WORKING GROUP 2
INJECTORS
H. Hayano and M. Ross, Chairmen

Presentations

H. Hayano, “Linac Beam Stability”
S. Takeda, “Injector Linac Performance”
S. Kashiwagi, “ECS Performance”
K. Kubo, “Lattice Diagnostic (Linear Optics and Beta-Match)”
T. Naito, “Performance of SR Monitor”
H. Hayano, “Performance of Alignment Method”
J. Urakawa, “Summary of Ring Circumference Issue (Including Wiggler Issue)”
N. Terunuma, “Summary of Vacuum Chamber Design Including Ring Impedance”
T. Okagi, “Performance of Orbit Measurement”
J. Urakawa, “Summary of Emittance Tuning”
T. Raubenheimer, “Parameters - Combined Session”
D. Yeremian, “Bunching Stability”
J. Turner, “Injector Linac Performance”
W. Decking, “Overview of ALS Performance”
P. Krejcik, “Overview of Ring Performance”
M. Woodley, “Model Performance and Aperture Measurements”
D. McCormick, “Loss Monitor Performance”
M. Minty, “Matching and Damping Monitors”
B. Podobedov, “Instabilities”
M. Minty, “RF System Performance”

F. Zimmerman, “Ion Effects”

S. Kurdoda, “Compressor Optics”

J. Frisch, “Laser Performance”

T. Kotseroglou, “Laserwire”
FIRST LC ISG WORKSHOP

SLAC

January 26-29, 1998

Summary Talk

WG 2: M. Ross
First meeting - begin collaboration work for developing the linear collider design.

Injector Working Group 2 -

Collect relevant performance and lesson issues from ATF, ALS, SLC.

Develop a prioritized list for work in the next 6 months annotated with expectations and goals

Examples:

* Beam transmission in the injector complex*
* Bunching, energy and intensity stability*

Do not detail specific hardware lessons

国際協力
Where are the challenges in Injector design?

How do we decide if the experience relevant?

Naive LC design priority table:

<table>
<thead>
<tr>
<th>Design</th>
<th>concern</th>
<th>physics</th>
<th>challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injector</td>
<td>reliability</td>
<td>stability</td>
<td>complexity</td>
</tr>
<tr>
<td>Linac</td>
<td>volume</td>
<td>optimization</td>
<td>cost</td>
</tr>
<tr>
<td>BD/IP (later ISG)</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

Top row of table is the first result from the group

Injector reliability- obvious concern: backed up with SLC experience

Stability issues - most serious physics involved

- Many time scales and sources

- Complexity - large range of design issues: most difficult design to optimize
FIRST DRAFT COST MODEL

BEAMLINE COMPONENTS
PLUS FACILITIES

Irwin
LC 97
SLC Damping Ring Lessons:

Publications since 1990 (crudely categorized):

<table>
<thead>
<tr>
<th>Date</th>
<th>Subject</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>Ions</td>
<td>3</td>
</tr>
<tr>
<td>1991-1997</td>
<td>Instabilities (mostly longitudinal)</td>
<td>5</td>
</tr>
<tr>
<td>1993-1997</td>
<td>Impedance (longitudinal stability studies)</td>
<td>3</td>
</tr>
<tr>
<td>1992-1997</td>
<td>RF, Longitudinal dynamics, bunch rotation (help compression)</td>
<td>8</td>
</tr>
<tr>
<td>1991-1995</td>
<td>Emittance, Damping</td>
<td>8</td>
</tr>
<tr>
<td>1991-1995</td>
<td>Kicker</td>
<td>5</td>
</tr>
<tr>
<td>1993</td>
<td>Polarization</td>
<td>1</td>
</tr>
<tr>
<td>1992</td>
<td>Multi-bunch instability ($\pi$)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>34</strong></td>
</tr>
</tbody>
</table>

2 most serious design problems: emittance/damping and longitudinal instabilities/RF

