PHOTON COLLIDER TECHNOLOGY SUMMARY* **

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The photon collider option is a major addition to the physics scope of the International Linear Collider. In the coming years there will need to be a development and demonstration of the laser systems required as well as a plan for the accelerator layout needed to accommodate the photon collider option. The outstanding technical issues for the photon collider are summarized in this note.

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1. Introduction

The Global Design Effort (GDE) has been formed to coordinate the R&D and planning for an International TeV scale electron linear collider, the ILC [1]. A photon collider based on Compton backscattering [2, 3] has been proposed as an option for the project. Work is required in two areas in order to realize this option. First, the accelerator needs to be able to accommodate the spent beam from the Compton interactions at one of the interaction regions. Second, a laser and optics system capable of generating the large amounts of laser power required must be designed and demonstrated.

The decision timeline for the ILC project sets the pace at which these issues must be resolved. The required modification to the accelerator and conventional facilities must be determined and costed before the start of construction. The development of the laser system can go in parallel and need only be ready once photon–photon collisions are desired.

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2. Laser and optics

To efficiently produce photon beams each electron bunch must be intersected with a laser pulse with flash energy of around 5 Joules. This would lead to prohibitive requirements for average laser power if each laser pulse were used once and then discarded. The long spacing between electron bunches at the ILC allows the possibility of reducing the laser power required by recirculating laser pulses. A collaboration from MBI and DESY [4,6] has developed a conceptual design for a recirculating cavity that would greatly reduce the average laser power required for a photon collider. As shown in Fig. 1, light would pass through the interaction region inside the detector and be brought outside and around to be recirculated. The total path length of 101 meters would be matched to the electron bunch spacing. A high power pulse within the cavity is built by stacking a series of external pulses provided by a laser. The laser power requirements are large but within the range of systems in development today [5]. However, for successful operation there will be a tight requirement on the matching of the phase and timing of the incoming pulse to the circulation of the pulse inside the cavity.

A staged R&D program should begin to demonstrate the operation and performance of such a system, starting with low-power and small-scale demonstration cavities and working up to a final full system demonstration before the beginning of operations. It is likely that the search for cost savings in the project will bring a critical review of the photon collider's state of readiness at some point. A series of successful demonstrations will strengthen the case for the photon collider.

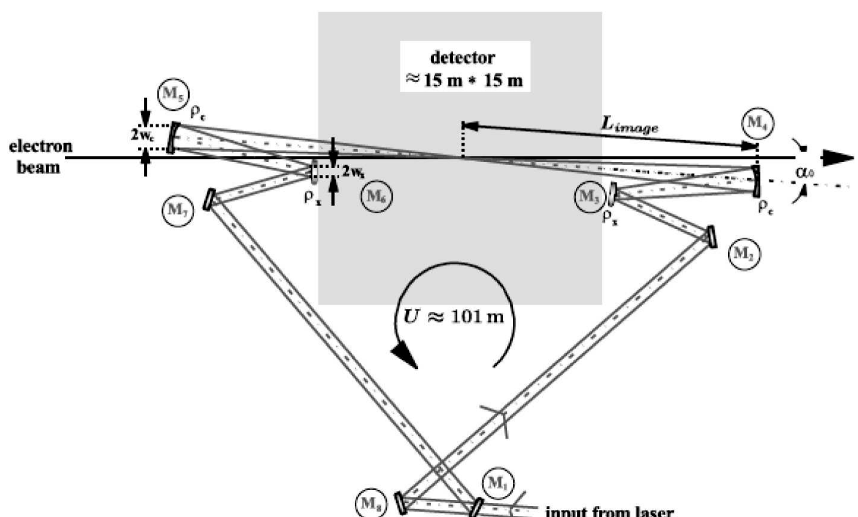

Fig. 1. A conceptual layout of a laser cavity for the photon collider [4, 6].

3. Modifications to handle the spent beam

The modifications of the detector and accelerator required for the photon collider option mainly deal with the disrupted spent electron beam. After the Compton backscattering, much of the beam energy will have been transferred to the photon beam. The electron bunch will have an enormous energy spread ranging from the beam energy of 250 GeV down to as little as 8 GeV. During the beam–beam interaction the low-energy particles will be deflected by as much as 10 milli-radian. Safely extracting these particles from the center of the detector and transporting them to the beam dump is a challenge.

3.1. Crossing angle

A sufficient exit aperture to allow the disrupted beam to pass is required. This sets the minimum crossing angle for the beams from the two accelerator arms. Additionally, the magnetic field in the exit aperture must be minimized so that stray fields from the final focusing quads do not cause excessive beam loss. A design for a final focus quad with corrector coils to minimize the field in the exit aperture [7] is under development and initial designs are shown in Fig. 2. The design for this system is fairly mature and constrains the crossing angle which is required at the photon collider interaction region.

