Extreme Light Scientific and Socio-Economic Outlook

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Book of Abstracts

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Extreme Light Scientific and Socio-Economic Outlook

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Extreme light is one of the most exciting domains in the laser field today. It relies on the generation of ultra high peak power obtained by delivering the energy over a short time. Today, laser peak power exceeds typically the PW or thousand times the world 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 to a floodgate of socio-economic applications.
France is a well-established academic and industrial leader in laser. Under the initiative of the Ecole Polytechnique, we proposed 10 years ago to the EU and Ile de France the construction of a Pan-European Infrastructure capable to generate the highest peak power ever produced and explore laser mater interaction at the highest possible intensities with the aim to carry out fundamental research and promote new societal applications.
The ELI infrastructure was built as a distributed three infrastructures, with ELI-Beam Line in Czech Republics, ELI-NP in Romania, ELI-ALPS in Hungary. In concert with ELI, France built a 10 PW project named Apollon on the plateau of Palaiseau. This infrastructure constellation will become operational and accessible in 2019, opening a new age in laser research.
The infrastructures are now halfway through completion. As the initiator of both projects ELI and Apollon, the Ecole Polytechnique has carried out a study; to gauge the socio academic impact of these world-class projects at all levels, regional, national and international. The conclusion of this report will be one of the conference highlights and will be reported at the meeting.
IZEST is about going beyond the horizon set by the ELI-Apollon facilities. During the conference we will have the opportunity to describe the most avant-garde laser concepts under development to gracefully segue from the petawatt to the exawatt, giving access to extremely 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 in the joule level yielding intensities in the Schwinger regime enough to materialize light. Among the remarkable application we note the generation of gargantuan accelerating gradients in solids enough to accelerate electrons over a centimetre 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.

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ELI-Beamlines: scientific and societal applications of ultra intense lasers

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ELI-Beamlines is the high-energy, repetition-rate laser pillar of the ELI (Extreme Light Infrastructure) project. It will be an international facility for both academic and applied research, slated to provide first user capability since the beginning of 2018. The main objective of the ELI-Beamlines Project is delivery of ultra-short high-energy pulses for the generation and applications of high-brightness X-ray sources and accelerated particles. The laser system will be delivering pulses with length ranging between 15 and 150 fs and will provide high-energy Petawatt (10Hz) and 10-PW peak powers. For high-field physics experiments it will be able to provide focused intensities attaining 1024 Wcm-2, while this value can be increased in a later phase without the need to upgrade the building infrastructure to go beyond the ultra-relativistic interaction regime in which protons are accelerated to energies comparable to their rest mass energy on the length of one wavelength of the driving laser. We will introduce the different experimental user areas with the emphasis of applications of secondary sources of x-rays and laser accelerated particles and the extreme field science area.
We discuss new approaches for efficient proton acceleration with higher repetition rate targets based on a solid Hydrogen ribbon for possible medical applications in the energy range above 60 MeV. The ion acceleration beamline ELIMAIA and the ELIMED concepts will be highlighted for their use in different fields including medicine.

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IZEST and the European Strategy for Particle Physics

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Efficient Extreme Light Compression and its Application

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High power laser facilities capable of generating petawatt (10^{15} W) level pulses are producing peak intensities that are approaching the threshold to a wide range of applications that include high energy physics; laser astrophysics and cosmology; vacuum physics; as well as medical imaging and treatments. State-of-the-art in high power laser systems consistently produce pulses within large diameter beams with nearly flat-top spatial modes and low divergences that suggest efficient nonlinear techniques for pulse post-compression that could dramatically extend the intensities achievable within existing facilities. Theoretical simulations demonstrate the potential for such a system and the efficiency of the process presents a route to compress the high power laser toward its wavelength-defined fundamental limit of a few femtoseconds while maintaining Joule-level energy within the pulse. At present, small-scale experimental tests of the methods involving the cooperative efforts of many research partners are demonstrating the conditions required to implement a full-scale test of the process while providing insight on the challenges that will arise. In addition, such high energy, single-cycle pulses show great promise as drivers of secondary sources for improved laser-driven ion acceleration, as well as hard X-ray pulses from solid targets capable of producing atto/zeptosecond-scale pulses at the exawatt level (10^{18} W).

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Extreme Light Induced Accelerating Plasma Mirrors to Investigate Black Hole Information Loss Paradox

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The question of whether Hawking evaporation violates unitarity, and therefore results in the loss of information, remains unresolved since Hawking's seminal discovery. So far the investigations remain mostly theoretical since it is almost impossible to settle this paradox through direct astrophysical black hole observations. Here we point out that relativistic plasma mirrors induced by state-of-the-art or soon-to-be ultrafast lasers can be accelerated drastically and stopped abruptly by impinging intense x-ray pulses on solid plasma targets with a density gradient. This is analogous to the late time evolution of black hole Hawking evaporation. A conception of such an experiment is proposed and a self-consistent set of physical parameters is presented. Critical issues such as how the black hole unitarity may be preserved can be addressed through the entanglement between the analog Hawking radiation photons and their partner modes.