(70% of the papers)
## ALS compared to Damping Ring

<table>
<thead>
<tr>
<th>Energy [GeV]</th>
<th>$\gamma \epsilon_x$ [mrad mm]</th>
<th>$\tau_x$[msec]</th>
<th>$\tau_y$[msec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9</td>
<td>21</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>1.5</td>
<td>10</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>1.0</td>
<td>2.9</td>
<td>52</td>
<td>74</td>
</tr>
<tr>
<td>1.5 (detuned QFA)</td>
<td>4.4</td>
<td>17</td>
<td>21</td>
</tr>
</tbody>
</table>

with Wiggler (4m long, $B = 2T$, $\lambda = 0.2m$) in 12 straights

<table>
<thead>
<tr>
<th>Energy [GeV]</th>
<th>$\gamma \epsilon_x$ [mrad mm]</th>
<th>$\tau_x$[msec]</th>
<th>$\tau_y$[msec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9</td>
<td>11</td>
<td>3.3</td>
<td>3.7</td>
</tr>
<tr>
<td>1.5</td>
<td>5.3</td>
<td>5</td>
<td>5.5</td>
</tr>
<tr>
<td>1.0</td>
<td>2.9</td>
<td>8.9</td>
<td>9.4</td>
</tr>
</tbody>
</table>

**NLC requirements**

|                |                               | 5              | 5              |

(* from 0th order design report)

**ATF design**

|                |                               | 3.7            | 6.8            | 9.1 | @ 1.54 |
Clearly - a different design strategy is required
(compared to the linac)

How should we optimize the injector design? (1)

(we see the linac optimization in progress!)
‘Over-design’ may be justified because of the complexity
SLC experience -> develop integrated design

Second result: Examine the process of defining
engineering margins

Enumerate (list) tolerance items, esp. stability, for
upstream subsystems. (2)

Since the injector cost is a small fraction of the LC total
and the tasks are difficult -> 1) will take several years to
converge and 2) must test if possible.

Develop questions for ATF, SLC injector, and ALS to
answer (3)
Some specific technical issues for our list:
consistent with ISG strategy - not inclusive - (yet)

Gun and Buncher

Gun performance
testing for SLAC high I fixed target exp. E158

Bunching optimization
How do we integrate this with downstream systems?

Linac and transport

Evaluate energy compensation techniques
Δf, Δt and PSK pulsing

Beam transmission issues - radiation concerns

RF stability and instrumentation

Ring

Longitudinal stability and bunch lengthening
actual 40% larger than design - SLC

Wiggler radiation power dissipation

Ring circumference control

Ring duty cycle control

Transient behaviour
With a 2D space charge ne [3] and the beam EGun [4]. The mag-was calculated using how good correspond-
ized the bunching and capture into 20° of 4x10^{10} e- in a 3.2 m-
traction.
Buncher amplitude was all other electric field.
utation, and emittance to the intensity moni-
chonic and relativistic.

% energy spread. For only those particles of S-Band, resulting
electron captured in buncher amplitude. As an almost parabolic
equation was used in peak. The peak lies at
by change per percent amplitude for change cappa-
sharp rise in jitter parameter amplitude.
red buncher is 0.4%, lower phase shifter. We this amplitudes jitter
of S-Band buncher is set at some nominal to vary by 0.4%, by

Figure 2. Capture vs. S-Band buncher amplitude.

Figure 3. Percent intensity change per percent amplitude change vs. S-Band buncher.

