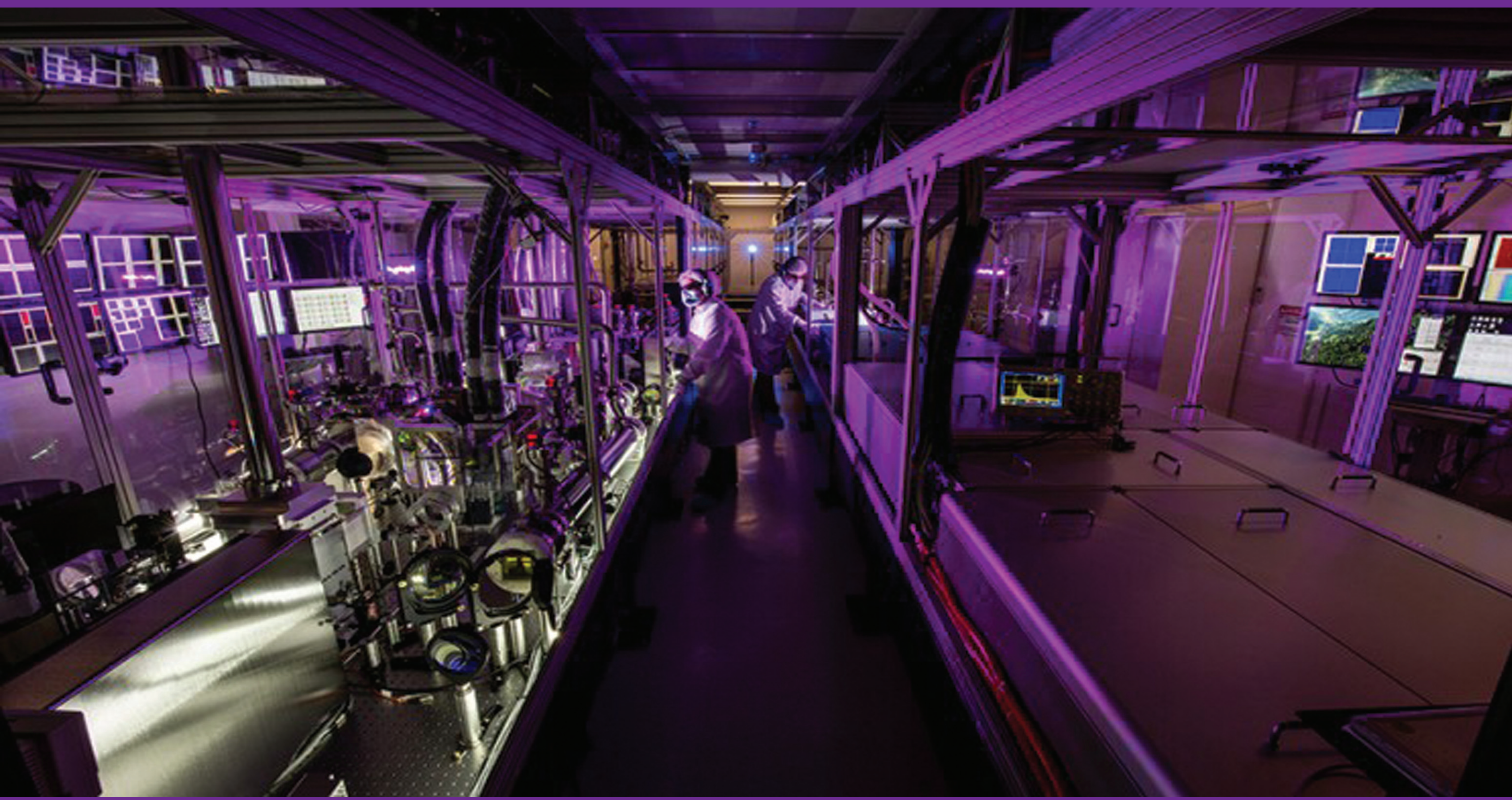
ICUIL News N°8

Volume 8 – June 2017

Chief Editor: Alexander Sergeev



The International Committee on Ultra-High Intensity Lasers

ICUIL Chairman's statement and welcome

As the incoming chairman of the International Committee on Ultrahigh Intensity Lasers (ICUIL), it is my honor to both welcome you to our 8th newsletter and to offer on behalf of the entire ICUIL community our sincere thanks to Professor Toshiki Tajima who for the previous eight years has served as ICUIL's chairman. Under Professor Tajima's leadership, ICUIL's activities have greatly flourished and new relationships with important, related communities have been formed. The strong linkage that exists today between ICUIL and the accelerator community is in large part due to Prof. Tajima's unwavering drive and leadership.

As is evident throughout the contents of this newsletter, worldwide activities related to the development and use of ultrahigh intensity lasers are growing. New user facilities are coming on line and existing facilities are making significant upgrades to their existing capabilities. It is our hope that you find this newsletter to be a convenient snapshot of worldwide activities and that you will use this document as motivation to visit the ICUIL website at www.icuil.org and to participate in upcoming ICUIL related activities.

sincerely

Dr. C. P. J. Barty - Chairman ICUIL

ICUIL World Map of Ultrahigh Intensity Laser Capabilities

2017 ICUIL Membership

The International Committee on Ultrahigh Intensity Lasers (ICUIL) created by the International Union of Pure and Applied Physics in 2003 at the Council and Commission Chairs meeting in Vancouver, Canada currently includes the following laser scientists

Officers:

Christopher P. J. Barty
Chair
Chief Technology Officer for NIF and Photon Science LLNL (Lawrence Livermore National Laboratory), USA

Alexander Sergeev
Co-Chair
Director, Institute of Applied Physics, Russian Academy of Sciences, Russia

G Ravindra Kumar
Co-Chair
Professor, Tata Institute of Fundamental Research, India

Terrance Kessler
Secretary
Group Leader of Optics and Imaging Sciences LLE, University of Rochester, USA

Tsuneyuki Ozaki
Treasurer
Director, ALLS INRS-ÉMT

Members:

Gerard Mourou, France
Toshiki Tajima, United States
Bedrich Rus, Czech Republic
Chang Hee Nam, Korea
Christine Labaune, France
Claes-Goran Wahlstrom, Sweden
Dino Jaroszynski, United Kingdom
Hiroshi Azechi, Japan
Heinrich Schwoerer, South Africa
John Collier, United Kingdom
Ken-ichi Ueda, Japan
Nilson Da Vieras Jr., Brazil
Ruxin Li, China
Ryosuke Kodama, Japan
Sandro De Silvestri, Italy
Thomas Kuehl, Germany
Wim Leemans, United States

The principal goals pursued by the ICUIL members are

- to provide a venue for discussions among representatives of the Ultrahigh Intensity Lasers facilities and members of the user communities on international collaborative activities such as the development of the next generation ultrahigh 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;
- to promote unity and coherence in the field by convening conferences and workshops dedicated to ultrahigh intensity lasers and their applications;
- to accelerate progress in the field by exploring opportunities of sharing information, joint procurement, and the exchange of equipment, ideas and personnel among laser laboratories world-wide;
- to attract students to high-field science by promoting their education and training, interactions with prominent scientists, and access to the latest equipment, results and techniques;
- to strengthen and exploit synergy with other relevant fields and techniques, notable accelerator-based free electron lasers.