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Enhanced laser-driven ion acceleration using nanometer targets

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Radiation Pressure Acceleration is quite promising for ion acceleration. In order to improve the laser energy transmission efficiency and restrain instabilities such as RTI and hole boring, an ultra-high intensity, ultra high contrast laser pulse with steep front is required and therefore a plasma lens with near critical density is proposed. When the laser passes through the nearly critical dense Plasma lens, the transverse self-focusing, longitudinal self-modulation and prepulse absorption can be synchronously happened. The enhanced ion acceleration using plasma lens can be implemented by a DLC foil attached by a nanotube foam target. In recent experiments at RAL in UK and GIST in Korea, it was testified that the proton and ion energy can be enhanced by 2-3 times.
Prompted by the possibility to produce high energy, single-cycle laser pulses with tens of Petawatt power, we have also investigated laser-matter interactions in the few optical cycle and ultra relativistic intensity regimes. A particularly interesting instability-free regime for ion production was revealed leading to the efficient generation of monoenergetic ion bunches with a peak energy greater than GeV. Of paramount importance, the interaction is absent of the Rayleigh Taylor Instabilities and hole boring that plague techniques such as target normal sheath acceleration and radiation pressure acceleration.

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Proton acceleration with light pressure and wakefield

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We discuss proton acceleration with 10PW lasers. In 2001, we proposed proton acceleration with light pressure for the first time [1]. Then in 2007, we explained that light pressure acceleration is actually multistaged acceleration of collisionless electrostatic shock driven by the laser pressure [2, 3]. However, the method of light pressure is hard to support proton acceleration of energy larger than 10 GeV. Therefore, we proposed to acceleration proton with laser driven wakefiled [4]. The main problem for proton acceleration with wakefield is the transverse defocusing force preventing persistent acceleration. To solve this problem we proposed to use vortex to drive a wakefield of an electron cylinder in the middle [5]. Recent experiment with clusters is also discussed.

[1] Baifei Shen et al., PHYSICAL REVIEW E 64 056406
[2] Xiaomei Zhang, Baifei Shen et al., Phys. Plasmas 14, 073101 (2007)
[3] Xiaomei Zhang, Baifei Shen et al., Phys. Plasmas 14, 123108 (2007)
[4] Baifei Shen, Xiaomei Zhang et al., Phys. Rev. E□055402□2007□
[5] Xiaomei Zhang, Baifei Shen et al. New J. Phys. 16, 123051(2014)

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Conventional electron and proton accelerators : the state of the art

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Based on the ongoing construction to the two major European facilities, namely the European XFEL electron accelerator and the ESS relativistic proton accelerator, the state of the art in terms of conventional acceleration will be described: technology, performance, and construction cost.

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Hadron Therapy - Present and Perspectives

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Evolution of fast electrons generated during interaction of high intensity laser with structured targets

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Interaction of high-intensity laser pulses with solid targets results in generation of large quantities of energetic electrons that are the origin of various effects such as intense x-ray emission, ion acceleration, and so on. Some of these electrons are escaping the target, leaving behind a significant positive electric charge. The electrons that are accelerated in the backward and forward directions are ejected from the target in vacuum, thus creating a potential drop in the Debye layer at the target surface.. The cooling process through collisions with the surrounding particles defines the maximal time of the target charging and existence of the accelerating potential. It is then important to conduct temporally resolved measurements capable of predicting the residual charge (thus the potential and its temporal profile) of a target irradiated by a short intense laser pulse.

Our, recent measurements related to the field enhancement conducted on FLAME laser will be presented. We realized a spatially - resolved Electro Optical Sampling by using a ZnTe crystal and a laser-probe directly split from the pump laser. Such solution allows monitoring temporal profile (with resolution < 100 fsec). in a non-intercepting and a single-shot way, the field generated by electrons bunch. By analyzing the signal intensity we retrieved the bunch Coulomb electric field, allowing retrieving the temporal profile and the quantity of the escaped electrons and demonstrated the field enhancement process by structured targets. In the case of the planar foil target, the signal shows the presence of a first emitted bunch with charge Qe ˜1. 2 nC and energy 6 MeV followed by a second broadened structure carrying a larger amount o of particles (Qe ˜3 nC), this bunch has energy of ˜ 1 MeV.. For the wedged target first bunch carries a larger charge (Qe ˜2 nC) while the charge in the second bunch is strongly reduced. Laser interaction with the tip target produced a much larger number of released electrons (Qe ˜ 7 nC) at higher energies 12 MeV.

