The ground motion feed-forward system at ATF2

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LCWS 2017 in Strasbourg, 23rd – 27th Oct. 2017

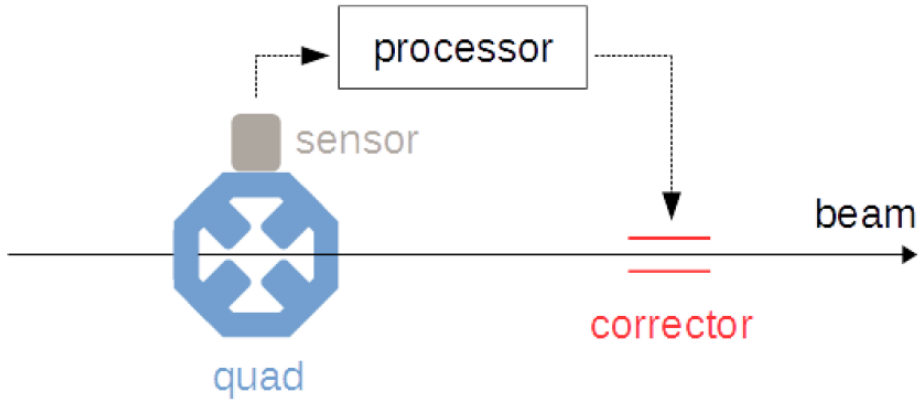
Introduction

Displaced quadrupole stears the electron beam

- Orbit distortion due to quadrupole motion
- Linear collider: potential luminosity reduction

Compensation with quadrupole motion feed-forward system:

1. Measure the (vertical) position of the quadrupole magnet
2. Calculate a correction
3. Apply the correction to the beam (as a vertical kick)



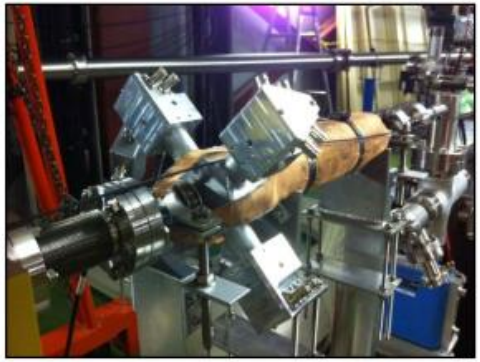
Drawing by D. BETT

GM FF Hardware at ATF, KEK, Japan.

FONT hardware

seismometers

stripline kicker



drive pulse

kicker amplifier

trigger

drive pulse

FONT5 board

velocity signal

feed-forward correction value
(dedicated digital link)

CompactRIO
(local control room)

trigger

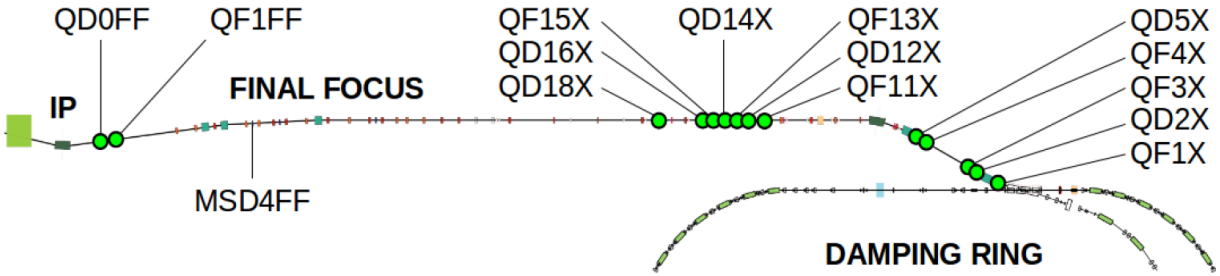
Slide by D. BETT

GM FF Hardware at ATF, KEK, Japan.

The ground motion sensors

14 Güralp 6T seismometers, installed at ATF by LAPP, Annecy, France.

Specified frequency range: 0.2 to 100 Hz.



