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Meeting to discuss laser cavity design for photon linear collider – Daresbury, UK, 10 January 2006

ALEXANDER JOHN FINCH
Lancaster University, Lancaster, LA1 4YW, UK
E-mail: a.finch@lancaster.ac.uk

Abstract. The outcome of the meeting to discuss the proposed design for a laser cavity for the photon linear collider is presented.

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1. Introduction

On 10 January 2006, a meeting to discuss laser cavity design for the photon linear collider was held at the Daresbury Laboratory, hosted by the Cockroft Institute. Those who attended the meeting were: Alexander Finch of Lancaster University, Graeme Hirst of Central Laser Facility RAL, Guido Klemz of DESY/Zeuthen, Steve Maxfield of Liverpool University, David Miller of University College London, Klaus Mönig of LAL-Orsay/DESY-Zeuthen, Mark Oxborrow of National Physical Laboratory, Andrew Rollanson of Keele University, Kenneth Strain of Glasgow University, Valery Telnov of Novosibirsk, David Walker of Zeeko Ltd. and Aleksander Filip Zarneki of Warsaw University.

The purpose of the meeting was to discuss the paper by Klemz *et al* [1] which is a detailed analysis of a possible design of laser cavity system for use in the photon linear collider [2].

2. Background

The motivation to use a cavity at the photon linear collider (PLC) is that there are 10^{10} electrons in each electron bunch. The small cross-section for the Compton scattering process dictates having at least 10^{19} photons in the laser pulse to obtain an efficient conversion of the incoming beam. This means that less than 1 in 10^9 of the photons in the pulse is used, and so if one could reuse the laser pulse, one would need a much lower powered laser.

The paper by Klemz *et al* describes the basic design criteria for such a cavity, and presents a possible design. Using GLAD [7] software the optimum size of the mirrors was calculated. They find that a realistic design for the laser cavity can be produced. The final focusing mirrors in their design need a diameter of around 1.2 m. The design is fairly insensitive to displacements transverse to the beam but very sensitive to change in length of the cavity (as the power enhancement of the laser cavity is lost). In fact an accuracy of less than 1 nm is required, which implies that adaptive optics are required to maintain the cavity enhancement. Power deposit on the mirrors appears to be below the damage threshold of typical materials. However there is no literature on running a system with the repetition rate required for PLC.

3. Comments on Klemz *et al* paper

Comments on the proposed design have already been given in writing by Frisch [3], Strain [4], Oxborrow [5] and Freise [6]. All these documents are available at the website http://www.hep.lancs.ac.uk/LaserCavity/. In summary their comments amount to saying that the design is fine so far as it goes, namely the 'statics' of the system, but they question whether it could be made to work in practice. In particular the 'dynamics' of the system in a real world situation need to be understood. Here is a very brief summary of their comments and the interested reader is encouraged to refer to the original.

Mechanical/infrastructure

Identify sources of vibration and reduce them [5].

Cavity stability

At the required $\lambda/100$ precision, will the sag of the optical cavity's mirrors be a problem [5]?

Pulsed power effects

Could the performance be affected by photomechanical shock, beyond the capacity of any servo to correct it [5]? The pulsed power effects seem less difficult than with gravity wave detection [4].

Feedback/locking/mode-matching

Is the cavity compatible with Pound–Drever–Hall locking as it is commonly implemented? How exactly can one measure the laser beam's profile [5]? Gravity wave experience suggests that the longitudinal stability problem is soluble. Similarly the angular control can be solved, for example, with preheating of the mirrors to compensate for heating during a train of laser pulses [4].

Adaptive optics

Can the mirrors be moved fast enough in view of their mass? Can information from a low-power continuous wave laser, be used to steer the high-power pulsed-mode. How would an adaptive wavefront corrector be implemented [5]? Passive adaptive corrections may help [4].

Who moves?

Should the driving laser's output track the optical cavity, or vice versa; and/or the electron beam [5]?

Modularization and assembly

Should optical cavity be designed separately from the drive laser? How can one match the laser's natural output onto the optical build-up cavity [5]?

Drive laser

The drive laser's power output is still close to the state-of-the-art, even with a cavity to amplify it [3].

Way forward

A full numerical model which includes typical aberrations and deviations from specification can be used to understand the feasibility of the proposed topology better [3,6].

4. Discussion

Following talks by Klemz and Oxborrow, there was a round table discussion of the various issues raised. It was extremely valuable to have a large range of expertise together. Off the wall comments and questions were raised, for example 'Are the linear collider parameters really given, for example the time structure?' The answer is probably 'Yes' but it is important to ask the question. 'Is it definitely best to have a separate laser and optical cavity?' The answer is not clear, the alternative of a single cavity needs to be seriously studied as well. 'How about having a mirror with a hole in it for the electron beam to pass through?' Radiation damage is almost certainly too big a problem for this to work.

In response to worries about manufacturing the mirrors, we were told that this is similar to the next generation of photolithography optics, so it should not be a problem. In response to questions about the viability of the adaptive optics required, it was stated that this was well within the current state-of-the-art in telescopes, although it has not been done with pulsed lasers, one would need to average over several pulses. Building parabolical mirrors or indeed any other shape is not a problem.

The concerns about optical damage remain as it seems there are no results in the literature using pulsed lasers at the power levels required for this design.

It was felt that photon pressure effects should not be a problem. Thermal distortions can be taken care of with adaptive optics. However, the question was raised as to how the mirrors get cooled? Other materials, e.g. aluminium or silicon carbide could help. In principle, the mirrors getting hot should not be a problem but must be taken care of in the design. In other words, the system must be designed for its working temperature.

It was explained that one can measure the aberration of the system once it is in place, and add a compensating optic to correct it. This relaxes the tolerance on the rest of the system.

5. Conclusions

It is hard to summarise such a large number of comments and questions. It is clearly important to continue making contact with people in fields outside the accelerator community. Few experts at this meeting from fields such as astronomy and gravity wave detection made many valuable comments. We need what the astronomy community describes as an 'end-to-end' simulation of the dynamics of the design. This will help to identify which elements are critical to the working of the system. The damage threshold issues need further investigation using pulsed lasers. It may need real R&D if no one else has studied it. We should learn as much as possible from other related ILC projects such as the work done for polarimetry, polarised positron sources and the laser wire. It is important to realise that many of these worries will reduce the efficiency of the cavity, and so potentially the luminosity but there is no known effect at present that would prevent it from working at all. Finally, as well as the cavity approach, alternative designs need to be looked at in at least as much detail. There is still clearly a lot of work to be done, but the path is becoming clearer.

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