The Extreme Laser Infrastructure: an international user facility

ELI is a new laser research infrastructure, which is part of the European ESFRI Roadmap. ELI currently consists of three different sites, which will be hosting the most intense and short pulsed lasers in the world, made available to an international academic and industrial user community to perform experiments.

The scientific profiles of the ELI pillars will be complementary, and the operation of the Research Infrastructure, starting progressively from 2018, will be unified under one single legal umbrella of the ELI-ERIC. Currently, the organization is transforming towards this ERIC-governed unified operation.

In this article, we briefly describe the current activities of the three pillars of ELI and their foreseen facilities.

ELI Nuclear Physics Facility

In Măgurele, Romania, the ELI Nuclear Physics (ELI-NP) facility will focus on photonuclear physics studies and applications, comprising unique features at the limits of the present-day's technology: a very High Power Laser System (HPLS) of 2 × 10 PW and a very intense Gamma Beam System (GBS) with $E\gamma$ up to 19.5 MeV.

Kazuo A. Tanaka, Scientific Director of ELI-NP: 'Our laser system will have an intensity which is higher than ever before, and the gamma beam will be the brightest one ever made. We can have the laser beam colliding with relativistic electron beams, which will cause dynamics predicted by QED theory which could not be tested before. Also for many other applications like fusion or fission, exciting possibilities will be tested. The name of the facility says it all: extreme laser infrastructure nuclear physics. It is all about combining laser technology and gamma beams on scales which have never been performed before. This will become a very attractive site for scientists from all over the world, namely a game changer in the field.'

ELI-Attosecond Facility

The ELI Attosecond Light Pulse Source (ELI-ALPS) in Szeged, Hungary is establishing a unique facility which provides light sources between THz (10^{12} Hz) and X-ray (10^{18}–10^{19} Hz) frequency range in the form of ultrashort pulses with high repetition rate.

Károly Osvay, Research Technology Director ELI-ALPS: 'The lasers which are going to be available at ELI-ALPS distinguish themselves in three major aspects: They have a high repetition rate, they will cover broad spectral ranges, and they will have as short pulses as possible, sometimes even consisting of a single optical cycle. But most of all, what we are aiming for is to achieve a combination of high average power and high peak intensity laser systems which are highly stable and reliable. We generate pulse durations as short as few tens of attoseconds, that is, 10^{-17} s. The major focus of ELI-ALPS is to use these pulses to investigate how fast atoms, molecules, clusters, and even proteins react to an excitation.'

ELI Beamlines Facility

In Dolni Brezany, near Prague, Czech Republic, the ELI-Beamlines facility will mainly focus on the development of short-pulse secondary sources of radiation and particles, and on their multidisciplinary applications in molecular, biomedical and material sciences, physics of dense plasmas, warm dense matter, laboratory astrophysics. In addition, the pillar will utilize its high-power, high-repetition-rate lasers for high-field physics experiments with focused intensities of about 10^{23} W/cm^2, investigating exotic plasma physics, and non-linear QED effects.

Georg Korn, Chief Scientist at ELI Beamlines: 'ELI-Beamlines is designed as the high-energy pillar of ELI. The laser sources were designed to address specific scientific aspects, namely in the fields of particle acceleration by lasers, generation of high-brightness XUV and X-ray pulses, and high-field physics. The generated ultra-short pulsed sources of energetic particles and radiation will serve fundamental research and multidisciplinary applications.'

Most of the laser systems will be shipped and installed in 2017 and 2018. From 2018 onwards, first experiments will be possible, and the facilities will be open to scientists from all over the world via a scientific excellence based selection process supported by an international peer review committee.

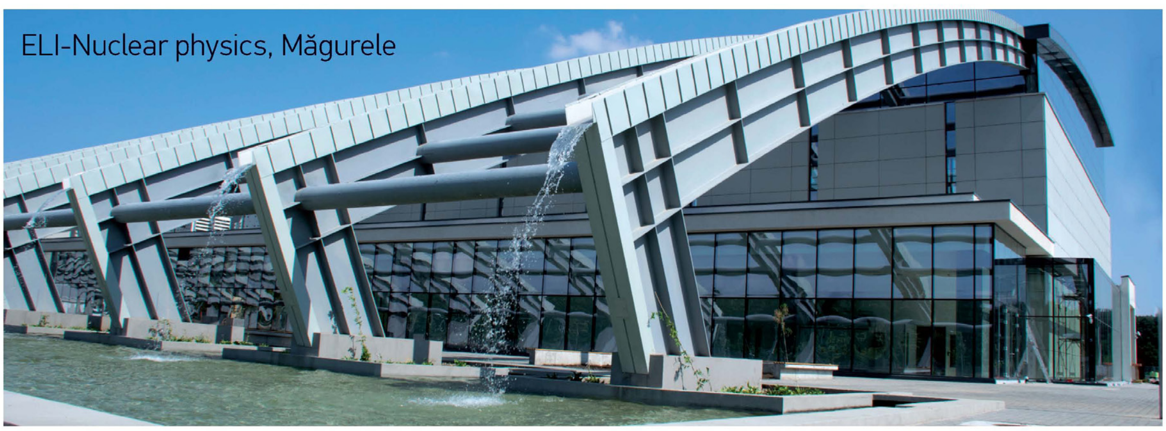
At the moment, all three pillars of ELI are actively looking for researchers and technicians to join their teams. If you are interested, present job openings can be found on:

www.eli-np.ro (Romania)
www.eli-alps.hu (Hungary)
www.eli-beams.eu (Czech Republic)

