Dispersion Measurements at VUV-FEL

FEL R&D Program – Week2 2006

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Overview

INTERMEDIATE GOAL
Obtain a dispersion in the undulator smaller than 1 cm in both planes

GOAL of WEEK2
Re-measure dispersion and perform 1st dispersion correction

DIFFICULTIES (week2)
Unstable machine

ACHIEVEMENTS (week2)
- Re-measured dispersion downstream ACC1 & ACC2/3
- First try to correct dispersion & orbit
- Global orbit correction performed
- Dispersion response measured for H8DBC2 & H11DBC2
How we want to correct (I)

We want to correct both orbit and dispersion, using the orbit and dispersion response matrices

- Orbit response term
  \[ O_{i,j} = \frac{\Delta x_i}{\Delta \theta_j} \]

- Dispersion response term
  \[ D_{i,j} = \frac{\Delta D_i}{\Delta \theta_j} \]

\( \Delta x_i / \Delta D_i \) \(
\Delta \theta_i \)
\(--->\) change of the orbit / dispersion at the BPM \( i \)
\(--->\) change of the kick angle of the steerer \( j \)
How we want to correct (II)

- **Required steps:**
  1. Calculate and/or measure orbit/dispersion response matrices
  2. Measure actual orbit/dispersion \( x_{\text{meas}} \) & \( d_{\text{meas}} \)
  3. Compute corrector strengths
  4. Apply corrector currents
  5. Repeat 2-3-4 until satisfactory result

\[
\left( \frac{Q \cdot (1-w)}{D \cdot w} \right) \cdot \Delta \theta = \left( \frac{x \cdot (1-w)}{d \cdot w} \right)
\]

\[
\sum \left[ \left( \frac{x_{\text{meas}}}{d_{\text{meas}}} - \frac{x}{d} \right) \right]^2 = \min \Rightarrow \Delta \theta
\]
Difficulties: unstable machine

Dispersion measurements

- $D_x$ [mm]
- $D_y$ [mm]
- $s$ [m]

- 14.57h
- 15.16h
- 15.22h
- 15.35h

14.57h
15.16h
15.22h
15.35h
1\textsuperscript{st} try to correct global trajectory ✓
1st try to correct dispersion ✗
Dispersion response simulations

How to calculate the dispersion

- **Twiss method**
  Transport of the beam main parameters through the linac ($\beta$, $\alpha$, $\gamma$, $\mu$, $D$...)

- **Orbit method**
  Track particles for different energies
  Look at the orbit and derive the dispersion
Dispersion response simulations

Dispersion response for H8DBC2

No agreement if there is an RF cavity downstream the dispersion source
Dispersion response simulations

Dispersion response for H10ACC7

Agreement if there is NOT an RF cavity downstream the dispersion source
Dispersion response simulations

Why these differences between “Twiss” and “orbit method”? 

In elegant RF cavities are modeled with a 1st order matrix, therefore the terms of the trajectory are not included in the Twiss calculation.

Meanwhile we believe the orbit method results
Dispersion response H11DBC2 measurements

Horizontal dispersion for different H11DBC2 kicks

- 1.05mrad
- 0.525mrad
- 0mrad
Dispersion response H11DBC2
measurements vs simulations

Measured and simulated dispersion response H11DBC2

Ideal model
~Agreement
Orbit response H11DBC2 measurements vs simulations

Measured and simulated orbit response H11DBC2

Ideal model ~Agreement
Dispersion response H11DBC2 measurements vs simulations

Measured and simulated dispersion response H11DBC2

↓ Q2DBC3 by 25% or ↑ Q3DBC3 by 30% or
↓ Q2DBC3 by 15% & ↑ Q3DBC3 by 15%

Agreement
Orbit response H11DBC2
measurements vs simulations

Measured and simulated orbit response H11DBC2

↓Q2DBC3 by 25% or ↑Q3DBC3 by 30% or
↓Q2DBC3 by 15% & ↑Q3DBC3 by 15%

~Agreement
Dispersion response H8DBC2
measurements vs simulations

Measured and simulated Dispersion response for H8DBC2

Ideal model
~ Agreement
Orbit response measurements and simulations for H8DBC2

Ideal model ~ Agreement
Dispersion response H8DBC2 measurements vs simulations

Measured TTF2 Dispersion response for H8DBC2

↓ Q2DBC3 by 25% or ↑ Q3DBC3 by 30% or
↓ Q2DBC3 by 15% & ↑ Q3DBC3 by 15%

Agreement
Orbit response H8DBC2 measurements vs simulations

Orbit response measurements and simulations for H8DBC2

↓Q2DBC3 by 25% or ↑Q3DBC3 by 30% or
↓Q2DBC3 by 15% & ↑Q3DBC3 by 15%

Agreement
Summary/conclusions

- 1\textsuperscript{st} try to correct global trajectory with success

- 1\textsuperscript{st} try to correct dispersion without success
  Why? Machine optics ≠ design optics???
  Any other error (energy...)???

- Dispersion measurements need high precision, stability and reproducibility. Therefore measurements are best done within a user run and not after a machine start-up.

- Optics of the machine have to be close to the design optics (or one has to use measured response matrices)
Next Steps

- Simulate global trajectory & dispersion correction (analyze sensitivity to errors)

- Re-measure dispersion response for all steerers (12 hours)

- Either fix optics (off-line) or correct dispersion with measured response matrix (4 hours)
Thank you!