAKI, Noritaka KUMAGAI and Toshiharu NAKAZATO

Accelerator Division, Japan Synchrotron Radiation Research Institute, Kouto, Mikazuki, Sayo, Hyogo 679-5198, Japan

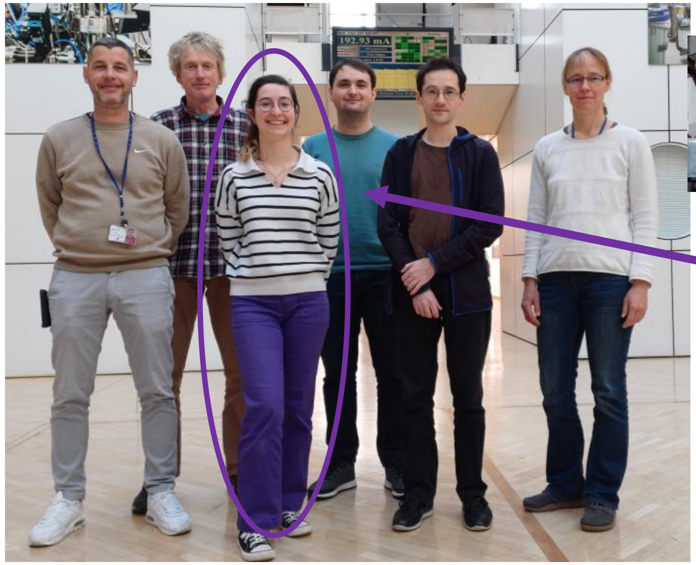
(Received December 17, 2002; accepted for publication January 29, 2003)

Which fraction of the beam's vibrations are due to vacuum chambers' vibration?

To answer this question, we can try to estimate the contribution from quadrupoles, and suppose the "missing" part is due to vacuum chambers

Part III: estimation of quadrupole’s vibrations contribution to beam’s position fluctuations

Diagnostics group (jan. 2025)



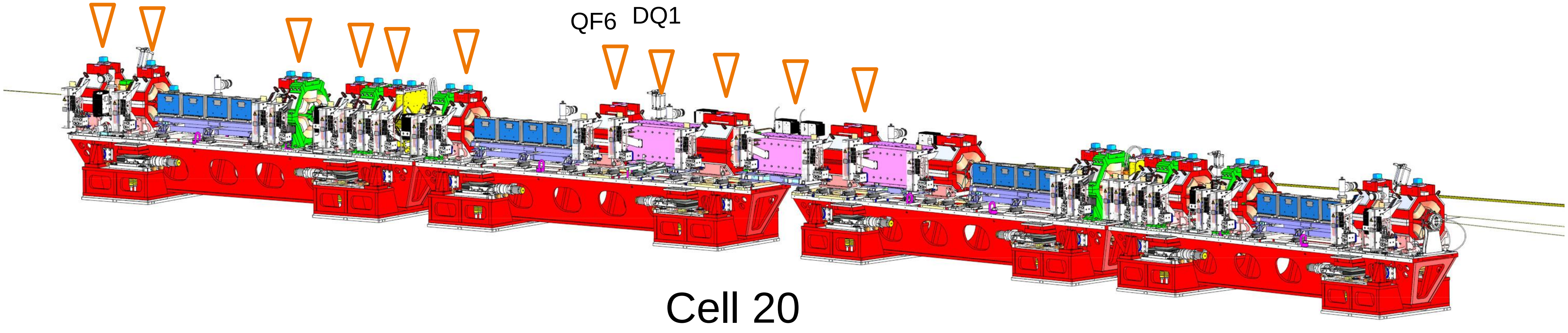
This was the internship of Laure Rivier

Quadrupoles vibrations (only vertical) has been measured in one cell (no beam)

Different tests were performed:

- **All cooling circuits ON**
- **Only magnet cooling circuit ON, absorber OFF**
- **All cooling circuits OFF**

quadrupoles and dipole-quadrupoles measured indicated with an arrow
→ only half of an unique cell measured