Figure 4. Total charge vs. S-Band buncher amplitude.
Experimental Setup for ATECS

We preliminary tested PM-to-AM modulation using two-klystoron combination at ATF linac. The 2856 MHz phase shifter (No. 1) tune rf phase to the beam. And by using Delay & Pulse Modulator, it is modulated into a short pulse with 4.5 μs width and the rf timing to klystron modulator main trigger is adjusted. The phase shifter (No. 2) is used to rotate the drive phase. A control pulse of the phase shifter is generated by combining two output pulse with 1.0 μs width of pulse generators (HP 8112A), and change a leading edge (LEE) of the other pulse generator.
Bunch lengthening:

- Microwave instability threshold peak current
  \[ I_p = \frac{2\pi n \left[ E_0 \left| \frac{Z_b}{n_{\text{effective}}} \right| \right]^2}{Z_s} \]

- Predict threshold 100 A peak, 1.75 mA average

- Bunch length above threshold
  \[ \sigma_l^2 = \frac{\alpha R^3}{2 n^2 E_0^2 Q_s^2} \left| \frac{Z_b}{n_{\text{effective}}} \right| I_b \]

- Measured threshold
  2 mA

- Measured \(|Z/n|_{\text{effective}}\)
  0.22 Ω
Instability pattern vs. beam current, $V_g=800\text{kV}$


Preliminary
IV POSSIBLE PROJECTS

1. CAVITY DESIGN TESTS (ALS, SLC/KEK B-FACTORY, ATE)
   Compare longitudinal spectrum w/ expectation
   (vs. current, phasing, voltage, etc.)

2. ATF/ILC BxD FB DESIGNS

3. DEMONSTRATE FFN TECHNIQUE FOR HI CURRENT,
   HI REP RATE INJECTION (SLC, ATF, ALS)
   (SLC c⁻², e⁻¹ - EFFECT ON STORRED BEAM)

4. FAST TUNER DESIGN

5. HIGH POWER KLYSTRON (CLW) DEVELOPMENT

6. EXTRACTION PHASE SPREAD, MULTIBUNCH
   a) SHORT CAVITY BE-CLEAN
   b) RF CONCEPT
   c) RF TEST (ATE)

7. TIMING FE DESIGNS FOR ILC
   a) DOUBLE KNOX SCHEME + SHIFT INJECTOR
      TIMING RELATIVE TO DR/DE COMPRESSOR
   b) DOUBLE LINACS + SHIFT ALL UPSTREAM
      SYSTEM RELATIVE TO IP

8. JITTER / BEAM DYNAMICS STUDIES: \( \tau_c(s) \) INSTABILITY
   (NOT OBVIOUSLY RELEVANT FOR ILC, BUT IN TUNE:
   WITH PRE-AntIcIPATeD PROBLEM PHILOSOPHY)
   75MHz operation

9. DEVELOP "NOISE" TOLERANCES
   Evaluate consequences of fixed \( f \) / FB for \( \Delta f \)
   \( \Delta f = 35 \text{ ppm} \)
   SLC DR FIXED \( f \), EVIDENCE OF \( \Delta f \)
   \( \Delta f \) MAX ~ 20 kHz (177)
   (J. Wiermeyer)
   ALS \( \Delta f \) \#0
   (M. Dekker)
   \( \Delta f = 16 \text{ ppm} \)
   APS BIJOURNAL \( \Delta f \) FEEDBACK
   (A. Limpert)
   \( \Delta f = 2 \text{ ppm} \)
   NIC MDR \( \Delta f = 1.4 \text{ ppm} \)
   \( \Delta f = 2 \text{ ppm} \)
Instrumentation items: evaluate applicability

Beam position monitor strategy
multi-bunch, multi-turn, dynamic range

Synchrotron radiation monitor

Bunch length and phase
SLC issue - shaping
Accuracy, resolution and operability

Beam loss monitor
Layout of the SR-interferometer
DR Emittance measurement by SR Interferometer (T. Mitsuhashi)

11/28/97

SR Interference Pattern

ATF group

Fringe Pattern

ATF Beam Size

<table>
<thead>
<tr>
<th>distance_of_double_slit (mm)</th>
<th>spatial_coherence</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>20</td>
<td>0.86</td>
</tr>
<tr>
<td>40</td>
<td>0.72</td>
</tr>
<tr>
<td>60</td>
<td>0.58</td>
</tr>
<tr>
<td>80</td>
<td>0.44</td>
</tr>
<tr>
<td>100</td>
<td>0.30</td>
</tr>
</tbody>
</table>

11/21/97

- $\sigma_y \leq 27.4 \mu m$
- $\epsilon_y \leq 3.3 \times 10^{-10} m$

11/28/97

- $\sigma_y \leq 34.0 \mu m$
- $\epsilon_y \leq 5.1 \times 10^{-10} m$

(assumed to design $\beta^*_y$)
Instability results in ≤10% bunch length variation.
Quadrupole mode contains ~3% of the beam.
Offline analysis. Here is a typical signal from a single point, single bunch loss.

