Experimental Measurements of the ORION Photoinjector Drive Laser Oscillator Subsystem

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Laser Issues for Electron RF Photoinjectors
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Stanford Linear Accelerator Center
1. Introduction
2. Laser System
   1. Oscillator Subsystem
   2. Amplifier Subsystem
3. Phase Noise
4. Discussion
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 X-Band

Diagnostics

111.4 cm

f_n = 2856.050 MHz  f_D = 2852.586 MHz
**250 pC**

<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>

**ORION Baseline case**

**J.B. Rosenzweig et al.**
NLC Structure Support Studies

• $Q_T = 1 \, nC$
• $E = 67 \, \text{MeV}$
• $r_o = 1 \, \text{mm}$
• $B_z = 3 \, \text{KG}$
• $B_z^a = 750 \, \text{G}$
• $E_z = 120 \, \text{MV/m}$
• $E_z^a = 33 \, \text{MV/m}$

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NLC Structure Support
ORION RF GUN Undergoing RF Cold Testing @ UCLA

Neptune Spare RF Gun
Waveguide Production Status

-50 dB Coupler  In production
45 H-Bend  Completed
X-Band spool piece  Completed
X-Band Window  ..........
E-Bends  ..........
H-Bends  ..........
Straight Sections  ..........
S-Band Window  Completed
5045 to Scarpuus  Completed
W\G pumping Station  Completed
RF Loads  On Hand
-3 dB High Power Coupler  On Hand
Laser System Overview

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- Pump Laser
- Ti:Sapphire Laser Oscillator
- Power Meter
- Power Meter Autocorrelator Spectrometer FROG SHG M2
- Multipass Pump
- Upgrade Path: +2 Multipass Amplifier + R & Z Pulse Shaper
- THG
- FROG Power Meter M2
- RF System
- 79 1/3 MHz RF Osc
- 5 W CW
- 1 W 750-850 nm 80 fs
- RS232
- Spare
- 1 mJ 266 nm
- LEAP Cell
# 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
Oscillator Subsystem

Laser Head Controls

- Output Coupler (M1) Horiz. Vert.
- Prism Dispersion Compensation Control (fs)
- Slit Wavelength Selector (fs)
- Slit Bandwidth Selector (fs)
- Laser Head Control Panel
- GT1 Dispersion Compensation Control (ps)
- Brewster Filter Wavelength Selector (PS)
- M1 GT1 (ps) or High Reflector (FS)
- Horiz. Vert.
- Water Inlet Connector
- Purge Breach Valve
- Water Outlet Connector
- Mode Locker Photodiode (ML PD) Connector
- Mode Locker (ML) Connector
- Model 3955 (TC 3955)
- Signal Connector
- Model 3950 (TC 3930)
- Signal Connector
- LTC Photodiode (LTC PD) Connector
- Figure 3-8: The Millennia Xs System (chiller not shown)
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

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

Evolution X

Spitfire

Tripler

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

Regenerative Amp +
Multi-pass Stage +
future upgrades
Phase Noise Circuit Diagram

VCO

3 dB Coupler

Δθ

Calibration

LASER

Photodiode signal

Mixer

1.9 MHz LP

O-Scope
0.142° = 1 mV

0.035° @ 79 1/3 MHz

1.28 psec @ 2856 MHz
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Accelerator Research Department B

△Τ ~ 500 fsec

Bandwidth: 1 Hz – 1 MHz

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Battery Powered External Diode 04/12/02

SSB Spectral Density dBc/ RBW @ 476 MHz

Measurement Noise Floor

RBW = 0.076

Timing Jitter

Frequency Hz - Start of Integration

Battery Powered External Diode 04/12/02

SSB Spectral Density dBc/ RBW @ 476 MHz

Measurement Noise Floor

RBW = 38.147

Timing Jitter

Frequency Hz - Start of Integration
Possible Noise Sources

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