High Gradient High energy gain Inverse Free Electron Laser

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On Behalf of the
RUBICON collaboration

ATF user meeting,
BNL, October 6th 2010

Outline

- Radiabeam-UCLA-BNL IFEL COllaboratioN (RUBICON) experiment
- Most recent undulator design modifications
- Undulator construction status report
- Outlook and project schedule

A new era for Inverse Free Electron Laser Acceleration scheme

- 2004 IFEL experiments: UCLA Neptune, BNL STELLA 2
- IFEL : a mature advanced accelerator scheme
  - Control of longitudinal phase space (prebunching)
  - 1D acceleration scheme
  - Efficient energy transfer
- Towards a mid-high energy range compact injector.
  - Helical IFEL undulator interaction.
- Applications as ICS or FEL based light source driver.

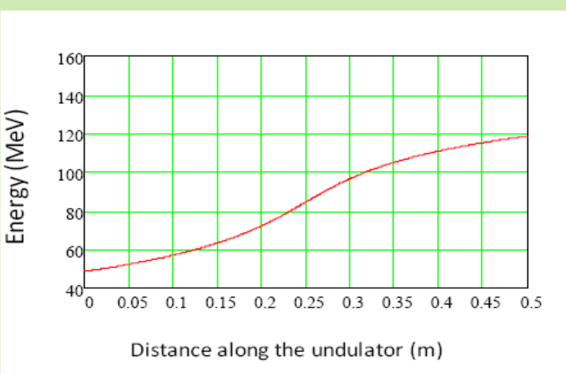
Inverse Free Electron Laser Roadmap

- Renovated interest in IFEL acceleration scheme
- Applications as compact scheme to obtain 1-2 GeV electron beam for gamma ray (ICS) or soft x-ray (FEL) generation.

Radiabeam UCLA BNL IFEL Collaboration

Strongly tapered optimized helical permanent magnet undulator

ATF @ BNL
0.5 TW CO2 laser
50 MeV -> 180 MeV in 60 cm
75 MeV energy gain
120 MV/m gradient

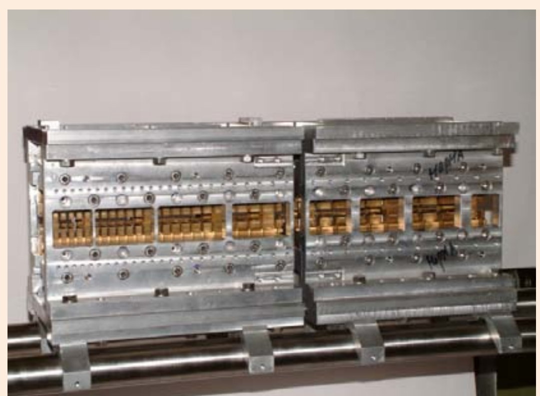


LLNL-UCLA IFEL experiment

Reuse UCLA- Kurchatov undulator

Use 5 TW 10 Hz Ti:Sa
50 MeV -> 150 MeV in 50 cm

High rep rate allows beam quality measurement



GeV IFEL experiment

If current experiments succesfull

Looking for access to facility with 50 MeV beam+20 TW laser (BNL, LLNL, LNF-Italy)

Praesodymium based cryogenic undulator

Initial energy	50 MeV
Final energy	1200 MeV
Avg gradient	1.1 GV/m
Final energy spread	1 %
Laser wavelength	800 nm
Laser power	20 TW
Laser spot size (w_0)	0.2 mm

Radiabeam Ucla Bnl IFEL COllaboratioN RUBICON

The experiment main goal is to achieve energy gain and gradient significantly larger than what possible with conventional RF accelerators to propose IFEL as a viable technology for mid-high energy range accelerators.

This can be achieved using the existing ATF e-beam and high power CO2 laser system

TOGETHER WITH

Helical geometry.

Permanent magnet double tapered undulator.

Parameter	Fixed Value
Initial *e*-beam energy	50 MeV
Laser wavelength	10 um
Laser peak power	0.5 TW
Nominal length of wiggler, L_w	60 cm
Rayleigh range	9 cm
Laser focal spot size (w)	550 um
Location of laser waist inside wiggler	30 cm
Undulator length	60 cm

