FAST ORBIT CORRECTION

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Diagnostic group

issue:

- Apply corrections to damp rapidly changing orbit distortions
- orbit distortion cause: mechanical vibrations of the magnets assembly and ripple on the power supplies.

Figure of merit:

- Residual versus initial orbit distortion

(with a different weight for specific ring location of range of the spectrum?)

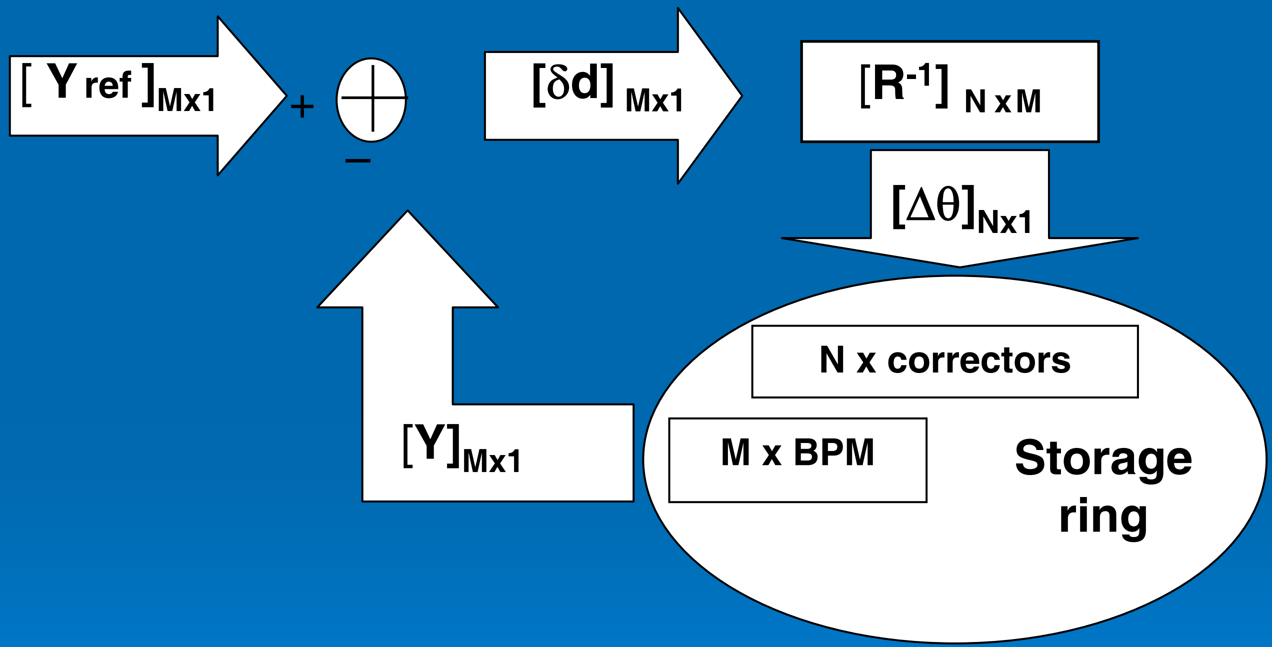
Static correction

- With perfect BPMs, the efficiency of the correction is function of the number and location of the BPMs and correctors number and location and of the correction algorithm
- => residual distortion in the 10^{-2} range typically

Some practical values (ESRF):
Qh=36.44 Qv=14.39
SVD correction algorithm
224 BPMs/96 correctors =>1% residual distortion

