BRIEF REPORT OF THE FIRST WORKSHOP OF THE JOINT ICFA-ICUIL TASKFORCE ON HIGH AVERAGE POWER LASERS FOR FUTURE ACCELERATORS

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Abstract

A new taskforce has been formed in 2009, jointly with the International Committee for Future Accelerators (ICFA) and the International Committee for Ultra-Intense Lasers (ICUIL). This Joint Taskforce (JTF) has as goal to understand the needs imposed by future accelerators on laser technology. A preliminary summary, from a personal perspective, is presented of the activities at the first workshop held at GSI (Darmstadt) from April 8-10, 2010.

INTRODUCTION

Accelerators, x-ray light sources and lasers have been essential tools for advancement of science and technology, and have provided the basis for a vast number of industrial activities and societal benefits in the 20th century. As we enter the second decade of the 21st century, key challenges in science and technology will require next generation accelerators, light sources and lasers that far exceed today's capabilities.

Modern accelerators have become increasingly dependent on laser technology ranging from the production and manipulation of electron beams, to novel acceleration techniques and advanced light sources. The high average power demands imposed by today's accelerators on lasers is rapidly exceeding their state-of-the-art capabilities. Future accelerators that may rely entirely on lasers to power them far exceed today's capabilities. In order to bridge the gap between what exists today and what will be needed in the future, a Joint Taskforce (JTF) was formed with endorsement by both ICFA and ICUIL, to develop a roadmap for laser technology for future accelerators.

JTF ORGANIZATION

The 2009-2011 membership of the JTF consists of members of the ICFA Beam Dynamics Panel (Ralph Assman, Weiren Chou -- Chair ICFA BD, Ingo Hofmann, Kaoru Yokoya), the ICFA Advanced and Novel Accelerator Panel (Bruce Carlsten, Dino Jaroszynski, WL, Akiro Noda, James Rosenzweig, Siegfried Schreiber and Mitsuru Uesaka -- Chair ICFA ANA) and ICUIL (Chris Barty, Paul Bolton, Robert Byer, Almantas Galvanauskas, WL and Wolfgang Sandner). The JTF is chaired by WL.

WORKSHOP ORGANIZATION

A first workshop was organized at GSI (Darmstadt) from April 8-10, 2010 by the JTF to discuss the needs of accelerators that drive collider facilities, light source facilities and medical applications as well as an overview of the state-of-the-art in laser technology. The Chair of the local organizing committee was Ingo Hofmann. Experts on high power laser technology as well as accelerator technology and their applications were invited to this first meeting. The 47 participants came from China (1), France (4), Germany (18), Japan (4), Switzerland (2), the UK (4) and the US (14).

The goals of the workshop were the following:

- Establish a comprehensive survey of requirements for laser-based light and particle sources with emphasis on sources that can advance light and particle driven science, and that require lasers beyond the state-of-the-art or state-of-current use. The emphasis was placed on the fact that the workshop was not intended to carry out a down selection of specific designs or technology choices but instead have an inclusive approach that represent a community consensus.
- Identify future laser system requirements and key technological bottlenecks.
- From projected system requirements, provide visions for technology paths forward to reach the survey goals and outline the required laser technology R&D steps that must be undertaken.
- Write a technical report.

Four work packages were identified:

- Colliders -- effort led by Weiren Chou
- Light sources -- effort led by WL
- Medical applications -- effort led by Mitsuru Uesaka
- Lasers -- effort led by Chris Barty and Wolfgang Sandner.

The first day of the workshop was devoted to plenary talks covering the different workpackages and discussions of the material presented. The second day was devoted to working group discussions and material development and gathering. One the third and final day, final discussions were held followed by a summary and assignment of follow-up tasks for manuscript preparation.

COLLIDER WORK PACKAGE

The largest challenge for laser technology is a laser-plasma e-e collider up to the 10 TeV goal. The consensus in the world high energy physics community is that the next large collider after the LHC would be a TeV-scale lepton collider. Options currently under study include the ILC (0.5-1 TeV), CLIC (up to 3 TeV) and the muon collider (up to 4 TeV), all using RF technology. The very high gradients (~10 GeV/m) possible with laser plasma acceleration, on the other hand, open up new avenues to

reach even higher energy and more compact machines (see W. Leemans and E. Esarey, Physics Today **62**, 44-49 (2009)). This workshop investigated the beam and laser parameters of a 1-10 TeV, 10^{36} $cm^{-2}s^{-1}$ e+e- collider based on two different technologies – laser plasma acceleration (LPA) and direct laser acceleration (DLA). The main challenges to the practical achievement of laser acceleration are: high average power (~100 MW), high repetition rate (kHz to MHz), high efficiency (~40-60%) at a cost that ideally would be an order of magnitude lower than using RF based technology. The workshop also studied the laser requirements for a 200 GeV $\gamma\gamma$ collider, proposed as the first stage of a full scale ILC or CLIC. The required laser systems for such a collider may be within reach of today's technology.

LIGHT SOURCE WORK PACKAGE

For light sources, lasers already play a significant role in existing facilities, and face new challenges with future light sources that aim at much higher repetition frequency. Ultrafast (femtosecond) lasers reaching 1-10 kW levels will be required for seeding and user driven experiments. Lasers, producing a few Joules in 30-50 fs pulses at high repetition rate (100-1000 Hz) could be used to drive laser plasma accelerators that thanks to their ability to produce GeV-class, ultra-short, high peak current electron bunches, could drive compact free electron lasers operating in the soft x-ray regime. Higher energy per pulse lasers (~40 J) would be needed to drive multi-GeV electron bunches for hard x-ray FELs.

MEDICAL APPLICATION WORK PACKAGE

The third area of application has been medical applications of laser acceleration of protons/ions and its potential to replace current technology used in tumor therapy. Such lasers are typically very high peak power (PW-class) and require special pulse shapes with very high temporal contrast. Again, multi-kW compact lasers will be needed.

LASER WORK PACKAGE

Laser requirements for the applications discussed above, are often many orders of magnitude beyond the capabilities of the lasers used in today's scientific demonstrations, i.e. MW's vs 10's of W's. Laser science representatives at the meeting discussed and outlined how, with appropriate R&D, emerging 100-kW-class industrial lasers, 10-MW-class laser fusion energy technologies and MW-class defense laser systems might be adapted to meet these challenging requirements. Approaches include the use of fiber based laser systems, novel materials for high efficiency pumping and extraction of laser energy, diode pumping and amplification media that include bulk materials shaped as rods or slabs. Since the required laser technology depends highly on the accelerator requirements, it is clear that not a single technological solution will be appropriate for all applications. Whereas some light source and medical applications need ultra-short laser pulses with pulse duration on the order of a few femtosecond, others need longer laser pulses such as is the case for colliders. A preliminary design for a laser plasma accelerator based collider suggests that laser pulses with pulse duration of order 150 fs may be suitable which opens up material choices that have smaller optical bandwidths but can be directly diode pumped and have excellent thermal properties. These tradeoffs will be the subject of a subsequent workshop.

SUMMARY

An interim report was presented of activities at the first workshop on High Average Power Laser Technology for Future Accelerators. Results of the workshop, including parameter tables on laser technology requirements and goals will be compiled in a workshop report and submitted to ICFA and ICUIL for their approval, prior to public release.

ACKNOWLEDGMENTS

The author gratefully acknowledges valuable input and contributions from all JTF members and workshop attendees, especially Toshi Tajima, Mitsuru Uesaka, Weiren Chou, Chris Barty, Wolfgang Sander, Ingo Hofmann, and Eric Esarey.