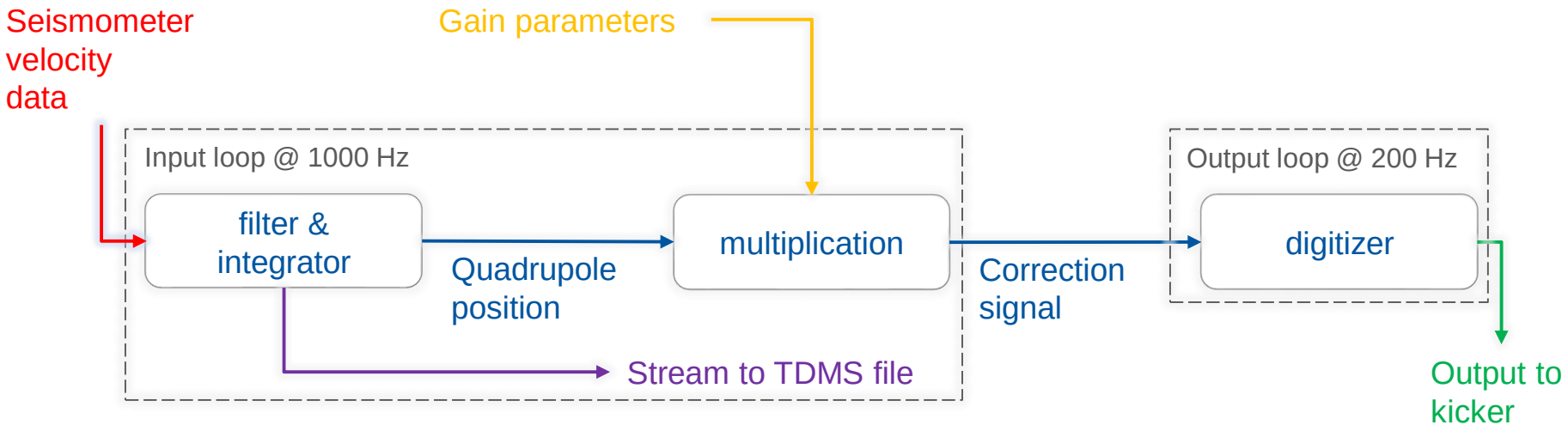
Feed-forward processor

- National Instruments CompactRIO-9064 real-time controller chassis running real-time LabVIEW
- Contains Artix-7 FPGA and following IO modules:
  9205 (analogue input), 9401 (digital I/O), 9263 (analogue output)

New laptop computer for communication with cRIO (data transfer, programming, ...)

Software

Labview real-time VI on the cRIO



Octave scripts for offline data synchronization and analysis

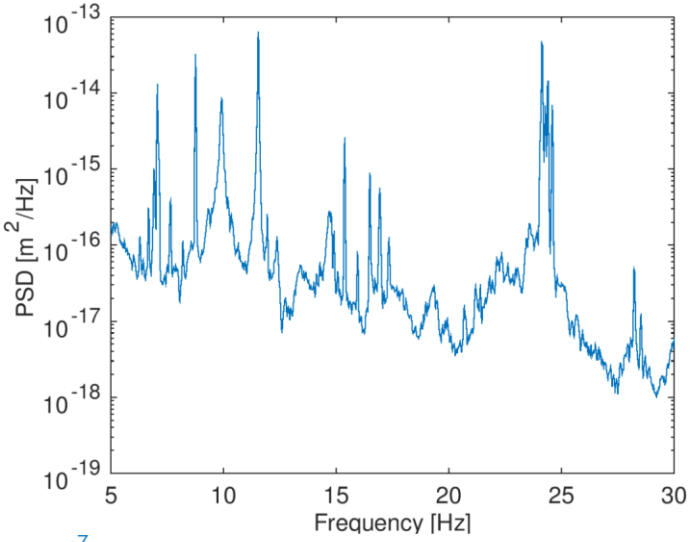
- Receive simultaneously recorded GM data and BPM data (from ATF Flight Simulator)
- Synchronize by identifying beam on / beam off in BPM and GM data
- Identify ‚missing triggers' in both datasets
- Downsample GM data to beam rep. rate, apply filters

➢ generates a synchronized dataset!!

