Advanced Concepts for High Peak Power Ultrafast Lasers (SYUL)

jointly organized by
the Quantum Optics and Photonics Division (Q),
the Atomic Physics Division (A), and
the Short Time-scale Physics Division (K).

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Overview of Invited Talks and Sessions

(Lecture room e415)

Invited Talks

SYUL 1.1	Fri	11:00–11:50	e415	**Exawatt laser concepts for extreme field science** — •Chris Barty
SYUL 1.2	Fri	11:50–12:20	e415	**Generation of short pulses with ultra-high temporal contrast at the PHELIX petawatt facility** — •Vincent Bagnoud
SYUL 1.3	Fri	12:20–12:50	e415	**Petawatt lasers for particle acceleration at HZDR Dresden** — •Ulrich Schramm
SYUL 1.4	Fri	12:50–13:20	e415	**High-intensity few-cycle pulses with ultrahigh temporal contrast** — •Stefan Karsch, Alexander Kessel, Christoph Skrobol, Mathias Krüger, Christoph Wandt, Sandro Klingebiel, Olga Lysov, Izhar Ahmad, Sergei Trushin, Vyacheslav Leshchenko, Zsuzsanna Major, Ferenc Krausz
SYUL 2.1	Fri	14:00–14:30	e415	**Coherent Combination of Ultrafast Fiber Lasers** — •Jens Limpert
SYUL 2.2	Fri	14:30–15:00	e415	**Cryogenic multipass amplifiers for high peak and average power ultrafast lasers** — •Luis E. Zapata
SYUL 2.3	Fri	15:00–15:30	e415	**Multi-TW infrared laser using Frequency domain Optical Parametric Amplification** — •Bruno E. Schmidt, Philippe Lassonde, Guilmot Ernotte, Mathieu Giguere, Nicolas Thire, Antoine Laramee, Heide Ibrahim, Francois Legare

Sessions

SYUL 1.1–1.4	Fri	11:00–13:20	e415	**Advanced Concepts for High Peak Power Ultrafast Lasers I**
SYUL 2.1–2.3	Fri	14:00–15:30	e415	**Advanced Concepts for High Peak Power Ultrafast Lasers II**

SYUL 1: Advanced Concepts for High Peak Power Ultrafast Lasers I

Time: Friday 11:00–13:20 Location: e415

Invited Talk SYUL 1.1 Fri 11:00 e415

Exawatt laser concepts for extreme field science — •Chris Barty — Lawrence Livermore National Laboratory, Livermore, CA, USA

This presentation will review worldwide, high-intensity laser activities and introduce new concepts that will enable extension of existing petawatt laser capabilities to the exawatt scale. Modern inertial confinement fusion lasers based on Nd:glass have amplification bandwidths that are capable of supporting pulses of less than a picosecond in duration. 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 [1]. While these systems are at the forefront of present high-energy, high-peak power capabilities, they utilize only a small fraction of the potential of the underlying Nd:glass laser amplification system and as such are very inefficient. A single beam line at the NIF, for example, has a stored energy in excess of 25 kJ. This presentation describes short pulse amplification architectures based on chirped *beams* [2], novel pulse compressors and existing beam phasing technologies that 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 mulit-beam, dipole focusing concepts [3]. With dipole focusing, it is anticipated that a single beam line of a large-aperture, mixed-glass exawatt-scale system will be capable of reaching intensities in excess of 1026 W/cm2 or more than 5 orders of magnitude beyond that possible from existing CPA based PW systems at NIF, LMJ, LFEX and Omega EP. At such intensities proton motion becomes relativistic during interactions with the laser pulse. Full extraction of beam line energy will also be enabling to full scale demonstration of fast ignition concepts, etc.

