A beam trajectory correction tool for the FLASH undulators

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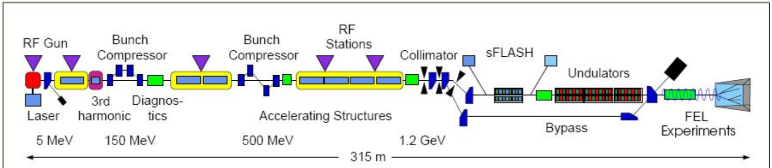
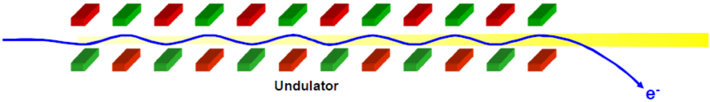
September 5, 2012

FLASH Accelerator



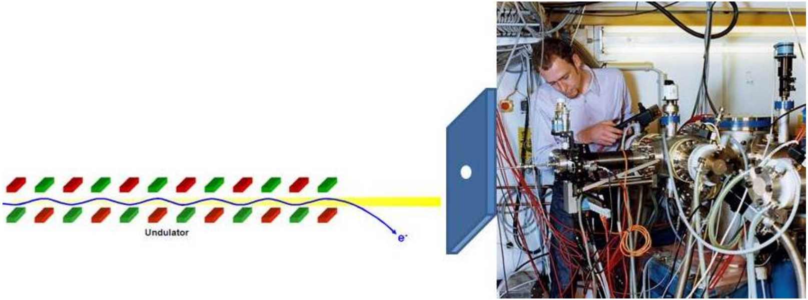
FEL - Reminder

Free Electron Laser is produced by sending an electron beam through an undulator, which is a series of equal dipole magnets with alternating magnetic field direction.



The problem

- In some cases the photon beam emerging from the accelerator deviates from the desired location in the transversal plane.
- For this reason we must correct the electron beam so that it will move on a certain path. This path will cause the emitted photons to reach the desired spot.



The tools to change the trajectory

Dipole magnets

Deflect beams:

$$x = x_0 + x_0' L + \frac{L^2}{2r}$$

$$x' = x_0' + \frac{L}{r}$$

x and x' are beam position and angle

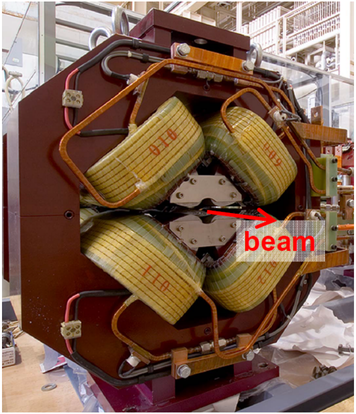
L - magnet length

r - Bending radius

$$\frac{1}{r_x} = \left| \frac{e}{\beta E} B_y \right|$$

The tools to change the trajectory

Quadrupole magnets



Focus beams ("lenses"):

$$x = x_0 \cos(\sqrt{k}L) + x_0' \frac{1}{\sqrt{k}} \sin(\sqrt{k}L)$$
$$x' = x_0' \cos(\sqrt{k}L) - x_0 \sqrt{k} \sin(\sqrt{k}L)$$

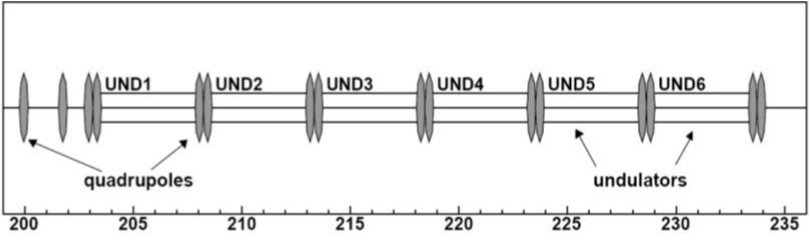
L - magnet length

k - focusing factor

$k = \frac{ce}{E} \frac{\mathrm{d}B_\varphi}{\mathrm{d}r}$

(bending force is proportional to the distance from the center)