Extreme Light Infrastructure


ELI ALPS, Szeged


ELI Beamlines, Dolni Brezany


ELI-Nuclear physics, Măgurele

Development of a 4 PW Ti:Sapphire Laser at CoReLS

Chang Hee Nam
Center for Relativistic Laser Science, Institute for Basic Science, Gwangju 61005, Korea;
Department of Physics and Photon Science, GIST, Gwangju 61005, Korea

A high-contrast 4 PW Ti:sapphire laser with a repetition rate of 0.1 Hz was developed at the Center for Relativistic Laser Science (CoReLS), Institute for Basic Science (IBS) in Korea, for the exploration of superintense laser-matter interactions. Ultrahigh power lasers with peak power of 1 PW or higher have been constructed in a number of institutes around the world. Laser-driven particle acceleration has been one of intensively pursued research topics with such ultrahigh power lasers. A multi-GeV electron beam can be produced from a He gas target driven by a PW laser, and the GeV electron source can be used for Compton backscattering to produce MeV gamma rays. The development of ultrahigh power lasers, thus, offers a new generation of particle and radiation sources, which can initiate another new challenging physics in astrophysics and nuclear physics as well as in plasma physics.

At CoReLS, two PW laser beamlines with outputs of 1.0 PW and 1.5 PW at 30 fs have been utilized for research on laser-driven particle acceleration since 2012. One of the PW beamlines was upgraded to a 4 PW beamline, as shown in Fig. 1. In order to boost the PW beamline to a multi-PW laser, we shortened the pulse duration while increasing pulse energy. For the reduction of the pulse duration, the spectral width of amplified laser pulses has to be broadened, while flattening the spectral phase over the whole spectral range as much as possible. We adopted the cross-polarized wave generation (XPW) and the optical parametric chirped-pulse amplification (OPCPA) techniques in order to compensate for gain narrowing and gain depletion effects.

For the upgrade, the front-end part of the existing PW beamline was significantly modified. An XPW stage consisting of a hollow-core fiber, a BaF_2 crystal, and a Glan-laser analyzer was installed after the front-end amplifier in order to broaden the laser spectrum and to enhance the temporal contrast. A 30 fs, 3 mJ laser pulse was sent through the XPW stage, and the XPW output had a spectral width of 107 nm, a temporal contrast ratio

Fig. 1. CoReLS PW laser beamlines with outputs of 4 PW (left) and 1 PW (right).

of about 10^{-12} and an energy of 0.5 mJ. Its spectral width and the temporal contrast were improved by a factor of two and by 4 orders of magnitude, respectively. The OPCPA amplifier was employed as a preamplifier of the PW laser for the generation of a broadband laser spectrum without the gain narrowing problem observed frequently in a high gain preamplifier. In addition, the spectral narrowing due to the gain depletion effect, occurring while extracting the maximum energy available at the subsequent amplifiers in the CPA scheme, was taken care of by shaping the laser spectrum at the OPCPA stage.

For the increase of the output energy, a final booster amplifier was added. The booster amplifier was pumped with the second harmonic of Q-switched Nd:Glass lasers with a total energy of 170 J in green. After double passage of the amplifier, the laser pulse was amplified to 112 J. With the pulse compressor made of four gratings we obtained compressed laser pulses with an energy of 83 J and a pulse duration of 19.4 fs, producing 4.2-PW laser pulses at the repetition rate of 0.1 Hz with the low energy fluctuation of 1.5 % (rms). In addition, the temporal contrast was measured to be 3×10^{-12} up to 100 ps before the main pulse. Consequently, we successfully upgraded one of the PW laser beamlines to the 20 fs, 4 PW beamline.

A series of commissioning experiments are planned this year. Three target chambers are available at CoReLS for physics experiments, as shown in Fig. 2. As its first run of the 4PW laser commissioning, an electron acceleration experiment has been performed in April, 2017 using the laser wakefield acceleration (LWFA) scheme. LWFA has been investigated at CoReLS to produce quasi-mono-energetic collimated GeV electron beams of centimeter-scale acceleration length. In the previous exploration of LWFA, we succeeded in controlling the acceleration process by manipulating the temporal structure of PW laser pulses, generating stable multi-GeV electron beams. We plan to carry out the Compton backscattering to generate MeV gamma-rays from the interaction of a GeV electron beam and another laser beam. Furthermore, the newly upgraded 4-PW laser can offer opportunities to produce a 10-GeV electron beam and 10-MeV gamma rays. Consequently, the development of high energy electron beam and ultrafast gamma-ray sources with multi-PW lasers will open a route to explore strong field QED processes in photon-particle, photon-photon interactions, laboratory astrophysics, and photo-nuclear physics as well as plasma physics at extreme laser intensities.