If the 63rd bunch hits the beam pipe wall 10% harder the signal might look like this.
Conclusions from Injector Working Group 2:

Not easy to directly develop task list
Nature of topic

Looked at symptoms, problems...
fascinating

Priority to stability issues

22 talks were given - one copy made for KEK and one for SLAC

Hayano and I will make a more comprehensive summary in the next week
(somewhat subjective)
SDRXCOR 'fudge' factors

SDRYCOR 'fudge' factors

ms = 42%

ms = 16%
NDRXCOR "fudge" factors

NDRXCOR 'fudge' factors

NDRYCOR 'fudge' factors

Ortho YCOR 'fudge' factors
FIRST LC ISG WORKSHOP

SLAC

January 26-29, 1998

Summary Talk

WG 2: P. Krejcik
Introduction to
Injector Working Group I
Effect of Bunch Spacing and Train Length
Working Group Coordinators: Krejcik/Kuroda
Scientific Secretary: Kotseroglou

Goals

1. Clarify exact injection requirements of high energy linac. Distinguish between required and optional specifications for injector.

2. Review parameters of each accelerator system in the injector
   - guns
   - source lasers
   - bunching system
   - S-Band injector linacs
   - damping rings
   - bunch compressors
   - beam diagnostics
   - positron production

3. Identify accelerator subsystems impacted by bunch spacing and train length, e.g.
   - lasers
   - damping ring RF
   - damping ring kickers
   - ....

4. Which subsystems need further design work and which components need engineering R&D.

5. Develop a time scale for accomplishing the above tasks and the resources required. Distinguish between short term (6 months) projects, e.g. making design parameters for a new kicker; and long term goals, e.g. making a comprehensive parameter list for the injector.

6. Make recommendations for what bunch spacings and train lengths are possible and still meet the beam parameter specifications.
1996:

\[ 90 \times 1.4 \text{ns} \quad 0.9 \times 10^{10} \text{ ppb} \quad 180 \text{ Hz} \]

1998:

\[ 81 \times 2.8 \text{ns} \quad 0.9 \times 10^{10} \text{ ppb} \quad 120 \text{ Hz} \]

Option:

\[ 162 \times 1.4 \text{ns} \quad 0.6 \times 10^{10} \text{ ppb} \quad 120 \text{ Hz} \]

Proposed Bunch Spacing and Train Length Changes
Injector Subsystem Components

Source Laser

Electron Gun

Bunching System

Damping Ring

First Bunch Compressor

2 GeV S-Band Linac

2 GeV Linac

10 GeV S-Band Linac

Second Bunch Compressor

6 GeV S-Band Linac

Pre Damping Ring

First Bunch Compressor

10 GeV S-Band Linac

Second Bunch Compressor

E+ High Energy Linac

E- High Energy Linac

Therm Gun

Positron Target

e+ Capture Section
Introduction to
Injector Working Group I
Effect of Bunch Spacing and Train Length
Working Group Coordinators: Krejcik/Kuroda
Scientific Secretary: Kotseroglou

Schedule
Monday 13:30 - 15:30
Monday 16:00 - 17:30
Wednesday 10:00 - 12:00
Total 5 ½ hours
Thursday 9:00 - 10:00 Summary talk planning

Topics
1. Goals and Intro to WG1
2. Gun and Bunching
3. Source Laser
4. Injector S-Band Linacs
5. Energy Compensation Scheme
6. Damping Rings Circumference and Optics
7. Damping Rings RF
8. Damping Rings Kickers
9. Bunch Compression
10. Injection/Extraction Timing
11. Instrumentation
12. Other Effects
13. Positron Production

