INTERNATIONAL COMMITTEE FOR ULTRA-HIGH INTENSITY LASERS

Annual Report to IUPAP
September 2015

www.ICUIL.org

ICUIL Activity Overview

ICUIL continues to be engaged with the advancement of the international field of ultra-high intensity lasers. Our goals are to provide a venue for discussions, among representatives of high-intensity laser facilities and members of user communities, on international collaborative activities such as the development of the next generation of ultra-high intensity lasers, exploration of new areas of fundamental and applied research, and formation of a global research network for access to advanced facilities by users. As described in this report, ICUIL continues to be active in promoting collaborations required to establish high-intensity laser infrastructures for the benefit of the international physics community. This activity overview highlights international progress made by members of the ICUIL community in 2014 to 2015.

Laser facilities around the world continue to push towards multi-petawatt power capability. For example, the Chinese initiative at the Shanghai Institute of Optics and Fine Mechanics (SIOM) is advancing rapidly towards a 10 PW laser facility. Lawrence Livermore National Laboratory (LLNL) is in the process of commissioning their Advanced Radiographic Capability (ARC) PW scale laser and the PETAL laser at CEA will begin operations at the 2 PW level this year. The University of Rochester's Laboratory for Laser Energetics announced its OPAL multi-phase laser initiative that could lead towards a 75 PW capability. In addition, the European ESFRI roadmap project, the Extreme Light Infrastructure (ELI), consisting of ELI-Beamlines, ELI-Nuclear Physics, and ELI-ALPS (attosecond science pillar), is moving towards an initial operation date of 2018.

ICUIL and ICFA (International Committee for Future Accelerators), another arm of the IUPAP Working Groups, are continually collaborating for the laser-driven wakefield acceleration for the purpose of future high energy accelerators. Since the publication of the ICUIL-ICFA Joint Taskforce Report on the laser accelerators in Dec. 2011, we tried to address the Report's findings. One of the main points is the need to improve the laser technology, in particular in its efficiency and repetition rate, so that the beam generated will have high enough luminosity. Along this line, the ICUIL community has invented the CAN laser technology based on the fiber laser technology. The progress on this technology push has been reported at the ICFA General Assembly at the Jefferson Lab at Newport News in Feb. 2015 by T. Tajima. In addition, with the CAN laser having high rep rate and high efficiency, additional important applications have been found, including the driver for the management of space debris (see Sec. IV of this Report). These will be further reviewed at the IZEST Conference at CERN this October. This will be another giant step in collaboration between the communities of ICUIL and ICFA. The possibility of future collaboration on high fluency laser technology at CERN will be discussed. In addition to the ICUIL-ICFA collaboration, ICUIL is happy to help send our members (ex officio) to the new toddler of our sister Working Group in Accelerator Science under the guidance of IUPAP. We continue to collaborate with the Asian Intense Laser Network and we sponsor the Russian Summer School on Intense Lasers to promote the young generation in furthering the reach of high intensity lasers.

International Teleconferences

Periodic teleconferences held throughout the year continue to be effective in maintaining progress in each of the primary activities below.

- ICUIL Newsletter

ICUIL continues to achieve its goal of publishing an annual newsletter. The sixth ICUIL Newsletter (Volume 6) was sent out to the high intensity laser community in June 2015 and is also available at the ICUIL website. The chief editor, Alexander Sergeev, managed the illustration and publication resources to distribute an eight-page newsletter to hundreds of readers, highlighting the major laser construction and laser science projects within the HIL community, major conferences, and related workshops.

- ICUIL Website

One of the features of the ICUIL website is an interactive world map that highlights the high intensity laser facilities around the world as shown below. Surveys of the worldwide laser community are conducted by ICUIL in an effort to provide an accurate accounting of all existing and planned ultrahigh intensity laser facilities that are capable of reaching intensities above 10^{19} W/cm^2. An updated survey will be implemented at the 2016 ICUIL conference next year.

- ICUIL Charter

The bylaws of the ICUIL Charter are being revised to maintain the experience and dedication of the current membership that has been assembled over the last decade. More than two terms of service would be allowed for members who continue to be active in this field and are able to provide service to the ICUIL community. A vote on the revised charter is anticipated to occur at the 2016 General Assembly meeting. A more gradual member rotation will be used to maintain continuity and ensure that ICUIL continues to advance while maintaining balance both geographically and between the various high field science working groups of IUPAP.