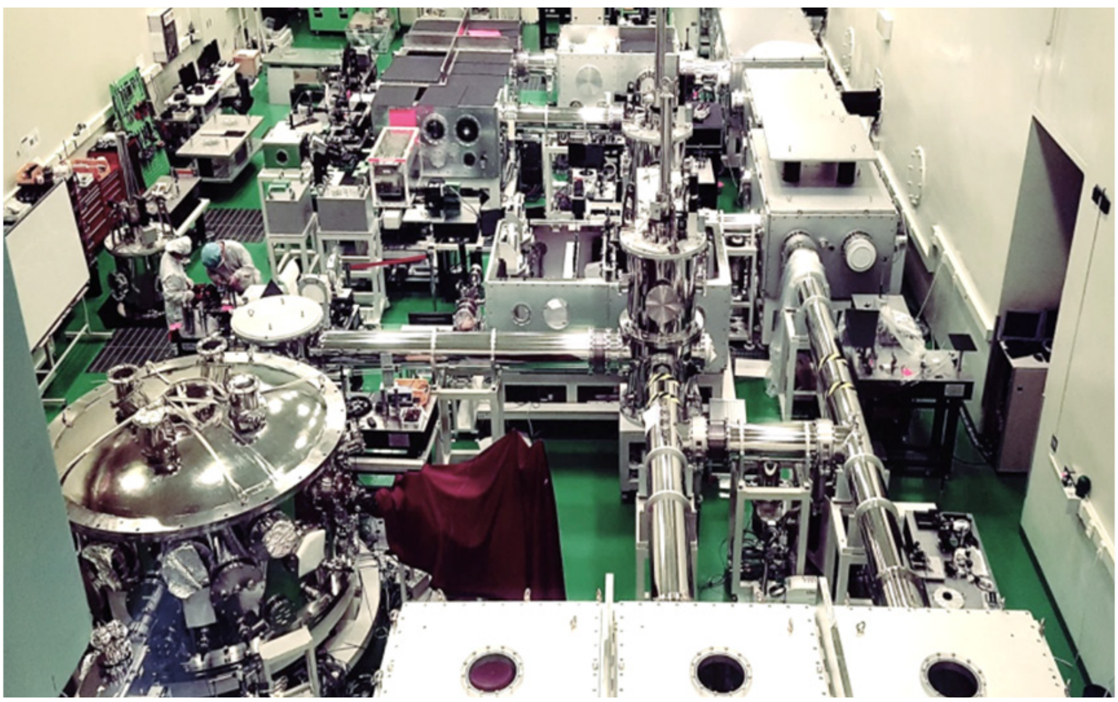


Fig. 2. Experimental area showing three target chambers and a double plasma mirror chamber along with two pulse compression chambers.

The European Cluster of Advanced Laser Light sources (EUCALL)

Synergy between accelerator and laser-driven light sources

Within the EUCALL project, which was launched in October 2015 and is coordinated by the European XFEL in Germany, the accelerator-driven and laser-driven X-ray sources of Europe collaborate for the first time in a comprehensive way on technical, scientific, and strategic issues. EUCALL involves approximately 100 scientists from European XFEL, DESY, and Helmholtz Zentrum Dresden-Rossendorf in Germany; ESRF in France; Elettra Sincrotrone Trieste in Italy; Lund University in Sweden; PSI in Switzerland; and each pillar of the Extreme Light Infrastructure (ELI) in the Czech Republic, Hungary, and Romania, including the ELI Delivery Consortium (ELI-DC). The project also involves the previously established scientific networks *FELs of Europe* and *Laserlab Europe.*

EUCALL's primary output consists of new technologies for standardisation and optimised access to different types of light sources for staff and users. Software is being developed to fully simulate photon science experiments at the light sources; and also for ultrafast data acquisition and data processing for experiments at the facilities. New hardware is under development for an intelligent, standardised sample delivery system for both X-ray and laser experiments at EUCALL's facilities, as well as advanced photon beam diagnostic tools for use at these light sources.

Further initiatives are dealt with under EUCALL's "Synergy" Work Package, which focuses on enhancing the combined research and innovation potential of the new cluster of facilities. An optimized database is under development, which will allow potential users to enter their requirements helping them to identify the most suitable beamline for their experiments. During 2017 and 2018, EUCALL will organize several workshops that aim to provide exchange of experience from the management of EUCALL's operational light sources like DESY and ESRF, to the facilities under implementation such as ELI and European XFEL. Further events planned for the scientific community involve experience exchange on the application of synchrotron, free-electron laser, and high-power laser-driven X-ray radiation to biology, as well as to problems of societal relevance such as climate change and green energy.

"EUCALL is a unique opportunity for two formerly independent scientific communities to meet, discuss, and work in synergy to identify joint solutions to common scientific and societally relevant challenges," said Catalin Miron, Deputy Director General of the ELI-DC. "From the operational point of view, newly established research infrastructures such as ELI have lots to learn from the well-established, accelerator-based user facilities, and EUCALL is the ideal forum for expertise and knowledge transfer."

"The EUCALL project brings together experts from different types of light sources", said Thomas Tschentscher, European XFEL scientific director and EUCALL's project director. "The exchange of know-how and the joint developments provide new impulses to the individual light sources, and also pave the way towards new science and technology applications."

At the halfway point of its three-year project period, EUCALL has successfullycompleted all of its project milestones and deliverables to date. In June 2017, the project partners will meet for the 2nd EUCALL Annual Meeting at ESRF in Grenoble, where a major goal will be to define a path for the "Future of EUCALL" after the end of its funding period in September 2018.

EUCALL has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654220.

www.eucall.eu / contact@eucall.eu

EUCALL's project participants gathered at the Annual Meeting 2016 at HZDR.

ICUIL 2016 Conference in Montebello, Canada (11-16 Sep. 2016)

T. Ozaki and D.A.Jaroszynski

The7th Conference of the International Committee on Ultrahigh Intensity Lasers (ICUIL 2016) was held in Montebello, Québec, Canada from the 11th to the 16th September 2016. This biennial meeting aims to gather ultrahigh intensity enthusiasts from around the world, to report new results, exchange information and to establish and enhance collaborations across borders. Following past conferences, ICUIL 2016 has focused on the following themes: (i) ultra-intense laser design and performance (such as Nd:glass-based, Ti:sapphire-based, DPSSL-based and OPCPA-based ultra-intense lasers, in addition to their pump lasers); (ii) novel technologies for ultra-intense lasers (such as grating and compressor modelling and fabrication, high-damage-threshold and ultra-broadband laser components, devices for spatial and temporal pulse control, diagnostics for ultra-intense lasers), and (iii) applications of ultra-intense lasers (such as laser acceleration, short-wavelength sources, attosecond sources, high-field physics and applications of extreme light). ICUIL 2016 included talks that showcased the latest on multilateral projects such as ELI, XCELS and IZEST, in addition to the efforts in individual institutions across the world.

The conference has been chaired by Dino Jaroszynski (U. Strathclyde, UK) and Tsuneyuki Ozaki (INRS, Canada),with the strong support from Technical Program Committee Co-Chairs, Marco Borghesi (Queen's U. Belfast, UK), Hiromitsu Kiriyama (QST, Japan) and Christophe Dorrer (U. Rochester, USA), along with 24 members of the Technical Programme Committee. The program consisted of 19 invited talks, 61 contributed talks and 77 poster presentations, held over the five days of the conference. The total number of participants was 148, coming from 56 institutes and 18 countries from around the world. We also had strong participation from young researchers, with17 postdoctoral fellows and 11 PhD students, who are the future of the ICUIL community. The ICUIL 2016 conference was also strongly supported by a total of 22 companies, agencies and universities. Participation from these companies was also active, with 44 participants, some of whom gave oral presentations, while the majority of companies presented posters during the conference.

