DISPERSION MEASUREMENT AND CORRECTION IN THE VUV-FEL (FLASH)

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Introduction

\[
\eta_x = \frac{\Delta x}{\Delta p / p}
\]

\[
\sigma = \sqrt{\epsilon \cdot \beta(s) + \eta(s)^2 \cdot \left(\frac{\Delta p}{p}\right)^2}
\]

**Goal:** dispersion in the undulator of **1 cm**

**VUV-FEL (FLASH)**

**Generation mechanisms**

<table>
<thead>
<tr>
<th>Source</th>
<th>Error (in all the lattice)</th>
<th>Error (only in the dog-leg)</th>
<th>Dispersion (after the dog-leg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quad malign</td>
<td>17 um</td>
<td>50 um</td>
<td>~ 1cm</td>
</tr>
<tr>
<td>Dipole field error</td>
<td>0.25 %</td>
<td>5 %</td>
<td></td>
</tr>
<tr>
<td>Quad field error</td>
<td>0.75 %</td>
<td>0.75 %</td>
<td></td>
</tr>
</tbody>
</table>

- Quad misalignment seems to be the most important dispersion source
- Dog-leg is a critical zone for dispersion generation
Dispersion Measurement Procedure

- Measure the orbit for different energies
  1. Change RF gradient of the module
  2. Apply orbit correction to restore launch conditions after the module
  3. Read BPM positions downstream last correction BPM

- Derive the dispersion

\[
x = x_0 + D_0 \frac{\Delta p}{p} + D_1 \left( \frac{\Delta p}{p} \right)^2 + \ldots
\]
Dispersion Measurements (Nov. 05)

From DBC2

From ACC4-5
Dispersion Correction Algorithm

It corrects 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**
  \[ D_{i,j} = \frac{\Delta D_i}{\Delta \theta_j} \]

\[ \Delta x_i / \Delta D_i \rightarrow \text{change of the orbit / dispersion at the BPM} \]
\[ \Delta \theta_j \rightarrow \text{change of the kick angle of the steerer} \]

\[ \sum \left[ \left( \frac{x_{\text{meas}}}{d_{\text{meas}}} - \frac{x}{d} \right)^2 \right] = \min \Rightarrow \Delta \theta \]
Dispersion Correction Procedure

Measurement

Set I to steerers
Set dx/dy to quad

Analysis

Orbit Dispersion

Correction

Response Matrices

E_1 x_1
E_2 x_2
... ...
E_n x_n

real measurement or simulation

real measurement or simulation

Corr strengths Quad dx/dy

real measurement or simulation
For dispersion correction, optics of the machine have to be close to the design optics or one has to use the measured response matrices.

Comparing the measured and simulated orbit and dispersion response will let to fix possible optic errors.

We have measured the complete response for the machine and the data is presently being analyzed.
Dispersion correction simulations

vertical plane, \( w = 0.1 \); quad malign = 200\,\mu m, dipole field error = 1%; quad field error = 1%; bpm noise = 20\,\mu m; bpm off-set = 100\,\mu m; all bpm’s; all steerers
Dispersion correction simulations

Peak and deviation of the orbit and dispersion for the different simulations

- Orbit [mm]
- Dispersion [mm]
- Combined function [mm]

Simulation number

Peak and rms
1st Dispersion correction measurements
(April 06)

Measurement of Horizontal Orbit and Dispersion along the VUV-FEL before and after correction (3 iterations)

- $x$ [mm]
- $D_{h}$ [mm]
- $\kappa_{h}$ [mm/rad]

Required correctors strengths for correction

FLS2006 Workshop, Hamburg

Eduard Prat, DESY
1st Dispersion correction measurements (April 06)

Peak and deviation of the Horizontal Orbit and Dispersion for the different measurements

Peak and deviation of the Horizontal Combined Function for the different measurements
Summary:
- A tool for measuring and correcting orbit and dispersion has been developed
- Several dispersion measurements done on November 05
- Complete response matrix measurement has been done
- Simulations of dispersion correction have been performed
- Dispersion correction in the undulator in the horizontal plane done

Next steps:
- Analyze data from orbit and dispersion response measurements
- Make dispersion correction program more user friendly
- Correct dispersion in vertical plane