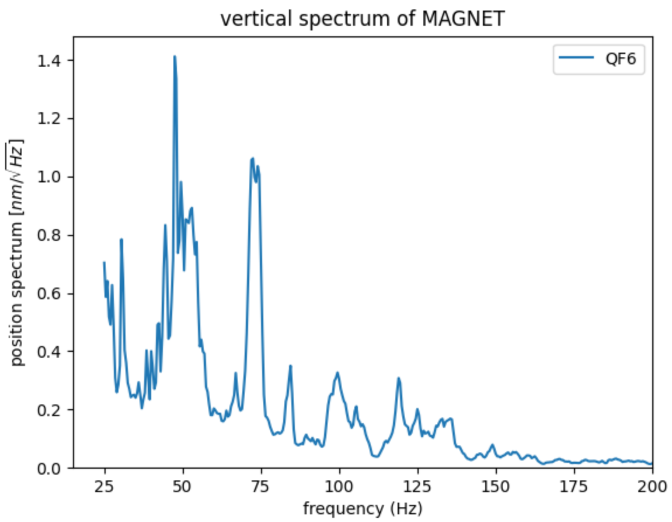


We can compute the effect of magnet vibrations on the beam.

Hypothesis:

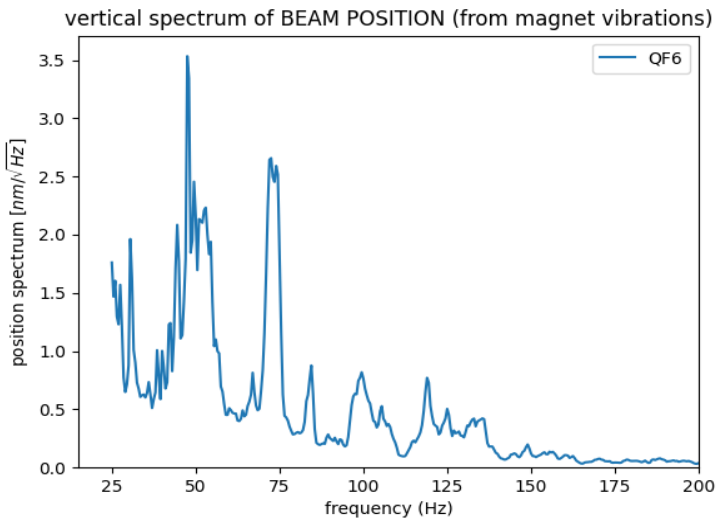
- **adiabatic regime, i.e.: only closed orbit considered, transient effects are neglected**
- **The quadrupolar field moves exactly just like the magnet moves**

The vibration spectrum of a magnet can be translated into beam position spectrum at a specific location of the ring. Example with QF6:



x Cij
i: magnet
j: ring location

here Cij = 2.5
(average value for magnet and BPM computed in AT)