Quadrupole motion and beam motion spectra

QD2X GM spectrum

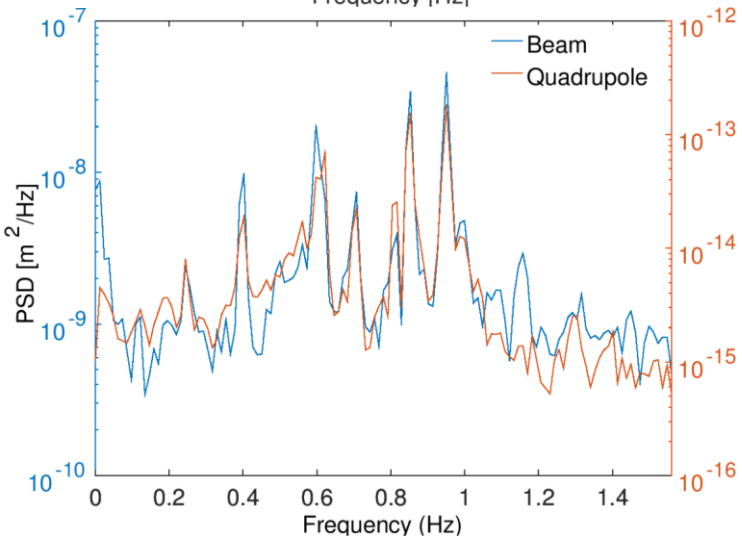
Recorded with PXI, 1024 Hz
15 min of data



QD2X GM spectrum
bandpass filtered 5...100 Hz
downsampled to 3.12 Hz

Beam motion spectrum at BPM MSD4FF

Max. correlation with this filter is ~0.71
Recorded with PXI, 1024 Hz
15 min of data



Alias frequencies from downsampling

$f_{3.12}$[Hz]	f_{1024}[Hz]
0.24	15.38
0.40	24.60
0.60	24.40
0.62	8.75
0.71	24.29
0.82	7.05
0.85	24.14
0.95	11.55

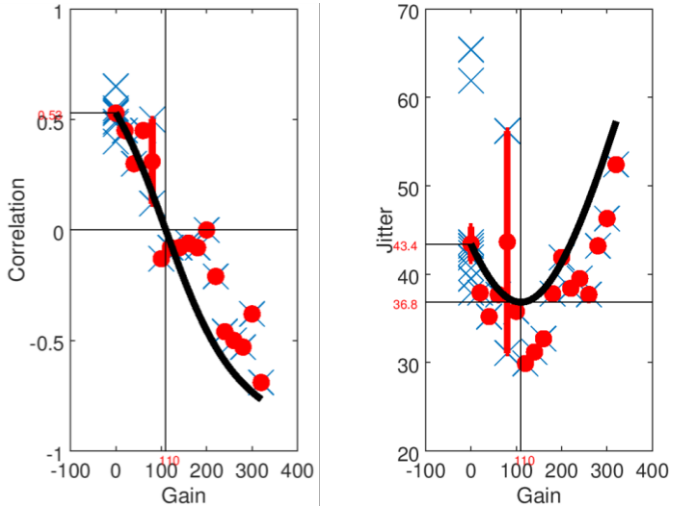
In review: D. R. Bett et. al., „Compensation of orbit distortion due to quadrupole motion using feed-forward control at KEK ATF“.

GM FF results

Effective reduction of correlation and beam position jitter

Quadrupole motion measured on QD2X
Beam position measured with MQD4BFF
Gain parameter varied for kicker 1

Results for FF with optimal gain:
total beam jitter reduced by 14%
QD2X-correlated beam jitter reduced by 80%

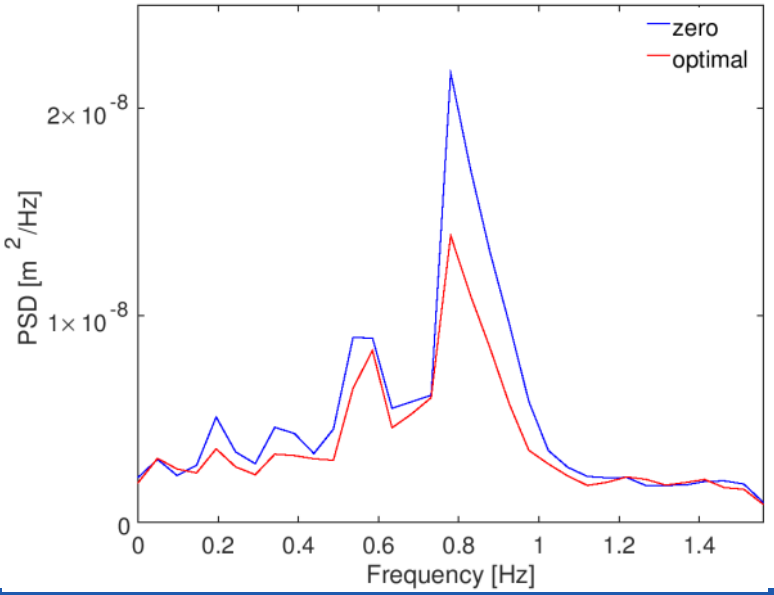


From: Preliminary report on GM studies in May/June 2017, by D. BETT

Beam position spectra comparison
FF off (zero) vs FF on (optimal)