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Apollon laser facility present status

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Recent large investments have been plan to build laser facilities for achieving intensity never reached before. The progress made in recent decade in laser technology allows us to envision laser facilities with repetition rate high enough to ensure the laser parameters stabilities and an increase of the statistic of the different measurement made in plasma physics with Laser.
High-intensity high-energy lasers are one of the best compact tools to concentrate in a controllable manner, large among of energy in space and time. Consequently, a whole range of high-energy particles (electrons, protons, highly charged ions, neutrons) and radiation, up to x-rays and gamma-rays can be produced as a result of the interaction with targets that can be either solid or gaseous. Studying interaction using higher and higher intensities is of fundamental interest because it continuously opens the possibilities to explored new regimes, like in particle acceleration or atto-second X-ray sources. Another motivation for the scientific community, is that the generation of such particle and radiation beams, intrinsically synchronised with the laser beam that has generated them, opens an extremely wide range of pump probe applications.
The Apollon is an upcoming laser facility capable of providing multi-PW peak power pulses at a repetition rate of 1 shot/minute. In order to achieve this extreme peak power level, Apollon is based on the generation of extremely short pulses of 15 fs. Employing state of the art technology, the OPCPA-based front-end generates high quality and high temporal contrast pulses at 820 nm with broad spectrum supporting sub-10 fs duration. Energy amplification up to 300 J is then realized in the power amplification section composed of 5 stages of Ti:Sapphire multi-pass amplifiers. The amplified chirped pulses will finally be compressed in an unfolded four-grating compressor. The objectif of Apollon facility is to deliver high intensity laser beams on target for users. The design and the status of the Apollon facility will be presented.

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Over-view and strategy of the ELI-Nuclear Physics Project in Romania

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Since chirped pulse amplification scheme[1] has changed the game in high energy density physics, the available laser intensity has kept increasing, can reach 10ˆ23 W/cmˆ2 or even higher, and can deliver radiation higher than the previously used in nuclear facilities. In order to make use of this capability in full depth, a laser-centered, distributed pan-European research infrastructure, involving ultra-intense laser technologies with ultra-short pulses was triggered through the European Light Infrastructure (ELI) project at the state of the art and beyond.
The European Forum of Infrastructure (ESFRI) has selected in 2006 a proposal of constructing a 200J laser system with intensities up to 10ˆ22-10ˆ23 W/cmˆ2, called ELI at the site of Bucharest-Magurele, Romania. The rest of two large scale high intensity ELI laser facilities are built in The Czech Republic, and Hungary[2].
The scientific research at ELI-NP includes two areas where only little experimental results were reported until now. The first one is 10 PW laser-driven nuclear physics, strong-field quantum electrodynamics and associated vacuum effects. The second area is that of study driven by a Compton-backscattering gamma beam (< 20 MeV), a combination of laser and accelerator technology at the frontier of knowledge. Typical experiments planned in the early stage [3] will be introduced with the system over-view.

Reference
1. D Strickland and G Mourou, Opt. Commun. 56, 219 (1985).
 2. https://eli-laser.eu/
3. Romanian Reports in Physics, <b>68</br>, Supplement, pp. S3-S443 (2016).

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Overview of the ELI-ALPS project and its few cycle phase controlled laser sources

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The major laser sources of the Attosecond Light Pulse Source of the Extreme Light Infrastructure (ELI-ALPS) deliver pulses with unique parameters: unparalleled fluxes, extreme broad bandwidths and sub-cycle control of the generated fields. The high repetition rate (HR) system delivers TW peak power, < 6 fs pulses at 100 kHz. The 1 kHz repetition rate single cycle (SYLOS) system provides 20 TW pulses with a pulse duration of <5 fs. The petawatt-class high-field (HF) laser will operate at 10 Hz repetition rate with 17 fs pulse duration. The above laser systems operate in a bandwidth window of 600 nm - 1400 nm. These lasers are complemented by the mid-infrared (MIR) laser system, which provides tunable (2.5 µm - 3.9 µm) sub-4 cycle laser pulses at 100 kHz repetition rate with 15 W average power. High energy THz pulses at 50 Hz repetition rate are to be generated with a half a joule, half a picosecond laser system at 1.03 µm.

These exceptional laser sources will generate a set of secondary sources with incomparable characteristics, including light sources ranging from the THz to the X-ray spectral ranges and particle sources. The laser and secondary sources foreseen at ELI-ALPS will push the frontier of attosecond science in three main directions as coincidence measurements, investigations of highly nonlinear processes in the XUV and X-ray spectral range, and ultrafast valence-shell and core electron dynamics. The photon sources of ELI-ALPS would also provide regional and national, basic and applied science projects with experimental opportunities in radiobiology, biophotonics, plasma and particle physics.