32 BPMs/32correctors=>
H static residual distortion: 20% (rms)
V static residual distortion: 15% (rms)

Global closed orbit correction principle



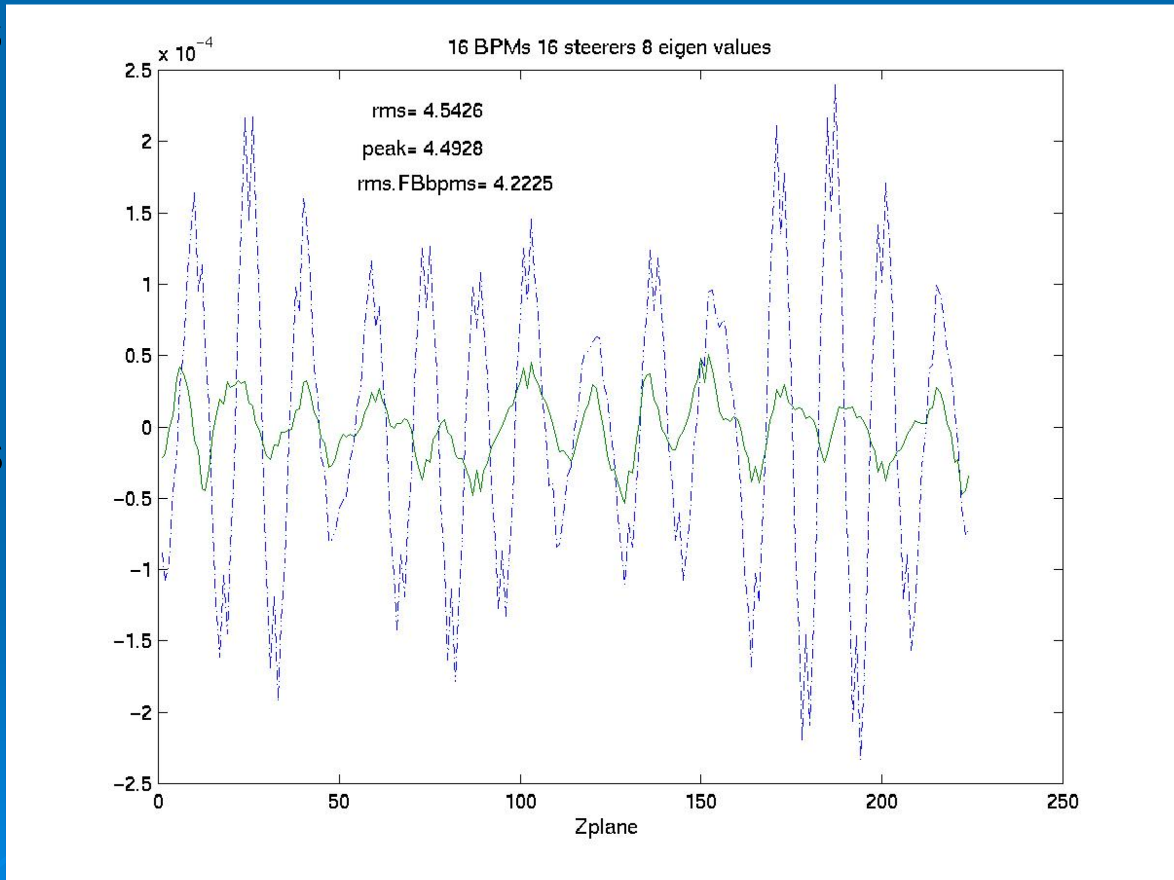
Corrected orbit = ($[Y]_{Mx1}$- $[\ Y\ ref\ ]_{Mx1)}$)-R $_{M\ xN}$ x $[\Delta\theta]_{Nx1}$

efficiency

- a limited number of monitors and correctors can correct all the machine =>

  global scheme

- According to simulations 16 monitors and correctors are enough in the vertical plane (Q=14.39)