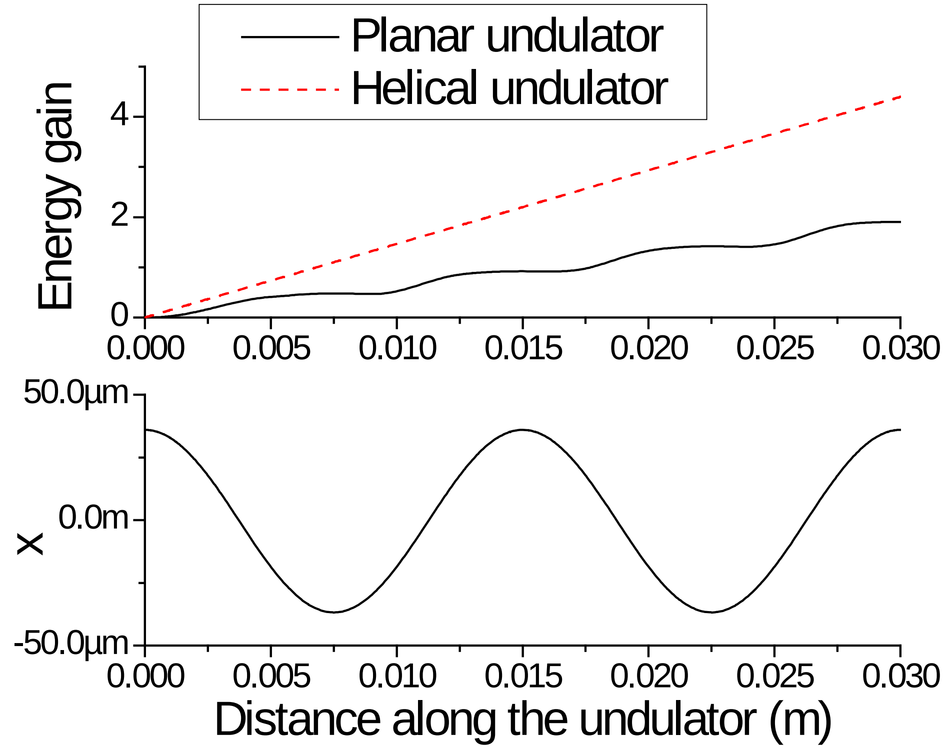
Table 1. Parameters for BNL high gradient high energy gain IFEL experiment

Helical interaction

Works at least two times better.

Interaction with
circularly polarized laser
is always ON

Factor ~2.3 extra gradient



Planar

$$\frac{\partial \gamma}{\partial z} = kK_l \frac{JJ(K)}{2} \cdot \frac{K}{\gamma} \sin(\psi)$$

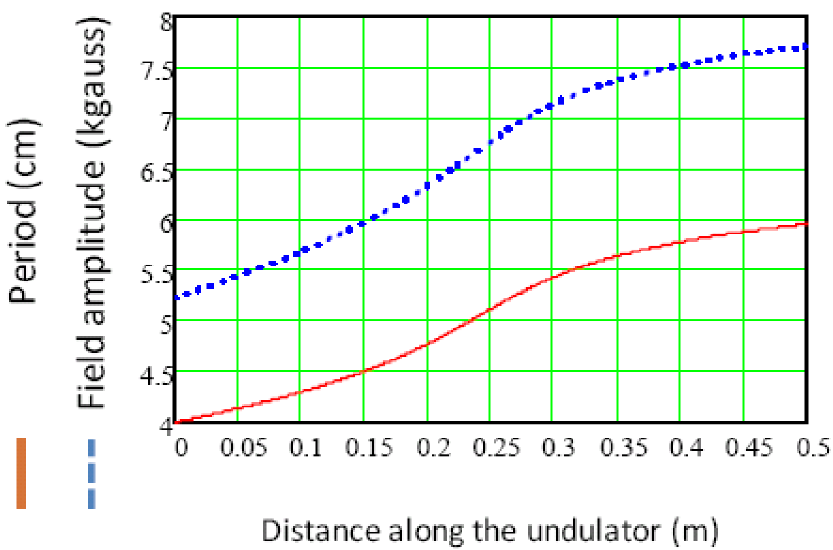
vs.

