Comprehensive Workshop on the Science and Applications of Ultra-fast, Ultra-Intense Lasers (SAUUL)

Introduction

The field of ultra fast, ultra intense laser science has received considerable attention in recent years. This has been driven by recent technical and scientific achievements These include such technological milestones, such as the demonstration of the first petawatt laser at LLNL in 1996.. Scientific achievements in recent years include advances in ultra fast x-ray source development and utilization, marked progress in compact particle (electron and proton) acceleration with lasers, and initial observations of strongly relativistic effects in laser-matter interactions, such as positron production and nonlinear optical effects. The international prominence of this field was recently highlighted by the OECD in a workshop hosted in Japan on Compact High-Intensity Short-Pulse Lasers during May of 2001. This meeting issued a report, which outlined many of the exciting applications of research in high intensity laser science and also illustrated the international vitality of research in this field. Given this growth and the future prospects, it is now appropriate for the research community in the United States to assess the current and future technical opportunities in this field.

Purpose of the Workshop

The principal purpose of this workshop is to pull together, in one meeting, all of the major researchers in the field. This will permit a dialogue on the science opportunities as well as the technical obstacles that must be overcome before these ultra fast, high intensity lasers can have wider application. At the workshop meeting, we will attempt to isolate the key technical challenges of this field in the coming years. One of our main goals will be to draw from the workshop a report on the science achievements and future directions of high intensity laser science. Such a report will aid both scientists and program managers to put into context the technical challenges and to determine where intellectual and financial resources may have the greatest impact.

Science Topics to be Addressed in the Workshop

We intend to address a broad a range of topics, all with the underlying theme that the science is enabled by high intensity, ultra short pulse lasers. Roughly speaking, this implies science performed with laser pulses of picosecond to femtosecond duration, and peak powers of terawatts to petawatts. Such a scope will encompass two principal laser technology frontiers, very high peak powers (science at one petawatt and higher) and high average power terawatt lasers (kHz and higher repetition rate).

A likely list of topics to be addressed and their impact areas is listed below:

1) Advanced ultra fast x-ray sources

This includes “traditional” laser plasma x-ray sources such as K-alpha sources and their application in time resolved materials and chemical dynamics experiments. Also important at the current time is research on “hyper fast” x-ray sources, such as atto second pulse production using high harmonic generation The potential application of such hyper fast pulses is a particularly timely topic right now.

2) Fusion energy research

Short pulse high intensity laser production of fast electrons (>MeV) is currently a promising candidate to aid in the ignition of an imploded inertial confinement fusion (ICF) pellet. Initial results from the LLNL Petawatt laser were promising and have sparked extensive supporting research around the world. This fast igniter concept also has some interesting variations that are now undergoing serious scrutiny, such as using fast protons accelerated by the laser to ignite the ICF fuel.

3) High energy density science

The ability of a high-energy ultra fast laser to heat solid density material on a time scale much faster than the material expands enables a whole range of interesting, high energy density experiments. In particular, this technique may enable novel equation of state measurements and atomic physics studies in the so-called warm-dense (T >1 eV, near solid density) and hot-dense (T > 1 keV) regime.

4) Laboratory astrophysics

The extremes in temperature possible with ultra intense short pulse lasers now make possible laboratory experiments of relevance to astrophysics. These experiments include hydrodynamic studies of shocks generated by the short laser pulse, studies relevant to the study of supernova dynamics. More exotic astrophysical applications include the production of relativistic, electron-positron plasmas with an ultra-intense focus. Such pair plasmas are believed to play a role in gamma ray bursts.

5) Advanced e- and p+ accelerators

There has been good recent progress on the acceleration of particles by lasers. Wakefield accelerators have demonstrated electron beams from gaseous targets with energies of > 100 MeV, and similar energies have been observed in the acceleration of protons from thin solid targets irradiated at relativistic intensity. More exotic acceleration ideas, such as the acceleration of short-lived particles (like pions), are also under discussion.

6) Pulsed ion and neutron sources

Intense laser interactions on solids and in gas targets can drive acceleration of heavy ions to high energy. Recent progress on the production of energetic neutrons with intense laser solid and laser cluster interactions has also been made. These sources may have application in studies of radiation damage of materials. Their pulsed nature is particularly promising in time-resolved damage studies.

7) Biology and medical applications

The application of short pulse lasers in biology and medicine is now achieving real viability. Laser generated x-ray sources have been used in proof of-principle biological imaging including ballistic imaging that uses the pulsed nature of the source. More speculative, but of great potential importance, is the use of laser accelerated protons and heavier ions in hadron cancer therapy.

8) Novel interactions with atoms, molecules and electrons

The interaction of intense, ultra fast laser pulses with atoms and molecules is the most mature field of study in this research area. Nonetheless, the development of lasers with focused intensity in the ultra-relativistic range (>1019 W/cm2) now presents a new range of unexplored phenomena. These include relativistic effects in photoionization or free electron nonlinear optics arising from relativistic motion of electrons in such an intense laser field.

9) Advanced laser technology

The driver of these science thrusts is the advanced laser technology. Advances in peak power to 1 PW and beyond and average power increases toward 100 W will be the driver for progress in the other areas outlined above. The technical challenges to further advances in the laser technology, therefore, require attention in parallel with the development of the science.