- Krejcik/Kuroda
- Hayano/Yeremian
- Frisch/Kotseroglou
- Takeda
- Kashiwagi
- Kuroda/Krejcik
- Kubo/Corlett
- Terunuma/Donaldson/Mattison
- Okugi
- Naito
- Hayano/Ross
- Urakawa
- Kulikov
Injector Working Group I
Effect of Bunch Spacing and Train Length

Draft Schedule

(based on average of 20 min + 5 min per topic)

Monday January 26
Sources and Linacs
13:30 Goals and Intro to WG1 - Krejcik/Kuroda
13:55 Gun and Bunching - Hayano/Yeremian
14:20 Source Laser - Frisch/Kotseroglou
14:45 Injector S-Band Linacs - Takeda
15:10 Energy Compensation Scheme - Kashiwagi
15:30 coffee
Damping Rings
16:00 Damping Rings Circumference and Optics - Kuroda/Krejcik
16:25 Damping Rings RF - Kubo/Corlett
16:50 Damping Rings Kickers - Terunuma/Donaldson/Mattison
17:15 Injection/Extraction Timing - Naito

Wednesday 28
10:00 Bunch Compression - Okugi
10:25 Instrumentation - Hayano/Ross
10:50 Other Effects - Urakawa
11:15 Positron Production - Kulikov
11:30 Discussion
12:00 lunch

Thursday 29
9:00 - 10:00 Discussion of Action Items and Summary Talk Planning
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Effect of Bunch Spacing and Train Length
Working Group Coordinators: KrejciKuroda
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10 GeV S-Band Linac

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Therm Gun

6 GeV S-Band Linac

Positron Target

e+ Capture Section

2 GeV Linac

Pre Damping Ring

Damping Ring

First Bunch Compressor

10 GeV S-Band Linac

Second Bunch Compressor

e+ High Energy Linac
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Injector Working Group I

Effect of Bunch Spacing and Train Length

Working Group Coordinators: Krejcik/Kuroda
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- Krejcik/Kuroda
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Highlights from Injector Working Group I

Day 1

Bunch Spacing/Train Length Issues

1. Goals
   Look for ways of keeping options open for
   1.4 ns and 2.8 ns
   future polarized e+ sources

2. Gun
   Thermionic gun easier at 357 MHz
   Bunching System
   Beam loading is less for longer trains
tolerances are looser at 357 MHz
   Will propose a prioritized list of studies/calculations for
gun/buncher

   Intensity
   Demonstrate ILC parameters
   possible on a 6-12 month time scale
   with laser development

3. Source Laser
   New design with frequency domain shaping
   plus dispersive temporal shaping of pulse
   investigate further fiber as dispersive element
   whose time delay also makes intensity stabilization
   feedback easier
   Development closely parallels LCLS laser
   develop oscillator system - 6 month time frame
   longer term development of YAG pump system for the
   Ti:Saphire Amplifier

4. Injector linacs
   no major problems going to longer bunch trains
   over the next 6 months recalculate
   long and short range wakes for long-train parameters
qualitatively, multi-bunch problems easier with lower average current of longer train.
Include DDS S-Band structures in new calculations

Energy Compensation Schemes
beam loading reduced when average current in train lower
but problem still exists since $T_{\text{train}} > T_{\text{fill}}$
Analyze relative merits of Af and At schemes
NLC and JLC schemes converging $\rightarrow$ to ILC design
need to calculate
AE in prelinac
tolerances on phase control
At scheme for long train parameters
review SLAC long pulse scheme Wednesday (F-J.D)

