Experimental Measurements of the ORION Photoinjector Drive Laser Oscillator Subsystem

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Laser Issues for Electron RF Photoinjectors
October 23-25, 2002
Stanford Linear Accelerator Center
OUTLINE

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2. Laser System
   1. Oscillator Subsystem
   2. Amplifier Subsystem
3. Phase Noise
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Introduction

SLAC CENTRAL RESEARCH YARD
## General Design Parameters of the ORION Facility

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beam Energies</strong></td>
<td>7 MeV (Source); 7-67 MeV (LE Hall); 67-350 MeV (HE Hall)</td>
</tr>
<tr>
<td><strong>Charge per Bunch</strong></td>
<td>0.25 nC optimum, adjustable up to a nominal maximum of 1 nC</td>
</tr>
<tr>
<td><strong>Number of Bunches</strong></td>
<td>1 or 2 (split charge)</td>
</tr>
<tr>
<td><strong>Transverse Emittance</strong></td>
<td>&lt; 2x10^-6 m, normalized rms (0.25 nC)</td>
</tr>
<tr>
<td><strong>Bunch Length</strong></td>
<td>1.8 psec, rms (0.25 nC)</td>
</tr>
<tr>
<td><strong>Charge Stability</strong></td>
<td>2.5% pulse-to-pulse</td>
</tr>
<tr>
<td><strong>Bunch Timing Jitter</strong></td>
<td>0.25 psec, rms</td>
</tr>
<tr>
<td><strong>Repetition Rate</strong></td>
<td>10 Hz</td>
</tr>
<tr>
<td><strong>Average Beam Power</strong></td>
<td>0.67 W at 67 MeV; 3.5 W at 350 MeV (1 nC bunches)</td>
</tr>
<tr>
<td><strong>Electron Source</strong></td>
<td>1.6 cell, S-band (2.856 GHz) Photoinjector, Mg cathode</td>
</tr>
<tr>
<td><strong>Drive Laser</strong></td>
<td>Commercial Ti:Sapphire, 266 nm wavelength, 1 mJ output</td>
</tr>
<tr>
<td><strong>Source RF System</strong></td>
<td>SLAC 5045 Klystron; Solid-State, NLC-type Modulator</td>
</tr>
<tr>
<td><strong>Injector Linac</strong></td>
<td>Two X-band (11.4 GHz), 0.9 m, 30 MV, NLC structures</td>
</tr>
<tr>
<td><strong>High-Energy Linac</strong></td>
<td>Four X-band, 1.8 m, 72 MV, NLC structures</td>
</tr>
</tbody>
</table>
Photoinjector Layout

S-Band

150 cm

Diagnostics

X-Band

111.4 cm

f₀ = 2855.050 MHz
f₀' = 2852.586 MHz
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gun RF gradient</td>
<td></td>
</tr>
<tr>
<td>Peak gun solenoid magnetic field</td>
<td>3.09 kG</td>
</tr>
<tr>
<td>Launch phase (centroid)</td>
<td>33 degrees</td>
</tr>
<tr>
<td>Bunch charge</td>
<td>0.25 nC</td>
</tr>
<tr>
<td>Injected bunch length (hard edge, T)</td>
<td>6.3 ps</td>
</tr>
<tr>
<td>Injected beam radius (hard edge)</td>
<td>0.63 mm</td>
</tr>
<tr>
<td>Initial accelerating gradient in X-band linacs</td>
<td>33.6 MV/m</td>
</tr>
<tr>
<td>Solenoid field in X-band linacs</td>
<td>0.7 kG</td>
</tr>
</tbody>
</table>

**J.B. Rosenzweig et. al.**

**ORION Baseline case**

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*Graphs showing the evolution of the beam radius and normalized emittance, as well as the evolution of the bunch length and energy spread along the beam propagation.*

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**Highlights:**
- **Bunch charge:** 0.25 nC
- **Launch phase:** 33 degrees
- **Gun RF gradient:** 140 MV/m
- **Peak gun solenoid magnetic field:** 3.09 kG
- **Injected bunch length (hard edge, T):** 6.3 ps
- **Injected beam radius (hard edge):** 0.63 mm
- **Initial accelerating gradient in X-band linacs:** 33.6 MV/m
- **Solenoid field in X-band linacs:** 0.7 kG
• $Q_T = 1 \text{ nC}$
• $E = 67 \text{ MeV}$
• $r_o = 1 \text{ mm}$
• $B_z = 3 \text{ KG}$
• $B_{az} = 750 \text{ G}$
• $E_z = 120 \text{ MV/m}$
• $E_{az} = 33 \text{ MV/m}$
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S. Davies
Accelerator Research Department B