Activities in the purpose-designed and built building complex will start with the installation of the MIR and the HR laser systems in Spring 2017. Simultaneously, we will also start the assembly of the high harmonic beamlines, the THz laboratory, and the nanoplasmonic experiments. The first XUV bursts of light with attosecond duration are expected to be generated by the end of 2017.

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Development of 10PW Super Intense Laser Facility at Shanghai

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We will introduce the 10PW laser project SULF (Shanghai Superintense Ultrafast Laser Facility), including the design of the laser facility and the potential applications of the laser facility in physics and chemistry researches.
As a first step, we have demonstrated the generation of 5.3PW, 24fs 800nm laser pulses from a CPA

laser system where a high gain 150 mm Ti:sapphire amplifier with 202J, 70nm (FWHM) output is measured.
We will also outline the future plan towards a 100PW laser facility at Shanghai.

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X-EUV Hartmann wavefront sensing.

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Imagine Optic works since early 2000 on Hartmann sensors and has acquired a unique expertise in X-ray wavefront sensing showing outstanding results. The very first experiment performed on the Advanced Light Source beamline at Lawrence Berkeley National Laboratory, USA in 2003 reached accuracy better than λEUV/120 rms (0.11 nm) at the wavelength of 13.4 nm [1]. Later we also demonstrated several examples of optimization of X-EUV sources by closed loop adaptive optics [2] and by active spatial filtering [3] of the amplified signal from high harmonics generation. Another application consists in X-rays beamline alignment, both automatically [4] and manually [5].

We report on our recent development and achievements in wavefront analysis in the extreme ultraviolet (EUV) and X-ray range via the Hartmann technique. Our sensor consists of an array of rotated squared apertures [6] to create a diffraction pattern on the surface of a CCD camera. The signal measured by the CCD contains both amplitude and phase of the sampled beam. To fully characterize the sensor, accuracy and sensitivity measurements in the specification range are performed. The standard range of the measurements of the incident beam's wavelength is from 4 to 40 nm in EUV and from 1 to 10 keV in soft X-rays while keeping the previously acquired calibration at a single wavelength. We also present a custom design of wave-front sensor. In 2016, a EUV sensor calibrated on a very large bandwidth (20 nm to 120 nm) with a best accuracy of λEUV/67 rms has been developed for ELI project in Czech Republic.

[1] P. Mercère et al., Opt. Lettr. 28, 17 (2003).
[2] J. Gauthier et al, Eur. Phys. Jour. D, 48, 3, (2008).
[3] J. P. Goddet et al., Opt. Lett. 34, 2438 (2009); J.P. Goddet et al., Opt. Lett. 34, 16, 2438-2440 (2009); J.P. Goddet et al., Opt. Lett., 32, 11, 1498-1500 (2007); L. Li et al., Opt. Lett. 38, 4011 (2013).
[4] P. Mercère et al, Optics Letters, 31, 2 (2006).
[5] L. Raimondi et al., NIMA 710:131 (2013).
[6] Imagine Optic Patent N° US 20040196450 A1.

POSTER SESSION / 9

New generation of deformable mirror dedicated to ultra high intensity laser

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Like in astronomy, Adaptive Optics (AO) has recently become a standard feature at the modern ultra-high intensity lasers facilities. AO aims in reaching both maximum peak energy and intensity by correcting both the thermal effects induced in the amplification stages and aberrations induced by the optical components of the laser chain. The new generation of ultra-high intensity femto-second petawatt and above class lasers requires new features of wavefront corrections. New challenges for AO consist in overcoming the constraints of potentially bigger diameters, larger aberration strokes, faster optics, higher risk of damaging optical components and faster and easier maintenance.

Imagine Optic being a pioneer company in the development of AO solutions proposes HASO wavefront sensors, ILAO STAR deformable mirrors with control and analysis software WaveView Suite, dedicated to ultra-high intensity lasers. Here, we will present the new generation of deformable mirror, ILAO Star, which is using a new patented design of mechanical actuators.

We will present these new actuators and their improvements compared to the previous generation. We will put special attention to principles of actuation, design of deformable mirror and its complete characterization. We will also introduce the advantages brought by these new actuators when integrated in the ILAO Star deformable mirror. Main advantages are to reach a better mechanical efficiency and better thermal stability with a faster speed. Wide correction capabilities for beam diameter dimension from 20 mm to 500 mm useful diameter working from 0° to 45° angle of incidence are achievable. Easier and safer maintenance have been also proven by replaceable mechanical actuators keeping the deformable mirror membrane.

