Update on IP feedback simulation

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IN2P3-KEK Collaboration meeting on ATF2
17 november 2007

Guidelines

1. Ground Motion Study
   - Measurement at KEK (Courtesy of R. Sugahara et al.)
   - PLACET implementation of ground motion
   - Developed generator
   - Conclusion on ground motion
2. Feedback on beam position at IP
   - Impact of ground motion on the beam
   - Proportional corrector
   - Proportional Derivative Integrator corrector (PID)
3. Conclusion & Prospects

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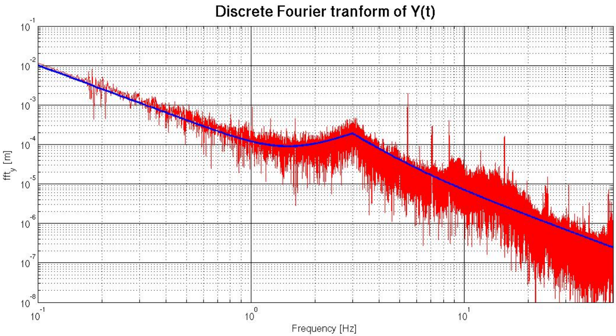
Fourier transform of measured ground motion

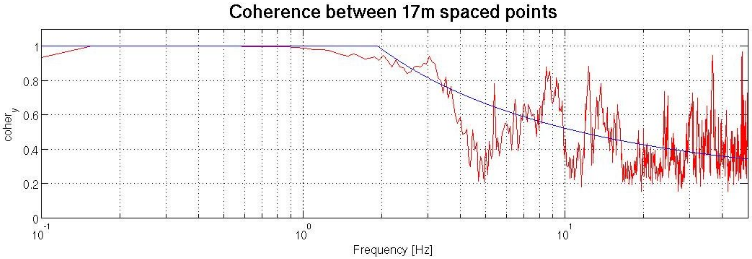


- In red: Measurements
- In blue: curve fitted on measurements

Coherence of ground motion

Definition

Coherence $C_{y_1,y_2}(\omega)$: Real function $\in [0, 1]$ which gives a measure of correlation between y_1 and y_2 at each frequency ω .



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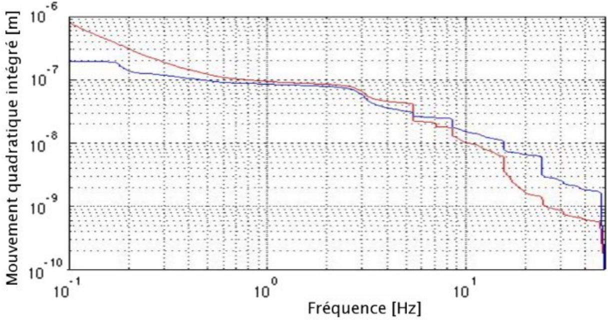
Integrated RMS displacement (IRMS)

Definition

IRMS is root square of integral of the PSD from high to ω frequency. It is equal to RMS displacement considering only frequencies above ω.



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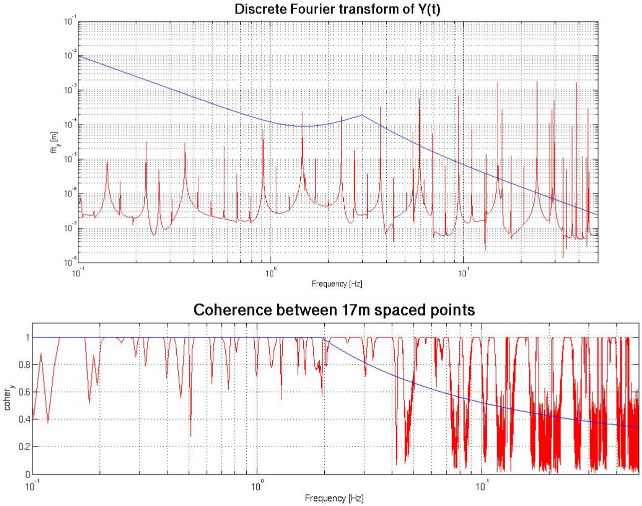
Description of the problem

Simulation was made with a program used by PLACET to generate ground motion implementing model B.

- FFT calculated from simulated data appears to be discrete and is not consistent with what we expect.
- Coherence computed from simulated data is not equal to 1 at low frequencies and does not vanish at high frequencies as expected.

It can be due to the input 2D spectra file which has not enough points over a too wide range. Further investigations is planned, but I need the software which has generated this data or even just data.