JANUARY 2025 MAGNET VIBRATIONS MEASUREMENTS

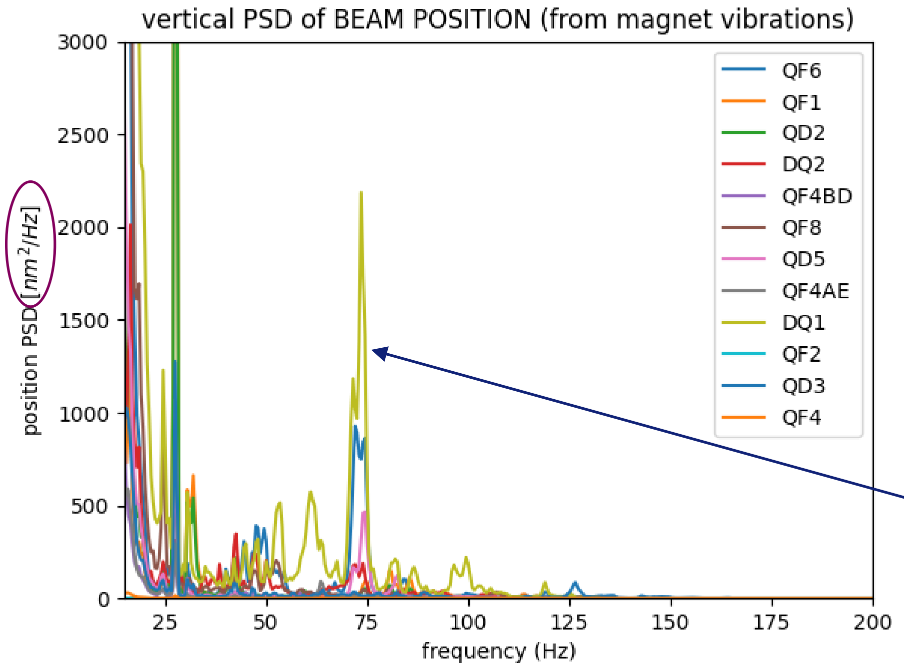
We compute the effect of groups of Q and DQ magnets on the beam by summing the contribution of multiple magnets on beam position fluctuations.

Hypothesis:

- **Every magnet in every cell acts exactly like their homologue in cell 20 (+ cell symmetry)**
- **There are no correlations between magnets' vibrations**

/!\ PSD is shown here
i.e.: amplitude is squared

It is necessary to use PSD to sum up magnets' contributions



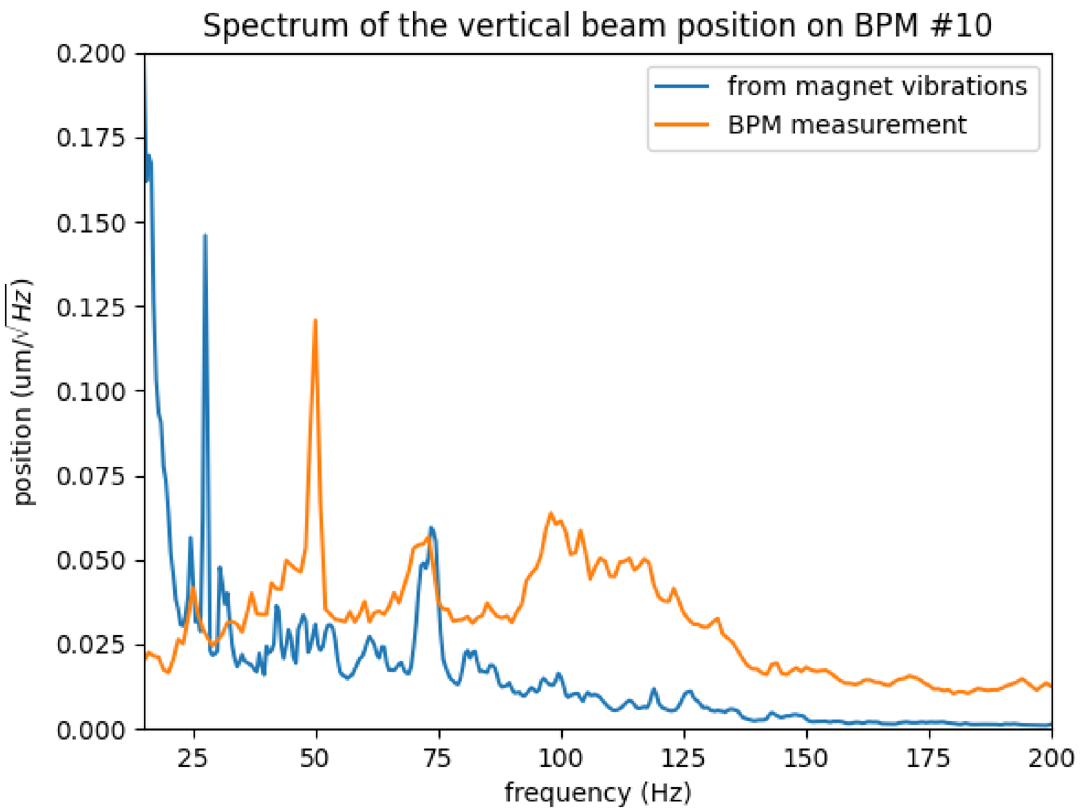
The effect of all magnets' vibrations on the beam is the sum of all these PSD

