LCLS Injector Overview
David Dowell, SLAC
November 3, 2003

- Injector Performance Requirements
- Description of the Injector Facility
- Schedule and Budget
- Critical Path Issues
- Presentation Schedule
## LCLS Injector Performance Requirements:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak current</td>
<td>100 A</td>
</tr>
<tr>
<td>Charge</td>
<td>0.1 – 1 nC</td>
</tr>
<tr>
<td>Normalized transverse emittance projected/slice</td>
<td>( \leq 1.2 / 1.0 , \mu m , \text{rms} )</td>
</tr>
<tr>
<td>Rate</td>
<td>120 Hz</td>
</tr>
<tr>
<td>Energy</td>
<td>135 MeV</td>
</tr>
<tr>
<td>Energy spread @ 135 MeV projected/slice</td>
<td>( \leq 0.1 / 0.01 , % , \text{rms} )</td>
</tr>
<tr>
<td>Gun laser timing stability</td>
<td>( \leq 0.50 , \text{ps rms} )</td>
</tr>
<tr>
<td>Booster mean rf phase stability</td>
<td>0.1 ( ^\circ ) , \text{rms}</td>
</tr>
<tr>
<td>Charge stability</td>
<td>( \leq 2.0 , % , \text{rms} )</td>
</tr>
<tr>
<td>Bunch length stability</td>
<td>( \leq 5 , % , \text{rms} )</td>
</tr>
</tbody>
</table>
Novel Features of the LCLS Injector

- Cathode load lock and a cathode lab located above the injector.
- RF gun with dual RF feeds to minimize field asymmetry, power load, etc.
- High-resolution energy and emittance diagnostics between the gun and the first linac section.
- Dual RF feeds on the first accelerator section to eliminate time-dependent RF kicks.
- Transverse RF deflecting cavity for direct measurements of the longitudinal phase space and slice emittance.
- Electro-optical bunch shape and timing diagnostics.
- Wire scanners for high-resolution, minimally intercepting, three-screen emittance measurements.
- High-resolution spectrometer for measuring beam properties at 135 MeV.
- A ‘laser heater’ for controlled increase of the uncorrelated energy to suppress coherent synchrotron radiation and longitudinal space charge instabilities.
The LCLS Injector

- Cathode Load Lock
- RF Photocathode Gun
- Low Energy Diagnostics
- SLAC 3-m Accelerator Sections (L0-1 and L0-2)
- EO Diagnostic (Bunch Shape & Timing)
- Transverse RF Cavity (Emittance & Energy)
- Wire Scanner, typ.
- Laser Heater Undulator
- Shield Wall
- DL1 Bend
- Straight Ahead Spectrometer & Diagnostics
The LCLS Injector Facility at Sector 20 (S20)

- Top View of S20 Alcove
- Side View of S20 Alcove, stairwell and injector off-axis vault
- Local Control Room
- Personnel and Equipment Access to Injector
- Laser Room
- Cathode Lab
Conventional Facilities at S20

- Control Consol With Racks
- Sliding 6 ft door
- Cable trays inside room
- Equipment Racks

Load Lock Rm

Laser Rm

Power Conversion and Controls Racks

Light Pipe
At Ceiling Ht.

Cable trays over top of laser room

Cut Concrete for Vibration Isolation

10 racks for PC and Controls @7.5 KVA/rack
5 racks for MCOR Crates @14 KVA/rack
Magnet Power Supplies:
- Gun Spectrometer: 0.2kVA, 120 VAC
- Gun Solenoid: 12 KVA, 208 VAC
- Linac Solenoid: 37.7 KVA, 480 VAC
- B01 Dipoles: 9.7 KVA, 208 VAC
- Straight Ahead Spectrometer: 9.7 KVA, 208VAC
Possible Cooling for Linac Solenoid Power Supply
4 Vacuum Racks @ 7.5 KVA/rack

RF Support 2 racks @7.5 KVA/rack
RF Hut (RF& Controls)
RF Hut: 3 racks @7.5KVA/rack
Waveguide water in 2 racks, 10 GPM total

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All Three Drive Laser Beam Colors Will be Used

- EO Diagnostic: Prototyping at GTF, J. Schmerge
- Laser Heater Implementation, J. Welch

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LCLS Will Use Part of the Existing High Power RF System, R. Akre
Current View of S20 Drive Laser Room
Current View of S20 Drive Laser Room
Current View of S20 Control Room
Gun to Linac Region of the Injector

- 1.6-cell S-band rf gun (G)
  - Cu/Mg cathode with load-lock
  - Ti:sapphire laser
  - Emittance compensation solenoid (S1)
- Booster (L0) - two SLAC 3-m sections
- Beam matched to L0 using solenoids S1 & S2
- Gun Energy Spectrometer
- EO Bunch Shape Diagnostic

