Overview of NLC Injector Systems Activities

J. C. Sheppard

Thursday, October 5, 2000
SLAC
NLC Injector Systems
Presentations This Morning

Injector Systems Overview: J. C. Sheppard
  Introduction/Reminder
    Return of S-Band
    180 Hertz Operation
    Central Injector

Electron and Positron Sources Status and Plans: D. C. Schultz

Damping Rings Status and Plans: J. N. Corlett

J. C. Sheppard
NLC MAC Review October 4-6, 2000
Report of the First Meeting of the NLC Machine Advisory Committee:

Injector System Comments

6. Development of a polarized/un-polarized positron source that can stand high power on the target: See David Schultz’s presentation

Central Injector Considerations: see John Sheppard’s presentation

Choice of C-band linac technology: see John Sheppard’s presentation
The NLC Injector Systems

The NLC Injector Systems include the Electron and Positron Sources, Damping Rings, and Prelinacs required for the generation and preparation of the beams that are injected into the NLC Main Linacs. There are approximately 1.5 km of beamline on the electron side and 2.2 km of beamline on the positron side. RF systems utilize UHF, L-Band, S-Band, C-Band and X-Band technologies. There are conventional electro-magnets, hybrid permanent magnets, superconducting solenoids, and pulsed kickers. It has three damping rings, about 24 GeV of acceleration in seven distinct linacs, a polarized electron source, and a high power, positron generation system. “It’s a big system all by itself.”
The NLC Injector Systems

Positron Injector Systems

Electron Injector Systems
# NLC Injector System Beam Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>$E = 8$ GeV</td>
</tr>
<tr>
<td>Energy Spread</td>
<td>$\Delta E/E = 1%$</td>
</tr>
<tr>
<td>Single Bunch Energy Spread</td>
<td>$\sigma_E/E = 1.5%$</td>
</tr>
<tr>
<td>Horizontal Emittance</td>
<td>$\gamma \varepsilon_x = 3 \times 10^{-6}$ m-rad</td>
</tr>
<tr>
<td>Vertical Emittance</td>
<td>$\gamma \varepsilon_y = 3 \times 10^{-8}$ m-rad</td>
</tr>
<tr>
<td>Bunch Length</td>
<td>$\sigma_z = 90$-$140$ µm</td>
</tr>
<tr>
<td>Electron Polarization</td>
<td>$P_e &gt; 80%$</td>
</tr>
<tr>
<td>Positron Polarization</td>
<td>$P_p =$ No (Stay Tuned)</td>
</tr>
<tr>
<td>Particles/Bunch</td>
<td>$N_b = 1.05 \times 10^{10}$</td>
</tr>
<tr>
<td>Number of Bunches</td>
<td>$n_b = 95$ bunches</td>
</tr>
<tr>
<td>Bunch Spacing</td>
<td>$T_b = 2.8$ ns</td>
</tr>
<tr>
<td>Repetition Rate</td>
<td>$f = 120$ (180) Hz</td>
</tr>
</tbody>
</table>

( for a 10 m $\beta$ function)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Beam Size</td>
<td>$\sigma_X = 44$ µm</td>
</tr>
<tr>
<td>Vertical Beam Size</td>
<td>$\sigma_Y = 4$ µm</td>
</tr>
<tr>
<td>Average Beam Power</td>
<td>$P_B = 150$ kW</td>
</tr>
</tbody>
</table>
e- Injector System CD 0.4, Rev 4

Note: Representations are not to scale, lengths are close approximations

Last Updated 5/9/00
**e+ Injector System CD 0.4, Rev 5**

Note: Representations are not to scale, lengths are close approximations.

