† Low Q Parameters

Table 3.1: Undulator-based positron system parameters:

Alternative Positron Source Description

The Compton scheme can also generate the high intensity positron beam which meets the ILC requirements with some margin. In contrast to the undulator scheme, the Compton scheme has advantages as follows;

- It is a completely independent system from the electron arm. It avoids complex interference between two arms that is important feature especially for the commissioning. This is also important for good availability of the collider.

- Because of the independency, there is much flexibility to change the beam structure, intensity, etc.

- The performance can be much improved by introducing some new technology, e.g. more powerful laser system, more precise high-gain optical cavity,etc. These improvement can be made after enough confirmation of the new technology in the laboratory without any risk.

- Because the operation is completely independent from the electron linac, there is no limitation at the lower energy operation. The collision at the energy from 5 GeV up to 250 GeV (500GeV eventually) can be easiliy made without any cost. On the other hand, in the undulator scheme, the energy spread is larger and/or the luminosity is lower at some energy region.

- The injection scheme is totally different from that of the undulator scheme. Any fast kicker, which is one of the most difficult device in ILC injector, is not necessary.

- It can generate the polarized positron. The polarization depends on the laser helicity which can be switched pulse by pulse. This polarization switching is very important for the physics experiment. It is hard to switch pulse by pulse the polarization in the undulator scheme requiring an extra section to implement the switching.

Addition to these advantage, the critical elements of the Compton scheme can be demonstrated prior to the real construction and partly demonstrated already. Then the Compton system can be developed step by step. This feature is remarkable in contrast to the undulator because the undulator scheme is hard to demonstrate with a reasonable scale prior to the construcution. Even these advantages compare to the undulator scheme, the

Compton scheme is still in an initial stage to develop the real ILC positron source because a high current electron beam needs to be produced and a high power multi-bunch laser scheme is needed. However, this concept is so attractive that the people keep their aggressive R&D efforts towards the well matured design based on the Laser Compton scheme.

Compton Scheme Design

The Compton based polarized positron source [1] consists of (1) an electron linac which is the injector of the Compton ring, (2) a electron storage ring named Compton ring, (3) a laser which send laser beam to pulse stacking cavities, (4) laser pulse stacking cavities which are installed in a straight section of the Compton ring, (5) conversion target and capture section, (6) positron injector linac, and (7) a damping ring.

Now two versions of design are under consideration. One uses CO_2 laser and the other uses YAG laser. The former is called CO_2-version, and the later is called YAG-version. In following description, the number corresponds to CO_2-version is firstly shown in each statement, then that of the YAG-version is shown in parentheses.

Compton ring is a high current electron storage ring. The energy of the ring is 4.1 GeV (1.3 GeV). The ring has long straight section in which 30 laser stacking cavities are installed. The circumference of the ring is 649.2 m (276.7m). Two trains are (one train is) circulating in the ring. In both CO2- and YAG-versions a train consists of 280 bunches with bunch-to-bunch spacing of 3.077 nsec, and the bunch population is 6.2E10. An electron linac which energy is 4.1 GeV (1.3 GeV) is employed to inject electron to the Compton ring. The linac is not necessary to be high current, because electron population loss due to Compton scattering is negligible. The collisions of electrons circulating in the Compton ring and photons stored in laser stacking cavities create polarized gamma rays. In one turn of the Compton ring, 280 (280x2) gamma ray bunches are created. Polarized positrons are created from those gamma rays on thin (~0.5 X0) target, then positrons in the high energy side of the spectrum are corrected in the capture section.

Each laser stacking cavity stored a photon bunch which energy is 210 mJ (600 mJ). The laser stacking cavity is designed to have enhancement factor of 100. Thus, each bunch of laser beam delivering from a laser should have energy of 2.1 mJ (6.0 mJ). The laser operates at 100 Hz and each pulse of laser contains 3.6E4 (2.9E4) bunches with bunch-to-bunch spacing of 3.077 n sec. The duration of the laser pulse is 110μs (90μs). Single laser provides a laser beam to 30 stacking cavities in daisy chain. The laser operates at 100Hz, thus laser cavities are filled by photons every 100ms.

Then positron injector linac accelerate positrons up to 5 GeV. A cold linac is employed. The linac is almost identical to the main linac, except that the injector operates at 100 Hz. Since the linac operates at 100 Hz, necessary cooling power per module is 4 times larger than that of main linac. However, the excess of total cooling power of the collider is not significant. After acceleration, positrons are sent to the damping ring. In the Compton scheme the damping ring has two functions: stacking and damping. Actually, main damping ring itself is the ideal choice of stacking ring, because it can store full number of positron bunches, it can be designed to have short damping time of ~10 m sec, and it has large longitudinal bucket area. The circumference of the damping ring is chosen to be 3247 m (2767 m), which is 5 times (10 times) larger than that of the Compton ring. The damping ring stores 10 trains with inter-train gap of 133 n sec (61 n sec).