ORION RF GUN Undergoing RF Cold Testing @ UCLA

Neptune Spare RF Gun
## Waveguide Production Status

<table>
<thead>
<tr>
<th>Component</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>-50 dB Coupler</td>
<td>In production</td>
</tr>
<tr>
<td>45 H-Bend</td>
<td>Completed</td>
</tr>
<tr>
<td>X-Band spool piece</td>
<td>Completed</td>
</tr>
<tr>
<td>X-Band Window</td>
<td>............</td>
</tr>
<tr>
<td>E-Bends</td>
<td>............</td>
</tr>
<tr>
<td>H-Bends</td>
<td>............</td>
</tr>
<tr>
<td>Straight Sections</td>
<td>............</td>
</tr>
<tr>
<td>S-Band Window</td>
<td>Completed</td>
</tr>
<tr>
<td>5045 to Scarpus</td>
<td>Completed</td>
</tr>
<tr>
<td>W\G pumping Station</td>
<td>Completed</td>
</tr>
<tr>
<td>RF Loads</td>
<td>On Hand</td>
</tr>
<tr>
<td>-3 dB High Power Coupler</td>
<td>On Hand</td>
</tr>
</tbody>
</table>
### Drive Laser Minimum System Requirements and Performance Enhancements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum System Requirement</th>
<th>Performance Enhancements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse Repetition Frequency</td>
<td>10 Hz</td>
<td></td>
</tr>
<tr>
<td>Laser Energy ¹</td>
<td>&gt; 1 mJ</td>
<td></td>
</tr>
<tr>
<td>Laser Energy Jitter</td>
<td>&lt; 5% rms</td>
<td>Best Effort</td>
</tr>
<tr>
<td>UV Timing Jitter ²</td>
<td>&lt; 500 fs, rms</td>
<td>Best Effort</td>
</tr>
<tr>
<td>Pulse Length (FWHM)</td>
<td>300 fs – 10 ps</td>
<td></td>
</tr>
<tr>
<td>Temporal Amplitude Profile</td>
<td>Gaussian</td>
<td>Uniform ³</td>
</tr>
<tr>
<td>Radial Amplitude Profile</td>
<td>Approx. Uniform</td>
<td>Best Effort ⁴</td>
</tr>
<tr>
<td>MTBF</td>
<td>5000 hours</td>
<td></td>
</tr>
</tbody>
</table>

Footnotes:
1) Measured on a Gaussian temporal and radial profile beam.
2) Measured with respect to a 79 1/3 MHz external master RF clock
3) ≤ 5% ripple, peak to peak, 1 ps rise/fall times on 10% - 90% of full amplitude.
4) ≤ 10% ripple, peak to peak
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Oscillator Subsystem

Laser Head Controls

- Output Coupler (M1 or M2)
  - Horiz. Vert.
- Prism Dispersion
  - Compensation Control (fs)
- Slit Wavelength Selector (fs)
- Slit Bandwidth Selector (fs)
- Laser Head Control Panel
- GTI Dispersion
  - Compensation Control (ps)
- Birefringent Filter
  - Wavelength Selector (FS)
- M1 GTI (ps) or High Reflectivity (FS)
- Water Inlet Connector
- Purge Breach Valve
- Purge Inlet Connector
- Water Outlet Connector
- Mode Locker Photodiode (ML PD) Connector
- Mode Locker (ML) Connector
- Model 3955 (TO 3955) Connector
- Model 3950 (TO 3930) Connector
- LTC Photodiode (LTC PD) Connector
- Blue: Vertical Adj
- Green: Horizontal Adj
ORION LASER OSCILLATOR

FIRST LIGHT @ 800 nm
Photodiode Signal

79.3333 MHz → 12.61 nsec
Spectral Measurement

$\Delta \lambda = 16.1 \text{ nm}$
Autocorrelation Measurement
Autocorrelation Calibration

\[
\frac{T}{t} = 28.33 \text{ psec/msec}
\]

Autocorrelator Calibration

\[
\Delta T_{\text{scope}} (\mu\text{sec}) = 235.3 \mu\text{sec/mm}
\]
Amplifier Subsystem

Evolution X

Diode Pumped Nd:YLF
10 mJ @527 nm 1KHz

Spitfire

Regenerative Amp +
Multi-pass Stage +
future upgrades

Tripler
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Phase Noise Circuit Diagram

VCO

3 dB Coupler

$\Delta \theta$

LASER

Calibration

Photodiode signal

Mixer

1.9 MHz LP

O-Scope
ORION LOW NOISE VCO @ 79 1/3 MHz

0.142° = 1 mV

0.035° @ 79 1/3 MHz

1.28 psec @ 2856 MHz
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\[ \Delta T \sim 500 \text{ fsec} \]

Bandwidth: 1 Hz – 1 MHz

R. Akre and B. Cowan
Possible Noise Sources

- AM/PM conversion of Pump Noise
- PZT Response
GO GIANTS !!!