This measurement is a bit suspicious, it should be performed again

JANUARY 2025 MAGNET VIBRATIONS MEASUREMENTS

We compare:

- **the contribution to beam vibration from all magnets (from accelerometer)**
- **Real beam position spectrum (from BPMs)**

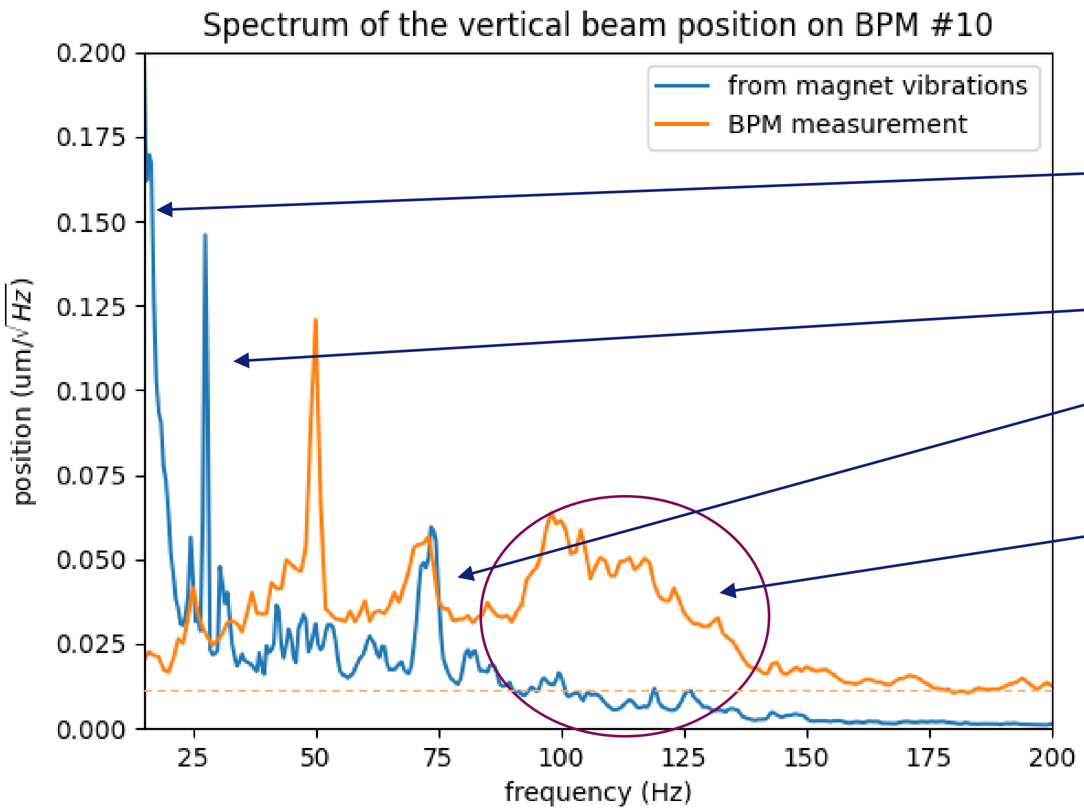


Very encouraging result!