Dynamic correction issue

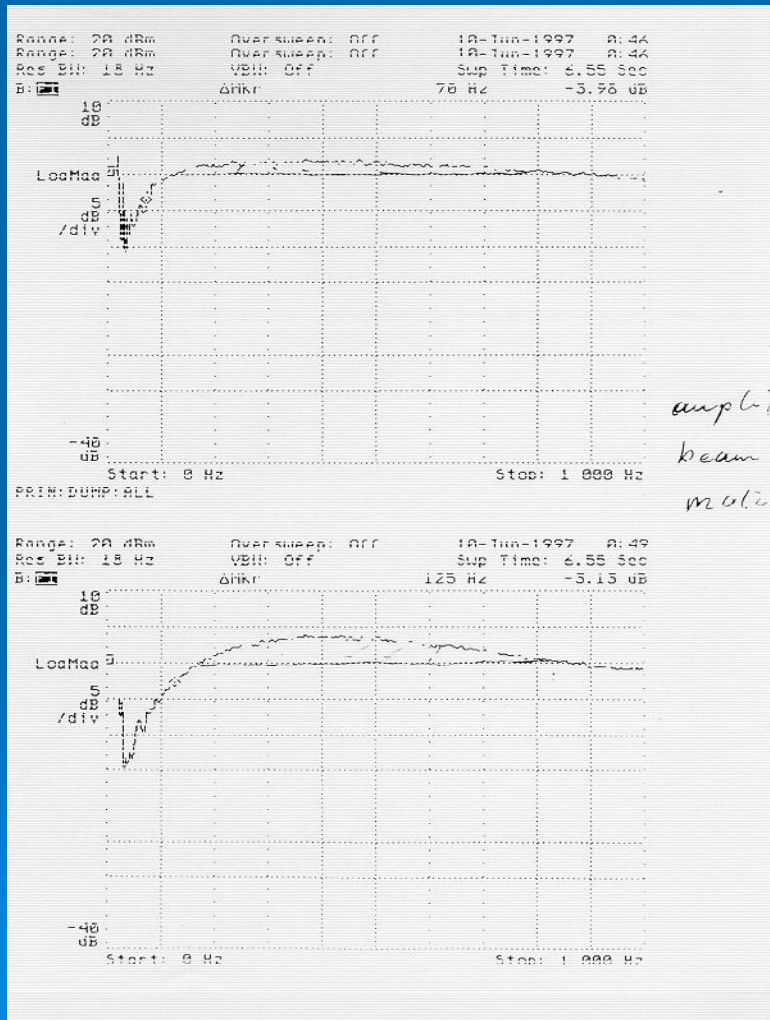
- The accuracy of fast beam position measurement is limited by the noise spectral density of the BPM electronics
- The bandwidth of the correction bandwidth will be limited in order:

1. to keep the loop stable .
2. to avoid amplifying the signal due to the orbit distortion or the BPM noise in the vicinity of the cutoff frequency

due to the time delay between the distortion measurement and the correction application.

LIMITING FACTORS: DELAY, NOISE

- τ = .6ms
- fc=100Hz
- fc=150Hz



vert:5dB/div

Hor: 100Hz/div

Dynamic correction issue

Limiting factors:

- DSP computation time
- Choice of the filtering algorithm
- rise time τ_r of the magnetic fields through the vacuum chamber

Practical values:

- computation time: not any longer an issue
- Filter delay: function of the requested BW and selectivity
- field rise time: τ_r = .2ms through 2mm of stainless steel (will forever be an issue!)

Dynamic correction issue

Achievable residual distortion:

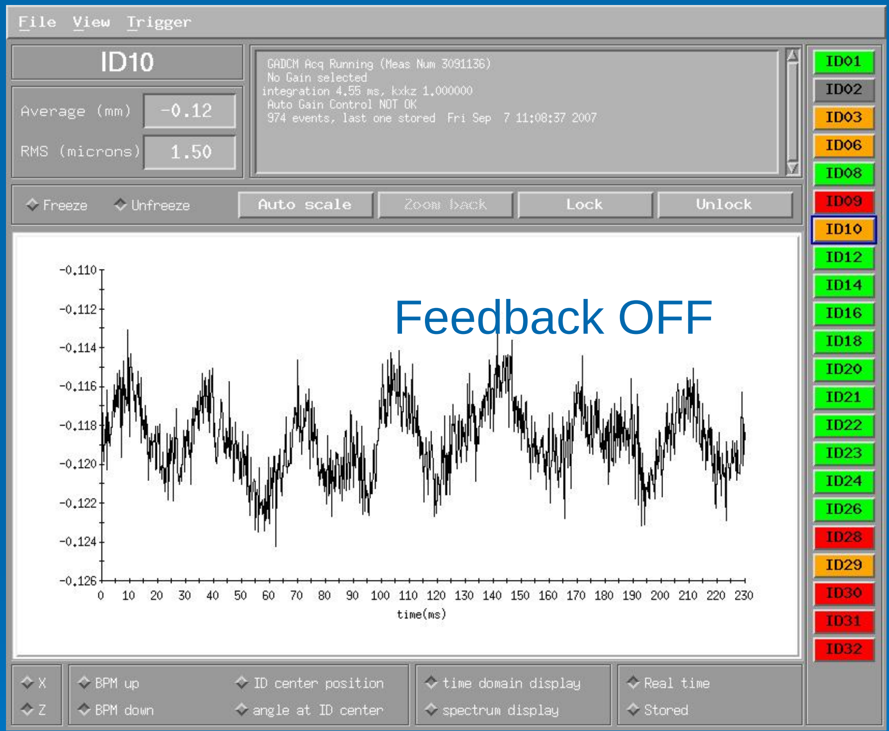
Given the spectrum of typical orbit distortion sources (ambient noise filtered by the girders or core magnets eigen frequencies):