Simulated data analysis (Model B in Placet)



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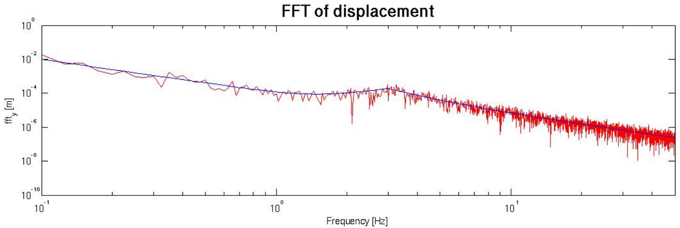
Simulated data analysis (Developed generator)

Really great accordance with the curve fitted on results.



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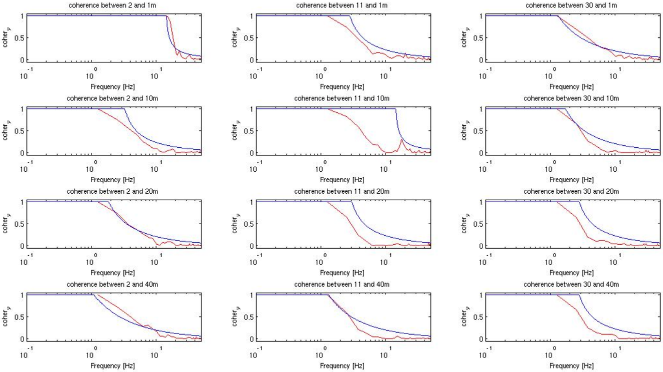
Simulated data analysis (Developed generator)



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Conclusion on ground motion

1. Frequency behavior seen in KEK-ATF measurement well reproduced by simple method.
2. Method to introduce spatial coherence not rigorous theoretically $\Rightarrow$ after tuning, underestimates the coherence for nearby points far away from IP, but seems OK elsewhere. Is not satisfactory but can be used for now to produce reasonably realistic and conservative results.
3. Will investigate more suitable techniques (2D FFT, ...)
4. Will try to understand observed comportment of the ground motion generator in PLACET.

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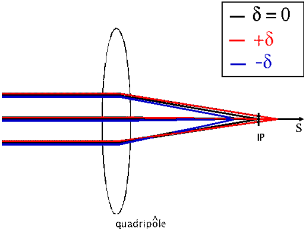
Impact of a y_0 magnet displacement

- for a quadrupole with g strength:
  - dipolar term : $B_x = g \cdot y_0$



- for a sextupole with m strength ($m \approx \frac{g}{r_0}$) :
  - quadrupolar term : $B_x = m \cdot y_0 y'$
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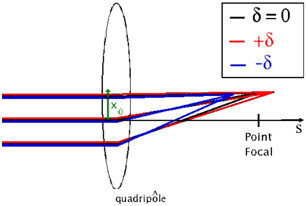

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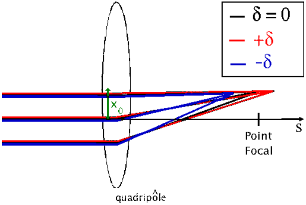

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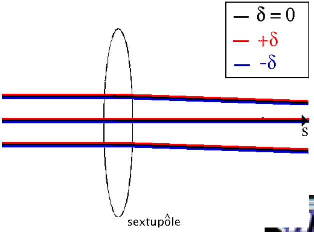

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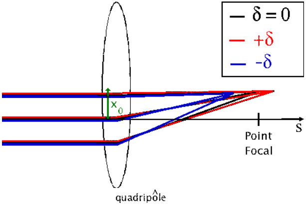

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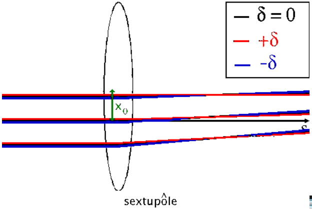

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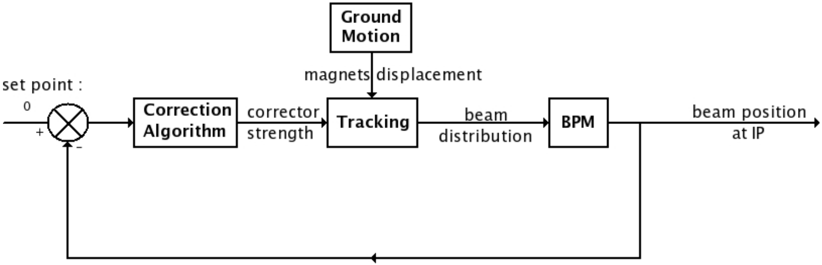
What is a proportional corrector ?

Schema of principle of the feedback :



$$C(p) = \frac{S(p)}{E(p)} = k_p$$

What k_p should be chosen ?