- The order of magnitude of the estimation is correct

- Some features are common on both curves (75 Hz)

Interpretation



- Low frequency dominated by accelerometer's measurement noise

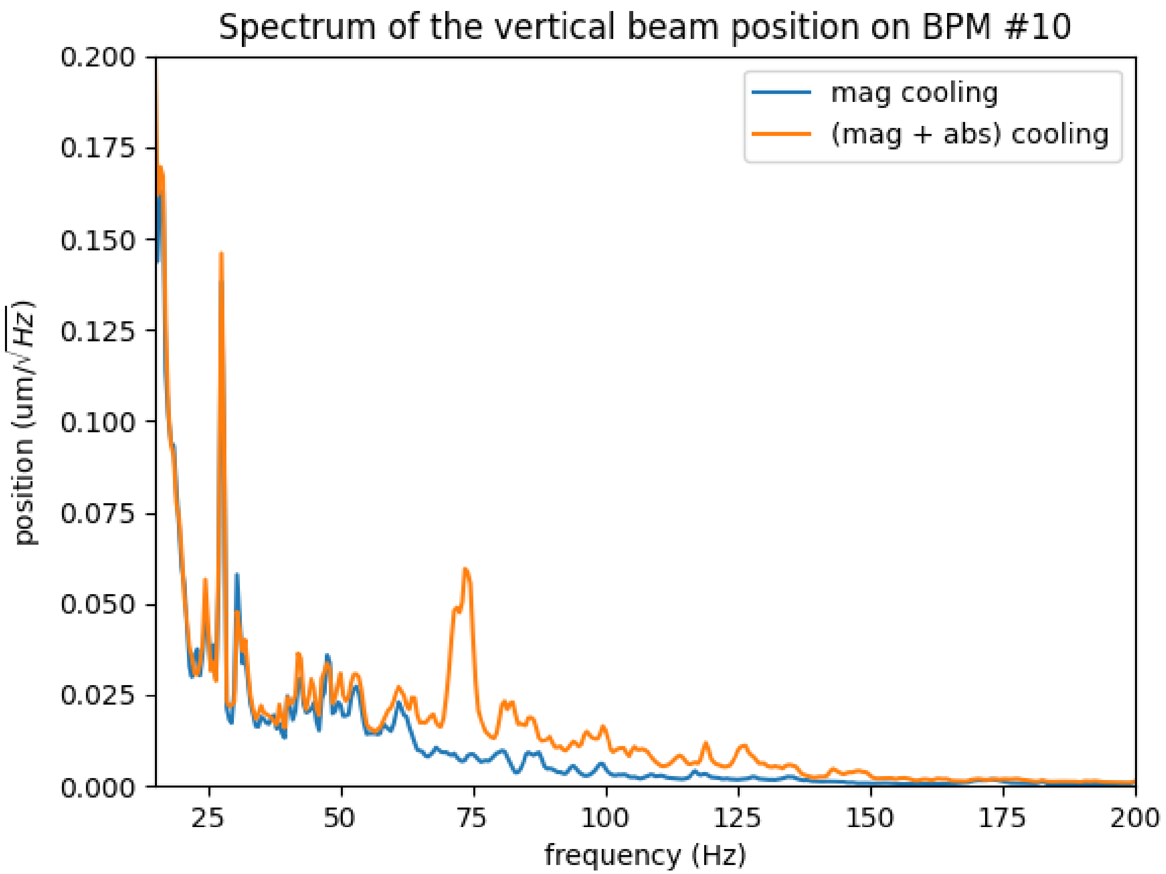
- There are measurement artefacts (accelerometer)

- Some features are common on both curves

- Contribution above 75 Hz not well explained, could it come from vacuum chamber vibrations?

Noise floor of the BPM measurement is roughly here

Comparison with an without absorber cooling (measurement performed 2 different days)



Part IV: plans for an “open source” bunch-by-bunch feedback front-end

There are already many “open source” projects for our key instruments:

- **BPM electronics (LNLS)**

LNLS Advanced Controls Group

Advacend Controls Group (GCA) at the Brazilian Synchrotron Light Laboratory - LNLS

18 followers   Campinas - SP - Brazil   https://github.com/lnls-dig

- **Fast Orbit Feedback (DLS, SOLEIL)**

DG   https://gitlab.synchrotron-soleil.fr/dg

Le groupe diagnostics est chargé de fournir tous les systèmes nécessaires à la caractérisation des faisceaux depuis la production des électrons par le LINAC jusqu'à la fourniture des photons aux lignes de lumière.