Updated 5/9/00

NLC MAC Review October 4-6, 2000
# NLC Injector Systems FY01 Budget Request

<table>
<thead>
<tr>
<th></th>
<th>SLAC</th>
<th>LBNL&lt;sup&gt;2&lt;/sup&gt;</th>
<th>LLNL</th>
<th>Coll</th>
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<tbody>
<tr>
<td></td>
<td>FTE (heads)</td>
<td>M&amp;S (k$)</td>
<td>Total&lt;sup&gt;1&lt;/sup&gt;</td>
<td>FTE (heads)</td>
</tr>
<tr>
<td>Injector</td>
<td>8.00</td>
<td>697</td>
<td>1497</td>
<td>5.8</td>
</tr>
<tr>
<td>Management</td>
<td>1.61</td>
<td>-</td>
<td>161</td>
<td>0.75</td>
</tr>
<tr>
<td>Design</td>
<td>3.77</td>
<td>297</td>
<td>674</td>
<td>2.2</td>
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<tr>
<td>R&amp;D</td>
<td>2.62</td>
<td>400</td>
<td>662</td>
<td>2.85</td>
</tr>
</tbody>
</table>

1. $100k per FTE per annum
2. 1.6 LBNL FTEs assigned to do DR AP; effort not shown here
3. $93k per FTE per annum
4. $123k per FTE per annum
## NLC Injector Systems FY01 Budget Request

<table>
<thead>
<tr>
<th></th>
<th>SLAC</th>
<th>LBNL²</th>
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<tr>
<td></td>
<td>FTE (heads)</td>
<td>M&amp;S (k$)</td>
<td>Total (k$)</td>
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</tr>
<tr>
<td>Management</td>
<td>1.61</td>
<td>-</td>
<td>161</td>
<td>0.75</td>
</tr>
<tr>
<td>Sources</td>
<td>3.65</td>
<td>415</td>
<td>780</td>
<td>-</td>
</tr>
<tr>
<td>Damp Rings</td>
<td>1.39</td>
<td>50</td>
<td>189</td>
<td>5.05</td>
</tr>
<tr>
<td>Inj. Linacs</td>
<td>1.35</td>
<td>232</td>
<td>367</td>
<td>-</td>
</tr>
</tbody>
</table>

1. $100k per FTE per annum
2. 1.6 LBNL FTEs assigned to do DR AP; effort not shown here
3. $93k per FTE per annum
4. $123k per FTE per annum

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J. C. Sheppard  
NLC MAC Review October 4-6, 2000
Return to S-Band

Replacement of C-Band in the 6-GeV prelinacs and drive linac with S-Band is being investigated

Concern over Tolerance Requirements at C-Band

Concern over Required Hardware Development Program for C-Band (Klystrons and Structures)

Cost Increase to Adopt S-Band is due only to longer Tunnel Lengths ($20-30M total for 3 6-GeV Linacs)
NLC Injector Linac Tolerances
(Summer, 2000)

<table>
<thead>
<tr>
<th>Linac</th>
<th>RF Frequency (MHz)</th>
<th>Quad Alignment (µm)</th>
<th>BPM to Quad Alignment (µm)</th>
<th>Struct.-Struct. Alignment (µm)</th>
<th>Cell-to-Cell Alignment (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>e-Booster</td>
<td>2856</td>
<td>500</td>
<td>200</td>
<td>500</td>
<td>??</td>
</tr>
<tr>
<td>e-Booster</td>
<td>1428</td>
<td>500</td>
<td>200</td>
<td>500</td>
<td>??</td>
</tr>
<tr>
<td>Prelinac (S)</td>
<td>2856</td>
<td>-</td>
<td>15</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Prelinac (C)²</td>
<td>5712</td>
<td>-</td>
<td>2 (3)</td>
<td>6 (10)</td>
<td>3(5)</td>
</tr>
<tr>
<td>Main Linac</td>
<td>11424</td>
<td>-</td>
<td>2</td>
<td>12</td>
<td>7</td>
</tr>
</tbody>
</table>

1. Z. Li and T. Raubenheimer
2. Tolerances in ( ) refer to larger iris, short fill, DLDS system
C-Band Technology Development Programs

C-Band Klystron Development: 75MW @ 4 µs 120 (180) Hz

RDDS Structure Development: Similar to X-band RDDS, fewer rf cycles for damping

High Power Pulse Compression Demonstration: Required for full power tests of structures