5. Damping Rings
slight increase in circumference to accommodate longer bunch trains
results in longer damping times
compensated in NLC design with longer store time (lower rep. rate)
compensated in JLC design by adding more wigglers to maintain $\tau_D$
then detune arcs to maintain $\alpha_{\text{mm}}$
recalculate ZDR DR parameters for new bunch trains
beam loading issues easier at lower average I

slight decrease in $f_{\text{rev}}$ can impact growth of multi-bunch instabilities from fundamental mode

RF system is easier at lower average I
prefer 357 MHz from point of view of beam loading
RF power excluding satellite bunches
but loses option for 1.4 ns spacing
Kickers
no problem with longer flat top pulse
main issue remains rise time
lower average current in ring would allow
thinner metallization of ceramic chambers,
allowing faster rise time
larger ring circumference means longer kicker
magnets can be accommodated. OK!
Propose R&D program on high impedance
kickers:
lower voltage permits use of faster FETs
instead of thyratrons
can use vacuum insulation instead of
epoxy, less susceptible to radiation
damage.

Kickers maybe critical for Pre-Damping Ring,
where beam size dominates required kicker
strength.

6. Timing
no problems foreseen
Summary
Injector Working Group I
Effect of Bunch Spacing and Train Length
Working Group Coordinators: Krejcik/Kuroda
Scientific Secretary: Kotseroglou

The Question
Compatability of injector parameters and components with:

a.) a longer pulse train, -227 ns and lower rep.rate of 120 Hz
b.) doubling the bunch spacing to 2.8 ns
c.) long train with twice as many bunches at 1.4 ns and reduced charge per bunch of 0.6*10^10

Constraints
Train length dictated by klystron requirements in HEL.
Detector considerations will strongly influence bunch spacing.

So prefer to maintain a flexible design.

Recommendation
is therefore based on indicating what tradeoffs are made in the new parameters set, plus identify which components need design changes and whether any systems would fail to meet the new specifications.
Proposed Bunch Spacing and Train Length Changes
What we did

- Review all accelerator systems:
  - Source Laser
  - Gun
  - Sub Harmonic Bunchers
  - Injector Linac and Energy Compensation Scheme
  - Damping Rings
  - Compressor and pre-linac
  - Positron Target

- Identify component changes
  - Source laser
  - Damping Ring
    - Circumference
      - fixed $f_{rep}$ and $\tau_D$ $\Rightarrow$ more wigglers (Kuroda)
      - or, lower $f_{rep}$ and $\tau_D$ $\Rightarrow$ scale existing design
    - Kickers
      - longer pulse is OK
        - rise time an issue, since sets train separation, circumference etc., so propose R&D
Injector Subsystem Components

Source Laser

Electron Gun

Bunching System

2 GeV S-Band Linac

Damping Ring

First Bunch Compressor

10 GeV S-Band Linac

Second Bunch Compressor

6 GeV S-Band Linac

Damping Ring

Pre Damping Ring

10 GeV S-Band Linac

Second Bunch Compressor

3.8 GeV Linac

Positron Target

e+ Capture Section

8 GeV Accumulator

High Energy Linac

Therm Gun

2 GeV Linac

First Bunch Compressor

Damping Ring

e- High Energy Linac

Second Bunch Compressor

10 GeV Linac

Second Bunch Compressor

e+ High Energy Linac
Tasks for the coming 6-12 months

1. define the number of e+ per pulse above which L-Band is required instead of S-Band in the capture section.

2. e+ target heating dynamics calculation

3. look for any possible conflicts in the injector with future options, e.g. e+ source

4. Evaluate the different ECS schemes for the new train parameters and compare them. Consider testing some of these at ATF.