The conference consisted of 14 oral sessions and 2 poster sessions, where Student Poster Awards were awarded to three students: First Prize (including a US$500 cash award) went to Mr. N. Stuart (Imperial College, UK), for his poster on "OPCPA Pump-Depletion Contrast Enhancement using a Seeded OPCPA Fluorescence Diagnostic", Second Prize (US$300 cash award) went to Mr. J. Pilar (Czech Technical U Prague, Czech Rep), for his poster on "Adaptive optics development at HiLASE", and the Third Prize (US$200 cash award) went to Ms. S. Bucht (U. Rochester, USA) for her poster on "Transforming the Idler to Seed Raman Amplification". There were also five Student Travel Grants (US$1,000 each) that were awarded to promote student participation. These went to Ms. C. Scullion (Queen's University Belfast, UK), Ms. G. Cantono (Université Paris-Saclay, France), Mr. R. Budriunas (Vilnius U., Lithuania), Mr. D. E. Cárdenas (Ludwig-Maximilians-Universität, Germany) and Mr. J. Pilar (Czech Technical U Prague, Czech Rep).

ICUIL 2016 provided an occasion to honour and remember an important figure of the ICUIL committee and community, Prof. Wolfgang Sandner, who passed away in December 2015. Among his many illustrious roles (including Director of the Max Born Institute, Coordinator of Laserlab-Europe, President of the German Physical Society, and the General Director of the ELI-Delivery Consortium), Prof. Sandner served as Co-Chair of the ICUIL committee for many years. To pay tribute to Prof. Sandner, the ICUIL 2016 conference dedicated one of its plenary sessions in his honour. This special session was organized by Prof. Catalin Miron of the ELI-DC, and included invited speakers who worked closely with Wolfgang over many years. We also had the privilege of Mrs. Sandner accepting an invitation to attend the conference, and to remember Prof. Sandner with all his profession colleagues and friends.

The ICUIL 2016 was a great success, owing to the excellent presentations from the participants from around the world, and to the support from the various sponsors. The conference again showed the strength of the ICUIL community, and we look forward to the ICUIL 2018 conference to be held in Germany.

ICUIL 2016 Student travel grant to promote student participation

Relativistic surface plasmon driven electron acceleration and high harmonic generation

Giada Cantono
CEA, CNRS, Université Paris-Saclay, CEA Saclay 91191 Gif-sur-Yvette, France
Istituto Nazionale di Ottica, CNR/INO, u.o.s Adriano Gozzini, 56127 Pisa, Italy
Dipartimento di Fisica Enrico Fermi, Università di Pisa, 56127, Pisa, Italy
Université Paris Sud, 91400 Orsay, France

Since the latest 20 years, laser-driven particle and radiation sources have been experiencing a continuous development, also encouraged by the tireless advance in the relativistically intense and ultra-short laser pulse technology. Acceleration schemes based on laser-solid interaction are now being explored as alternative mechanisms to produce high quality ion, electron beams and XUV pulses. A key element to these processes trusts in the most efficient laser-target coupling, which can be cleverly increased by employing nano-structured targets. In particular, solid targets with a sharp engraved surface (gratings) allow for the excitation of resonant surface plasmons (SPs), which already have many applications in the limit of low electromagnetic fields [Nat. Mat. **9**, 193 (2010)]. Yet, it has been recently demonstrated that ultra-high contrast laser pulses make SP excitation accessible also in the relativistic regime (i.e. for laser intensities $>10^{18}$ W/cm^2), where new possibilities for the manipulation of intense electromagnetic fields and the development of short, high-energy, laser-synchronized radiation sources can be explored.

SPs are collective oscillations of the electrons at a steep metal-dielectric interface. They can propagate along the surface through μm distances and they are evanescent across nm lengths in the transverse direction. Gratings are usually employed to excite SPs with laser pulses. For a metal described by the cold plasma dielectric function $\varepsilon(\omega) = 1 - (\omega p/\omega)^2$, phase-matching requirements between laser and SP result in a resonance condition that links the laser wavelength λ_L and the incidence angle θ to the grating period d, giving: $\sin(\theta res) \sim 1 + n\lambda_L/d$ (Eq.1). This last actually derives from a linear, non-relativistic theory, but both experiments and simulations performed in the relativistic regime show that resonance still occurs at the angles predicted by Eq.1. Laser-driven relativistic SPs increase the laser-target coupling and consequently affect ion acceleration via the TNSA mechanism, surface electron acceleration as well as high-order harmonic generation. The most recent investigation concentrated on electron and harmonic emission, the cut-off energy enhancement of TNSA-driven proton beams having been already demonstrated in the previous experimental work [Phys. Rev. Lett. **11**, 5001 (2013)]. Electrons can be extracted from the target plasma by the transverse component of both the laser and the SP electric field, and accelerated along the surface by the longitudinal component of the Lorentz force [Phys. Plasmas **22**, 3103 (2015)] as long as they stay in phase with the SP. This can occur over few μm distances, allowing electrons to reach tens of MeV energy [Phys. Rev. Lett. **116**, 5001 (2016)]. Electrons oscillating at the target surface also generate high-order harmonics (HHs), so the field enhancement achieved by SP excitation is also expected to increase HHs intensity while overlapping with the angular dispersion performed by the grating, this point being beneficial for practical applications. This effect was recently shown by means of numerical simulations [App. Phys. Lett. **110**, 1002 (2017)], where an enhanced HH emission was observed along the surface of grating targets irradiated at the resonance angle.

Experiments in this regime were recently performed at CEA-Saclay with the UHI100 laser system. The laser pulse (100 TW, 25 fs, $\lambda_L \sim 0.8$ μm) was focused down to a ~7μm 1/e^2 focal spot, reaching an intensity of about 5×10^{19} W/cm^2. A double plasma mirror ensured a ~10^{12} pulse contrast, which was crucial to preserve the periodic structure of the targets from pre-pulse induced damage. Gratings with sinusoidal profile (~250 nm depth) were produced by embossing 13μm thick Mylar foils: the step d was chosen according to Eq.1 to give a resonance angle of 30° (i.e. $d = 2\lambda_L$). The electrons spatial distribution was recorded with a scintillating Lanex screen covering the laser-irradiated side of the target, from tangent (0°) to normal (90°), and energies were measured by an electron spectrometer in the 2–30 MeV range. The harmonic emission at different observation angles was recorded with an XUV spectrometer within a 20–90 nm spectral range (i.e. ω_H/ω_L from 9 to 40).