System Integration Test: No similar systems extant from which to base confidence in success
## C-Band RF Options

<table>
<thead>
<tr>
<th>p.c. system</th>
<th>structures</th>
<th>klystrons</th>
<th>kly. power</th>
<th>pulse width</th>
<th>systems</th>
<th>delay line</th>
<th>linac length</th>
<th>active length</th>
<th>energy/pulse</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLED</td>
<td>58</td>
<td>29</td>
<td>77 MW</td>
<td>3.6 us</td>
<td>29</td>
<td>58 cav. (or 29)</td>
<td>191 m</td>
<td>174 m</td>
<td>8.6 kJ</td>
<td>least efficient (if handle power)</td>
</tr>
<tr>
<td>SLED III (3-cell)</td>
<td>60</td>
<td>29</td>
<td>77 MW</td>
<td>2.97 us</td>
<td>29</td>
<td>58 cav. (or 29)</td>
<td>191 m</td>
<td>174 m</td>
<td>6.6 kJ</td>
<td>Shintake san's</td>
</tr>
<tr>
<td>SLED III</td>
<td>58</td>
<td>29</td>
<td>77 MW</td>
<td>2.97 us</td>
<td>15</td>
<td>2.57 km (1.29 km)</td>
<td>191 m</td>
<td>174 m</td>
<td>6.6 kJ</td>
<td>standard (w/ &quot;circulator&quot;)</td>
</tr>
<tr>
<td>SWIRL</td>
<td>51</td>
<td>17</td>
<td>77 MW</td>
<td>4.74 us</td>
<td>17</td>
<td>1.46 km</td>
<td>169 m</td>
<td>153 m</td>
<td>6.2 kJ</td>
<td>switch not yet developed</td>
</tr>
<tr>
<td>RFD</td>
<td>58</td>
<td>30</td>
<td>77 MW</td>
<td>2.37 us</td>
<td>15</td>
<td>8.69 km</td>
<td>191 m</td>
<td>174 m</td>
<td>5.5 kJ</td>
<td>323m footprint</td>
</tr>
<tr>
<td>SRFD</td>
<td>68</td>
<td>30</td>
<td>77 MW</td>
<td>2.37 us</td>
<td>15</td>
<td>2.48 km</td>
<td>191 m</td>
<td>174 m</td>
<td>5.5 kJ</td>
<td>310m footprint</td>
</tr>
<tr>
<td>MDLDS</td>
<td>60</td>
<td>40</td>
<td>74 MW</td>
<td>1.78 us</td>
<td>5</td>
<td>0.87 km</td>
<td>240 m</td>
<td>180 m</td>
<td>5.2 kJ</td>
<td>extra beamline length</td>
</tr>
<tr>
<td>FMLDLS (1)</td>
<td>60</td>
<td>40</td>
<td>75 MW</td>
<td>1.78 us</td>
<td>5</td>
<td>1.07 km</td>
<td>198 m</td>
<td>180 m</td>
<td>5.3 kJ</td>
<td></td>
</tr>
<tr>
<td>FMLDLS (2)</td>
<td>60</td>
<td>32</td>
<td>76 MW</td>
<td>2.37/1.77 us</td>
<td>4</td>
<td>1.69 km</td>
<td>198 m</td>
<td>180 m</td>
<td>5.5 kJ</td>
<td></td>
</tr>
</tbody>
</table>

C. Nantista, ISG5 February, 2000 SLAC
Unit C-Band RF Module

G = 35 MV/m

ΔE = 420 MeV

RDDS Structure
Folded Multi(2)-Moded DLDS for NLC C-Band Injector Linacs

(scheme 2)

60 structures: \(L=3\text{m}, \quad T_f=300\text{ns},\)
\(\tau=0.49, \quad r=75\ \text{M}\Omega/\text{m}\)

32 klystrons: \(P_k=77\text{MW}, 24 @ \quad T_k=2.37\mu\text{s}\)
\(8 @ \quad T_k=1.78\mu\text{s}\)