5. Evaluate the necessity of a DDS for the S-Band linac

6. If required, then what would it look like, in engineering terms.

7. Study beam loading compensation in bunchers, e.g. direct feedback, possibly tested at ATF.

8. Calculation of gun, SHB, ECS, linac with new train parameters

9. Calculation of long and short range wakes for new parameters

10. Continue damping ring evaluation with new parameters, especially pre-damping ring. Do wigglers effect polarization?

11. High impedance, fast rise-time kickers (<60 ns) R&D

12. Source laser R&D, low risk, but take advantage of other laser projects

13. Draw up specifications for diagnostic requirements e.g. BPMS

14. How does variable intensity, train length, rep.rate (necessary for machine protection) impact all of the above.
Conclusions Regarding Choice of:

a.) longer pulse train

lower av. current beneficial everywhere,

design changes to laser, kicker are reasonable.

b.) 2.8 ns bunch spacing

wider bunch spacing would also allow lower RF frequency in SHB and rings, easier still for beam loading

effect of long and short range wakes also less;

diagnostics able resolve individual bunches in train.

c.) long train plus short 1.4 ns spacing

beam loading increases 50%, but still lower than NLC ZDR;

need to keep RF frequencies as before;
lose individual bunch resolution.
don’t exclude satellite bunches.
Diode pumped, frequency doubled YAG laser. 5W CW, (commercial)

Pockels cells for bunch control

Ti:Sapphire mode-locked oscillator. 300fsec, 714MHz 1mJ.

Diode pumped frequency doubled YAG laser. Long pulse, High stability 1μs 50nJ, 0.1% RMS stability

1mJ

Ti:Sapphire multi-pass amplifier G = 1000. Spectrometer for spontaneous rejection

100nJ

Macropulse rate control

50μJ

Intensity control

Electron gun

Fourier shaping and dispersive section

~500psec, 714MHz, 100pJ

Liquid crystal spatial modulator for bandwidth selection

ILC Source Laser (no satellite bunches)
2.8ns Bunch spacing effect to Gun and Bunching Section design

H. Hayano

Thermionic Electron Gun

240kV Pulse HV + 714MHz burst grid-pulser

\[ 1.4\text{ns} \sim 120\text{ms} \]

\[ \downarrow \]

240kV Pulse HV + 357MHz burst grid-pulser

(similar to ATF)

85 bunch, 150Hz, \( 2 \times 10^{10} \) /bunch\@Gun

longer flat HV pulse (240ns)

357MHz grid response will be better than 714MHz

Polarized Electron Gun

200kV DC HV + Photo-cathode + 1.4ns spacing burst Laser

\[ \downarrow \]

200kV DC HV + Photo-cathode + 2.8ns spacing burst Laser

burst laser by split & combine

not so much difference
© Effect of changing bunch spacing and pulse length

- **Δf method**
  - Energy spread: 0.1% → 0.6%
  - ΔE in pre-sinus.

- **ΔT method**
  - Energy spread: 0.1 → 0.8%
  - (linear control)

- rf phase control
  - (optimum structure parameters)
  - (filling time etc.)
At Beam Loading Compensation in the Injector Linac

Inject the beam on the slope of the filling time of the RF in the accelerator section.

Shape the slope of the accelerator voltage by amplitude modulating the SLED 1 output, which is achieved by modulating the input RF into the SLED 1 by shifting the 2 klystrons by 90° opposite from each other and then shifting them by another 90° in the same respective directions during the fill time of the RF.

Using this method we are able to reduce the train energy spread to less than 0.003% in the injector linac.
Advantages of 28ns scheme:

1. Have been current
2. Reduce coupled bunch instabilities growth rates (?)
3. Reduce beam loading
4. Reduce RF power requirements

Advantages of 357 MHz system:

1. No "parasitic" bunches @ 1.4 ns
2. RF power readily available
3. Power density reduced (?)
4. Beam loading reduced

Advantages of 714 MHz system:

1. Fewer HEM's to damp
2. Slightly reduced power requirements (with 28ns bunch spacing)

Need more detailed studies of 357 MHz system, but looks promising.
Bunch Spaceing 1.4ns --&gt; 2.8ns
for the JLC Bunch Compressor Design

There are several energy compensation system for the both of pre-linac and BC2 cavity section. If the bunch spacing is changed to 2.8ns, the superior of each methods also are changed. Fortunately, the requirements of bunch compression for the pre-linac and BC2 cavity are not so tight. ( except for the emittance growth at pre-linac etc. )

So, the bunch compressor can be corresponds to 2.8ns bunch spacing below conditions.