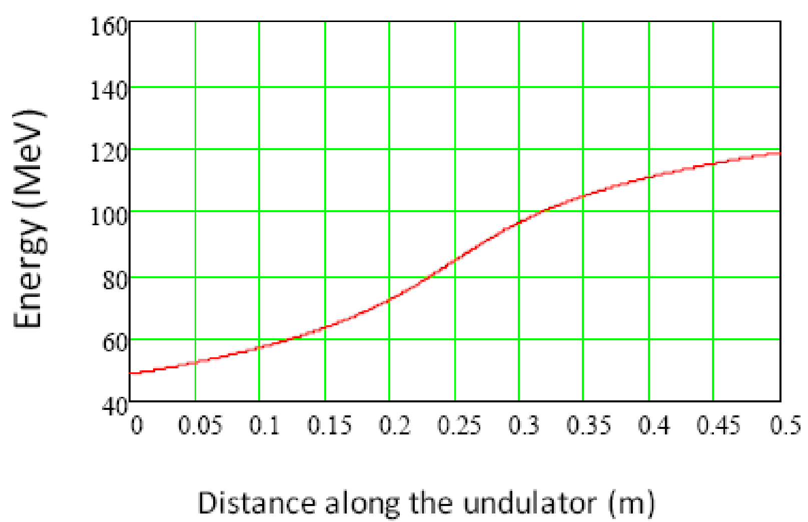
Helical

$$\frac{\partial \gamma}{\partial z} = kK_l \cdot \frac{K}{\gamma} \sin(\psi)$$

Modified undulator tapering design

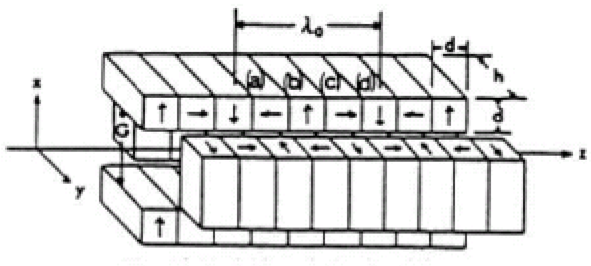
- Use commercially available NdFeB magnets. Br = 1.22 T
- Take into account not ideal laser transverse profile $M^2 = 1.5$
- Provide large enough gap (15 mm) to minimize laser losses
  - >98 % transmission to allow for recirculating schemes.