PRESENTATION AVAILABLE UPON DIRECT REQUEST AT AUTHOR'S ATTENTION AT nvarkentina@imagine-optic.com

POSTER SESSION / 13

Toward spatially uniform pulse compression of top-hat beams at the subpetawatt level of peak powers

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High-peak-power laser beams with a top-hat transverse intensity profile are shown to offer unique options for the spectral and temporal nonlinear-optical transformations of high-intensity laser fields, promising a new technology of spatially uniform pulse compression at the subpetawatt level of peak powers.

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Dispersion management of the front end in SULF

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Recently, the race to build a petawatt or even higher-power laser system with the pulse duration of few tens of femtosecond is initiated worldwide. Such ultrahigh-peak-power laser systems are greatly benefit for fundamental research areas, such as accelerating the charged particles (electrons and protons), and generating high-energy photon (X-ray and γ-ray) sources. The Shanghai Super-intense Ultrafast Laser Facility (SULF) is a large-scale project aimed at delivering 10 PW laser pulses. The CPA Ti: sapphire laser system consists of a front end, a power amplifier, a final three-pass booster amplifier, and a grating compressor .The front end starts from a commercial 1 kHz CPA laser system (Astrella, Coherent Inc.) delivering 95 μJ-level sub-30 fs pulses. The pulses are injected into the pulse

cleaner based on cross-polarized wave (XPW) generation. The spectral width of the cleaned pulses is over 65 nm (FWHM), which can support sub-15fs pulse duration [1]. The cleaned pulses with an energy of 20 μJ are stretched to about 2ns by an aberration-free Öffner-triplet-type stretcher with a 1480 lines/mm gold-coated grating (Jobin Yvon, Inc.). Following the stretcher, the stretched pulse is amplified in the regenerative amplifier and three-stage multi-amplifier such that the energy reaches 7 J at a 1 Hz repetition rate.
To balance the spectral phase in the laser system, a double-pass grism pair is inserted into the petawatt laser system to compensate the residual dispersion up to the fourth order.The inserted position of the grism is between the stretcher and regenerative amplifier. Using this technique, the spectral phase distortion over the spectrum is less than 2.5 rad. The pulse duration is compressed to 22.2 fs, which is only 1.03 times that of the Fourier-transform-limited pulse.Experimental results show that near Fourier-transform-limited pulse can be achieved. In our next work, the grism pair and the main compressor will be used cooperatively to achieve the dispersion management of the 10 PW laser system.

POSTER SESSION / 16

Particle-in-Cell Simulation of X-ray Wakefield Acceleration and Betatron Radiation in Nanotubes

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Laser wakefield theory shows that for a given laser, the energy gain and accelerating length are both inversely proportional to the plasma density [1]. This means that the lower the gas density, the longer the acceleration distance, which is undesirable in reaching ultra-high energies. The recent proposed generation of the X-ray laser pulse provides an attractive way to achieve ultrahigh energy [2]. Benefitting from the much higher critical density which is inversely proportional to the square of the laser wavelength, solid density materials can be chosen for the X-ray laser pulse driven case [3]. On the other hand, functional nanomaterials such as carbon-nanotubes have a large degree of dimensional flexibility and higher than 10 TV/m wakefield is possible, Accordingly, compact structures to obtain ultrahigh energy gain can in principle be realized through the state-of-the-art nanotube technology. Motivated by these, we explored the X-ray wakefield accelerator in a nanotube. We investigate the acceleration due to a wakefield induced by a coherent, ultrashort X-ray pulse guided by a nano-scale channel inside a solid material. By two-dimensional particle-in-cell computer simulations, we show that an acceleration gradient of TeV/cm is attainable. This is about three orders of magnitude stronger than that of the conventional plasma-based wakefield accelerations, which implies the possibility of an extremely compact scheme to attain ultrahigh energies. In addition to particle acceleration, this scheme can also induce the emission of high energy photons at ˜O(10-100) MeV. Our simulations confirm such high energy photon emissions, which is in contrast with that induced by optical laser driven wakefield scheme. In addition to this, the significantly improved emittance of the energetic electrons has been discussed.

