Positron Source Target Development Update

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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.

In the baseline design, the photon beam is directed at a thin, rotating, water-cooled target wheel. In this paper I review the role of the target in the positron source and present plans for a first prototype.

1 Introduction

In the baseline design for the ILC positron source an intense photon beam is used to produce positrons from a conversion target [1]. The intensity and bunch structure of the photon beam require a novel target design which has previously been presented in [2]. Updated details have recently been published in the ILC Reference Design Report [3]. The main characteristics of the photon beam and target are reviewed in sections 2 and 3 of this paper.

A concern with the current design is the effect of eddy current generated in the target wheel rim due to the interaction between the rotating metal surface and the magnetic field of the adjacent capture optics. In collaboration with Lawrence Livermore National Laboratory and the Stanford Linear Accelerator Centre in the US, the Cockcroft Institute and Daresbury Laboratory in the UK are currently in the process of developing a first prototype of the target wheel with the aim of investigating the eddy current and benchmarking the associated numerical simulations. Recent simulations [1] differ in their predictions for the eddy current power losses by as much as 50%. Details of the prototype are given in section 4 of this paper, and future work is summarized in section 5.

2 Photon beam characteristics

The intense circularly polarised photon beam from the helical undulator insertion device of the ILC positron source will have the same time-structure as the main ILC electron beam [3]: nominally 5 pulses per second, with each pulse having a duration of approximately 1 ms. The undulator will have a total active length of 147 m, giving photons with a first harmonic energy of 10.06 MeV.

The required undulator length of 147 m has been determined assuming that the target is immersed in the magnetic field of a pulsed flux concentrator in order to maximize the

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positron capture efficiency. With this geometry, the average integrated power of the uncollimated photon beam will be approximately 131 kW, with each bunch of photons carrying a total energy of approximately 10 J and consisting of order 10^{13} photons.

3 Target design

The proposed target wheel consists of a circular titanium alloy (Ti-6%Al-4%V) rim connected to a central drive shaft by five equally-spaced radial struts. The wheel will be oriented with the photon beam parallel to the drive shaft, such that the photons strike the rim, which has a radial width of 30 mm and an axial thickness of 0.4 radiation lengths (14 mm). The target will be positioned 500 m downstream of the centre of the undulator, giving a photon beam spot with a rms radius of approximately 2 mm.

Particle tracking simulations [4] predict that approximately 8% of the power of the photon beam will be dissipated in the target. The total energy deposition from each photon pulse is therefore expected to be approximately 22 J/g for a rim speed of 100 ms^{-1} (compared with 0.9 kJ/g for a static target).

As the target wheel will be housed in a vacuum vessel at a pressure of 10^{-7} Torr or less, the wheel will be cooled by water flowing through the hollow drive shaft via a rotating water union and through an internal water-cooling channel contained inside the target rim.

4 Prototype

The prototype wheel will closely resemble the baseline target but will not have internal water cooling channels, and will be operated in air rather than in a vacuum. In addition, there are no plans to expose this first prototype to a photon or other particle beam, as its main purpose is to investigate eddy currents. The mechanical design and data acquisition system for the prototype are discussed in sections 4.1 and 4.2 respectively. The experimental programme is outlined in section 4.3.

4.1 Mechanical design

The prototype target wheel is being manufactured from the same titanium alloy as specified for the baseline target and will have the same outer diameter, radial wheel width and number of spokes. The thickness of the prototype wheel will be 16.6 ± 0.1 mm, which corresponds to a standard thickness of Ti plate. The drive shaft will connect the wheel via a flexible coupling to a 15 kW drive motor and will be supported by two Plummer block bearing units.

The (constant) magnetic field will be generated by a water-cooled dipole electromagnet with cylindrical pole caps 250 mm in diameter. The minimum pole gap envisaged during operation of the rotating wheel is 50 mm, which allows for a maximum peak field of 1.5 T. The magnet support structure will enable the fraction of the wheel rim immersed in the high-field region to be adjusted by varying the relative distance between the centre of the wheel and the centre of the pole caps. The magnet geometry limits the maximum length of the immersed arc to be 190 mm.

Simulations predict that the eddy current induced heating in the prototype for a 1 T field at 2000 rpm could be as high as 10 kW. As the prototype does not have an internal cooling channel, this heat must be dissipated by another mechanism. Initial calculations show that convective cooling of the rotating wheel in air at room temperature will lead to an equilibrium temperature of the wheel rim of approximately 200° C. It is anticipated that a jet of cold dry air will be used to increase the cooling rate.

4.2 Data acquisition

The data acquisition system will consist of a PC interfaced to the power supplies (for the drive motor and the magnet) and a suite of transducers. A rotary torque sensor will be mounted on the drive shaft to measure the torque acting on the wheel. Infra-red sensors and thermocouples will be used to monitor the temperature of the magnet polecaps, target rim, drive shaft and support structures. An optical system will be used to monitor the angular velocity of the drive shaft. Uniaxial accelerometers will be mounted on each of the two bearing units to measure jitter due to vibrational instabilities and component fatigue. Finally, a Hall probe will be used to monitor the magnetic field between the pole caps.

4.3 Experimental programme

Following balancing and initial commissioning, the first phase of the experiment will aim to measure vibrations of the wheel as a function of angular velocity in the absence of a magnetic field. During the second (subsequent) phase of the experiment, the magnetic field strength and wheel speed will be systematically incremented and the resulting torque and temperature readings will be compared with the predictions of the computer simulations. During the third phase of the experiment, the wheel will be operated for long periods and the components will be monitored for wear. Additional investigations into methods of adjusting the conductivity of the wheel rim may also be carried out.

5 Summary and Outlook

A design for a titanium target wheel that satisfies the requirements of the ILC baseline positron source has been developed, and construction has begun of a target wheel prototype to investigate eddy currents effects. Further prototypes to demonstrate the cooling and vacuum systems are also envisaged.

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References

[1] Slides:
`http://ilcagenda.linearcollider.org/contributionDisplay.py?contribId=486&sessionId=61&confId=1296`

[2] I.R. Bailey *et al.*, EPAC 2006 Conf. Proc. 2484 (2006).

[3] G. Aarons *et al.*, “ILC Reference Design Report”, `http://www.linearcollider.org/`.

[4] A. Ushakov *et al.*, EPAC 2006 Conf. Proc. 2478 (2006).