The procedure of collision in the Compton ring and positron stacking in the damping ring is as follows. The collisions with laser photons make negligible loss of electron population in the Compton ring, however collisions make bunch lengthening. Due to bunch lengthening, number of gamma rays created by collisions decreases as a function of turn number. Therefore number of gamma rays becomes practically zero, if laser photons always exist in cavities. Pulse mode operation is applied to cure this problem. Laser cavities are filled by photons only in 110μs (90μs). This corresponds 50 (100) turns of the Compton ring. Then laser is turned off in ~9.9ms of cooling time. In the cooling time, electron bunch length become shorter and go back to primary length. Average number of gamma rays per turn is 1.8E10/bunch (1.4E10/bunch) in the energy range of 23-29 MeV. Then the average number of positrons is 2.4E8/bunch (1.9E8/bunch). 50 (100) turns of the Compton ring corresponds 10 turns (10 turns) of the damping ring. During this 110μs (90μs), injection to the damping ring continues and 10 times of stacking in each bucket are made in the damping ring. This stacking is performed using large longitudinal phase space of the damping ring. After the first injection, there is a ~9:9ms of damping time which corresponds the cooling time of the Compton ring. In a ~9:9ms, the area in the longitudinal phase space occupied by injected positrons is damped to the size which is small enough to accept the next injection. Since the laser operates at 100 Hz, next injection starts at this timing. This alternate cycle of injection and damp is repeated 10 times. Therefore, 100 times of stacking in each bucket are made in total. At this moment, the damping ring still has 100ms which is enough to make the emittance of positron beam fully damped. The simulation shows that the average stacking loss is 18%. Taking this into account, total number of stacked positrons in the damping ring is 2.0E10/bunch (1.6E10/bunch).

Compton Scheme R & D

There are several important components and technologies for the Compton scheme. Among of them, a couple of essential components were already demonstrated in KEK-ATF as follows,

- High gain laser cavity[2],

- The Compton scattering to yield enough gamma rays[3] with polarizaion[4], and to yield polarized positron[5],

that means the proof of principle of Compton scheme is reasonably confirmed. There are several issues to be studied for the Compton scheme as follows.

- High current Compton Ring.

- Positron beam stacking into the main DR.

- High power CO2 or YAG laser system.

- Control the chain of the laser cavities.

R&D Plans for these items are under scheduling as international collaboration. Regarding to High current Compton Ring.[6][7] and Positron beam stacking into the main DR., since we have developed of full beam tracking simulation code, research of the realistic values on beam parameters will be finished within one year. Then, parameters on laser systems and laser cavity will be redetermined.

On the other hand, we already started the design of the double chain of the YAG laser cavities and the installation will be planned at ATF. Test of laser focus to 5μm will be established at the center point in the cavity in this JFY and we will install the double chain of the laser cavities into ATF damping ring next JFY and generate gamma rays for the demonstration.

Another challenge of our scheme is the necessity of high power and high quality laser. For the YAG-version, we have to develop long laser pulse amplification system using commercial available components. In the R&D program, both flash lamp excitation and solid state excitation are under consideration for this long pulse operation. Furthermore, the study to make the pulse stacking cavity which has higher enhancement factor[9], which reduce requirements to the laser. For the CO2, slicing of a long laser pulse into multiple bunches is the point. Essentially, the technology of slicing is already established[10]. However, in the Compton scheme, we need many bunches, thus heat load of the Ge-plate is not negligible. The engineering study to cure this problem is necessary.

References

[1] S. Araki et al., Conceptual Design of a Polarized Positron Source Based on Laser Compton Scattering. *A Proposal Submitted to Snowmass 2005* CLIC Note 639, KEK Preprint 2005-60, LAL 05-94
[2] M. Nomura et al., Proceedings of EPAC 2004, Lucerne, Switzerland., pp.2637-2639
[3] I. Sakai et al., Physical Review Special Topics-Accelerators and Beams, 6,

091001(2003).
[4] M. Fukuda et al., Phys. Rev. Lett. 91, 164801 (2003)
[5] T. Omori et al., arXiv:hep-ex/0508026, KEK Preprint 2005-56
[6] Eugene Bulyak and Vyacheslav Skomorokhov. Parameters of x.ray radiation emitted by Compton sources. In *Proc. EPAC.2004 (Luzern, Switzerland)*, 2004. http://accelconf.web.cern.ch/accelconf/ e04/papers/weplt138.pdf.
[7] Eugene Bulyak. Laser cooling of electron bunches in Compton storage rings. In *Proc. EPAC.2004 (Luzern, Switzerland)*, 2004. http://accelconf.web.cern.ch/accelconf/ e04/ papers/thpkf063.pdf.
[8] F. Zomer, Habilitation, Universit´e Paris 11-Orsay (2003) LAL/0312.
[9] F. Zomer, Habilitation, Universit´e Paris 11-Orsay (2003) LAL/0312.
[10] I. V. Pogorelsky et al., IEEE J. Quantum Electron., 31 (1995) 556. *Alternative Configuration Document for ILC Positron Source Based on Laser Compton Scattering, August 2005*