ILC Particle Sources
-Electron and Positron-

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Introduction

- Electron Polarization is important for ILC.
  - NEA GaAs is practically the only solution.
- Positron polarization is desirable, but not mandate.
  - E-driven Positron source is unpolalzed.
  - E-driven is matured and simple.
  - Undulator Positron source is polarized 30%.
  - Undulator Positron source is complicated resulting a long commissioning and potential less availability.
Electron Source
ILC Electron Source

- DC photo cathode gun with GaAs cathode.
- Two identical guns are for redundancy.
- Buncher for short bunch length.
- NC up to 76 MeV followed by SC up to 5 GeV.
- Spin rotator and energy compressor.
ILC Pulse Structure

Macro Pulse

Macro Pulse:
- Duration: 0.6ms
- Interval: 200ms
- Charge: 8400nC

Micro Pulse

Micro Pulse:
- Duration: 550ns
- Interval: 1ns / 10ps
- Charge: 3.2nC
DC photo-cathode gun

- Laser photocathode with NEA GaAs for polarized electrons.
- Beam extraction by a static electric field, because RF gun is not compatible with NEA GaAs cathode.
- Due to the voltage limitation, the bunch length is 1.6 ns to extract 4.8 nC bunch charge.
Polarization

- Energy and helicity limitation, only two of six transitions are possible.
- Number of excited electron are polarized by 3:1 matrix amplitude.

Unstrained GaAs

Right handed polarization

Left handed polarization
Towards 100 % polarization

- Super-lattice structure breaks the degeneration.
- It enhances the polarization to 92% with 1.6 % quantum efficiency.

\[
\text{GaAs} / \text{GaAs}_{0.62} \text{P}_{0.38}
\]
Strain compensated
Super-lattice, 24 layer

\[
\text{Al}_{0.1} \text{Ga}_{0.9} \text{As}_{0.81} \text{P}_{0.19}
\]
Buffer layer, transparent for laser

GaP Base plate
Bunching(1)

- According Child-Langmuir law, peak current of ILC Electron gun (120kV, d~5cm, and 1cm diameter) is ~3A.
- To generate ILC bunch (4.8nC), 1.6ns is necessary.
- It is significantly longer than RF acceleration and should be shorten down to 10ps.
- Bunching section : SHB(Sub Harmonic Buncher) and Buncher to shorten the bunch length.
  - 216.7 MHz (1/6 of 1.3 GHz)
  - 433 Mhz (1/3 of 1.3 GHz)
  - Buncher : 1.3 G Hz NC tube.
Bunching (2)

- Velocity modulation to shorten the bunch length for RF acceleration.
- RF cavity for acceleration is placed where the bunch length is minimized.
E-Driven Positron Source
E-driven ILC Positron Source

- 20 of 1us pulses are handled with NC linacs operated in 300Hz.
- A simulation with off-the-shelf RF components shows an enough positron yield.
- Target prototyping
The beam handling and format

Damping Ring

Positron Booster

29 Nov. 2017

ILC MP
Electron Driver

- 3.0 GeV Electron beam in the format with 2.5 nC bunch charge.
- S-band Photo-cathode RF gun for the beam generation.
- 80 MW klystron-modulator drives 2 structures giving 50 MV/3m with 0.4A beam-loading.
- 60 of 3m S-band TW structures for the acceleration.

<table>
<thead>
<tr>
<th>Lattice</th>
<th># of cell</th>
<th>Cell length(m)</th>
<th>Section length(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4Q+2S</td>
<td>6</td>
<td>8.0</td>
<td>48.0</td>
</tr>
<tr>
<td>4Q+4S</td>
<td>12</td>
<td>14.4</td>
<td>172.8</td>
</tr>
</tbody>
</table>
Target

- W-Re 14mm thick.
- 5 m/s tangential speed rotation (180 rpm, 0.5m radius) in vacuum.
- Water cooling through channel.
- Vacuum seal with ferro-fluid.
- A prototype compatible to vacuum in test.
- $3.0 \times 10^{-7}$ Pa is kept with 225 rpm rotation with 100 l/s Ion pump.
- The radiation test was already done. It is vital against 1 year ILC operation.
Flux Concentrator
(P. Martyshkin)

- Flux Concentrator for AMD (Adiabatic Matching Device)
- 16 mm aperture
- 5 Tesla Peak field, 40mT trans.
- 25 kW ohmic loss.
Positron Capture Linac

- L-band SW structure designed by J. Wang (SLAC) for the undulator capture section is employed.
- Two structures are driven by one 50 MW klystron.
- The effective accelerating voltage depends on the beam loading current.
- The transient beam loading has to be compensated.