[1].T. Tajima, J.M. Dawson, Laser Electron-Accelerator, Phys. Rev. Lett. 43, 267 (1979).
[2].G. Mourou, et al., Single cycle thin film compressor opening the door to Zeptosecond-Exawatt physics, Eur. Phys. J. 223, 1181 (2014).
[3].T. Tajima, Laser acceleration in novel media. European Physical Journal-Special Topics Eur. Phys. J. 223, 1037 (2014)

POSTER SESSION / 10

Observation of space parity gravitational violation in laser-Compton scattering

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Gravity independence on rotations or spin direction is
postulated in general relativity and experimentally
constrained for low energy, non-relativistic matter.
An evidence for high energy CP violation in gravitational
field has recently been found in the HERA Compton polarimeter's
2 spectra measured with electron and positron beams.
Here I report analysis results of 838 thousand spectra,
acquired during the 2004-2007 running period and tagged
by laser polarization state.
The tagged spectra allow to separate charge (C) and space (P)
parity contributions. While the C asymmetry is
contaminated by change of the accelerator parameters
for the electron and positron runs, the laser helicity frequent
flips eliminate most of the potential systematic errors.
Measured Compton edge energy asymmetry induced by the laser
helicity change is as high as (4.62 ± 0.06)x10^{-5}
which corresponds to helicity dependent gravitational potentials'
difference of (8.1 ± 0.1)x10^{-15}.
The measured sign applies a stronger gravitational coupling to
left helicity particles.
In case of the observed coupling universality i.e. energy
independence, the gravity will induce 3.69 ± 0.05 GHz and
2.01 ± 0.02$ MHz spin resonances in nuclei and atoms respectively.

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Multifilamentation. Interaction and reduction of the filaments as nonlinear process.

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The recent experiments with high power Ti: Sapphire laser pulses demonstrate that it is not possible to produce a homogeneous beam pattern. Hot zones are situated across the beam cross section. Each hot zone self-focuses into a filament, if the intensity and power are high enough. Each of the multiple filaments has a core intensity clamped down to that of a single filament of the order of 0.5-5 TW/cm2. These intensities are two to three orders less than the intensity needed for defocusing by ionization. From other hand, the filaments without ionization of the media were observed in silica, liquids and other materials. The filaments with such intensities attract and exchange energy during their propagation. The final result is that at long distances survived only few of them.
The absence of ionization in these processes forced us to seek other linear and nonlinear mechanisms for description of the above mentioned effects and to answer the following basic questions:
1. What kind is the diffraction of broad-band (attosecond and phase-modulated femtosecond) pulses?
2. What is the physical process that leads to asymmetrical broadband of powerful laser pulse in the early moments of filamentation?
3. What kinds are the mechanisms of merging and energy exchange between the filaments?
Recently in [1] and in some previous works we try to answer of the first question, solving the problem analytically and numerically. The result is that broad-band pulses diffract under new regime

with semi-spherical deformation of the intensity profile.
In [2] we try to solve the second question, providing experimental and theoretical investigation of the first picoseconds of formation of white continuum from 100 fs laser pulse in 0.5 cm BK7 glass. We point that the asymmetric spectral broadening of femtosecond laser pulses towards the higher frequencies in isotropic media due to nonlinear effect of cascade generation with THz spectral shift for solids and GHz spectral shift for gases. This shift is equal to three times the carrier-to-envelope frequency. The process works simultaneously with the four-photon parametric wave mixing.
To answer of the third question we investigate in details in [3] and [4] the process of nonlinear attraction between the pulses, due to cross-phase modulation, and energy exchanges due to degenerate four-photon mixing. The results were compared with the experimental results from other authors and demonstrate very good coincidence.
In our Lab there are also first results on nonlinear rotation of the vector of electrical field during process of filament propagation.

[1] A. M. Dakova, L. M. Kovachev, K. L. Kovachev, D. Y. Dakova, "Fraunhofer type diffraction of phase-modulated broad-band femtosecond pulses", Journal of Physics Conference Series 594 012023 (2015).
[2] D. Georgieva, L. Kovachev, N. Nedyalkov, "Avalanche parametric conversion in the initial moment of filamentation", Proc. SPIE, 18th International School on Quantum Electronics: Laser Physics and Applications, Sozopol (26-31September 2016), accepted.
[3] L. M. Kovachev, D. A. Georgieva and A. M. Dakova, "Influence of the four-photon parametric processes and cross-phase modulation on the relative motion of optical filaments', Laser Phys. 25 105402 (7pp), (2015).
[4] Daniela A Georgieva and Lubomir M Kovachev, "Energy transfer between two filaments and degenerate four-photon parametric processes", Laser Physics, 25 035402 (7pp) (2015).