- Fund Raising

ICUIL has continued its corporate support program to afford maintenance of the ICUIL website, publish an annual newsletter, and support biennial conferences. The remaining funds are being targeted towards support of new outreach activities including student competitions held at the biennial conferences.

- ICUIL Biennial Conferences

The 6th biennial ICUIL conference was held September 12-17, 2014 in Goa, India and was hosted by the TIFR, with Ravi Kumar serving as the conference chairman. The INRS will host the 2016 ICUIL Conference at the Fairmont le Château Montebello, Canada which is situated on the shore of the Ottawa River. Tsuneyuki Ozaki and Dino Jaroszynski are serving as the conference chairmen who are organizing a full technical program that will focus on the generation, amplification, compression, and measurement of ultra-high-intensity lasers as well as a variety of novel scientific applications.

ICUIL
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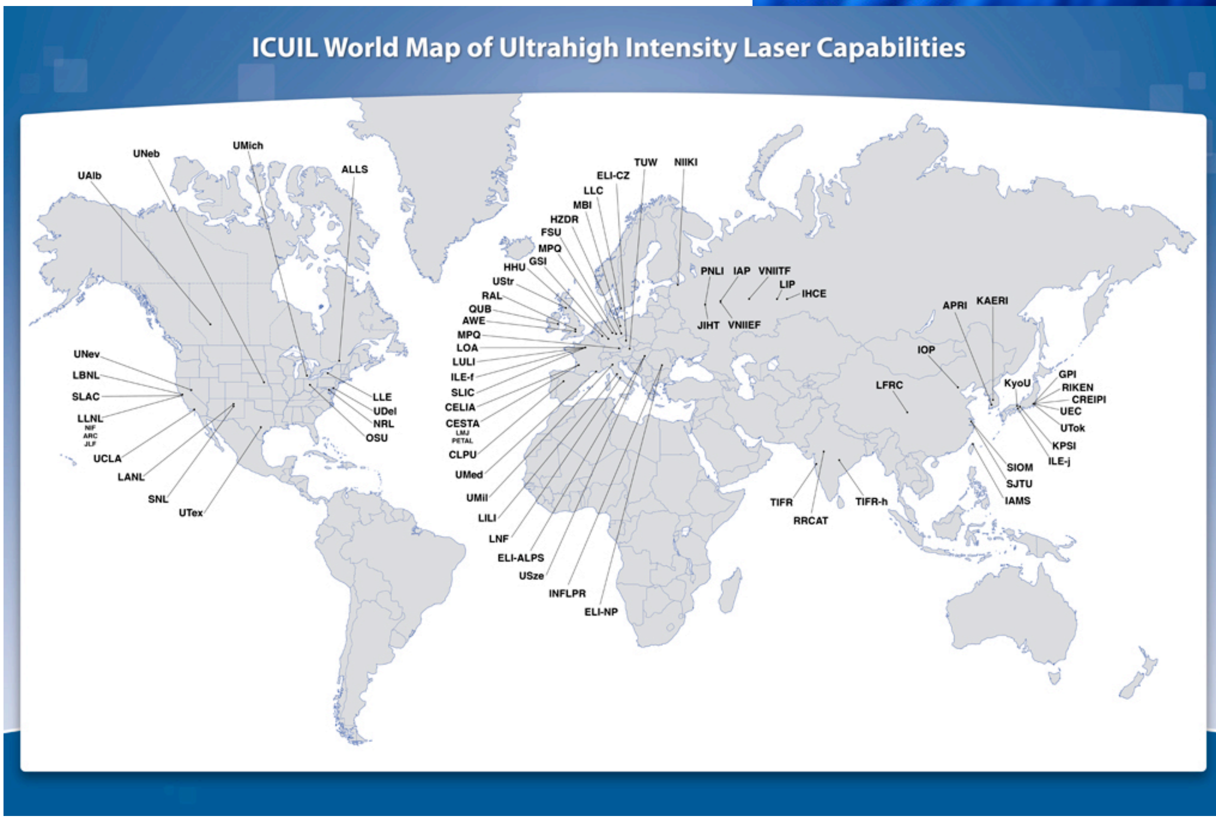

