X-Ray Diagnostics
Commissioning at the LCLS
- Selected Studies -

J. Welch, SLAC National Accelerator Laboratory
Commissioning Studies

- Microbunching Instability
- Laser Heater tune-up
- Gas Attenuator alignment
- Undulator Taper optimization
- Undulator Segment alignment
- Undulator Longitudinal Wakefields
- High Fluence Damage
Acknowledgements


XFEL: J. Gruenert, H. Sinn
Layout

X-Ray Diagnostics

Experiments

LINAC  Undulator & Dump  FEE  XRT

Hutches  Hutches

35 m
"FEE" and Surroundings

XRay Beam

"ST-0 Can"

YAG, Ni foil

GA

K-Mono

DI

35 m

FEE

SXR Spectrometer

FEL2010
Aug. 23-27, 2010
James Welch
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Electron beam has extremely small initial slice energy spread: 2-3 keV.

Such “cold” beams can undergo a microbunching instability in bunch compressors which can degrade beam quality.

A Laser Heater device was developed to add a controlled amount of energy spread: enough to suppress the instability, but not enough to degrade the FEL performance.
Microbunching Instability

- FEL2010
- Aug. 23-27, 2010
- James Welch
- welch@slac.stanford.edu

Diagram:
- LINAC
- Vertical Bend Magnet
- FEE
- Hutches
- XRT
- Dump YAG Screen
- SXR Spectrometer
- Plain VLS grating
- Mirror
- YAG
- Exit slit
- CCD
Microbunching Instability

Turn Laser Heater Off

SXR Spectrometer
Microbunching Instability

Turn Laser Heater Off

SXR Spectrometer

Dump YAG Screen
Microbunching Instability

Laser Heater ON – No Instability
Measuring Laser Heater Gain Curves

kick to turn off FEL in downstream undulator

“ST0 Can”

Optical Filters

Camera

YAG
Laser Heater

- 6 Gain Curves, one for each level of Laser Heater Power
- Optical filters used to extend dynamic range.

From Yuantao Ding
3 mm apertures in circular Be disks mounted on gate valves

~10^{-6} T

2 T N₂

~0.7 T

~10^{-6} T

SR

YAG

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GA Aperture Alignment

FEL+SR, wide open
GA Aperture Alignment

SR, wide open
GA Aperture Alignment

J. Turner

#5 in, SR only

Corrected

Initial

Vertical position [mm]

Vertical before any move

Vertical after move of table 2

vertical position [mm]

aperture number
FEL Spectrum – K Monochromator

- Designed for Undulator K measurements using SR
- Can also measure FEL spectrum
- Passes only one energy 8.234 keV at one angle
- Spectra obtained by scanning electron beam energy.
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Undulator Taper Control

Beam Energy = 13.640 GeV

Taper Options
- Use Spontaneous Radiation
- Use Wakefields
- Add Gain Taper
  - Start Segment: 6
  - End Segment: 33
  - Taper Amplitude: -15 MeV
- Add Post Saturation Taper
  - Start Segment: 26
  - End Segment: 33
  - Taper Amplitude: -33 MeV

Undulator K Control
- Move K values to red line
- Restore Initial K values
  - 05/28/2009 11:20:55
- Save Reference K values
- Restore Reference K values
- Make Present Taper Official

Electron Beam Parameters
- Use Actual Energy (13.640 GeV)
- Set Energy: 13.64 GeV
- Use Actual Bunch Charge (0.5 pC)
- Set Bunch Charge: 250 pC
- Use Actual Peak Current (2813.1 A)
- Set Peak Current: 3000 A

X-Ray Beam Parameters
- Fundamental Wavelength: 0.150 nm
- Photon Energy: 8281.1 eV
- YACXRAY Amplitude: 0.0 AU

H-D. Nuhn

Thursday, May 28, 2009 11:29:10
Undulator Taper

- Spectra measured for different settings of a linear taper.
- Highest spectral power and narrowest BW occurs for a taper with ~20 MeV loss.
Undulator Vertical Alignment

- Vertical alignment is determined by measuring $\Delta K$ as a function of vertical position.
- Spectra of SR from single segments are taken with data concentrated on the steepest slope.
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- Spectra of SR from single segments are taken with data concentrated on the steepest slope.

- $\Delta K$ is varied by adjusting the relative horizontal position of the segments and interpolated to the 0 position. A slight wedge in the gap provides the tuning range.

Graph:
- Reference Segment 31, 6.1325 +/- 0.0002
- Segment 30
  - Position for match [mm]: 0.0847
  - \( (K_{\text{test}} - K_{\text{ref}})/K \times 10^4 = 0.6 \)
  - Fit method: midpoint
  - Delta $K \times 10^3$ per mm: -2.5

Additional information:
- Test data
- Test fit corrected for WF
- Ref
Undulator Vertical Alignment

- Theoretical dependence based on $K < B < \cosh(2\pi y/\lambda_u)$ is $10^4 x \Delta K/K = 2.19 e^{-4} y^2$
- Vertical tolerance is only 100 microns
- Undulator is physically moved with the electron beam at a constant position near 0.
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Undulator Wakefields

- Vacuum chamber: 135 m long, 12 mm and 5 mm
- Wakefield depends on bunch charge and current.

- Set K's equal and measure spectrum with K-monochromator

Graph:
- 66 keV/m
- 5.4 MeV
- 250 pC, 2000 A
Damage

- Ni foil was used to try to better calibrate the Xray wavelength

- Foil was not visible in ST-0

- Coherent Edge Radiation used to illuminate regions of foil.

FOIL is retracted
Damage

- When inserted the Foil blocks CER
- But holes in foil would let CER show!
- Foil was removed and inspected. Holes were confirmed.
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- But holes in foil would let CER show!
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Conclusion

- X-Ray diagnostics provided a means of investigating a wide variety of interesting phenomena and optimizing the LCLS performance during commissioning,…

- … but we still have a lot to learn about what more they can do.