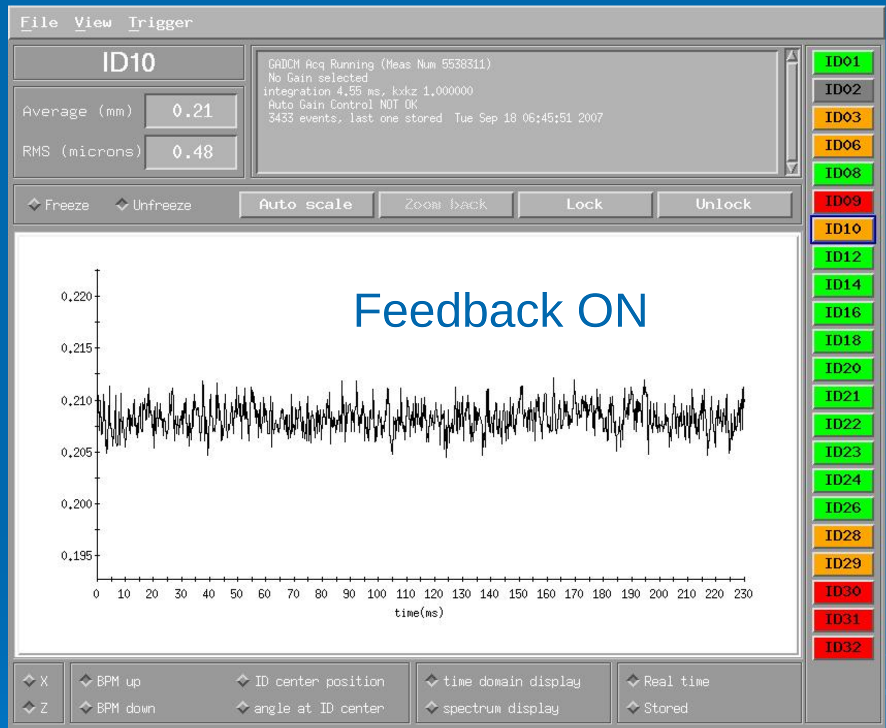
In the $3\ 10^{-2}$ range for a feedback bandwidth in the 100Hz BW range and a reasonably good BPM resolution versus the amplitude of the beam movement.

The exact figure are different for each ring but the conclusion is the same:

Latency and noise spectral density are much more important issues than the number of BPM or correctors when the goal is the fast orbit correction (ie above 1Hz)

Feedback effect (vertical)