<u>2014 ICUIL Membership</u>

Toshiki Tajima	Chairman	International
Chris Barty	Co-Chairman	United States
Alexander Sergeev	Co-Chairman	Russia
Terry Kessler	Secretary	United States
Tsuneyuki Ozaki	Treasurer	Canada
Gerard Mourou		France
Hiroshi Azechi		Japan
John Collier		United Kingdom
Dino Jaroszynski		United Kingdom
Thomas Kuehl		Germany
Ravi Kumar		India
Christine Labaune		France
Wim Leemans		United States
Ruxin Li		China
Chang Hee Nam		Korea
Bedrich Rus		Czech Republic
Wolfgang Sandner		Germany
Heinrich Schwoerer		South Africa
Ken-ichi Ueda		Japan

<u>Associate Members (without vote)</u>

Ryosuke Kodama	Japan
Sandro de Silvestri	Italy
Nilson Dias Vieira Jr.	Brazil
Claes-Goran Wahlstrom	Sweden

ICUIL Related Science and Technology Highlights

I. Extreme Light Infrastructure (ELI)

ELI is a pioneer among the research infrastructures contained in the European ESFRI Roadmap in using EU structural funds for construction. One of the three ELI pillars is Nuclear Physics (ELI-NP), a European research center to study ultra-intense lasers interaction with matter and nuclear science using gamma and laser driven radiation beams. It will be located in Magurele, Romania. The total cost of the facility will be 300 million Euros and commissioning is expected to take place in 2018. The ELI-NP facility combines a high power laser system (HPLS) with two arms of 10 PW having intensities on the target in the range of 10^{23} W/cm^2. A gamma beam system (GBS) will deliver up to 19 MeV photons with extreme brilliance and bandwidth and is based on Compton scattering of a high repetition pulsed laser beam on a relativistic electron beam produced by a warm linac of 720 MeV. The GBS is being constructed by EuroGammaS, a European Consortium of academic and research institutions and industrial partners with expertise in the field of electron accelerators and laser technology from 8 European countries, the consortium led by INFN Italy. The scientific program for ELI–NP was elaborated by an international collaboration of more than 100 scientists from 30 countries. The ELI-NP team together with their collaborators from the international scientific community shaped the future scientific program of ELI-NP in a series of workshops and defined ten development directions for the facility. The latest workshop was convened in June. The Technical Design Reports were approved by ELI-NP International Scientific Advisory Board, chaired by Toshiki Tajima, and submitted in July, 2015.

II. International Center for Zetta-Exawatt Science and Technology (IZEST)

IZEST endeavors to unify a number of exawatt class facilities around the world. Almost 30 laboratories in 13 countries have signed a collaboration agreement. A new pillar within the IZEST organization, known as ZeptoScience, was formed. Preliminary theoretical models show the possibility to convert single-cycle femtosecond, near-infrared, ultra-relativistic intensity laser pulses to atto or zeptosecond, gamma ray pulses through the interaction with a thin, superdense plasma. This can be considered as an extension of the creation of XUV, attosecond pulses through sub-cycle processes at the femtosecond-scale within the strong-field processes of atomic, molecular and solid target plasmas. With increasing field strength, the subsequent gradients involved within a relativistic laser-plasma interaction create a small sub-cycle window for the photon up-conversion to reach gamma-ray energy scales. Efficient post-compressing these types of pulses using a thin film of thermoplastic to produce the spectral broadening to support a single-cycle pulse (~250 nm) followed by dispersion controlled chirped mirrors offers the possibility to produce the driving NIR pulses required to produce zeptosecond-scale x-ray pulses within a plasma. A ZeptoScience team is performing experiments to test the methods to efficiently compress existing laser technologies to the few-cycle, femtosecond regime with a sufficient intensity to pursue the creation of zeptosecond pulses. This work is being performed by a team based at Ecole Polytechnique (France), National Institute for Laser, Plasma and Radiation Physics (INFLPR, Romania), and ELI-NP (Romania). Theoretical studies are underway at the University of California Irvine to explore the potential properties and applications of such short gamma-ray pulses such as laser wakefield acceleration within solid-density plasmas leading to crystal accelerations of TeV/cm, and vacuum QED studies leading to x-ray nonlinear responses through vacuum propagation.