1) ECS system of the pre-linac should be select within the energy deviation of 0.7% and phase deviation of 1 degree.
2) ECS system of the BC2 cavity should be selected the \( \Delta f \) method without SLED cavity.
2.8ns Bunch spacing effect to Instrumentation

H. Hayano

357MHz pulse measurement is clearly easier than 714MHz

Each Bunch Measurement in the train

BPM(Beam Position Monitor)
Fast S/H BPM

BSM(Beam Size Monitor)
Wire scanner + gate PMT
Laser Wire scanner + gate PMT
Laser Interference + gate PMT

streak camera

BCM(Bunch Charge Monitor)
Wall-current monitor + Fast S/H
Positron Target Limits

1. Single pulse limit

\[ \theta = 2 \, E \cdot \Delta T \propto W \cdot \frac{\Delta E}{c \cdot A} \]
\[ \theta \leq \frac{G_T}{2} \]

2. Average power

\[ \bar{\theta} \]

3. Pulse length effects

short pulse \(<\ 100\ \text{sec} \ <\ \text{long pulse} \)
**Highlights** from Injector Working Group I

**Day 1**

**Bunch Spacing/Train Length Issues**

1. **Goals**
   Look for ways of keeping options open for 1.4 ns **and** 2.8 ns future polarized e+ sources

2. **Gun**
   Thermionic gun easier at 357 MHz

   **Bunching System**
   Beam loading is less for longer trains
   tolerances are looser at 357 MHz
   *Will* propose a prioritized list of studies/calculations for gun/buncher

   **Intensity**
   Demonstrate ILC parameters
   possible on a 6-12 month time scale
   with laser development

3. **Source Laser**
   New design with frequency domain shaping
   plus dispersive temporal shaping of pulse
   investigate further fiber as dispersive element
   whose time delay also makes intensity stabilization feedback easier
   Development closely parallels LCLS laser
   develop oscillator system - 6 month time frame
   longer term development of YAG pump system for the Ti : Saphire Amplifier

4. **Injector linacs**
   no major problems going to longer bunch trains
   over the next 6 months recalculate
   long and short range wakes for long-train parameters
qualitatively, multi-bunch problems easier with lower average current of longer train.
Include DDS S-Band structures in new calculations

Energy Compensation Schemes
beam loading reduced when average current in train lower
but problem still exists since $T_{\text{train}} > T_{\text{fill}}$
Analyze relative merits of $A_f$ and $A_t$ schemes
NLC and JLC schemes converging $->$ to ILC design
need to calculate
AE in prelinac
tolerances on phase control
At scheme for long train parameters
review SLAC long pulse scheme Wednesday (F-J-D)

5. Damping Rings
slight increase in circumference to accommodate longer bunch trains
results in longer damping times
compensated in NLC design with longer store time (lower rep. rate)
compensated in JLC design by adding more wigglers to maintain $\tau_B$
than detune arcs to maintain $\alpha_{\text{min}}$
recalculate ZDR DR parameters for new bunch trains

beam loading issues easier at lower average I

slight decrease in $f_{\text{rep}}$ can impact growth of multi-bunch instabilities from fundamental mode

RF system is easier at lower average I
prefer 357 MHz from point of view of beam loading
RF power
excluding satellite bunches
but loses option for 1.4 ns spacing
Kickers

no problem with longer fiat top pulse
main issue remains rise time
lower average current in ring would allow
thinner metallization of ceramic chambers,
allowing faster rise time
larger ring circumference means longer kicker
magnets can be accommodated. OK!
Propose R&D program on high impedance
kickers:
lower voltage permits use of faster FETs
instead of thyratrons
can use vacuum insulation instead of
epoxy, less susceptible to radiation
damage.
Kickers maybe critical for Pre-Damping Ring,
where beam size dominates required kicker
strength.

6. Timing
no problems foreseen