Figure 1 (*a*) shows the profile of the electron spatial distribution recorded on the incidence plane for, respectively, a grating (blue curve) and a flat target (red curve) irradiated at the SP resonance angle (30°). Gratings produce a highly collimated bunch in the tangent direction, where the maximum signal is ~25 times more intense than the emission from a flat target, which in turn is localised around the specular reflection of the laser pulse

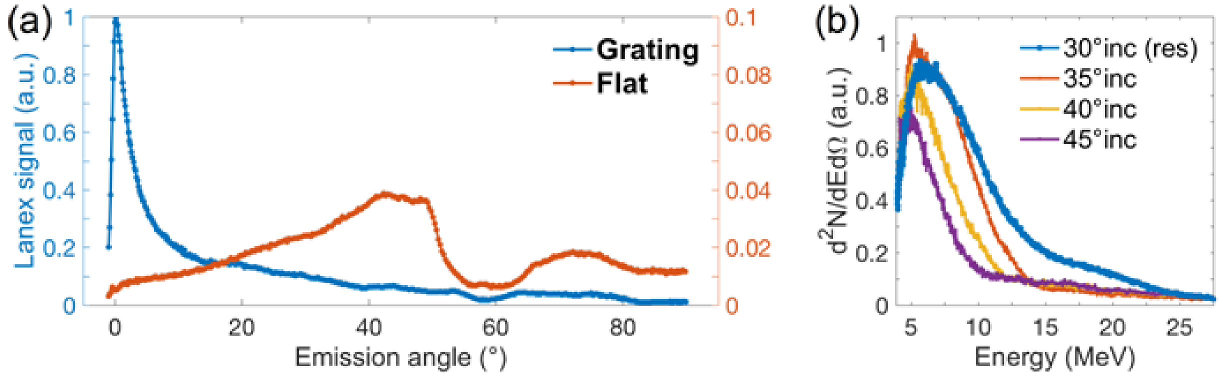


Figure 1(a): Electron spatial distribution from tangent (0°) to normal (90°) for flat and grating targets irradiated at 30°; (b): electron energy spectra collected at tangent for gratings irradiated at various incidence angles.

(i.e. 60°). The charge amount contained in the electron bunch (~6° full angle cone) was estimated after running the absolute calibration of the scintillating screen to be about 100 pC. Electron energy spectra collected in the tangent direction for different incidence angles are shown in Fig. 1 (*b*): no signal above the noise level was ever recorded with a flat target, whereas gratings show electron acceleration up to ~15 MeV with most of the population around 7 MeV. When moving out of the resonant configuration, degradation of the electron bunch is proved by both a loss of intensity and weaker maximum energies. A SP-induced effect on HH generation was observed in the increase of the maximum harmonic order obtained with gratings with respect to flat targets. HH spectra collected in the tangent direction with gratings irradiated at resonance expand over the 30th order of the laser frequency, whereas flat targets produced at most 25 orders in the specular direction. Simulations performed with a laser intensity ~10 times higher than in the experiment suggest that HHs above $40\omega_L$ could be stronger along the tangent rather than at specular, leaving room for further optimization of this process.

ICUIL 2016 Student travel grant to promote student participation

Ion acceleration from ultra-thin solid targets using femtosecond laser pulses

Clare Scullion
Centre for Plasma Physics, Queen's University Belfast, United Kingdom

The acceleration of ions generated by the irradiation of thin solid targets by ultrashort linearly polarized (LP) and circularly polarized (CP) laser pulses has been investigated. The work presented aims to further understand the ion acceleration mechanisms which take place when thin solid targets are irradiated under different conditions as part of the Advanced Strategies for Accelerating Ions with Lasers (A-SAIL) project, which involves the investigation and optimization of emerging ion acceleration schemes, with a focus on processes based on the radiation pressure of an intense laser pulse, namely Light Sail, Hole Boring and shock acceleration; and assessment of the radiobiological effects of ultrafast ion energy deposition.

Experimental Setup

Investigations of the interactions of high intensity, ultrashort LP and CP laser pulses with ultrathin amorphous carbon foils (10–100 nm) were carried out on the GEMINI Ti:Sapphire laser system at the Rutherford Appleton Laboratory, STFC, UK. The laser delivered ~6 J energy on target in pulses of 800 nm wavelength (λ), and 45 fs full width at half maximum (FWHM) duration (τ), after being reflected off a double plasma mirror arrangement. The recollimated laser beam after the plasma mirrors was focused on the targets at normal incidence by an *f*/2 off-axis parabolic mirror, delivering peak intensities on target ~ 6×10^{20} W·cm^{-2}. The laser polarization on the target was varied from LP to CP by employing a zero order quarter wave plate (WP), placed between the plasma mirror and the focusing parabola (Fig. 1).

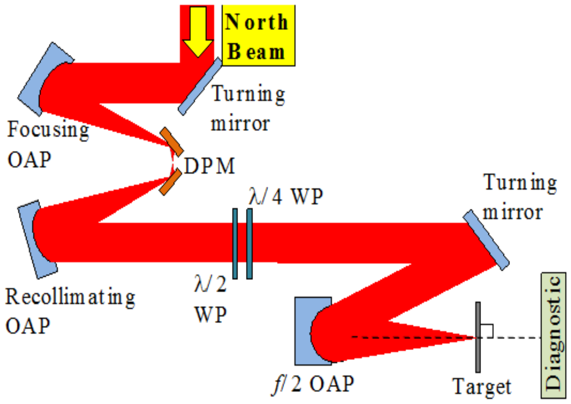


Fig.1. Experimental setup at the Gemini laser. Central Laser Facility, UK.

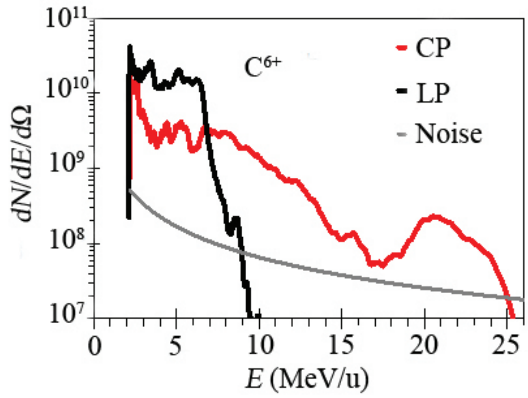


Fig.2. C^{6+} spectra with vertical axis units of particles/MeV/sr for 10 nm amorphous carbon targets irradiated with CP (red) and LP (black) laser pulses.

Amorphous carbon targets of thickness in the range of 10–100 nm were irradiated. The energy spectra of the ions accelerated from the interaction were diagnosed by a Thomson Parabola Spectrometer (TPS) with BAS-TR image plate (IP) detectors, along the laser axis (also target normal axis) with an acceptance angle of 1.1 μsr.