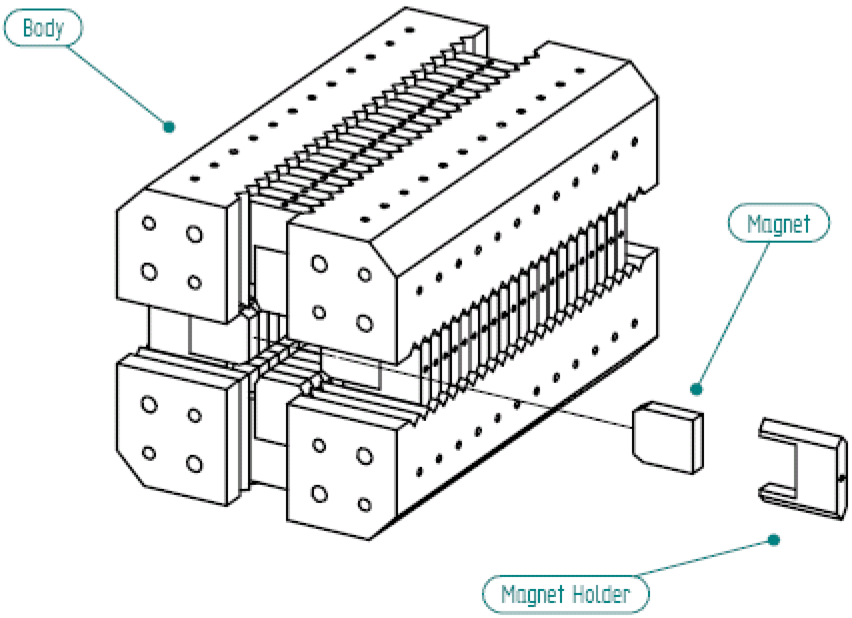


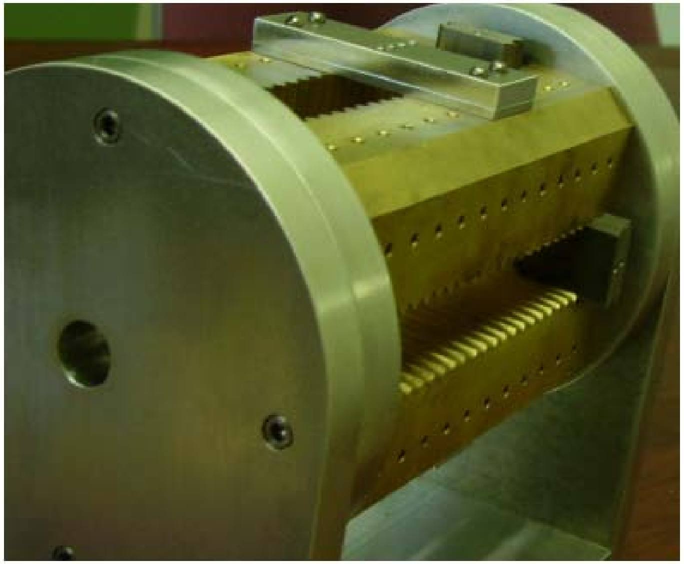
Permanent magnet helical undulator

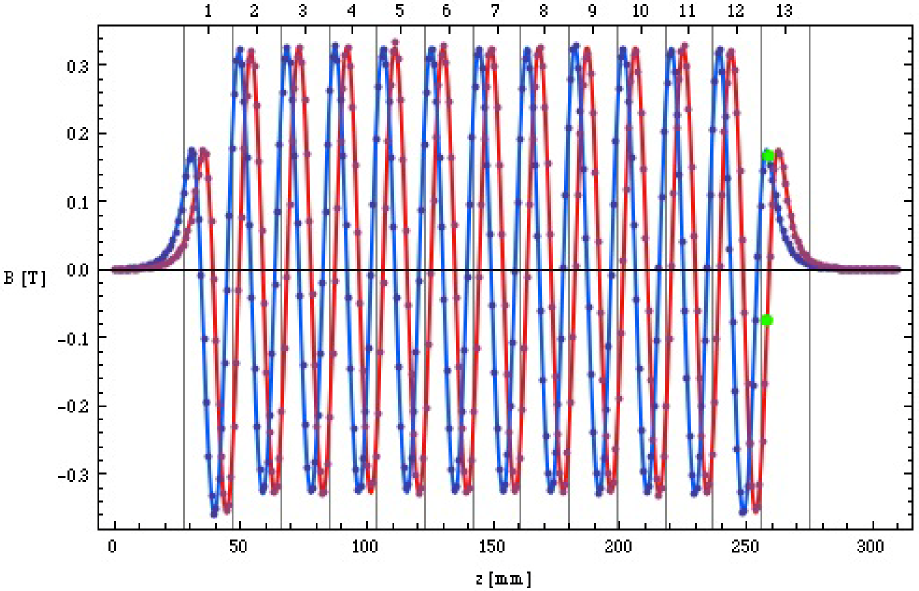
- Helical permanent magnet undulator.



- Prototype (30 cm long) built and measured at UCLA
- Measurements in very good agreement with simulation predictions.

