Notes on “EUROTeV Photon Conversion Target Project”

Author: I. Bailey, University of Liverpool (ian.bailey@physics.org)
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Introduction

The future International Linear Collider (ILC) will require of order 10^{14} positrons per second to fulfil its luminosity requirements. The current baseline design produces this unprecedented flux of positrons using an undulator-based source.
In this concept, a collimated beam of photons produced from the action of an undulator on the main electron beam of the ILC is incident on a conversion target.
Positrons produced in the resulting electromagnetic shower can then be captured, accelerated and injected into a damping ring. The positron source community is pursuing several alternative technologies to develop a target capable of long-term operation in the intense photon beam.

Although the power and energy spectra of the incident beams differ, aspects of the target design are shared in common between the undulator positron source and the proposed Compton backscattering source; e.g. similar vacuum and remote-handling requirements would apply.

Below are brief noted on each slide presented in the talk given at POSIPOL 2006.

Slide 2
The University of Liverpool, SLAC and LLNL have been working together on the design of a rotating water-cooled titanium alloy wheel target. The wheel has been designed to be thin (~0.4 radiation lengths). In order to maximise the positron capture efficiency by keeping the emittance of the positron beam emerging from the back of the target small.
The required velocity of the wheel rim (100 m/s) is determined by the cooling rate of the cooling system and the dependence of the mechanical properties of the wheel on temperature.
The required radius of the wheel (1 m) is determined by the estimated rate of radiation damage to the wheel and the required lifetime of the wheel (6 months minimum).

Slide 3
Generally, the photon beams striking the targets in the Compton backscattering source designs operate at a lower power than the photon beam in the undulator design, and therefore any target able to operate in the undulator source could also operate in a Compton backscattering source. The LBNL concept presented at the POSIPOL workshop may be an exception.

Slide 4
The baseline positron source uses an undulator 100 m long with a 1 cm period and a ‘deflection parameter’ (K-factor) of 1, which requires an on-axis magnetic field flux density of approximately 1 T. This causes the 150 GeV electrons travelling through the undulator to describe helical trajectories with typical radii of 5 nm.

These specifications differ slightly from the practical devices being prototyped at Daresbury Laboratory which will consist of ~4 m cryomodules containing 2 × 2m superconducting helical undulators with period ~12 mm and magnetic flux density of ~0.8 T.

If we assume the ILC electron beam is operating with its nominal beam parameters, and if we ignore collimation of the photon beam prior to the target, then the baseline undulator gives a 145 kW photon beam incident on the target with a beam spot rms radius of approx 1 mm (assuming the target is ~400 m from the end of the undulator). The average photon energy is 13 MeV. The first harmonic peak of the undulator energy spectrum is at 10 MeV.

The plots show the undulator energy spectrum, the beam spot profile on the target, and the dependence of the photon polarisation as a function of the position of the photon in the beam spot (for photons at 10 MeV).

Slide 5
The range of ILC electron beam parameters is shown and the effect upon the positron source highlighted. In the 5640 bunch/pulse mode the power incident on the photon beam target is shown to be ~600 kW, which is higher than the design power of 300 kW. However, the power is proportional to the undulator length and there is good reason to believe that an undulator less than 200 m in length would be sufficient to produce polarised positrons for the ILC. (Only 100 m or less is needed to provide an unpolarized positron beam.)

Slide 6
The target consists of key sub-systems and its operating conditions are determined by neighbouring support systems. The figure is shown for illustration only.

Slide 7
One key support system is the photon collimator that lies before the target and scrapes the beam. By varying the aperture, the collimator can be used to control the degree of polarisation of positrons produced from the target.
At these high photon energies electromagnetic showers instigated in the spoiler are strongly scattered outwards, and no external field is required to sweep the charged particles into an absorber. Therefore, a simple design with two concentric cylinders is sufficient.
One concept was developed at DESY by N. Golubeva and V. Balandin. An alternative design has been developed at Cornell by A. Mikhailichenko.

Slide 8
EGS4 simulations of the DESY collimator concept are shown. In the top figure the absorber is connected to the spoiler by vanes so that heat can flow from the spoiler to the absorber, which can be actively cooled. In the bottom figure an alternative design is shown in which the spoiler is divided into discs and then tilted (to form cones) to reduce forward-scattering of charged particles along the photon beam direction.

Slide 9

The latest LLNL design for the target wheel is shown. The photon beam strikes the thin rim (~30mm wide radially and 14mm thick in the beam direction) of the target wheel. The rim is connected to the driveshaft by spokes.

Slide 10
The target wheel design has evolved from a solid disc to a thin rim mainly to reduce the strength of eddy currents circulating in the target (caused by the wheel rotation in the 5 T magnetic field of the adiabatic matching device).
Preliminary numbers estimated using the Maxwell 3D software package from Ansoft are shown, but these numbers have not yet been calibrated with experimental data gathered at SLAC.

Slide 11
The cooling system has to dissipate ~30kW of heat during the target operation. A summary of the energy deposition in the target and the effect of the target rotation are presented.
The cooling system consists of internal water cooling channels. The circular channel in the rim is ~7 mm in diameter and follows the radial curvature of the target at a radius of 0.98 m. Water is pumped into the channels via a rotating coupling attached to the driveshaft.

Slide 12
Neutron production in the target is low compared to conventional target schemes which use an electron beam incident on a WRe target, as the average photon energy in the undulator design lies below the giant neutron resonance for titanium. However, the expected activation of the target is still high enough to require a complete remote-handling system.

Slide 13
The concept for a remote-handling design offering full-maintenance capabilities is shown. Damaged targets can be withdrawn into a hot-cell for maintenance whist a spare is deployed into the photon beam from the opposing hot-cell. Master-slave manipulator arms are used to maintain and repair the damaged target.

Slide 14
An alternative concept is shown in which only one target and one hot-cell is used. Such a system might be suitable if two or more target stations are used in series. Another alternative would be to remove and replace damaged targets, with the damaged targets being kept in a holding cell until they can be handled manually. Such a system requires a large number of holding cells and replacement targets.

Slide 15
The University of Liverpool and other UK groups (Daresbury Laboratory and Rutherford Appleton Laboratory) are proposing to prototype the target wheel and operate it at a test facility at Daresbury Laboratory. Such a project is subject to funding from UK and European funding agencies. This project is supported by SLAC, LLNL and BINP.

Slide 16

Remote-handling design efforts are underway at Rutherford Appleton Laboratory and LLNL. Simulations of the radiation environment are being carried out at DESY.

Slide 17
Further collaboration is welcome.