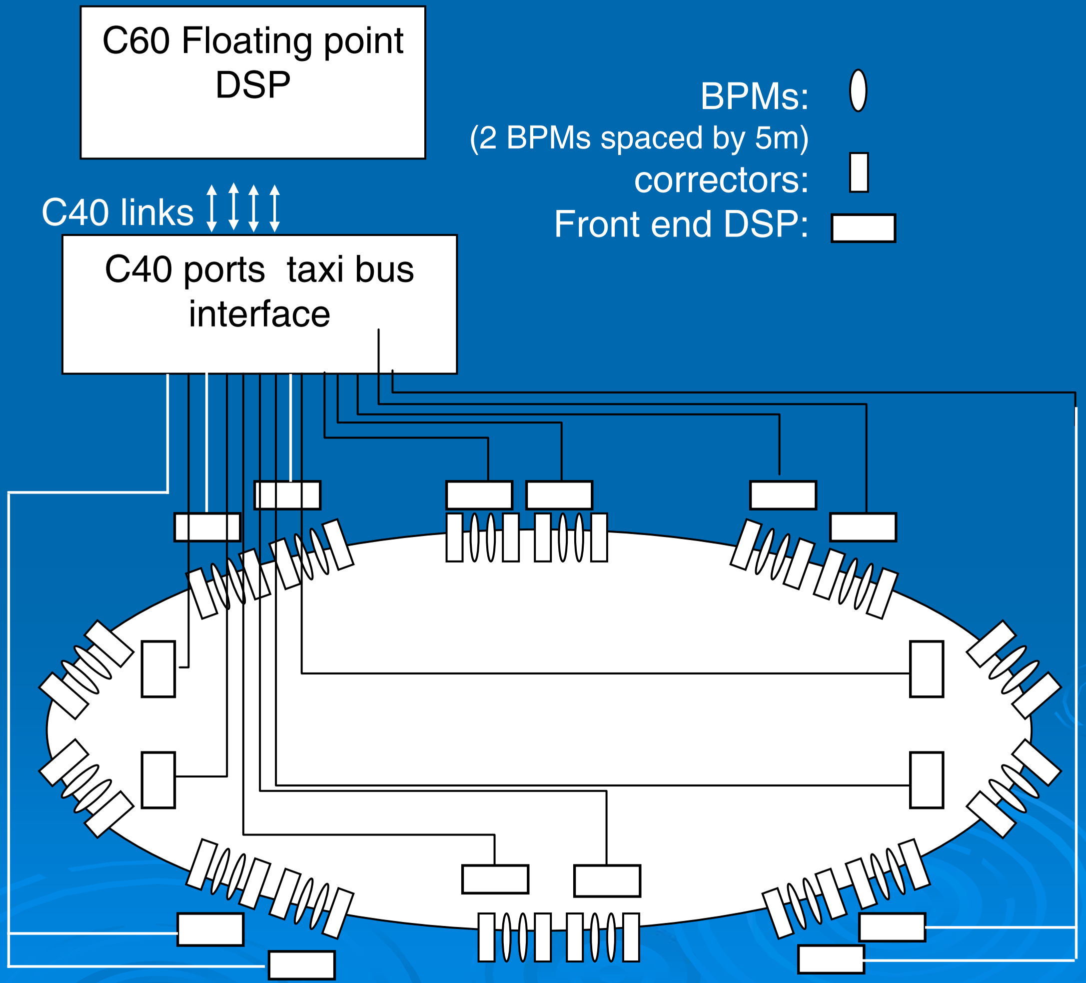
BPM in the loop, β =4m, rms measured in 200 Hz BW