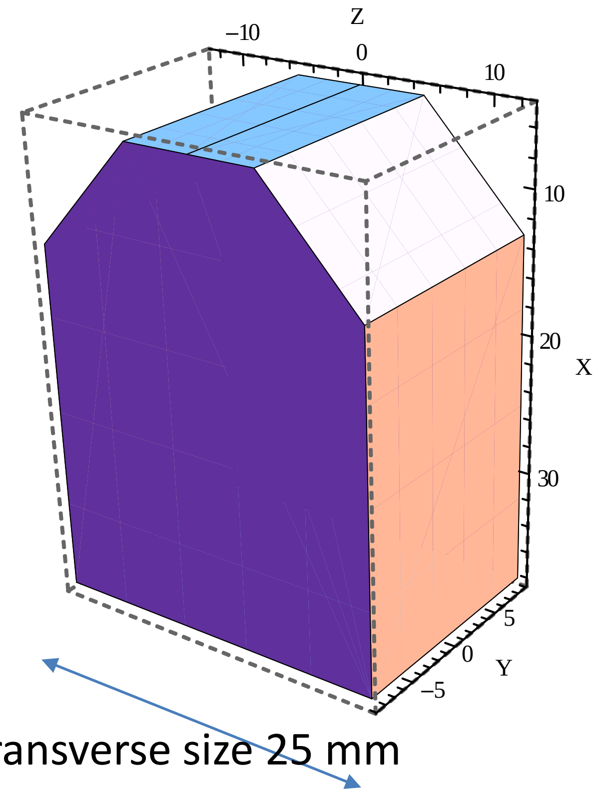




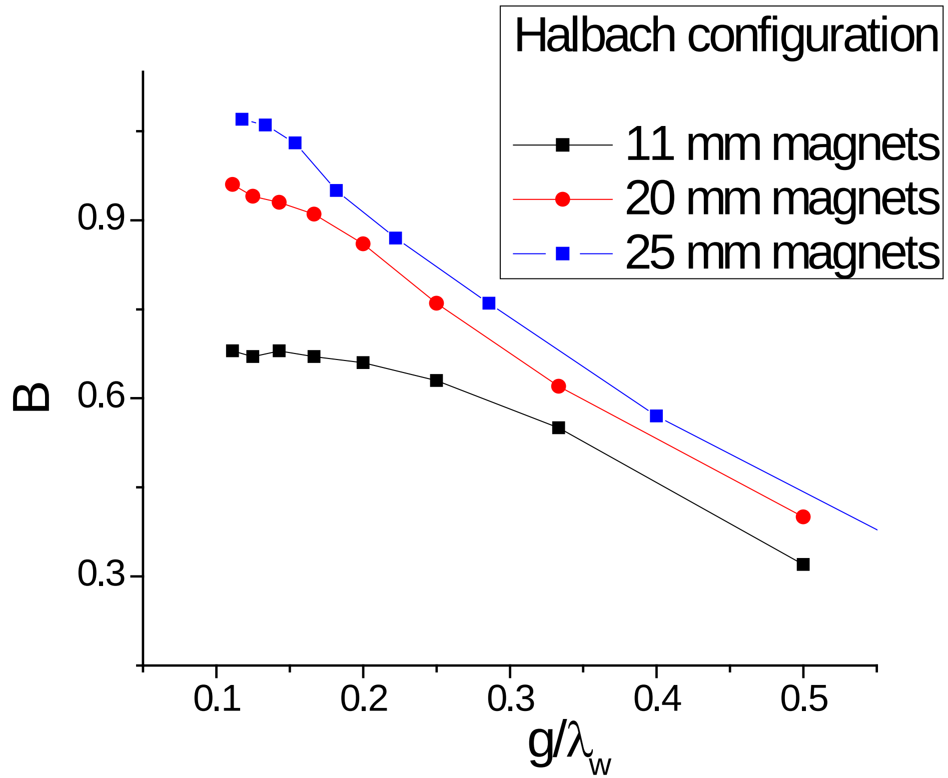


Permanent magnet helical undulator optimization

- Transverse magnet size ~ λ /4
- Gap 1.5 cm
- Need to put magnets close together -> Trapezoidal shape.

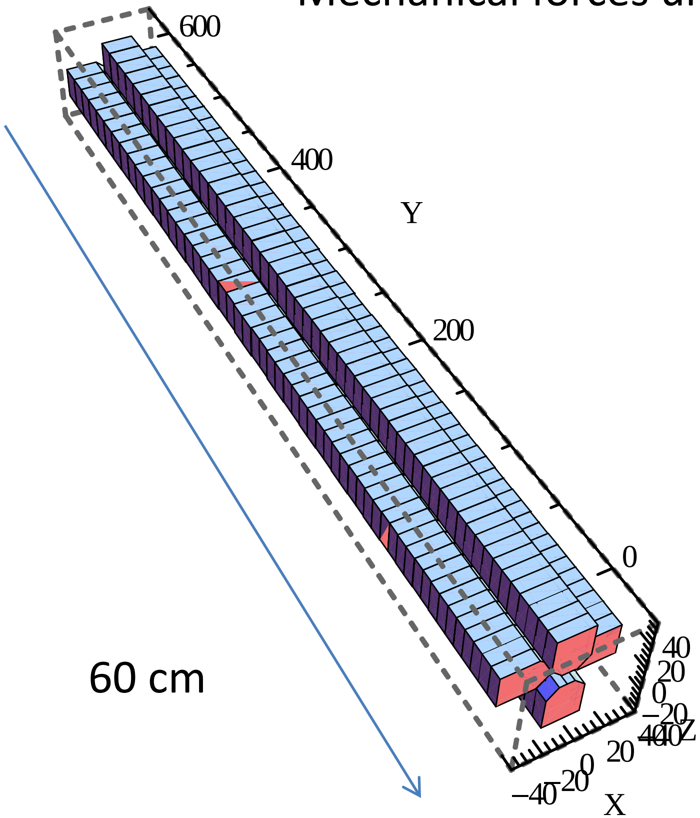


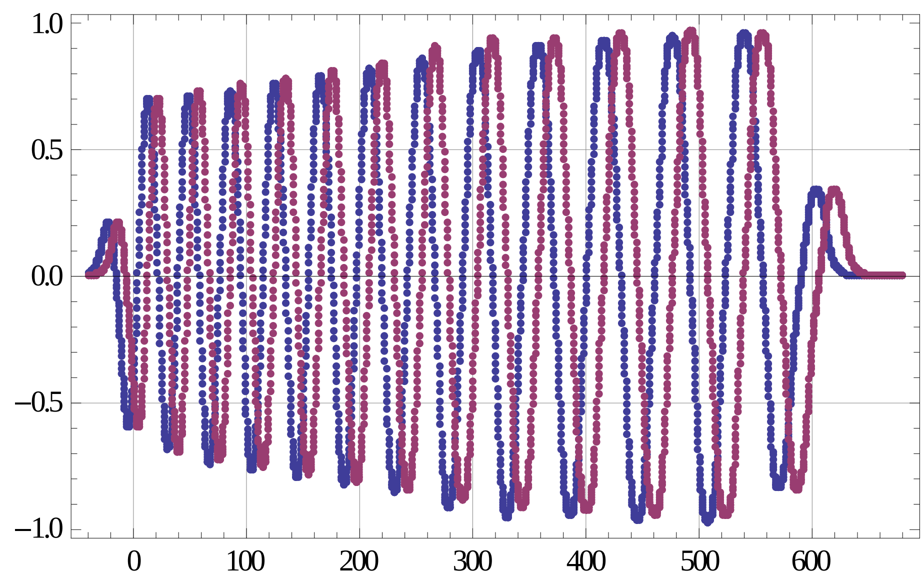
Transverse size 25 mm



3D magnetostatic simulation

Use RADIA magnetostatic code
Evaluate demagnetization field for each magnet.
Mechanical forces under control.