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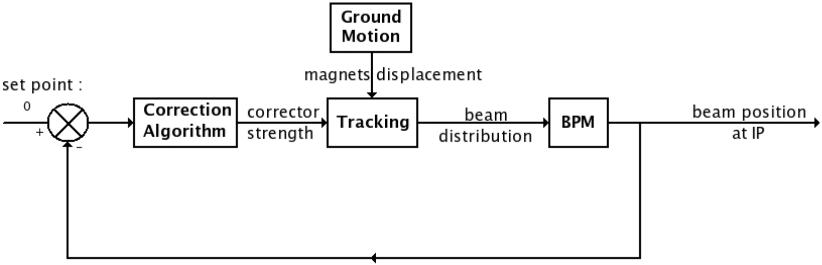

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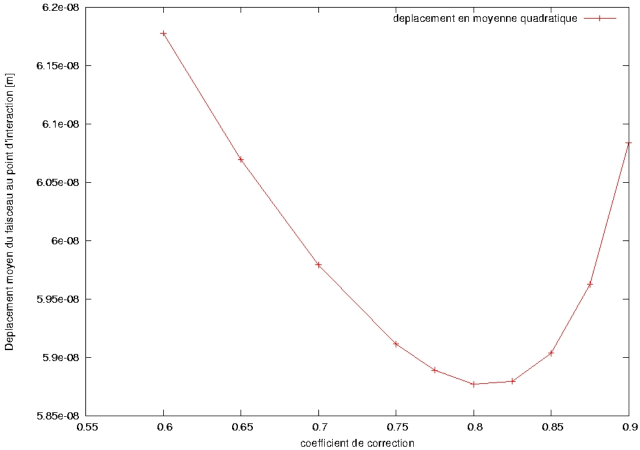
What k_p should be chosen ?

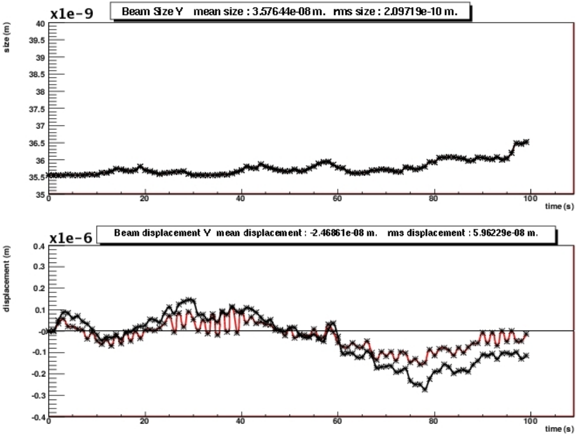
Tuning corrector

Method

Simulation for various coefficient and choose the most adapted.



Simulation results



Legend

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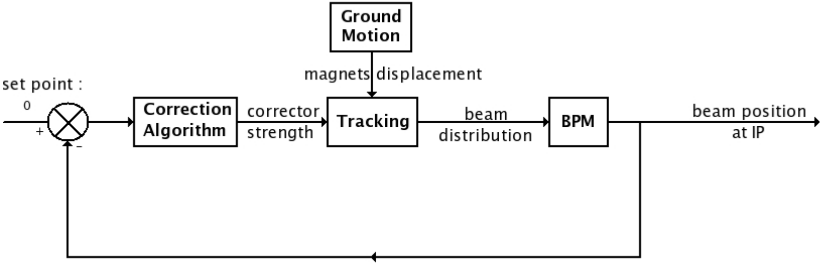
What is a PID corrector ?

Schema of principle :



$$C(p) = k_p + \frac{k_i}{p} + k_d \cdot p$$

Tuning of corrector

3 coefficients : hardly adjustable “manually” as previously.

Major tuning method

Type	Settling Criteria	Name
Set-point change / disturbance	25% damping	Zieglar-Nichols
Set-point change, no overshoot & min.	response time	Chien, Hrones & Reswick
Set-point change, 20% overshoot & min.	response time	Chien et. al.
Disturbance, no overshoot & min.	response time	Chien et. al.
Disturbance min	control area	Takahashi

Tuning of corrector

As it minimizes the error without any other constraint, Takahashi's method was implemented.

