LCC-0154
SLAC-TN-04-04
September 2004

Linear Collider Collaboration Tech Notes

# ILC Conventional Positron Source: Long Drive Pulse Option

V. Bharadwaj, Y. Batygin, D.C. Schultz, J.C. Sheppard
September 2004

Stanford Linear Accelerator Center
2575 Sand Hill Road
Menlo Park, CA

**Abstract:** A conventional positron source for the ILC using a very long macro-pulse for the electron drive beam is proposed. In comparison with an undulator based positron source, a conventional positron source decouples positron production from the main linac electron beam, leading to faster commissioning and improved positron system up-time. Of the 200 ms in between ILC pulse trains, 100 ms will be used to make positrons. While this will make the positron target design easier, it will require the electron drive, positron capture linacs and the adiabatic matching device to run at 50% duty cycle or more and a pre-damping ring with sufficient damping power to prepare the beam for injection into the damping ring in 100 ms.

September 16, 2004

# ILC CONVENTIONAL POSITRON SOURCE: LONG DRIVE PULSE OPTION

Vinod Bharadwaj, Yuri Batygin, Dave Schultz, John Sheppard
Stanford Linear Accelerator Center

*Abstract*

*A conventional positron source for the ILC using a very long macro-pulse for the electron drive beam is proposed. In comparison with an undulator based positron source, a conventional positron source decouples positron production from the main linac electron beam, leading to faster commissioning and improved positron system up-time. Of the 200 ms in between ILC pulse trains, 100 ms will be used to make positrons. While this will make the positron target design easier, it will require the electron drive, positron capture linacs and the adiabatic matching device to run at 50% duty cycle or more and a pre-damping ring with sufficient damping power to prepare the beam for injection into the damping ring in 100 ms.*

## Introduction

The ILC design is based on being able to build a positron source that is capable of delivering a pulse train of many thousands of positron bunches with intensities of a few $10^{10}$ positrons at a pulse repetition rate of five Hz. There are two competing approaches to providing such pulse trains of positrons. One idea, derived from the original TESLA design, is to use the main linac electron beam at high energy (>150 GeV) passing through an undulator to generate multi-MeV photons which can be used to produce positrons in a thin target. This scheme has the added advantage that it may be possible to generate polarized positron beam. The other, more conventional, scheme is to use a few-GeV electron drive linac to generate positrons in the electromagnetic shower that occurs when such a drive beam hits a high-Z target. For this scheme there has been a large amount of experience with the SLC positron source (both with the actual operation of the source and calculation and analysis of its design). The design of a conventional positron source for the ILC necessarily starts with the SLC experience and further refinements derived from the R&D associated with the NLC positron source design. Contrary to conventional wisdom, the bunch structure associated with the ILC may in fact make a conventional positron target easier to design as compared with an NLC target and exhibit less stress that the SLC positron source that ran successfully for many years.

This note discusses the flexibility afforded by the ILC design for a conventional positron source and details a scheme based on a long macro-pulse drive electron beam. Although this note will mention some aspects of the undulator based scheme, it is not a comprehensive comparison of the pro’s and con’s of the two approaches.

**Assumptions**

For the purposes of this discussion, the needed positron pulse structure for the ILC is taken to be that from the U.S. Linear Collider Technology Options Study. The delivered beam to the positron main linac has the following parameters

| | |
|---|---|
| Bunch Intensity | $2 \times 10^{10}$ positrons |
| Number of Bunches/Pulse | 2820 |
| Bunch Separation | 337 ns |
| Pulse Length | 950 $\mu$s |
| Pulse Repetition Rate | 5 Hz |

Typically the positron yields ($e^+$ into the damping ring/$e^-$ in the drive linac) are 1.0.
The SLC positron source operated for many years without failure and can be used as reference. Its parameters were

| | |
|---|---|
| Drive Beam Bunch Intensity | $3.5 \times 10^{10}$ electrons |
| Drive Beam Energy | 30 GeV |
| Number of Bunches/Pulse | 1 |
| Pulse Repetition Rate | 120 Hz |
| Target | 6 r.l. W26Re |
| Positron Production Eff. | ~1 |