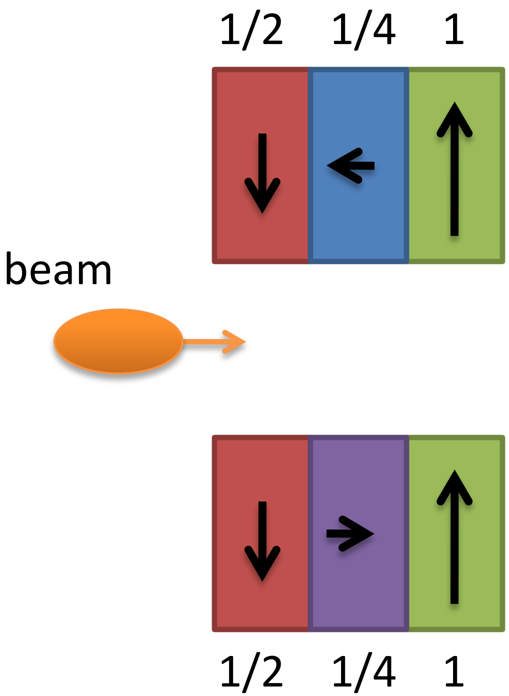


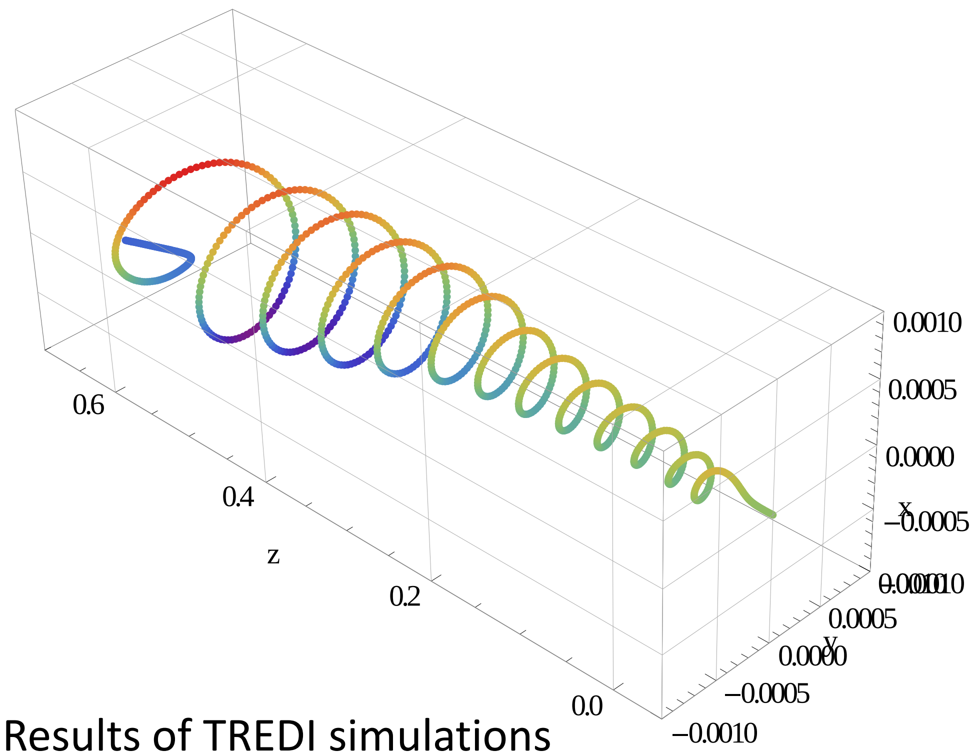


Trajectory of particles within helical undulator

Need to choose end sections to minimize first and second integral
Design for trajectory to oscillate around axis.