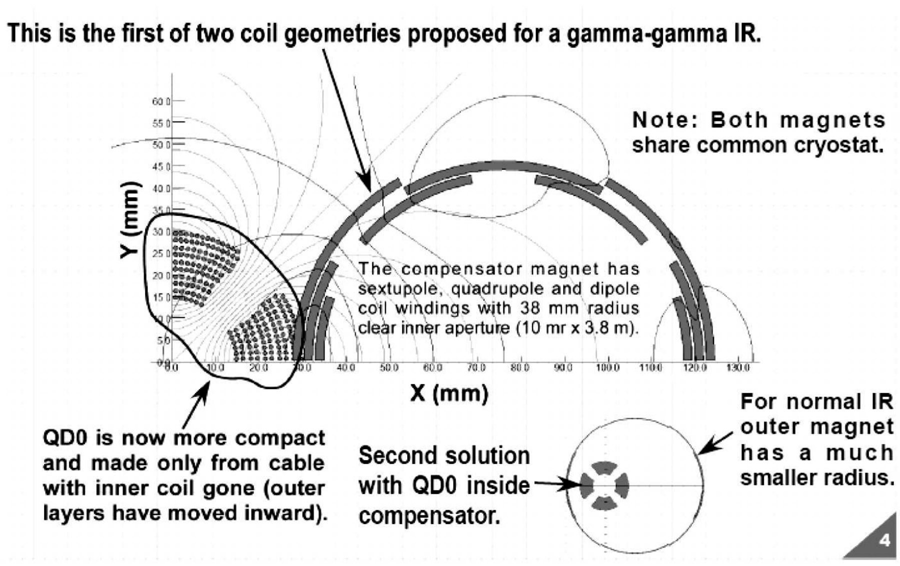

Fig. 2. A conceptual design [7] of a final focusing quad with compensator coils to create a low-field extraction line.

3.2. Exit line and beam dump

The exit line for the spent beams is simply a magnetic field free tube, since the beam has too much energy spread to be steered. This implies that all beam diagnostics will need to be placed before the IP. The beam dump is more difficult to design for the photon collider spent beam since most of the energy is in neutral photons that cannot be steered. For a standard water dump it is expected that the energy loss would vaporize the water and cause cavitation. A design for a gaseous beam dump has been investigated [8]. It should be able to safely dissipate the beam power without cavitation but a full simulation of the energy deposition, cooling, and activation should be undertaken. This idea needs to be developed into an engineered design so that the cost of this beam dump can be evaluated.

3.3. Beam–beam feedback

In order to bring the two nanometer beam spots into collision the accelerator uses beam–beam deflection to measure the miss distance between the beams. This deflection is measured by beam position monitors located just downstream. In the photon collider case the spent beam has a large energy spread and low-energy particles are strongly deflected. Work remains to be done to determine how beam position monitors will react to the spray of low-energy particles and to create feedback algorithms that can handle this situation. This is a significant issue that can and should be resolved in the near term.

4. Accelerator improvements

The basic ILC accelerator design can support the photon collider option without modification. The main difference to the baseline operation is the need for electron–electron collisions in order to maximize the useable high-energy luminosity and suppress backgrounds. This is already foreseen as part of the baseline capability of the project.

A major difference between photon–photon and electron–positron running is that the photon–photon luminosity is not affected by the beam–beam disruption. The ILC is designed to focus the electron beams into a flat ribbon at the IP in order to minimize the luminosity loss to beam–beam disruption. That accelerator configuration is not optimal for maximizing the photon–photon luminosity. Two modifications have the potential to increase the photon–photon luminosity. First, one could improve the damping ring performance by the addition of laser cooling. This can reduce the emittance of the electron beam and thus the beam spot size at the IP. The required improvements in low-emittance transport of the beams in the main linac requires further study before this can be evaluated. Second, the design of the final focus section can be modified [8] to reduce the beam spot size in the x-direction. A study showed that by changing magnet strengths some improvement could be achieved, limited by the energy spread in the beams.

5. Outlook and conclusions

It will be important for the progress on photon collider technical R&D to keep pace with the ILC project. Of primary importance will be the issues that influence the baseline configuration of the accelerator; beam dump, crossing angle and beam–beam feedback systems. The timescale for the demonstration of the laser system is longer but should be pushed forward expeditiously.

The photon collider is an option for the ILC that has a unique physics potential. There are no fundamental technical reasons why this option could not be realized. The photon collider community has successfully made the case that the photon collider should be an option for the ILC and now is the time to embark on the demonstration of the laser technologies needed for the project.

The author would like to thank the photon collider community whose work is reported in this summary.

REFERENCES

[1] `http://www.linearcollider.org/cms/`

[2] I. Ginzburg, G. Kotkin, V. Serbo, V. Telnov, *Pisma ZhETF* **34**, 514 (1981); *JETP Lett.* **34**, 491 (1982) [Preprint INF 81-50, Novosibirsk (1981) in English].

[3] V. Telnov, *Nucl. Instrum. Methods* **A355**, 3 (1995).

[4] I. Will, T. Quast, H. Redlin, W. Sander, *Nucl. Instrum. Methods* **A472**, 79 (2001).

[5] L. Hackel *et al.*, UCRL-TB-136126-01-20.

[6] G. Klemz, K. Monig, I. Will, Design study of an optical cavity for a future photon-collider at ILC, submitted to *Nucl. Instrum. Methods.*

[7] B. Parker, Brookhaven National Laboratory, private communications.

[8] V. Telnov, *Acta Phys. Pol. B* **37**, 1049 (2006),these proceedings.