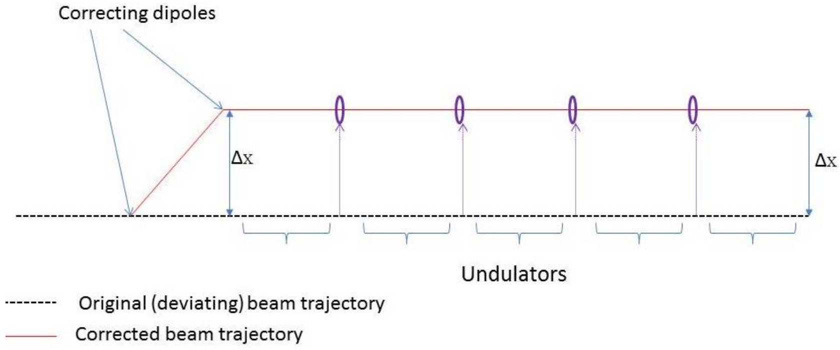
FLASH undulator section



The quadrupoles in the undulator section are mounted on micromovers, which allow transversal displacement.

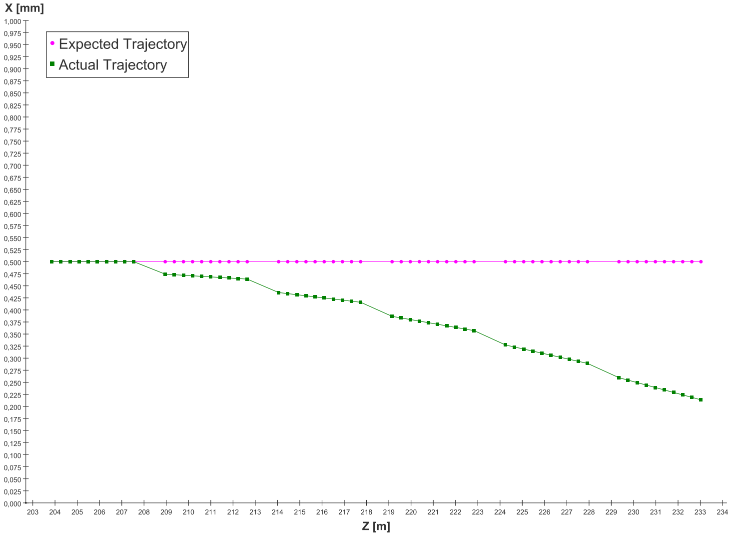
How to correct?

Introducing an offset



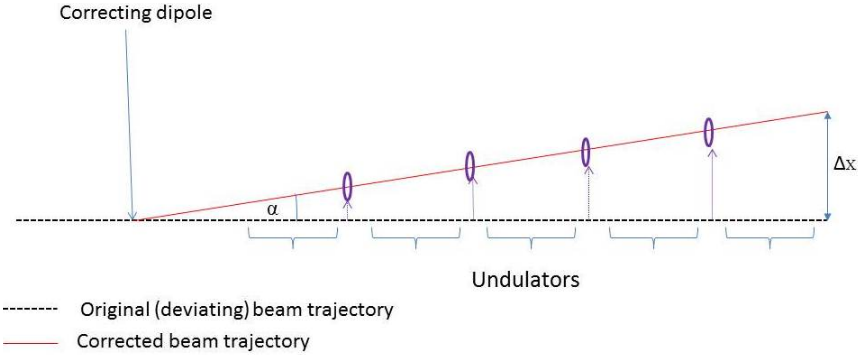
How to correct?

Introducing an offset



How to correct?

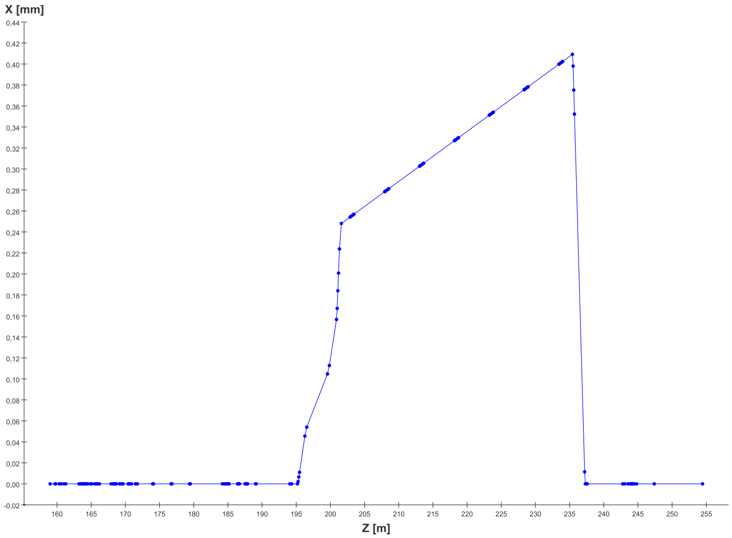
Introducing an angle



$$\alpha \approx \tan \alpha = \frac{\Delta x}{\ell}$$

How to correct?