III. The International School on Ultra-Intense Lasers

The School is organized by the International Committee on Ultra-Intense Lasers (ICUIL), Institute of Applied Physics of the Russian Academy of Sciences (IAP RAS), National Research Nuclear University MEPhI and Russian Federal Nuclear Center (RFNC-VNIIEF). This event is primarily aimed at providing postgraduate students and other early career researchers working in ultra-intense laser science with a thorough pedagogical grounding in high power laser physics, laser-matter interaction physics, laser-plasma accelerators, laser-based x-ray sources and inertial confinement fusion. The organizers believe that quite a wide scope of topics and the brilliant lecturers will attract more young researchers to this promising field of modern science. This is really one of the key goals and the intrinsic stimulus to hold the school. The school will be held will be held in the Hotel@Resort "Yunost" 40 km from Moscow, Russia, from 4 to 9 October, 2015.

IV. Laser Solutions to Orbital Space Debris

The first international workshop on the topic of Laser Solutions to Orbital Space Debris was organized by Ecole Polytechnique researchers including Dr. Mark N. Quinn and Prof. Gerard Mourou from the IZEST group; the workshop was by collaborators at the Astro Particle Cosmology (APC) Laboratory at the University of Diderot Paris. Over 30 million kg of debris including small fragments, rocket bodies and whole satellites have accumulated in Earth's orbit since the beginning of the space age. With large relative velocities in orbit surpassing10 km/s, even small cm size debris can impact and explode large multi-ton bodies creating many more additional fragments. Potentially, the very useful orbits containing the majority of communications satellites could be lost in a few decades unless strong mitigation and active remediation are introduced. This workshop brought together over 60 researchers from many different fields and nationalities, including Japan, Australia, Europe and the USA together with representatives from aerospace companies, including ESA, NASA and Airbus. It has become clear that these different pursuits can collaborate together and a key outcome of the workshop is the building of links in this worldwide community.

V. NIF EXAWATT

Chris Barty, an ICUIL Co-chairman, has presented his vision of the next generation of high intensity lasers at several conferences this year. With the implementation of chirped pulse amplification (CPA), it is possible for beam lines at the National Ignition Facility at the Lawrence Livermore National Laboratory, the Laser Mega-Joule (LMJ) facility in Bordeaux, France, the LFEX laser at the Institute for Laser Engineering in Osaka, Japan and the Omega EP facility at the Laboratory for Laser Energetics in Rochester, New York to create petawatt peak power laser pulses of nominally 1-ps duration and 1-kJ energy. New short pulse amplification architectures based on chirped "beams", novel pulse compressors and existing beam phasing technologies are capable of extracting the full, stored energy of a NIF or NIF-like beam line and in doing so produce from one beam line a near-diffraction-limited, laser pulse whose peak power would be in excess of 200 petawatts or 0.2 exawatts. This architecture is well suited to either low-f-number focusing or to multi-beam, dipole focusing concepts. With dipole focusing, it is anticipated that a single beam line of a NIF exawatt or so called Nexawatt system will be capable of reaching intensities in excess of

10^{26} W/cm^2 or more than 5 orders of magnitude beyond existing systems. The novel amplification architecture is based entirely on existing technologies, proven optical damage performance and straightforward extensions of existing manufacturing technologies.

VI. Highlights of High Intensity Laser Facilities

National Ignition Facility's ARC

The commissioning of the Advanced Radiographic Capability (ARC) laser system in the National Ignition Facility (NIF) is currently in progress. ARC is designed to ultimately provide eight beamlets with pulse duration adjustable from 1 to 50 ps, and energies up to 1.7 kJ per beamlet. The beamlets will be used to create x-ray point sources for dynamic, multi-frame high-energy x-ray radiographs of the imploded cores of ignition targets. They are critical for creating precision x-ray backlighters needed for NIF experiments studying complex hydrodynamics and material strength at extreme high energy density regimes. ARC can also produce MeV protons and electrons for future experiments in advanced fusion, TeV acceleration and proton radiography. Recently, a new front-end was installed to achieve higher pulse contrast, resulting in 80 dB for the preceding 200 ps. The ARC laser is integrated into the NIF laser system utilizing four of the NIF beams (1 quad) to produce 8 beamlets. The quad of beams can either be configured for NIF 3ω operation or for high-energy ps pulses, using hardware controlled during the automated shot cycle. Commissioning of 4 of the 8 beamlets is currently underway to operate at 1.2 KJ energy in 30 ps pulses to irradiate Au-wire backlighting targets.