Peaks reduced by 35... 40% at frequencies
0.78 Hz and 0.97 Hz
(aliased 11.55 Hz and 24.14 Hz)

Recorded with ATF FS, 3.12 Hz
90 sec. of data



Towards a ‚global' GM FF system

14 sensors total (13 operational, 4 might migrate to another KEK experiment)

2 kickers are available at ATF2.

The cRIO is ready with the simple implementation:

$$\boldsymbol{k_1 = s_1 * g_{11}} + s_2 * g_{21} + \cdots$$
$$k_2 = s_1 * g_{12} + s_2 * g_{22} + \cdots$$

Issues to be solved:

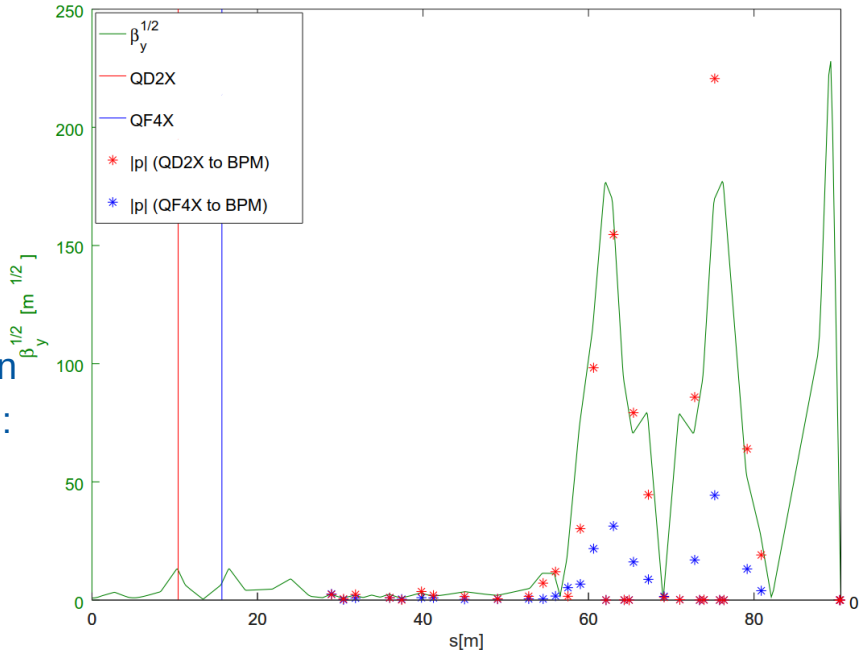
- Finding up to 2*10 gain parameters

  Gain scans take too long time in the current implementation of the system.

  Knowledge of beamline optics not used so far!

  Example: how does the fit from quadrupole motion to beam motion relate to the vertical beta function:

  - ➢ Find beam optics-GM correlations
  - ➢ Derive gain parameters!



- How to measure the advantage of global over single GM FF?

  GM is only source of ~17% beam jitter and QD2X is the dominant source

  - ➢ Remove / subtract non-GM related beam jitter?

Plan for Nov/Dec shifts

Nov (1 GM shift): Vera, Doug, Jonas

- Start the GM system (D. Bett will be there, although already with FONT group)
- Establish FF (1sensor/1kicker) and take long data sets
- Take transfer function (TF) data (magnet top to magnet stand (to floor))

Week inbetween at CERN and LAPP:

- Compute TF and implement in FF software (with help from LAPP colleagues)

Dec (2 GM shifts): Vera, Andrea, Gael, Jonas

- Identify peaks in GM spectrum with sources (magnet movers, ...)
- Continuing FF
- Record beam optics during GM shift -> for offline analysis
- Multi-sensor attempt?

Thank you!