FEE Diagnostics and Commissioning

June 17, 2008

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**LCLS Installation and Commissioning Time-Line**

- **PEP-II run ends** now
- **LTU/Und/Dump Install**
- **PPS Cert. LTU/Dump FEE/NEH Install**
- **First Light in FEE**
- **X-Rays in NEH FEH Hutch BO**
- **First Light in FEH**

**Timeline:**

- **2008**: PPS, Linac/BC2 Commissioning
- **2010**: NEH Operations/Commissioning

**Graphical Elements:**

- April 18, 2008
- CD-4 (7/31/2010)
- CDC-44 (7/31/2010)

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**LLNL-PRES-403341**

**FEE Diagnostics and Commissioning**

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XTOD Commissioning Diagnostics and Offset Mirrors in the Front End Enclosure (FEE)

- Fixed Mask
- Slit
- Solid Attenuators
- Reticule
- K-Monochromator
- Collimators
- Thermal Sensor
- Pop-in cameras
- FEL Offset Mirror Systems
- C0 collimator (in e-beam dump)
- Gas Attenuator
- Gas Detector
- Direct Imager (Scintillator)
- Pop-in cameras

Beam Direction
FEE pre-beam commissioning I (Mar-May 09)

- FEE HVAC System Checkout
- EPICS Control System Checkout
  - Network, Timing, and Server functionality
  - Basic IOC startup
  - Common Services
    - Archiving
    - Logging
    - gateways to/from e-beam
- Basic Services Checkout
  - Air system / valves
  - Water cooling
  - SOMS/HOMS temperature control
- Vacuum pump down of all devices
  - PLC ladder logic checkout
  - EPICS control and monitoring of controllers
  - Full cycles for instruments
  - State control for Gas Detector/Attenuator
FEE pre-beam commissioning II (Mar-May 09)

- Verification of individual Device Operation
  - Slit
    - Motion control
  - Gas Detector/Attenuator
    - Pressure control
    - Motion control
    - Solid Attenuator control
    - PMT & APD digitizer operation (triggering) and HV control
  - $K$ monochromator
    - Motion control
    - Photodiode digitizer operation (triggering)
  - Thermal sensor
    - Motion control
    - Cooling control
    - Laser energy measurement and triggering
    - Sensor digitizer operation (triggering)
  - Direct Imager
    - Motion control
    - Camera operation (triggering) with UV illuminator
FEE Commissioning with Spontaneous, Single Undulator (May 09)

- RP Survey
- Measure centroids with Direct Imager
- Check positions of apertures
  - Fixed Mask, Slits, C0
FEE Commissioning with Spontaneous, All Undulators at 13.64 GeV (May-Jun 09)

- RP survey and verification of apertures
- Insert reticule and center
- Commission Pop in 1
- Verify position of collimators
- Align Gas Attenuator Apertures
- Commission Gas Detector
- Commission Thermal Sensor
- Commission K-Monochromator
  - Measure flux in fundamental
Absorbed in 50 microns YAG

Hard X-Ray spontaneous, all undulator segments, viewed by Direct Imager
Measurements of Direct Imager YAG yield: $12 \pm 3$ photons / keV

![Diagram showing the setup of ion chambers, vacuum window, camera, optic, and YAG, with measurements of average gray vs. integration time and photons/keV as functions of transmission.]

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Reticules in Direct Imager

1 mm reticule

100 micron reticule
Reticules in Pop-in cameras

XY Energy Distribution in Pop-in P3S2 Scintillator, 10x10 mm View
Alignment of Attenuator apertures with Direct Imager

XY Energy Distribution at 211.1226, 20x20 mm View
Align Soft x-ray mirrors (Jun-Jul 09)

- Use Pop-in cameras with Spontaneous
  - A pop-in camera exists behind each mirror
  - Pop-ins can see reflected and not-reflected beam
  - Measure distance between reflected and non-reflected beam to set angle
  - Translate mirror to center beam on mirror
  - Alignment can be performed with spontaneous radiation
Simulations of Pop-in imagery

\[ \Delta y = -1.737 \text{ mm} \]

\[ \theta = 12.9 \text{ mRad} \]
\[ \theta = 13.9 \text{ mRad} \]
\[ \theta = 14.9 \text{ mRad} \]

\[ \Delta y = 0 \text{ mm} \]

\[ \Delta y = 0 \text{ mm} \]

\[ \Delta y = 0 \text{ mm} \]
FEE Commissioning at low energy (4.3 GeV) (Jul-Aug 09)

Find beam center with 9\textsuperscript{th} harmonic using K-monochromator

With Soft X-FEL

- Use Direct Imager, no apertures
  - “See” FEL at $\sim 100$ nJ
    - K measurement of undulators (if necessary)
  - Optimize FEL to 50 micro J
  - Align gas attenuator and gas detector
  - Continue optimizing FEL pulse energy and measure attenuated FEL with Direct Imager

- Measure absolute pulse energy with thermal sensor
- Calibrate Gas Detector with Thermal Sensor
- Calibrate Direct Imager with Gas Detector
9th harmonic at 4.3 Gev through $K$-mono viewed by Direct Imager