Specifications for Electron Diagnostics, C. Limborg
RF Gun Temperature Distribution at 120 Hz

Water bulk $T = 20 \, ^\circ C$, $h = 20 \, \text{kW/m}^2/\text{K} \Rightarrow T_{\text{max}} = 90.3 \, ^\circ C$

Temperature ($^\circ C$) in mode 2 from 3676 W total power dissipation

Applied heat flux ($\text{W/m}^2$)

120 Hz Gun and Load Lock, J. Schmerge
Dual Feed RF Gun and Solenoid
Gun with Load Lock:

- UHV All Metal Gate Valve
- Treatment / Transfer Chamber
- Long Bellows Assembly
- Spool From Valve Seal
- Stage for Cathode Insertion / Alignment
- Rail System
- Cooled Cathode Carrier
- T-1 Precision Mount
- Vacuum Pumps
- Porcupine Cathode Holder
Plan to Install Shield Wall During 2004 Down Time
LCLS Injector Critical Path Issues:

- **Insufficient FY04 Funds to Finish All PED Before FY05**
  - Design gun to operate both with & without Load Lock
  - Delay load lock PED until FY05
  - Delay most of Controls PED until FY05
  - Delay most of RF Distribution PED until FY05
  - Attempt to finish essential and standard designs in FY04

- **Shield wall needs to be installed during Linac downtime.**
  - Install shield wall in Aug-Sept ‘04

- **Sector 20 Alcove needs to be finished before installing drive laser:**
  - Use Conventional Facilities PED ($218K) to design Alcove in FY04
  - Begin Alcove installation at start of FY05
  - Consider vendor integration of drive laser
PED Plans for FY04 & FY05:

In FY04:
- Delay Load Lock, Etc. Until FY05
- Design 120Hz Gun to Work Either With or Without Load Lock
- Install Injector Shield Wall
- Prepare Sector 20 for Alcove Installation
- Finish Drive Laser Engineering & Design
- Concentrate PED funds on:
  - Drive laser
  - 120 Hz Gun
  - RF System
  - E-beam Diagnostics
  - Controls
  - Vacuum Chambers

In FY05:
- Complete Engineering & Design for Controls, LLRF Distribution, Load Lock, etc.
PED Prototyping in FY04:

- **Gun Prototyping:**
  - Magnesium Cathode Performance (QE, thermal emittance, etc.)
  - RF Pulse Shaping (reduces gun average power from 3 to 1.2 kW)
  - Time-Domain Laser Pulse Shaping

- **Injector Diagnostics:**
  - E/O Bunch Length & Timing Diagnostic (sub-ps resolution & RF controls)
  - Slice Emittance at High-Charge (slice & projected, wakefield effects, RF kicks)

- **Drive Laser Prototyping:**
  - Transverse Profile Flattening (Aspheric Optic)
  - Temporal Pulse Shaping (Frequency Domain at SLAC, DAZZLER at INFN, Milan)
  - IR&UV FROG Diagnostics
Acquisition Plan for the Injector:

**In FY05:**
- Finish PED effort
- Build Sector 20 Alcove
- Begin Procurements/Fabrication for:
  - Drive Laser
  - 120 Hz Gun
  - Solenoids, Energy Spectrometers, Quads, Dipoles
  - Accelerator Sections

**In FY06:**
- Complete Procurements/Fabrication
- Begin Installation
## Acquisition and PED Schedule for the Injector:

### Manpower for FY04:
- 1 Conv. Fac. (Paid by CF PED)
- 2 Drive Laser
- 2 120 Hz Gun
- 1 LLRF Distribution
- 1 Controls
- 1 Magnets & Supports
- 1 Vacuum
- 1 E-Diagnostics
- 1 Acc. Structures

### Total FY04 Manpower:
- 10 Injector PED
- 1 Conventional Facilities PED

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### Table: Acquisition and PED Schedule for the Injector:

<table>
<thead>
<tr>
<th>Work Package</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<tbody>
<tr>
<td>1.2.1 Injector</td>
<td>2003 PED ($1.1M)</td>
<td>2004 PED ($1.2M)</td>
<td>2005 PED ($2.7M)</td>
<td>Sector 2B Modifications</td>
<td>(PEL) Acquisition Modifications Design &amp; Procurement ($111.3M)</td>
<td>(PEL) Shielding Seismic Design &amp; Procurement ($15.8M)</td>
<td>(PEL) Construction Approvals, Bids, etc ($17.8M)</td>
<td>Shielding &amp; Construction ($88M)</td>
</tr>
</tbody>
</table>