POSTER SESSION / 17

Ti:Sapphire CPA booster amplifier for a 5 PW laser system

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In the recent years, 10 Peta-watt (PW) laser system is a hot topic in the field of laser technology. Many countries and laboratories are building or having a plan to build a 10 PW laser system [1, 2]. The CPA technique particularly using Ti:sapphire (Ti:S) CPA systems is still the main method to achieve PW and 10 PW-levels laser pulses for its high efficiency and stability [3, 4]. However, the transverse amplified spontaneous emission (TASE) and parasitic lasing (PL) within the booster amplifier volume are the main barriers to achieve a higher energy amplification when the larger-aperture Ti:S crystals are pumped at higher pump fluence and energy. In this letter, we reported on the energy amplification for a 5 PW laser system based on Ti:S CPA by using a new method to restrain the PL. The amplified energy was up to 202 J based on a Ti:S crystal with diameter of 150 mm. The pulse was compressed to 24 fs in pulse duration and the peak power was up to 5.3 PW.
After being amplified by a regenerative amplifier and three multi-pass amplifiers, the energy of the stretched pulse was about 7 J and the spectrum width was 90 nm from 750 nm to 840nm. And then, the pulse was send to a Ti:S amplifier with diameter of 80 mm. The pump energy was generated by frequency-doubled Nd:glass amplifiers at 527 nm. The amplified pulse energy was about 48 J pumped by a pump pulse energy of 100 J. The amplified pulse was expanded to a diameter of 120 mm and then injected into a 150-mm-diameter Ti:S booster amplifier. The pump energy was 320 J with diameter of 130mm. To suppress the PL in the booster amplifier, we used the Cargille Series M refractive index liquid doped with an absorber (IR 140) as the cladding material. Besides, we used a method called temporal-dual-pulse pump as an important method to suppress the PL in the booster amplifier. After optimizing the time delay among the pump pulses and the signal pulse, the PL was suppressed when the 150-mm-diameter Ti:S was pumped by a 320 J pump energy. The amplified

energy was up 202 J and the conversion efficiency was about 49%. The amplified spectrum width was about 85 nm from 750 nm to 835 nm.

The amplified pulse from booster amplifier was expand to 300 mm by an achromatic spatial filter and send to a compressor with four gratings. After being compressed, the pulse duration was 24 fs. The total transmission of the spatial filter and the compressor was 64% and the peak power was 5.3 PW.

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Generation of multiple isolated attosecond pulses

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Isolated attosecond pulses are essential tools used in the time-resolved studies of some of the fastest electronic processes in atoms, molecules and solids. These pulses are synthesized from high-order harmonics generated in inert gases by intense, femtosecond laser pulses. During this process an attosecond pulse is generated in every half-cycle of the laser pulse, thus forming an attosecond pulse train. A possible way to isolate a single pulse from this pulse train is the lighthouse technique. This relies on the generation of a laser pulse with rotating wavefront, producing multiple isolated attosecond pulses which propagate in different directions. These pulses become spatially separated in the far field if their divergence is smaller than the difference between their propagation angles. we show that the nonlinear propagation of the laser pulse through the generating gas medium can enhance the angular separation of the generated attosecond pulses through dynamic wavefront rotation.

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TBD

Extreme Light around the world (2) / 55

Relativistic Flying Mirror for Extreme Light Sciences

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A relativistic flying mirror is breaking wake wave excited in tenuous plasma by an intense, short laser pulse. This highly nonlinear wave has a singularity of electron density and has a velocity nearly equals to the speed of light. Thus the electrons can work as a partially reflecting mirror moving nearly at the speed of light. This concept was first proposed by Bulanov et al. So far some of the features of the flying mirror have been confirmed in several experimental campaigns proving the frequency upshifting and reflectivity. We report our recent experimental results and discuss possible applications in extreme light sciences.

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Short overview of laser physics and applications research activities of Institute of Electronics – Bulgarian Academy of Sciences

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In this report would be presented a short overview of the recent research activities in the field of laser physics and applications of the Institute of Electronics at the Bulgarian Academy of Sciences (IE-BAS).
The Institute was established in 1963 as a non-profit state organization conducting research, education and dissemination of scientific knowledge in the fields of physical electronics, photonics and quantum electronics and radio sciences. Soon, IE-BAS evolved as a leading scientific institution in these areas of applied physics and engineering within the Bulgarian Academy of Sciences and in the country.
The IE-BAS was where the first Bulgarian laser, lidar, micro-channel electron-optical converter, optical magnetometers, laser therapeutic and diagnostic systems for biomedical applications were built, followed by the development of several advanced e-beam technologies, novel types of optical gas sensors, pioneering achievements in laser nanostructuring and nanoparticle formation, laser and plasma high technologies, biomedical photonics and applications.
IE-BAS is a host and main organizer of a biannual International School on Quantum Electronics "Laser Physics and Applications", which has more than 38-years history and become a well-known scientific event for training of young researchers and PhD students, covering different aspects of laser-matter interactions, laser spectroscopy and metrology, laser remote sensing and ecology, lasers in biology and medicine and laser systems and nonlinear optics.
Through the years, the Institute's research field and structure have developed dynamically in response to the changes taking place in the main trends in applied physics and technologies: materials science and technologies, physics of nano-sized objects and nanotechnologies, nanoelectronics, photonics, opto-electronics, quantum optics, environmental physics and monitoring, biomedical photonics and biomedical applications.
Nowadays, IE-BAS is a leading research organization in Bulgaria in the field of laser physics and applications. The research in photonics and quantum electronics comprises theoretical and experimental studies on the interaction of short and ultrashort lasers pulses with matter; development of novel nano-structuring technologies; laser thin-films deposition and treatment; light-induced absorption and transmission in alkaline vapors; development of complex laser systems for analysis and modification of semiconducting and superconducting materials; theoretical and experimental investigation of non-linear optical phenomena and biomedical photonics.