**Long Drive Pulse Scheme**

In an LC the positrons produced in the target are stored and damped in a damping ring or rings. The output of these ring(s) is required to have the pulse train structure needed by the main linac. In the case of the SLC with one bunch per "pulse train", the damping rings did not present an issue in this regard and in fact there were two positron bunches in the damping ring, allowing for 16.6 ms of time for damping the beam. In the case of the NLC (192 bunches in a train, separated by 1.4 ns) the damping ring can have a circumference of about 300 ns and bunches can be extracted to the main linac in a single turn. For the ILC a similar scheme will require a damping ring with a circumference of 950 microseconds or 285 kilometers. However if the bunches can kicked out one at a time (every 337 ns) then the damping ring can be much smaller. This method of kicking out pulses from the ILC damping ring at a rate slower than the bunch spacing in the ring can also be used for injecting into the rings (as is done in PEP2). Specifically the positron bunches can be produced in a longer time than the 950 microseconds that is the ILC pulse train length.

The ILC inter-pulse-train timing is 200 ms (5Hz). To analyze the advantages of taking longer to produce the positron bunches, it is proposed that one train of positron bunches are produced in 100 ms and the remaining 100 ms can be used to pre-damp the positrons. Table 1 shows a comparison of various conventional positron sources. The four sources considered are the SLC, the NLC, the USLCOS design study and the proposed 100 ms scheme. Of these only the SLC source has been built and operated. It is also noted that both the NLC and USLCOS designs resort to multiple target stations to get the required positron fluxes. The advantage of the long macro-pulse is apparent, i.e. 33 microsecond bunch to bunch separation is long enough to allow the target to move 1 mm at modest target speeds of 30 m/s (e.g. a 1 meter diameter ring spinning at 600 rpm). The "Target Motion Factor" is ratio of the total area of the target hit by a pulse train to the area of the target hit by a single bunch. For the long macro-pulse, the parameters for energy deposition into the target are significantly relaxed from the SLC values (e.g. the energy deposition is 13 J/mm$^2$ as compared with 83 J/mm$^2$). This allows the electron beam spot size to be reduced from the USLCOS case leading to improved capture efficiency. The only parameter that is significantly bigger is the average beam power and the table indicates the required cooling flow to remove the power absorbed in the target.

**Table 1.** **Comparison of Conventional Positron Sources**

## CONVENTIONAL POSITRON SOURCES

| | Units | SLC(94) | NLC | ILC | ILC(long) |
|---|---|---|---|---|---|
| **ELECTRON DRIVE BEAM** | | | | | |
| **Energy** | *GeV* | 30.00 | 6.20 | 6.20 | 6.20 |
| **Intensity** | *$10^{10}$* | 3.50 | 1.50 | 2.00 | 2.00 |
| **Bunches/pulse** | | 1.00 | 192.00 | 2820.00 | 2820.00 |
| **Bunch Spacing** | *microsec* | 8333.33 | 0.0014 | 0.34 | 33.69 |
| **Pulse Length** | *microsec* | 0.00 | 0.30 | 950.00 | 95000.00 |
| **Pulse Repetition Rate** | *Hz* | 120 | 120 | 5 | 5 |
| **Bunches/sec** | | 120 | 23040 | 14100 | 14100 |
| **Spot Size on Target** | *mm* | 0.80 | 1.60 | 2.50 | 0.80 |
| **TARGET** | | | | | |
| **Target Velocity** | *m/s* | n/a* | 1.20* | 200.00 | 30.00 |
| **Number of Targets** | | 1.00 | 3.00 | 2.00 | 1.00 |
| **Bunch Energy per Target** | *J* | 168.00 | 4.96 | 9.92 | 19.84 |
| **Pulse Energy per Target** | *kJ* | 0.17 | 0.95 | 27.97 | 55.95 |
| **Average Power per Target** | *kW* | 20.16 | 114.28 | 139.87 | 279.74 |
| **Bunch-to-Bunch Target Motion** | *mm* | n/a* | 0.00 | 0.07 | 1.01 |
| **Target Motion Factor** | | 1.00 | 1.00 | 49.36 | 2106.76 |
| **Beam Energy Incident per Target** | *$10^{10}$Gev/mm$^2$* | 52.22 | 74.00 | 18.04 | 8.26 |
| **Beam Energy Incident per Target** | *J/mm$^2$* | 83.56 | 118.40 | 28.86 | 13.21 |
| **Cooling Water Flow**(30degC/20%$E_{dep}$) | *GPM* | 2.12 | 12.03 | 14.72 | 29.45 |