End section

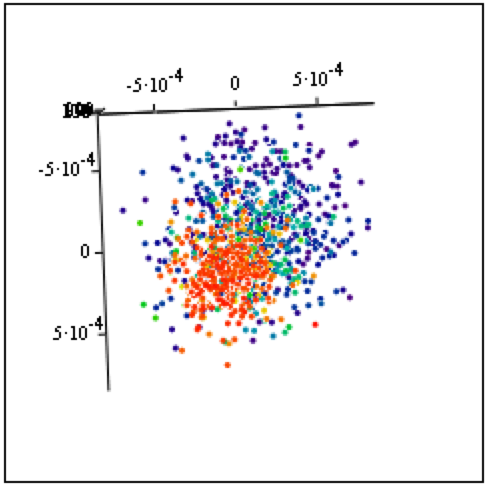




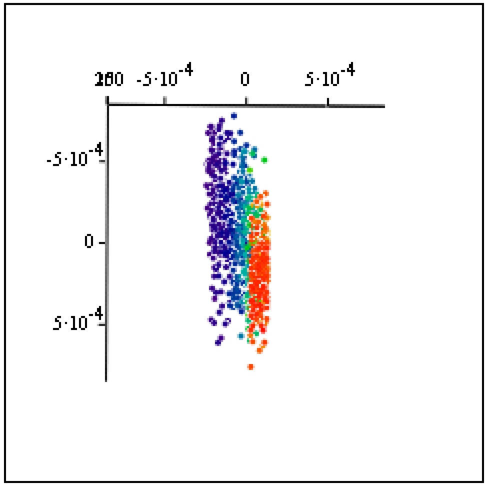
Results of TREDI simulations

Fully three dimensional simulations

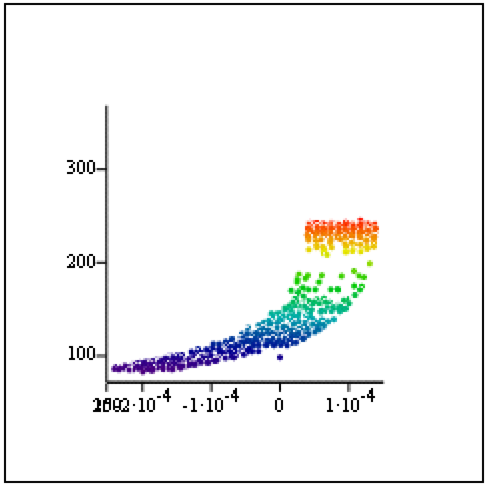
- Focusing effects included using 3dimensional field map from RADIA.
- Non accelerated particles will be separated both in energy and transverse position/focusing.
- Next step. Include radiation field evolution.
  - Modified GENESIS version. In progress.
  - Beam loading effects
  - Phase front distortion for recirculation



(xpart , ypart , pzpart)



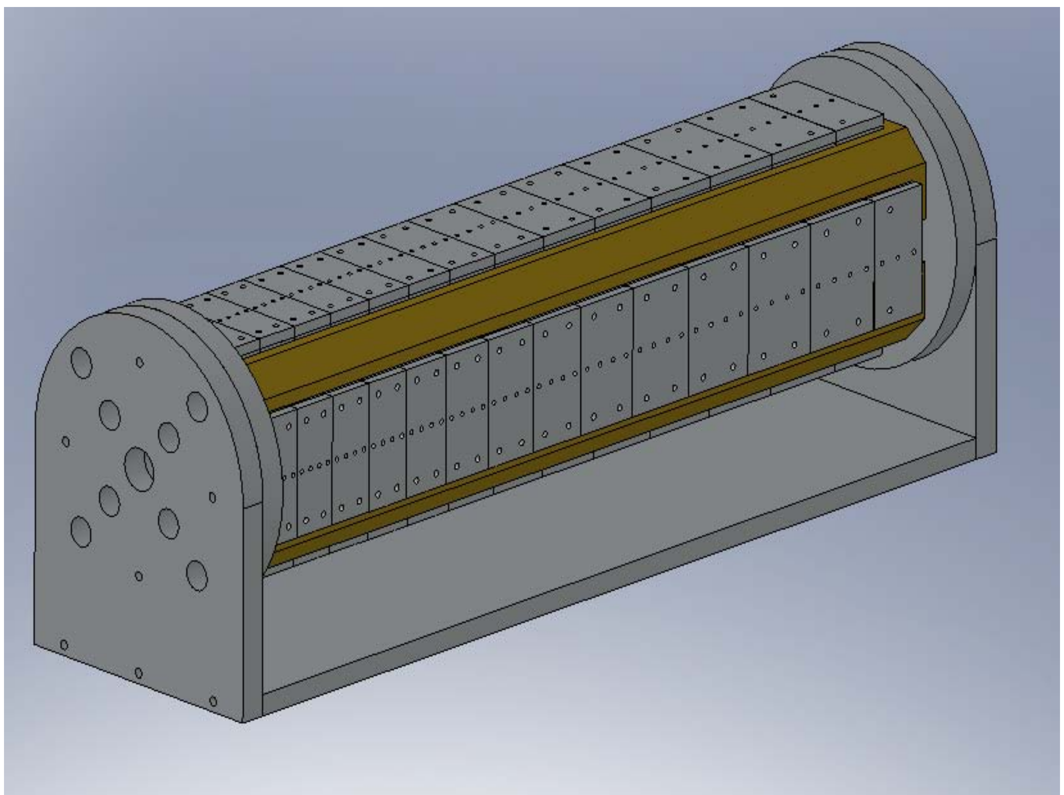
(xpart , zpart , pzpart)