ESRF Global feedback

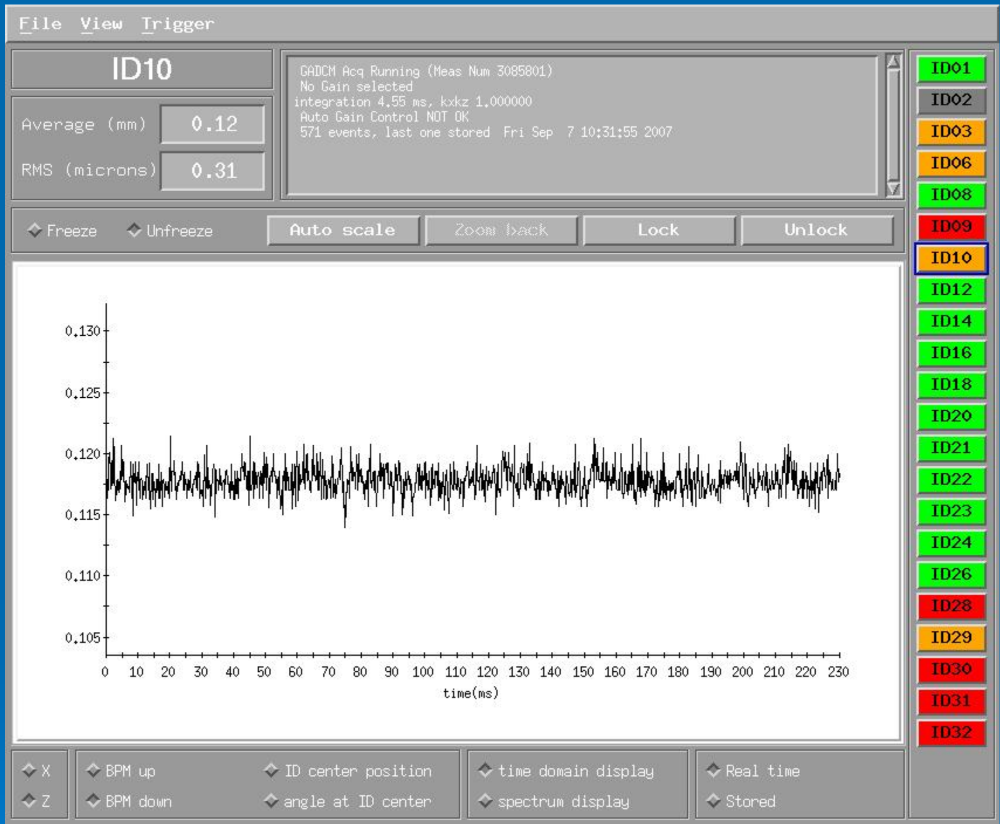
32BPMs

24 correctors

vertical and horizontal correction



BPM noise



BPM resolution:.3µm noise measured in a 200Hz BW (or 20pm/Hz1/2)
$\Rightarrow$ the amplitude of the beam movement with feedback shown on the previous slide is probably close to .3µm if we remove the BPM noise contribution

- Signal measured on a test signal generated by the beam

How much better would it be using Libera?

- We need to increase the gain without increasing the noise in the feedback bandwidth and overshoot span
- We need to reduce at the same time the noise and the feedback latency

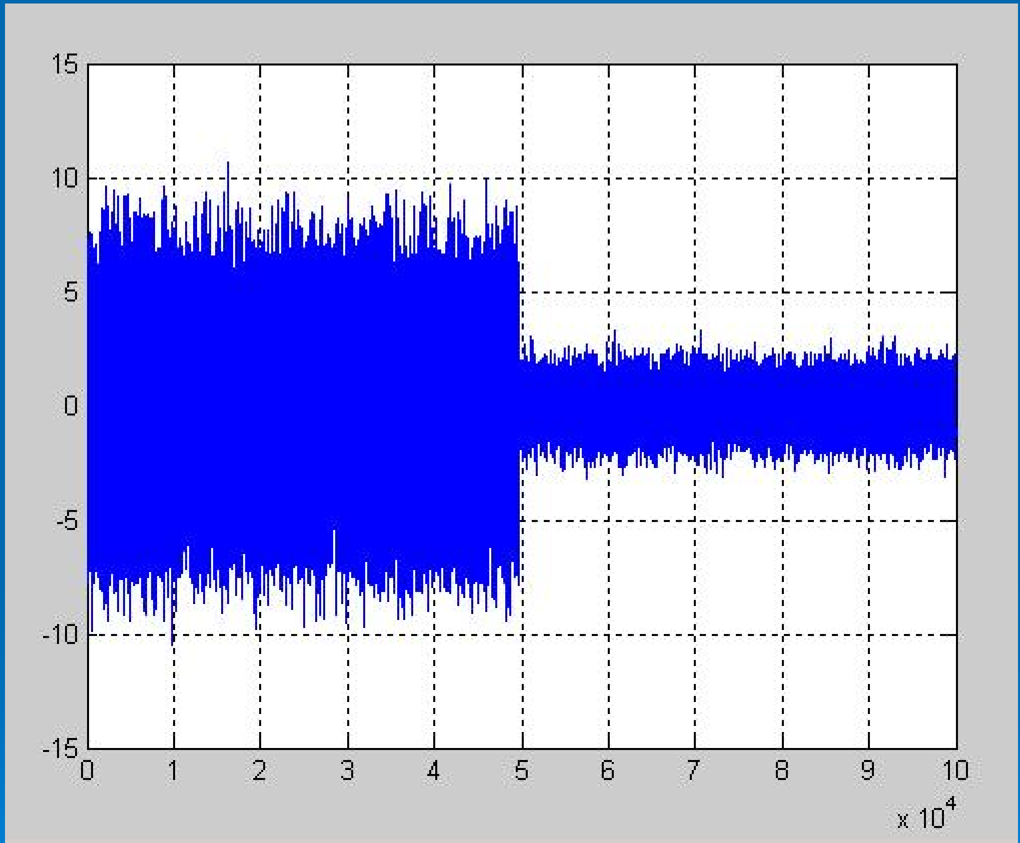
Libera advantage

- Resolution:10nm/Hz$^{1/2}$ (K=20mm)
- BPM number: 224

$\Rightarrow$ equivalent to 3nm/Hz$^{1/2}$ with 32 BPM

- Can we then have a much larger gain?