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[1] D. Zuegel, S. Borneis, C. P. J. Barty, B. Legarrec, C. Danson, N. Miyanaga, P. K. Rambo, C. Le Blanc, T. J. Kessler, A. W. Schmid, L. J. Waxer, J. H. Kelly, B. Kruschwitz, R. Jungquist, E. Moses, J. Britten, I. Jovanovic, J. Dawson, and N. Blanchot, "Laser challenges for fast ignition," Fusion Science and Technology 49, 453-482 (2006) [2] C. P. J. Barty *Optical Chirped Beam Amplification and Propagation.* US Patent #6,804,045 B2, (2004) University of California. [3] A.Gonoskov, A. Bashinov, I. Gonoskov, C. Harvey, A. Ilderton,A. Kim, M. Marklund, G. Mourou, and A. Sergeev Phys.Rev.Lett. 113, 014801 (2014)

Invited Talk SYUL 1.2 Fri 11:50 e415

Generation of short pulses with ultra-high temporal contrast at the PHELIX petawatt facility — •Vincent Bagnoud — GSI-Darmstadt, Darmstadt, Germany

With the construction of laser facilities capable of delivering peak powers at the 10-petawatt level, the temporal contrast of short laser pulses has received a growing interest in the last decade. The standard amplification scheme based on chirped-pulse amplification (CPA) is long known to introduce temporal pedestals and artifacts that can be detrimental to experiments and their proper understanding. In the last 10 years, several technical solutions have been proposed to overcome this limitation with good success. The crossed-polarized wave cleaning technique associated with a double CPA laser system can be found now in several implementations and is available commercially from several vendors. An alternative method based on a fast OPA is also available at various facilities like the OMEGA EP laser in the US or the PHELIX facility in Germany. In this talk, I will cover the general problematic of temporal contrast at petawatt-class laser facilities from the requirements to the current limitations. The latest results obtained with the fast OPA at the PHELIX laser where a nanosecond contrast of 10^{-12} is routinely achieved will also be presented.

Invited Talk SYUL 1.3 Fri 12:20 e415

Petawatt lasers for particle acceleration at HZDR Dresden — •Ulrich Schramm — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Focal intensities far beyond 10^{18} W/cm^2 have allowed for the development of compact laser plasma based particle accelerators. Applications are envisioned in the fields of cancer therapy or ultra-fast probing with energetic photons. However, such applications require peak power in the Petawatt range as well as average power.

Here, the development and status of the two Petawatt projects at the HZDR will be presented, one based on the upscaling of established Ti:Sapphire technology, the other on the energy efficient approach of exploiting directly diode laser pumped Yb:CaF_2. Special emphasis will be given on diagnostics concepts that allow for online monitoring of crucial parameters of these pulses as, e.g., temporal pulse contrast.

Invited Talk SYUL 1.4 Fri 12:50 e415

High-intensity few-cycle pulses with ultrahigh temporal contrast — •Stefan Karsch[1,2], Alexander Kessel[1], Christoph Skrobol[1], Mathias Krüger[1], Christoph Wandt[1], Sandro Klingebiel[1], Olga Lysov[1], Izhar Ahmad[1], Sergei Trushin[1], Vyacheslav Leshchenko[1], Zsuzsanna Major[1,2], and Ferenc Krausz[1,2] — [1]Max-Planck-Institut für Quantenoptik — [2]Ludwig-Maximilians-Universität München

Increasing the single-shot photon flux of attosecond XUV-pulses by surface harmonic generation calls for novel few-cycle laser sources: Here, the XUV radiation is generated by reflecting a few-cycle pulse from a relativistically oscillating plasma surface driven by the pulse itself.This requires few-cycle light pulses with intensities well above 10^{19} W/cm^2 and a temporal contrast that prevents target expansion before the arrival of the main pulse.

The Petawatt Field Synthesizer (PFS) project at the MPQ follows a novel approach to generate energetic, ultrabroadband light pulses with unprecedented temporal contrast. By employing a chain of optical paramtetric amplifiers pumped by 1-ps green laser pulses from a purpose-built, diode-pumped high-energy CPA laser we ensure that no premature light can reach the target outside the 1-ps pumping window. The high-contrast requirements also call for a high-energy, temporally clean octave-bandwidth seed in the 700-1400 nm range.

We report on the status of the three project branches, namely the seed generation and optical synchronization, the pump laser development and finally the OPA amplification and dispersion control.