* in the SLC case there is only one bunch in a pulse train, so the target motion is not relevant to the instantaneous energy deposition or shock. In the case of the NLC the target motion in the 1.4 second bunch-to-bunch spacing is negligible and does not help spread the energy and shock of a pulse train.

**R&D Consequences**

The long macro-pulse scheme will make the ILC target station easier to design for high reliability and will allow a bigger overhead (i.e. one can increase the produced positrons by just increasing the drive beam power to allow for unanticipated inefficiencies in downstream accelerator systems). It also allows for the use of a single positron source target system, although having a second as a hot spare may be desirable. The scheme, however, adds complications to other systems.

*Drive and Capture Linacs*

The drive and capture linacs need to run at 50% duty cycle instead of the 0.5% for the USLCOS scheme. The increased duty cycle will lead to increased refrigeration capacity. In addition the first part of the capture linac may have to be normal conducting. The drive linac is nominally 6 GeV and the capture linac is 5 GeV. It might be possible to use one linac as both the drive and capture linac. L-band SC linacs have run CW at JLAB so this is clearly not a technical issue. The drive linac will have to be optimized (e.g. is it possible to run more beam at a smaller energy).

*Pre-Damping Ring*

The long macro pulse generates the positrons over a 100 millisecond period. If these go directly into a damping ring the time for damping the beam is halved. It is possible to allow room for two pulse trains in a damping ring, but it may be easier to contemplate a pre-damping ring which is used to store and damp the positrons. This may also allow a better optimization for the design of the damping ring. Also there is nothing "magic" about dividing the 200 ms equally between positron production and damping (even a 50 ms positron production time is an improvement over the USLCOS scheme).

*Adiabatic Matching Device*

In existing schemes, immediately following the positron target, there is an adiabatic matching device that matches the positron emittance coming out of the target to the capture linac. This consist of a pulsed "flux concentrator" followed by a tapered solenoid followed by a regular solenoid. The flux concentrator design is difficult even for the 0.5% duty factor in the USLCOS design. At a 50% duty cycle it is effectively a DC device and is probably impossible to scale from existing ideas. The matching scheme for the positrons will have to be re-evaluated and re-designed. It may be possible to get higher fields in the tapered solenoid by using a superconducting device if sufficient attention is paid to shielding it from beam losses. Any modest reduction in positron yield (factor of 2-3) can be easily made up by increasing the drive linac bunch intensity by a corresponding amount.

*Radiation Shielding*

In a conventional source a multi-GeV electron beam hits a thick target. Almost all of the beam energy ends up in the positron target area and generates more radiation than an equivalent undulator based positron source, although not orders of magnitude more. R&D on how to handle the high radiation environment of a positron source will be needed.

## Conclusion

The long ILC pulse train length allows for the possibility of designing a much less technically challenging and much more reliable conventional positron target system. A conventional system utilizing a long drive macro-pulse, as proposed in this note, has a very large overhead should the need arise to increase the positron intensity. The changes to the surrounding systems need to be analyzed but do not appear to be "show stoppers".