Present system

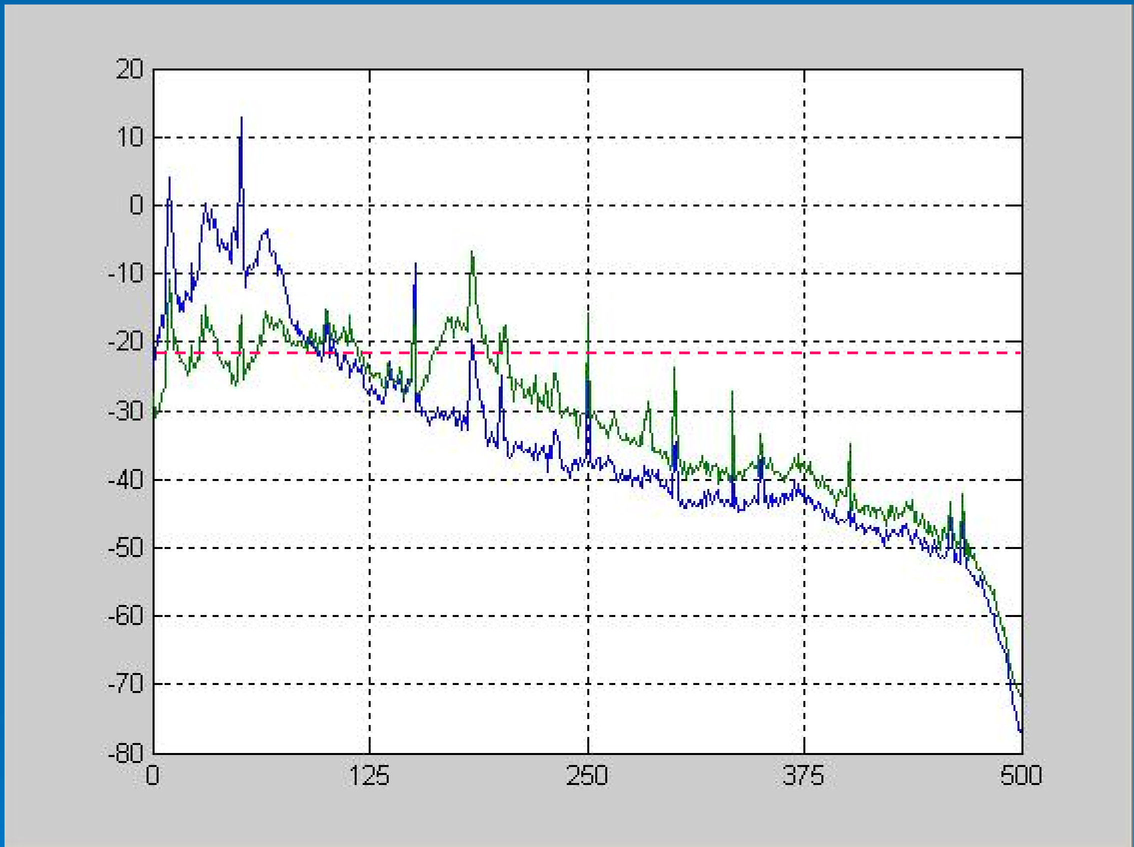


dipole "in air "XBPM
β= 36m
resolution: 3nm/Hz$^{1/2}$
signal from a BPM out of the loop

Scale:
Vertical:1μm/div
Horizontal: 1ms/div

- Feedback nearly as efficient as at the location of BPM in the loop…

Spectrum



Blue : feedback OFF
Green: feedback ON
Cut off: 120 Hz

Scale:
Vertical:dBμm/Hz$^{1/2}$
Horizontal:1Hz/div

Feedback BPM resolution: - - - - - - - -

- Amplification of beam signal above 100Hz…

Latency issue:

- With the standard 10KHz Libera output:

.4ms latency (for the full loop)

=> No dramatic improvement

- With a feedback dedicated 10KHz output:

.3ms latency (for the full loop):

=> The upgrade makes sense

Drawback of a low latency 10KHz filter

Aliasing:

- All the processing must be synchronized with the revolution frequency
- Even so, we will have DC dependency with the filling pattern

(but we will make up for it using the standard slow Libera output)

Conclusion:

Let us discuss it…