SYUL 2: Advanced Concepts for High Peak Power Ultrafast Lasers II

Time: Friday 14:00–15:30 Location: e415

Invited Talk SYUL 2.1 Fri 14:00 e415

Coherent Combination of Ultrafast Fiber Lasers — •Jens Limpert — Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Albert-Einstein-Str.15, 07745 Jena, Germany

Even the most advanced laser technologies have been pushed to their specific limitations in labs around the world. A significant increase in performance can not be expected in the coming years. New concepts have to be considered to address these issues and to enable new application fields. In that context, I will review the basics and achievements of coherent combination of amplified femtosecond pulses, a concept which has already out-performed single aperture femtosecond laser systems and which allows for a scaling to unprecedented performance levels. The spatially and temporally separated amplification of ultrashort laser pulses followed by coherent beam and pulse addition can bypass all performance restrictions of a single aperture laser system, therefore, enabling a quantum leap in performance of ultrafast lasers.

Invited Talk SYUL 2.2 Fri 14:30 e415

Cryogenic multipass amplifiers for high peak and average power ultrafast lasers — •Luis E. Zapata — Center for Free-Electron Laser Science, Deutsches Elektronen Synchrotron, Notkestrasse 85, 22607 Hamburg, Germany

Ultrafast laser sources are in demand for many scientific and industrial applications. For example, few-mJ pulses are useful for driving the OPCPAs in pump-probe experiments and, Joule class pulses are necessary for the generation of x-rays through inverse Compton scattering. Ultimately, high average power determines the usefulness of a given laser system by shortening the time necessary for the collection of data or, the throughput when a process yield is derived. The success of the laser system also markedly depends on its size, weight and reliability, which are strongly tied to its complexity. Liquid nitrogen cooled DPSSLs based on Yb3+ offer a clear advantage with regards to all the above points. Engineering leverage is gained by an intrinsic several-fold improvements in thermo-optic and thermo-mechanical properties as well as ~decade higher gain-coefficients, which enables simple, passively switched multipass geometries to be implemented. Our progress in scaling chirped-pulse amplifiers has produced 250-Watt at 100-kHz and 160-mJ at 250-Hz based on liquid nitrogen cooled Yb:YAG in rod and composite-disk geometries operating at high gain. Clear scaling towards 1-kW average power at 100 kHz in cryogenic rods and, one-Joule pulse energy in cryogenic composite disks has emerged. We propose an advanced monolithic array of gain-cells for scaling to multi-Joule energies and multi-kW average powers.

Invited Talk SYUL 2.3 Fri 15:00 e415

Multi-TW infrared laser using Frequency domain Optical Parametric Amplification — •Bruno E. Schmidt[1], Philippe Lassonde[2], Guilmot Ernotte[2], Mathieu Giguere[1], Nicolas Thire[2], Antoine Laramee[2], Heide Ibrahim[2], and Francois Legare[2] — [1]few-cycle Inc., (few-cycle.com), 2890 Rue de Beaurivage, Montréal, Qc, H1L 5W5, Canada — [2]Institut National de la Recherche Scientifique, Centre ÉMT, 1650 bd Lionel Boulet, Varennes, Qc, J3X1S2, Canada

The universal dilemma of gain narrowing occurring in fs amplifiers prevents ultra-high power lasers from delivering few-cycle pulses. This problem is overcome by a new amplification concept: Frequency domain Optical Parametric Amplification - FOPA. A proof of principle experiment was carried out at the Advanced Laser Light Source (ALLS) on the sub-two cycle IR beam line and yielded record breaking performance in the field of few-cycle IR lasers. 100μJ two-cycle pulses from a hollow core fibre compression setup were amplified to 1.43mJ without distorting spatial or temporal properties [1]. Pulse duration at the input of FOPA and after FOPA remains the same. Recently, we have started upgrading this system to be pumped by 250 mJ to reach 40 mJ two-cycle IR few-cycle pulses and latest results will be presented at the conference.

[1] B. E. Schmidt, N. Thiré, M. Boivin, A. Laramée, F. Poitras, G. Lebrun, T. Ozaki, H. Ibrahim, and F. Légaré, *Frequency domain optical parametric amplification.,* Nature Commun. 5, 3643 (2014).