- **Bunch-by-bunch feedback (DLS)**

Diamond Light Source Multi-Bunch Feedback Processor (MBF)   https://github.com/DiamondLightSource/DLS-MBF

This repository contains the firmware and software sources for running bunch by bunch feedback on a synchrotron. The firmware and software was developed at Diamond Light Source and is designed to run on specific hardware documented below.

Full documentation for using the system can be found at the MBF Documentation pages. See the Bringing up MBF page for instructions on setting up MBF for first operation.

What is missing today?

To my knowledge, there is only a commercial solution for a bunch-by-bunch feedback front-end electronics. Dimtel electronics:

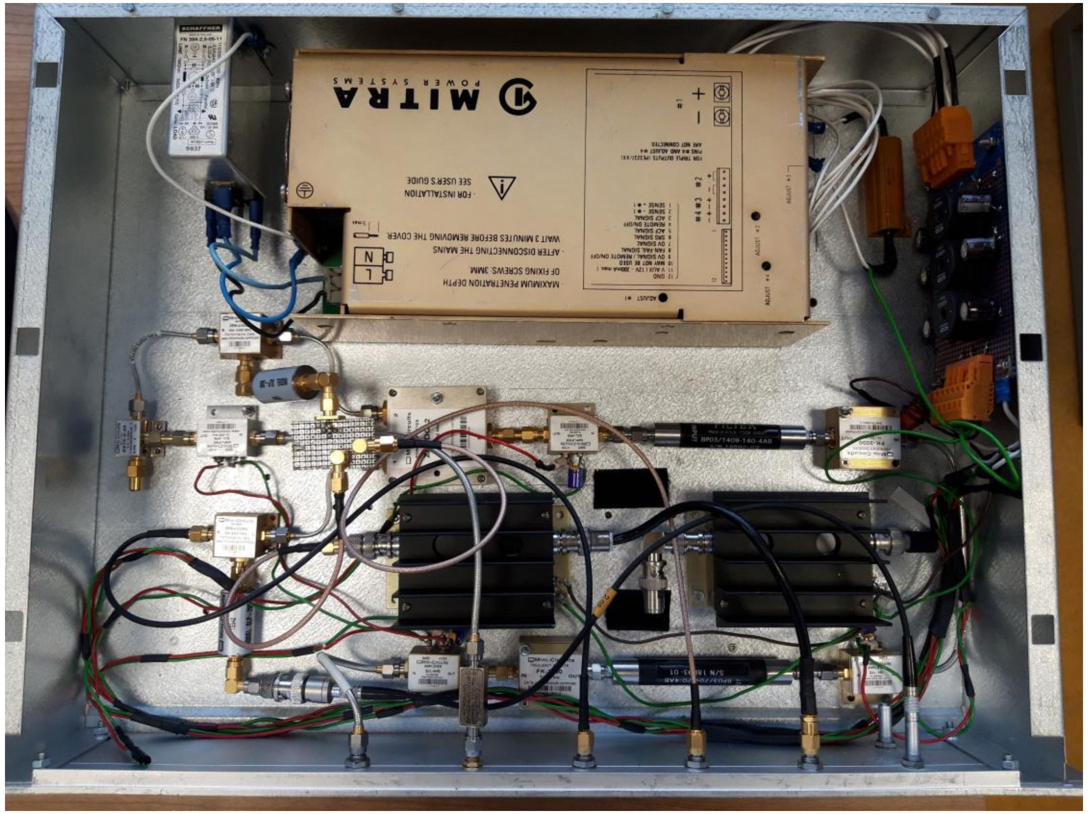
Bunch-by-bunch Front/Back End

The series of FBE-LT RF signal processors incorporates front-end and back-end electronics for bunch-by-bunch feedback in three planes. The units are designated FBE-NNNLT where NNN specifies the RF frequency. Three front-end channels are designed for converting BPM signals from a hybrid network to baseband signals which can be directly digitized by the iGp/iGp12. Front-end channels are designed for detection frequencies around 1.5 GHz (dependent on the RF frequency) and use comb filters to lengthen beam signals and reduce front-end sensitivity to sampling clock drifts and jitter. The back-end channel upconverts the baseband longitudinal kick signal to the kicker frequency for driving the power amplifier and the kicker. The FBE-LT interfaces to the iGp/iGp12 digital I/O port for control of front- and back-end attenuators and phase shifters. The same interface is also used to read out unique FBE-LT ID, monitor its internal temperature, and control the cooling fan speed.