<table>
<thead>
<tr>
<th>Structure Type</th>
<th>Simple π Mode</th>
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<tbody>
<tr>
<td>Cell Number</td>
<td>11</td>
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<tr>
<td>Aperture 2a</td>
<td>60 mm</td>
</tr>
<tr>
<td>Q</td>
<td>29700</td>
</tr>
<tr>
<td>Shunt impedance r</td>
<td>34.3 MΩ/m</td>
</tr>
<tr>
<td>$E_0$ (8.6 MW input)</td>
<td>15.2 MV/m</td>
</tr>
</tbody>
</table>
At the end of capture linac

Accelerator Aperture

29 Nov. 2017
ILC MP
ECS Section

- By adjusting the angle of ECS chicane, the phase-space distribution can be matched to DR acceptance.
- The yield (e+/e-) is 2.0.
Summary for E-driven

- The conceptual design was made based on off-the-shelf components.
- The positron yield 2.0 is enough for operation.
- Target prototype is currently smooth.
- Now, the CFS and engineering design is on-going.
Undulator Positron Source
Undulator ILC Positron source

- 231m active undulator length,
- 500m drift space between the undulator and target,
- NC RF up to 400 MeV for capturing,
- SC RF up to 5 GeV,
- Energy Compressor,
- Spin rotator (SC solenoid).
Target Technology

- The target is 15 mm Ti-alloy.
- To avoid any damage on target, it should be rotated with 100 m/s tangential speed in vacuum.
- There are several proposals, but there is no silver bullet yet.
  - Water cooled target with ferro-fluid seal.
  - Radiation cooling,
  - Contact cooling.
Target system

- Heat is removed by water in channel.
- Vacuum seal with rotation rod by ferro-fluid.
- R&D is pended.
Radiation Cooling Target (DESY/CERN)

- Thermal heat is removed by radiation between the radiator and cooler.
- No seal on moving parts.
- The feasibility of the concept is not fully established yet.
Flux Concentrator

- Flux Concentrator (B-field) to compensated Pt of positron for good capture.
- A device in air is prototyped and demonstrated 1ms flat top.
- There are technical and fundamental issues to be solved.
Obstacles

- The skin depth becomes deeper in time causing temporal variation of B field.
- $e^+$ intensity depends on time.

- PEDD in FC is $59/2$ J/g.pulse.
- The limit on Cu is 7-12 J/g; The FC will be damaged soon.
QWT

- QWT (Quarter Wave Transformer) is composed from a couple of pulsed solenoid coils for capture device.
- Positron yield (capture efficiency) is less than that of FC, but it is an only solution for Undulator positron source.
- The yield could be recovered by modifying the basic scheme for lower energy beam.
Summary of Possible Operation mode

- Target vitality and the capture efficiency (positron yield) give the operability of the source.
- No operation is expected with FC.
- With QWT, 250 GeV beam energy with reduced luminosity is possible.
- 125 GeV beam energy with thinner target might be possible with designed luminosity.

<table>
<thead>
<tr>
<th>Ebeam[GeV]</th>
<th>15mm+FC</th>
<th>15mm+QWT</th>
<th>6m+QWT</th>
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</thead>
<tbody>
<tr>
<td>125</td>
<td></td>
<td>Reduced L</td>
<td>Designed L?</td>
</tr>
<tr>
<td>175</td>
<td></td>
<td>Reduced L</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td></td>
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</tr>
<tr>
<td>125</td>
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<tr>
<td>250</td>
<td></td>
<td>Reduced L</td>
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</table>
Summary for Undulator

- The conceptual and technical designs are established.
- FC has principle and technical issues for the actual operation.
- QWT is the practical baseline for the matching device.
- Need a significant amount of R&D for the radiation cooling target.