Takahashi's method

1. Start with all coefficients to 0.
2. Increase k_p up to auto-oscillation. Take :
   - T_0 : The period of auto-oscillation.
   - k_0 : k_p at this moment.
3. Use following coefficients (T is repetition rate):

k_p	k_i	k_d
$0.6k_0 - 0.5k_i T$	$1.2\frac{k_0}{T_0}$	$\frac{3}{40}k_0 T_0$
0.5533	1.1067	0.2767

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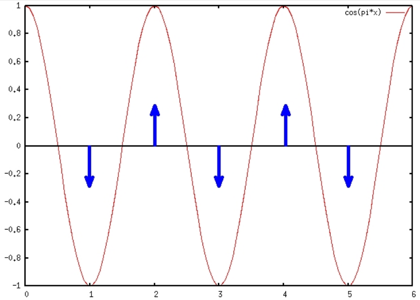
Implementation of Takahashi's method

1. The most unstable frequency is $2T$ as at such frequency correction will each time increase the error $\Rightarrow T_0 = 2T$.
2. Coefficient at this frequency which produce exponential increase of the displacement is the one correcting an y displacement by a -y position on the next beam.
$\Rightarrow k_0 = \frac{1}{R_{43}(kicker \to IP)}$.



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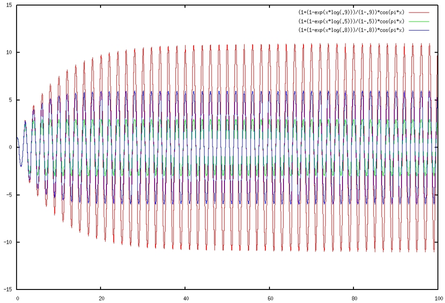
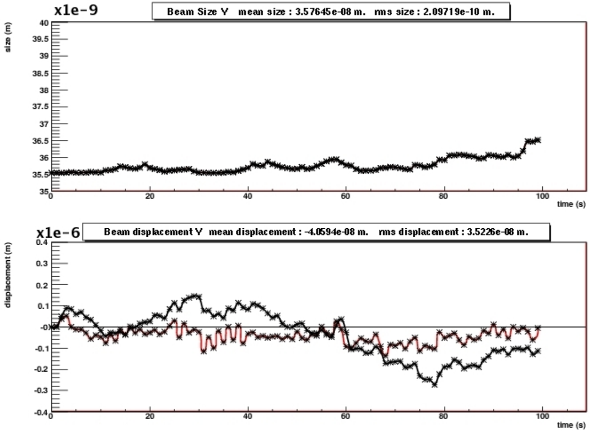


Results of simulation



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Tuning of corrector - 2

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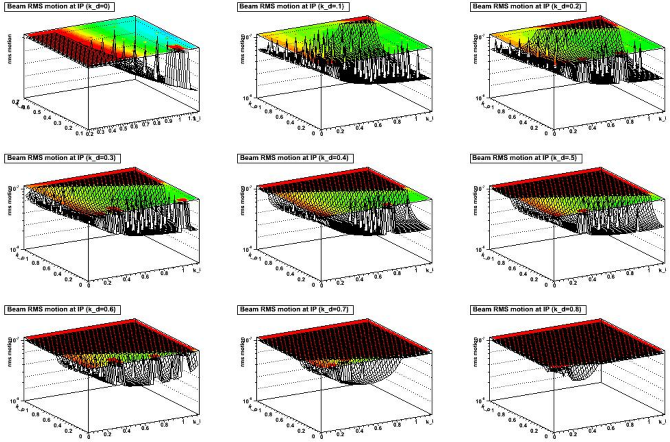
But not impossible ! Min at $k_p = 0.38$ $k_i = 1.18$ $k_d = 0$



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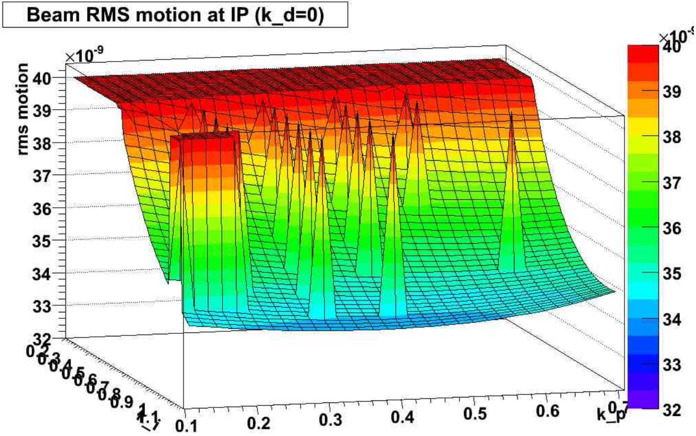

Conclusion

- Analysis of ground motion and creation of a generator.
- Simulation of effects of these vibrations with a position feedback.
- Decrease by 3 the amplitude of simulated vibrations thanks to a fully optimized PID controller.
- Nevertheless, vibrations remain 3 times bigger than objectives.

Prospects

- Thanks to A.Seryi and G.R.White, get software to generate spectra and GM generator, so verification of existing generator will be done.
- Simulation of full lattice from extraction to IP thanks to informations given by Faus-Golfe et. al.

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