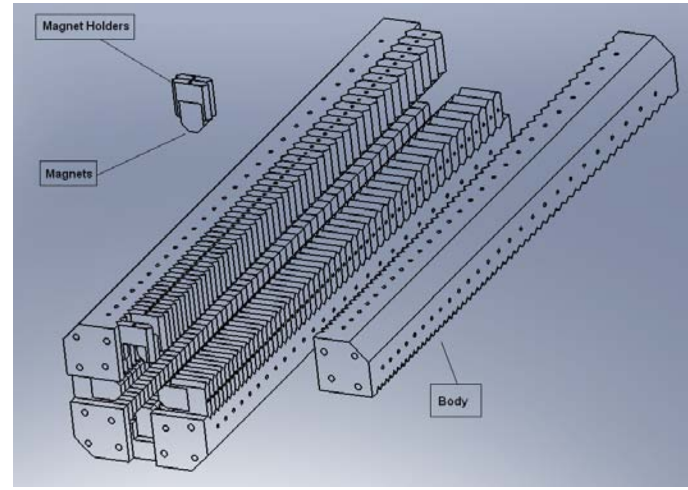


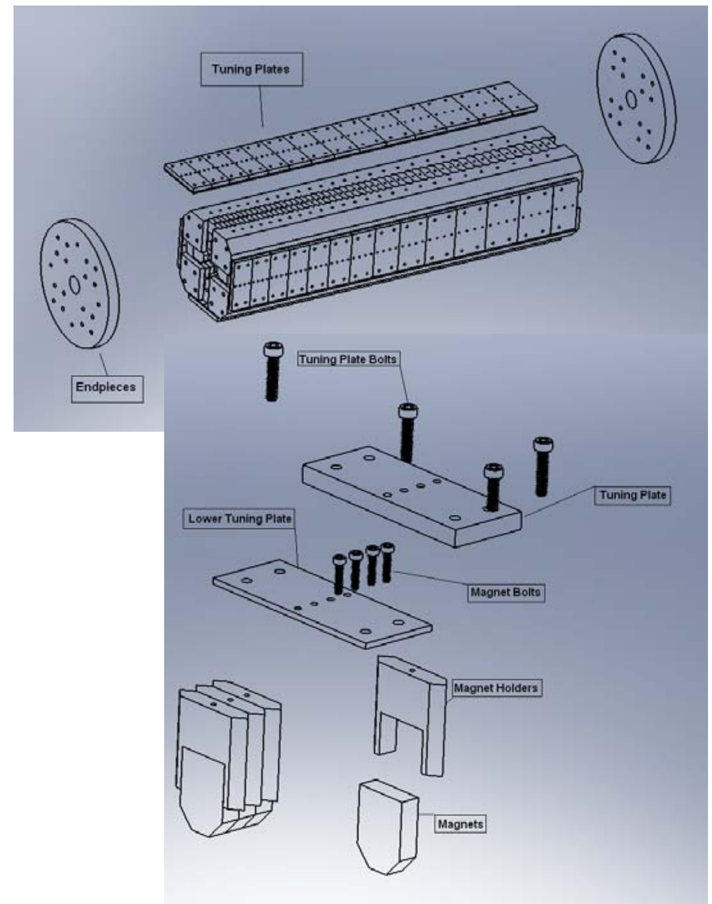
(pzpart , zpart , pzpart)

Mechanical design of undulator

- Design finalized
- Drafted and out to the machine shop
- Magnets have been ordered. Delivery in 40 days.
- Beam pipe ordered.
- Assembly and B-field measurements to start before the end of 2010.







Schedule

- Funding has been secured. DTRA + UCOP + DOE-HEP.
- Postdoc (R. Li) + graduate student (J. Duris) started working on project this summer.
- Undulator construction (next six months)
- Single pass IFEL acceleration scheme
  - Beam time required starting Spring 2011
- Recirculation scheme would be very important.
  - First advanced accelerator to show this.
  - Dramatic increase in wall-plug efficiency.
- Need to advance IFEL simulation capabilities.