<table>
<thead>
<tr>
<th>LCLS &quot;Setting&quot;, i.e., fundamental $hν$ (eV)</th>
<th>Harmonic</th>
<th>Observation $hν$ (eV)</th>
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<td>908</td>
<td>9</td>
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</table>
Absorbed in 5 um YAG,
Absorbed in 5 um YAG,

**Peak pixel has 160 photoelectrons / nJ of FEL**
Thermal sensor, theory (blue) and experiment (red)

Assumptions for simulation:
- 2mm x 2mm sensor, E = 1 mJ
- Perfect heat sinking at boundaries

Assumptions for experiment:
- $\Delta V = AV_{\text{bias}} TCR \Delta T$
- Voltage gain $A = 82$
- Bias voltage $= 1.7 \text{ V}$

Prompt non-thermal pulse

Temperature, K

Time [ms]
Thermal sensor measurements vs. calibration laser energy

Thermal sensor measured energy, micro J vs. Calibration laser energy, micro J
High level control software

- **Direct Imager**
  - Image display, peak finder and centroid calculation, pulse energy measurement, stage motion, camera settings, focus, UV lamp and illuminator, cross calibration with Gas Detector (MATLAB/EPICS)

- **Gas Detector**
  - Waveform display, peak finder, prompt signal removal, cross calibration with Thermal Sensor, pressure control, pulse energy measurement, phototube HV (MATLAB/EPICS)

- **Thermal sensor**
  - Waveform display, sensor selection and positioning, peak finder, calibration with laser, prompt signal removal, R vs T measurement, pulse energy measurement (MATLAB/EPICS)
High level control software (cont.)

- **K-monochromator**
  - Waveform display, quad cell positioning, quad cell pulse position calibration, removal of prompt signal, total pulse energy measurement, crystal pitch angle, crystal placement (MATLAB/EPICS)
  - Acquire pulse energy, shift photon energy, plot undulator spectrum, move undulator, maximize slope (Paul Emma’s group)

- **Pop-in cameras**
  - Image display, cross hair position extraction, camera control, scintillator positioning (EPICS)

- **Slit**
  - Aperture width, aperture center (EPICS)
High level control software (cont.)

- Gas and Solid Attenuator
  - Pressure, solid attenuator selection, stage control, apertures in/out control (EPICS)

- Others
  - Reticule positioning, SOMS and HOMS transverse position and angle, vacuum and isolation valve monitoring and control (EPICS)
Commissioning Manpower

**PIs**
- R. Bionta (Direct Imager, Pop-ins)
- S. Friedrich (Thermal Sensor)
- S. Hau-Riege (Gas Detector)
- S. Shen (Gas Attenuator)
- T. McCarville (Mirrors)
- E. Ables (Electronics)
- P. Stefan (Mirrors, K-Monochromator)

**Software**
- S. Lewis (EPICS lead, vacuum, attenuator, and motion controls)
- L. Ott (Direct Imager and K-mono MATLAB, EPICS, Simulations)
- K. Fong (EPICS, Photon Monte-Carlo)
- C. Gardner (Thermal sensor MATLAB)
- S. Hau-Riege (Gas Detector MATLAB)
Handover to operation

Safety Reviews
- All instruments have had formal reviews by LLNL
- SLAC citizen committees reviews in Jun-Aug 08
- Readiness review for FEE + NEH in Mar-Apr 09

Documentation
- As built drawings
- ESDs
- IWS safety plans and seismic analysis

Training
- Peter Stefan working closely with LLNL staff for all instruments
- Controls developed by Steve Lewis according to Guinther Haller’s guidance
- Other SLAC personnel will be trained during commissioning
FEE Diagnostic Hardware

Status

- Fixed Mask / Slit
  - In house, Integrated testing
- Attenuator
  - Under assembly
- Gas Detectors
  - In house/integrating
- Thermal Sensor
  - Vessel on order
  - Sensors in fabrication
- Direct imager
  - Vessel on order
  - Cameras, scintillators, filters in house
- **K monochromator in final design**
- Pop-in Monitors ready for PDR
- Controls
  - 4 of 5 FY08 FEE racks complete
  - FEE Vacuum Rack complete
  - 98% of **all** other controls h/w received
Summary

- FEE diagnostics will be ready for installation
  - November 2008: Fixed Mask, Slit, Gas Detector, Attenuators, Direct Imager, Thermal Sensor
  - January 2009: K monochromator, SOMS/HOMS mirror system and Pop-ins
- Initial checkout of FEE instruments without beam in Mar-May 09
  - Controls, motion, vacuum, pressure, calibration laser
- Initial commissioning and alignment of FEE instruments with high-energy spontaneous in May-Jun 09
  - Direct imager, Attenuator, Gas Detector, Calorimeter, K-Monochromator
- Mirrors will be aligned with spontaneous in Jun-Jul 09
  - Using Pop-in cameras
- Low energy FEL will be commissioned in Jul-Aug 09
  - Direct Imager will be main diagnostic for finding FEL