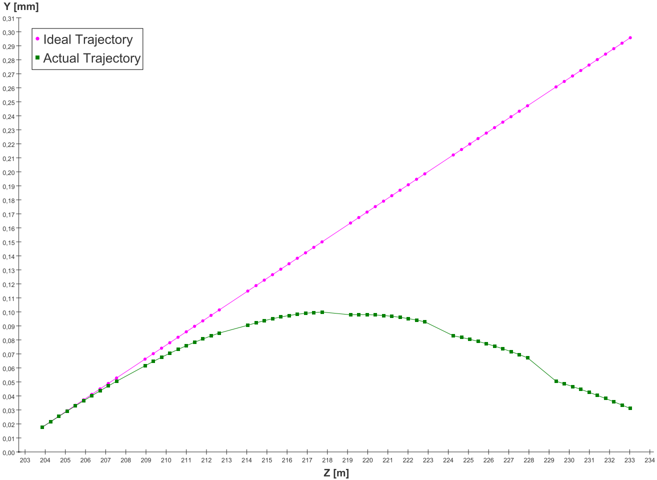
Linear combination of offset and angle



The problem on the vertical plane

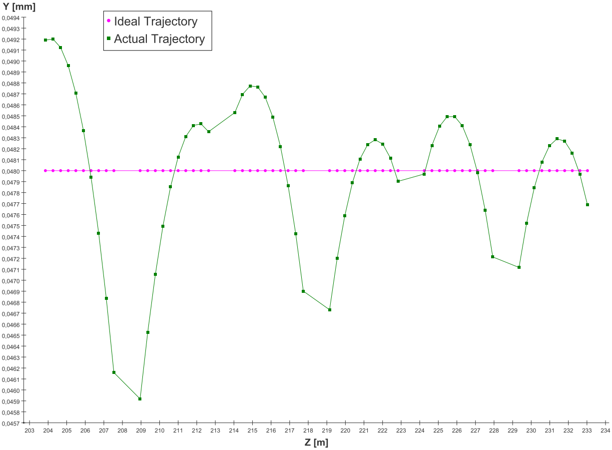
The undulators introduce a focusing effect in the vertical plane.

For this reason, the correction described before is insufficient.



The problem on the vertical plane

Fit Solution



The problem on the vertical plane

Analytical Solution

The ideal trajectory inside an undualtor:

$$\hat{y}(\ell) = a\ell + b$$

The actual trajectory inside an undualtor:

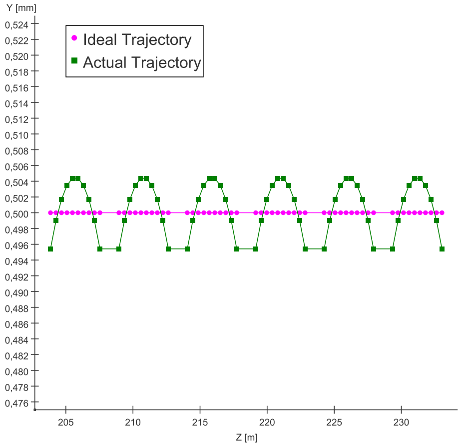
$$y(\ell) = y_0 \cos(\sqrt{k}\ell) + y_0' \frac{1}{\sqrt{k}} \sin(\sqrt{k}\ell)$$

Minimize:

$$RMS(y_0, y_0') = \sqrt{\frac{1}{L} \int_0^L (y - \hat{y})^2 \, \mathrm{d}\ell}$$

The problem on the vertical plane

Analytical Solution - Results



$$RMS \approx 3\mu m$$

Summary

- There is a deviation of the photon beam on the transversal plane
- Correction of the electron beam is achieved using dipoles and quadrupoles
- In the horizontal plane: a perfect, accurate solution
- In the vertical plane: RMS is minimized (analytically or using a fit)
- Outlook: the program will be incorporated into FLASH control room

Questions?