Texas Petawatt

Center for High Energy Density Science researchers have completed a year-long project to improve the pulse contrast on the Texas Petawatt Laser. The new design started with two BBO-based OPCPA stages pumped by an optically synchronized pump laser. These stages amplify slightly chirped few ps pulses by six orders of magnitude and reduce the contrast pedestal width to a few ps. There are two LBO-based OPCPA stages that are pumped by 4 ns pulses. These have much less gain and the overall reduction in parametric fluorescence is about three orders of magnitude. All lenses in the glass amplifiers were replaced with off axis parabolic mirrors, eliminating all discrete prepulses. All problematic wave plates and thin transmissive optics in the laser were eliminated to prevent post pulses that would result in prepulses by nonlinear conversion. An Acousto-Optic Programmable Dispersive Filter was added to improve fourth order dispersion and steepen the rising edge of the compressed pulse. These enhancements resulted in a final contrast of nine orders of magnitude. This improvement enables the use of thin and reduced mass targets for ion acceleration and reduces pre-plasma effects for all experiments.

CEA's PETAL

Petawatt Aquitaine Laser (PETAL) will allow unique experiments in the field of ultrahigh intensity sciences, extreme plasma physics, astrophysics, radiography, and fast ignition by a combination of its own multipetawatt kilojoule beam and the nanosecond multikilojoule beams of the Laser Mégajoule (LMJ). The PETAL facility is designed and constructed by the French Commissariat à l'énergie Atomique et aux énergies alternatives (CEA) to deliver energy up to 3 kJ in 500 fs at the wavelength of 1053 nm and is an additional short pulse beam to the Laser MegaJoule (LMJ) facility. PETAL has recently achieved 1.4 KJ at 2 ns with a 3.5 nm bandwidth to produce 1.15 PW with a 700 ps pulsewidth. The focal spot was measured to have 60% of its energy contained within a 20 μm and 80% within an 80 μm diameter. The goal is to reach 10^{20} W/cm^2 on target. The facility will be operated at a 1 kJ energy level for initial experiments due to the current damage threshold of the final optics.

SIOM's Petawatt Laser

Ruxin Li, an active member of ICUIL, reports significant progress from the State Key Laboratory of High Field Laser Physics at the Shanghai Institute of Optics and Fine Mechanics (SIOM) in China. In 2013 the output energy of the Ti:sapphire CPA laser system at SIOM reached 72.6 J at a pump energy of 140 J, corresponding to a peak power of 2.0 PW. At the end of 2014, a high gain chirped pulse amplifier based on a Ti:sapphire crystal 150 mm in diameter was demonstrated, with the highest output pulse energy of 192.3 J at the pump laser energy of312 J, corresponding to a pump-laser efficiency of 50.4%. The amplified chirped pulse had a bandwidth of 53 nm at 800 nm central wavelength. With the grating compressor efficiency of 72% and the 27.0 fs compressed pulse width obtained with part of the energy, this Ti:sapphire laser system could support a peak power of 5.13 PW. Meanwhile, a CPA/OPCPA hybrid laser system has achieved the peak power of 1.0 PW, where an LBO 100 mm in diameter was used in the final OPCPA, and the output energy of 45.3 J was obtained. A 10 PW level femtosecond laser system, combining this Ti:sapphire based CPA chain and this OPCPA booster amplifier, is currently being constructed.

LLE's OPAL Laser

The University of Rochester's Laboratory for Laser Energetics is developing plans to construct a 15 PW laser system that is pumped by its existing OMEGA EP facility, with a potential upgrade to 75 PW. Optical parametric chirped-pulse amplification (OPCPA) provides broadband gain for large-aperture beams by using Nd:glass lasers to pump deuterated potassium dihydrogen phosphate crystals. Scaling to kilojoule energies would enable focused intensities exceeding 10^{23} W/cm^2 with 20 fs pulses. A mid-scale optical parametric amplifier line (OPAL) pumped by the Multi-Terawatt laser (MTW) is being constructed to produce 7.5-J, 15-fs pulses and demonstrate technologies that are suitable for a kilojoule system pumped by OMEGA EP (EP-OPAL). In parallel, a novel Raman plasma amplifier is being developed; MTW is the picosecond pump laser and MTW-OPAL provides a tunable femtosecond seed. The ultra-broadband front end consists of a white-light continuum seed that is amplified by three noncollinear optical parametric amplifiers (NOPA's). The pulses are stretched to 1.5 ns before further amplification in NOPA4. The radial group delay of the lens-based image relays is compensated before the final DKDP amplifier, NOPA5, which is pumped by MTW using three switchyards to provide narrowband pump pulses at 526.5 nm. Completion of MTW-OPAL would lead to the final design and planning for an EP-OPAL laser system.