Results

These experiments demonstrated a strong dependence of the characteristics of the accelerated ions on the target thickness and the laser polarization. Figure 2 shows spectra obtained from 10 nm carbon targets irradiated by LP and CP laser pulses. Figure 3 shows representative experimental measurements of the proton beam profile for CP and LP pulses and a comparison with similar data obtained through 3D PIC simulations. It is evident that there is qualitative agreement with the experimental images, as the most prominent features and differences between CP and LP are broadly reproduced by the simulation, which gives confidence in the theoretical interpretation.

Conclusion

In conclusion, in an interaction regime employing ultrashort (50 fs) laser pulses and ultrathin foils (10–100 nm carbon), we have observed a strong dependence of the characteristics of the accelerated ions on the target thickness and the laser polarization, providing evidence that a regime in which RPA is the dominant acceleration mechanism can be accessed at current intensities by careful control of the interaction parameters (pulse contrast, polarization and target thickness).

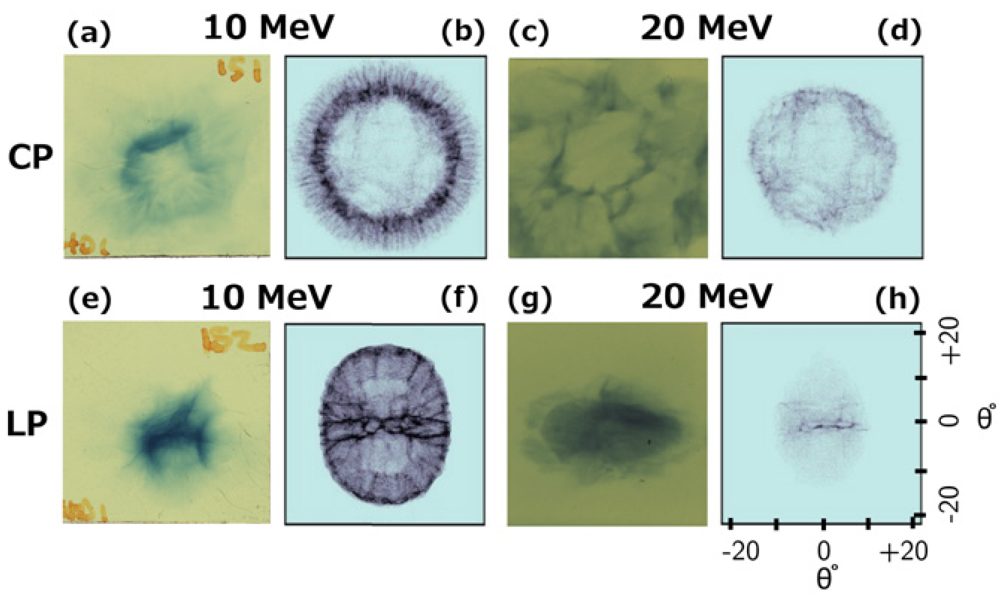


Fig.3. CP (a-d) and LP (e-h) proton beam profiles at 10 MeV (left) and 20 MeV (right) obtained experimentally from 10 nm amorphous carbon targets on RCF (a,c,e,g) and through 3D PIC simulations (b,d,f,h). All images represent the same solid angle of the beam profile (marked in h).

Nuclear Photonics 2016

The first international conference devoted to the pursuit of photon-based nuclear science and applications, Nuclear Photonics 2016 (http://nuclearphotonics2016.org), took place at the Monterey Plaza Hotel and Spa in Monterey, California from October 16th to the 21st, 2016. The conference brought together 144 participants from 17 countries and included experts in gamma-ray source development, ultrahigh intensity laser development, nuclear physics and nuclear-related applications.

The rapidly evolving field of nuclear photonics has been enabled by the development of ultra-bright, quasi-mono-energetic gamma-ray sources based on laser-Compton scattering and by the worldwide development of $B-scale user facilities housing ultrahigh intensity lasers capable of producing field strengths of relevance to nuclear interactions.

Nuclear-related topics discussed during the Monterey meeting included:

- fundamental nuclear science and spectroscopy,
- nuclear medicine including radiography and radiotherapy,
- industrial non-destructive material imaging and evaluation,
- isotope-specific, nuclear materials detection and management,
- photo-fission and materials transmutation,
- photon-based production of rare isotopes,
- photon-enabled pulsed neutron generation and science,
- photon-enabled pulsed positron generation and science,
- photon-based hadron beams and applications,
- nuclear astrophysics and cosmology
- gamma-ray science above the giant dipole resonance

Sessions devoted to mono-energetic gamma-ray technology and to ultrahigh intensity laser technology were also a key part of the meeting. The former included discussion of the development of compact accelerators, optimization of laser-Compton interactions, novel detectors for bright gamma beams, gamma-ray monochromators, gamma-ray optics, advanced lasers for Compton light sources, high-brightness photoguns and novel scintillator materials. The latter included overviews of state-of-the-art laser facilities, advances in beam focusing and transport, novel pulse diagnostics, methods for control of pulse contrast, and the development of high average power, intense laser systems. Special efforts were made to integrate applications and technology development sessions so that each could motivate the other with respect to the development of nuclear photonics as a new scientific discipline.

Nuclear Photonics 2016 was the first of a planned series of biennial topical meetings devoted to this topic. At the conclusion of the Monterey conference it was announced that Nuclear Photonics 2018 will be held in Romania and will be hosted by the ELI – Nuclear Physics project.

IZEST: Searching for a Particle Physics Renaissance

The IZEST Spring meeting was held at Ecole Polytechnique, Palaiseau, France on April 4, 2017. 64 researchers from around the world took part in the meeting focused on the different techniques leading to efficient and affordable particle acceleration schemes in the TeV regime.

Invited talks were given by Roy Aleksan- Georg Korn- Ralph Assmann / Massimo Ferrario- Catalin Miron- Patrick Audebert- Gerard Mourou- Franck Brottier /Federico Canova- Karoly Osvay- Jean-Christophe Chanteloup- Michel Spiro- Pisin Chen- Toshiki Tajima- Toshikazu Ebisuzaki- Kazuo Tanaka- Sydney Gales- Satoshi Wada- Spencer Gessner- Jonathan Wheeler- Bernhard Holzer.