Consult the price list for FBE-LT pricing. Contact Dimtel, Inc. for customization options, and delivery schedules.

FBE	Single-channel RF front-end *only*	$30,000.00	(+ tariff ?)

ESRF BbB Front-End:



Made > 15 years ago by E. Plouviez

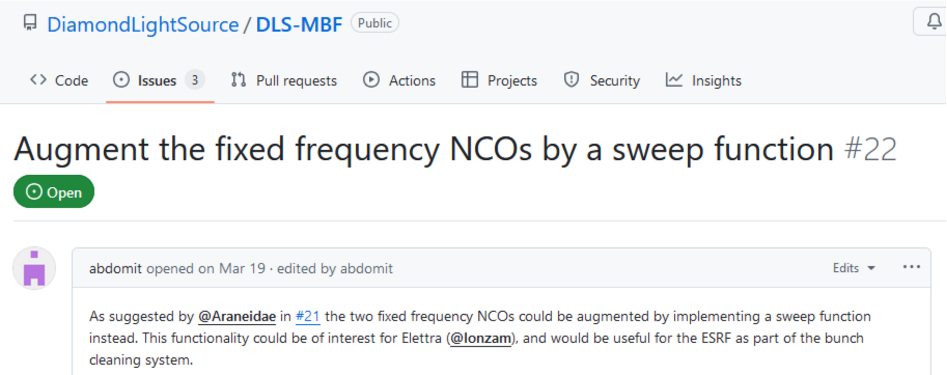
Working very well!

But there is no monitoring and no tuning knobs: it has to be adjusted with attenuators and cables for the fine delays

Definitely not worth 30,000.00 $

Plans for the years to come:

- **Continue to improve the DLS-MBF:**



Could also benefit to Elettra!
(M. Lonza express his interest in this new feature)

- **Make a new Front-End ("open source" if possible):**
- Integrate the components on a PCB as much as possible
- Add monitoring (signals level, phase)
- 2 possible gains + fast switching (for hybrid filling mode)
- …

Don't hesitate to contact me if you have ideas for this (hopefully) future instrument

benoit.roche@esrf.fr

Questions?

What is the purpose of the SOLEIL-FOFB?

According to this website: it is to control solar power plant….

https://etabli.incubateur.net/initiative/bf6807de-2e74-4076-9b2d-279ba9cb9e1c

meta-soleil-fofb

Ce projet est un layer Yocto pour SOLEIL FOFB, destiné à être utilisé avec les layers petainux et DAMC-FMC2ZUP. Il permet de gérer et surveiller des centrales solaires, contrôler l'état des onduleurs et gérer l'énergie produite.

DÉPÔT DE CODE { }

https://gitlab.synchrotron-soleil.fr/dg/fofb/meta-soleil-fofb

CAS D'UTILISATION MÉTIERS

Gestion de l'énergie produite | Contrôle de l'état des onduleurs | Surveillance de centrales solaires

Fiche mise à jour le jeudi 21 mars 2024 à 14:51:19