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### Additional Information:
- **D. Dowell**, SLAC
- **dowell@slac.stanford.edu**
- Linac Coherent Light Source
- Stanford Synchrotron Radiation Laboratory
- Stanford Linear Accelerator Center

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**LCLS Injector Review, 3 Nov 2003**

**INJECTOR OVERVIEW**
### Summary of Acquisitions

<table>
<thead>
<tr>
<th>WBS#</th>
<th>WBS name</th>
<th>Long Lead (K$)</th>
<th>Overhead (K$)</th>
<th>Direct+OH (K$)</th>
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<tbody>
<tr>
<td>1.2.1.2</td>
<td>Injector Lasers</td>
<td>2,996</td>
<td>313</td>
<td>3,309</td>
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<td>1.2.1.3</td>
<td>RF gun and load lock</td>
<td>714</td>
<td>108</td>
<td>822</td>
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<td>1.2.1.4</td>
<td>rf power/waveguide/structures/monitoring</td>
<td>1,629</td>
<td>221</td>
<td>1,850</td>
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<td>1.2.1.5</td>
<td>Magnets and supports</td>
<td>683</td>
<td>116</td>
<td>799</td>
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<tr>
<td>1.2.1.6</td>
<td>Injector vacuum</td>
<td>440</td>
<td>50</td>
<td>490</td>
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<tr>
<td>1.2.1.7</td>
<td>electron diagnostics, beam dumps, supports</td>
<td>1,455</td>
<td>202</td>
<td>1,758</td>
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<td>1.2.1.8</td>
<td>Controls and power conversion</td>
<td>2,393</td>
<td>312</td>
<td>2,705</td>
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<tr>
<td><strong>Totals (K$):</strong></td>
<td></td>
<td><strong>10,310</strong></td>
<td><strong>1,322</strong></td>
<td><strong>11,732</strong></td>
</tr>
</tbody>
</table>

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**Diagram:**

- **Totals (K$):**
  - Controls and power conversion
  - electron diagnostics, beam dumps, supports
  - Injector vacuum
  - Magnets and supports
  - rf power/waveguide/structures/monitoring
  - RF gun and load lock
  - Injector Lasers

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**Long Lead, Direct+Overhead (K$):**

- 0 2,000 4,000 6,000 8,000 10,000 12,000
Summary and Review of Critical Path Issues

• On Going Effort:
  • Beam Characterization, Injector Simulations
  • Testing the E/O diagnostic, Mg cathode, RF Pulse Shaping
  • Shield wall radiation design
  • Preliminary design of Sector 20 Alcove, gun load lock, 120 Hz gun
  • Resource loaded schedule

• Critical Path Issues:
  • FY04 PED funding less than needed to complete PED by FY05
  • Shield Wall needs to be coordinated with SLAC downtime
  • Drive Laser forces early construction of Sector 20 Alcove
Summary and Review of Critical Path Issues

• Proposed Plan:
  • Design gun to operate both with & without Load Lock
  • Delay load lock PED until FY05
  • Delay most of Controls PED until FY05
  • Delay most of RF Distribution PED until FY05
  • Attempt to finish essential and standard designs in FY04
  • Use Injector PED ($113K) to install shield wall in Aug ’04
  • Use Conventional Facilities PED ($218K) to design Alcove in FY04
  • Begin Alcove installation at start of FY05
  • Consider vendor integration of drive laser

• Request in FY05:
  • $11.7M for Long Lead Items (Direct + Overhead)
  • $4M for PED in FY05
LCLS Injector Review Schedule
Research Office Building, Redwood Room C&D
Monday, November 3, 2003
Overview
8:30 - 8:45 Greetings from John Galayda;
8:45 - 9:00 Charge to the Committee, M. Reichanadter;
9:00 - 9:30 Committee Executive Session
9:30 - 10:00 Overview of the LCLS Injector, D. Dowell
10:00 - 10:30 break & discussion

Simulations and Gun Design
10:30 - 11:15 Injector Simulations, C. Limborg
11:15 - 11:45 120 Hz Gun and Load Lock, J. Schmerge
11:45 - 1:00 break for lunch

Major Injector Components
1:00 – 1:30 RF System, R. Akre
1:30 – 2:15 Specifications for Electron Diagnostics, C. Limborg
2:15 – 2:45 Prototyping at GTF, J. Schmerge
2:45 – 3:00 break

Beam Quality Issues
3:00 – 3:30 Laser Heater Justification, Z. Huang
3:30 – 4:00 Implementation of the Laser Heater, J. Welch
4:30 – 5:00 Expt. Status of Beam Requirements for LCLS, D. Dowell
5:00 – 6:00 Open discussion and Committee meeting

Tuesday, November 4, 2003
Discussion and Closeout
8:00 – 10:00 Committee Executive Session
10:00 – 11:00 Closeout Session