Extreme light is one of the most exciting domains in the field of lasers today. It relies on the generation of ultrahigh peak power obtained by delivering the energy within a short time. Today, laser peak power typically exceeds the PW or a thousand times the world's grid power. The ability to produce and focus this gargantuan power over a size 10 times smaller than a hair offers unfathomable possibilities in science, technology, medicine and is a harbinger of the flood gate of socio-economic applications to come.

Towards the demonstration of the shortest pulse duration in the X-ray regime the highest field gradient and Schwinger Intensity: IZEST looks beyond the horizon set by the ELI-Apollon facilities. It wants to push the most avant-garde laser concepts to demonstrate short time structures down to the attosecond-zeptosecond regime. Pulses will be so short that the highest peak power in the x-ray regime could be reached with a modest amount of energy at the joule level yielding intensities in the Schwinger regime enough to materialize light. Among the remarkable applications we note the generation of gargantuan accelerating gradient in solids enough to accelerate electrons over a centimeter to the TeV level or relativistic protons widening the range of applications in subatomic physics, cosmology, vacuum physics and the like. In addition, trying to develop a new breed of laser sometime opens the way to new applications, like space debris removal which is a big issue in space activity in the near future.

Relativistic Proton Generation: The generation of ultrahigh energy particles like protons in the GeV regime strongly depends on high peak power and short pulse duration. One technique recently proposed and actively investigated is the thin film compression concept. Used in conjunction with a PW laser, this technique could produce a single cycle pulse with energy in the tens of joules. The simulation showed that relativistic GeV protons can be produced by interacting the single cycle pulse with a thin target.

Fundamental Physics: Black hole information Paradox: A newly proposed experiment promises to create a "tabletop" black hole that could prove whether information is truly lost when black holes evaporate. The idea that information could be lost this way has created a paradox in our current understanding of basic physics.

Societal Application: Novel laser-based architecture finds an important application in the mitigation of space debris produced by the few thousands launches. Novel laser architecture and pulse compression technique open the door to new societal space field.

CFA Mini-workshop on Future Gamma-Gamma Colliders

On April 23–26, 2017 IUPAP's International Committee on Future Accelerators (ICFA) convened a mini-workshop on future gamma-gamma colliders. The purpose of the gathering was to discuss the status and prospects for gamma-gamma colliders. The meeting brought together experts in conventional accelerators, advanced accelerator concepts, high-energy physics, laser-Compton technology and high peak and average power laser science. The gamma-gamma collider is a challenging new type of particle collider based on interactions of energetic gamma-rays produced via Compton scattering of intense, high power laser radiation on highly energetic electron or positron beams. This type of collider can produce complimentary and unique new physics when compared with conventional proton and electron-based machines and enables access to annihilation reactions with precisely understood point like interactions without requiring positron beams. Such gamma-gamma collider systems allow emerging accelerator concepts such as laser wake field acceleration to become part of the conversation for future high field physics. For example, one proposal suggests that relatively low energy electron (or positron) beams could be used in a gamma-gamma configuration as a "Higgs factory". The required e-beam energy for such a machine is in the sub-70 GeV range. The workshop discussed gamma-gamma colliders based on several different technologies: linear colliders (e.g. ILC, CLIC), recirculating LINACs (e.g. SAPPHiRE, HFiTT), circular colliders (e.g. FCC-ee, CEPC) as well advanced accelerator concepts (e.g. laser driven plasma acceleration, beam driven plasma acceleration, dielectric wakefield acceleration). Discussions of near term light source opportunities and of applicable high peak and average power laser technology were also key part of the meeting. Workshop presentations may be found on line at http://indico.ihep.ac.cn/event/6030/overview

Because gamma-gamma colliders require both a high power laser system in addition to an accelerator, this concept provides a strong opportunity for the laser and accelerator communities to work together. The gathering included participation by both the present ICUIL chairman Dr. Chris Barty and ICUIL's first chairman Prof. Gerard Mourou as well as leading laser experts from the United States and China.

ICUIL 2018 Conference in Lindau Germany (09-14 Sep. 2018)

Thomas Kuehl, GSI-Helmholtzzentrum, Darmstadt, Germany

The ICUIL 2018 Conference, the 8th CONFERENCE OF THE INTERNATIONAL COMMITTEE ON ULTRAHIGH INTENSITY LASERS will again welcome high intensity laser enthusiasts from across the world, this time back in Europe. The conference will take place at Hotel Bad Schachenin Lindau, Germany, from September 9th to 14th, 2018. The hotel is located right on the shore of Lake Constance boasting a wonderful view of the lake, but also the panoramic backdrop of the Austrian and Swiss Alps. It can be reached via the international airports in Munich (2 hours by car or 3.5 hours by train) and Zurich (2 hours by car or 2 hours by train). There is also a local airport at Friedrichshafen (30 minutes by taxi) with several connections per day from Frankfurt and London. The hotel offers park-like grounds with a spacious lakeside lido, a private boat jetty and a beautiful terrace. The conference will be held in the hotel's congress center, with plenty of adjacent space for participants and vendors to interact.

ICUIL 2018 is again expected to showcase the latest on multilateral projects like ELI, XCELS and IZEST as well as other efforts across the world in the direction of ultra-intense lasers. Following the spirit of the ICUIL conferences, in particular the last meeting at Montebello, Canada, technical and scientific themes concerning ultra-intense lasers will be addressed: (i) ultra-intense laser design and performance including Nd:glass-based, Ti:sapphire, DPSSL and OPCPA and novel architectures, (ii) novel technologies for ultra-intense lasers, e.g compression components and strategies, modelling and fabrication, high damage-threshold and ultra-broadband laser components, pulse control, and diagnostics, and (iii) applications of ultra-intense lasers for laser acceleration, short-wavelength sources, attosecond sources, exploration of warm-dense matter, high-field physics and more. This conference will emphasize the many contributions from students and young scientists in this dynamic field of ultra-high intensity lasers.

Preparation for the conference has started in November 2016. A Local Organization Board has been formed by members of the GSI Helmholtz Center Darmstadt and the Helmholtz Institute Jena: V. Bagnoud, A. Blazevic, Ch. Brabetz, T. Kuehl, S. Kunzer, D. Schumacher, T. Stoehlker, B. Zielbauer, and D.Lang.

We invite the interested community and industrial partners to mark down the date, and hope to meet you in Germany in September 2018!

Chief Editor
Alexander Sergeev, ams@ufp.appl.sci-nnov.ru