4 FMDLDS’s: 3 \(\text{w/ 4 feeds, } \eta=0.80?\)
\(\text{w/ 482m of WC950}\)
1 \(\text{w/ 3 feeds,}\)
\(\text{w/ 241m of WC950}\)

198 m
(180m active)

1.687 km total delay line / 6GeV linac

C. Nantista, ISG5 February, 2000 SLAC
Unit S-Band RF Module

- $G = 17 \text{ MV/m}$
- $\Delta E = 408 \text{ MeV}$
- RDS Structure
Work Needed to be Done in regards to the C-Band to S-Band Replacement

Write the Memo on C-Band
- Document the Design Choices and Options
- Document the Estimated Capital Costs
- Document the Required Technology Development Programs

For S-Band
- Redo Injector linac layouts
- Redo Conventional Facility requirements and estimates
- Redo overall Estimated Capital Costs

Make the Decision, and
- Begin S-Band rf Modeling and Power Combiner Demonstration
  or
- Begin C-Band Technology Development Programs

J. C. Sheppard
NLC MAC Review October 4-6, 2000
Issues Related to 180 Hertz Operation

Specifications unchanged except for rate change from 120 Hz to 180 Hz

Average power increase, largely conventional facilities issues

Average power for sources and solenoid klystrons should not be too much of a problem (more water)

Biggest issue is the need to rethink the damping ring design; not enough time-to-damp at 180 Hz with present layout

Are concerned with increased radiation levels
Issues Related to 180 Hertz Operation, cont’d

Sources

Increase average power of source laser by 50%,
Do not think this is a problem but need to ask the experts;
No changes within time frame of a single pulse.

Peak power deposition unchanged in positron target;

Can increase diameter of target and water flow to mitigate average temperature, expect same rate of material fatigue due to radiation damage in a larger diameter target

Higher average power supplies for flux concentrator
Issues Related to 180 Hertz Operation, cont’d

Damping Rings

Major redesign effort required to handle reduced interpulse period; presently looking into doubling the number of damping rings; also need to look into the predamping ring performance.

Higher average power supplies for pulsed injection/extraction kickers;

Heighten concern in regards to radiation damage to beamline components; this is already a problem at 120 Hz.
Issues Related to 180 Hertz Operation, cont’d

Linacs

More electrical power and cooling capacity required

Klystrons should not be a problem

Modulators need larger dc supplies

Increased time slot jitter (line lock?)

More vibration from increased water flow in beamline components

Increased bandwidth for feedbacks, could be better
Plan of Attack for 180 Hertz Operation

Collect Issues and Concerns

Address them Individually

Call on Experts as Needed

Update Functional Requirements

Roll into the Machine Configuration

Update and Track Costs
Central Injector Considerations

From an Operations standpoint expect reduction in required injector staff, maintenance inventory and staff, and time to repair

Potential reduction of required utilities (?)

Possible to share beam housings to reduce cost

Well matched to a short linac now, long linac later approach to an NLC upgrade scenario

More complicated commissioning tactics required

Should work well, costs are down from the 1999 values, in general, and to the surmise of the use of permanent magnets for the added transport line arcs, in particular
The NLC Injector Systems

Positron Injector Systems

Electron Injector Systems
The NLC Injector Systems
Initial Central Layout

- **Positron Injector Systems**
  - e+ Main Linac
  - e+ Transport line
- **Electron Injector Systems**
  - e- Main Linac
  - e- Transport line

IR 1
IR 2
Basic Central Injector Layout
(Expanded Vertical Scale)

~26 km

10 mrad Big Bend

1 km

5 km
Central Injector Considerations, cont’d

There are many other variants

There are at least 2 variants per “expert”

And there are lots of “experts”

The problem is to settle out on a “favorite” central scheme

This is not a complaint, just an observation
Central Injector Development Plans

Develop layout

Identify Required Technology Development
(long pulse klystrons and modulators)

Generate Cost Estimates

Do Tracking Studies to Determine Alignment Tolerances

Revisit Bunch Compression Scheme

Develop Installation/Commissioning Scenarios

Present Layout to NLC Group in January, 2001