Socio-Economic Impacts / 62

The socio-economic impact of research infrastructures: a generic evaluation framework and insights from selected case studies

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After a short reminder on the evolution of growth theories, the presentation will focus on the role research infrastructures can play in the framework of such theories. Using this framework, the presentation will feature the different channels through which a research infrastructure contribute to economic growth, and the different parameters to take into account for a research infrastructure to deliver a maximum social and economic impact. The presentation will then discuss the specific modalities found for the different research infrastructures the author worked for/with.

Socio-Economic Impacts / 56

ELI-NP as a crucible for innovation: the ELAP project

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ELAP is the Extreme Light Applications Park of the ELI-NP facility in Magurele (RO).

The Extreme Light physics is a novel approach to laser-matter interaction, made possible by the groundbreaking works of Prof T. Tajima (UCI, CA, USA) and Prof. G. Mourou (IZEST-Ecole Polytechnique, FR). The unique characteristic of the extreme light laser is to produce enormous amounts of energy and pressure; enough to rip matter apart, releasing sub-atomic particles such as protons, moving close to the speed of light. The core activities of ELAP are based on the breakthroughs in the field of the nuclear physics made possible by extreme light, especially in the field of nuclear medicine, but also to other real life applications like nuclear waste disposal.

Since the preparation of the ELI-NP white book [1], the project team identified the need of an application park to transform the scientific results into real-life applications. ELAP is the natural outcome of such an ambitious and unique project.
The present project for an Extreme Light Applications Park was defined by the brainstorming activity of the IZEST laboratory team (Ecole Polytechnique, France), the ELI-NP (Magurele, Romania) scientific team and private sector representatives (industry, investment).

Within the EUCALL project, senior scientists from SRS, FEL and HPL facilities will join to identify novel research opportunities, methodologies, and technologies. Strategies will be implemented towards optimum use of the laser light facilities, promotion of innovation, and coordinated user training/experience exchange. These activities help actively innovation projects like ELI-ELAP by supporting the following activities:

- collect information about scientific opportunities and instrument implementation,
- collect information about innovation opportunities, technical transfer, industrial access to the research facilities, success stories of laboratories spin-offs and start-ups,
- study of a few cases of existing cross-community collaborations.

In conclusion, ELAP answers, on the short term, to the need of building applications on the scientific novelties discovered at the ELI-NP facility. On the long term, the creation of an innovation activity in the environment of Magurele will represent a unique advantage for the development of the ELI-NP project and of Romania in general.

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[1] The White Book of ELI Nuclear Physics, Bucharest-Magurele, Romania, The ELI-Nuclear Physics working groups

Socio-Economic Impacts / 3

Socio-Economics for Energy: Extreme Laser Pulses for Boron Fusion Power Reactors

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Socio-Economics for Energy: Extreme Laser Pulses for Boron Fusion Power Reactors

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ABSTRACT

Application of extreme laser pulses of less than picoseconds duration but with powers between Peta- and Exawatt is an example for direct use against the climatic changes by generating fusion energy from boron without nuclear radiation problem. Fusion of hydrogen nuclei (protons) with the boron-11 isotope (HB11) was known as extremely difficult or impossible. But this was of high interest being environmentally clean with less radioactivity per generated energy than from burning coal. This changed radically when it was discovered in 2008, that a non-thermal ignition of fusion in un-compressed fuel was converting the energy of extremely powerful very short laser pulses directly into the ultrahigh acceleration of macroscopic plasma blocks. This kind of ignition was similar to heavy ion fusion [1], but now the extreme laser pulses offer the necessary sufficient non-thermal conditions of plasma acceleration techniques. This is related to the science based results on a unique avalanche multiplication of HB11 reactions in the presentation by Moustaizis et al. with the discovery with many orders of magnitudes increased reaction gains measured [2] and explained by theory [3]. This paper presents details for designing a fusion reactor using the combination of the accelerated plasma blocks with ultrahigh laser generated magnetic fields [4]. An advantage for the technology consists in the fact that the cylindrical geometry for the trapping of the reaction volume permits the application of plane wave interaction of the >petawatt laser pulses as a direct drive ignition process. This avoids the complications known from indirect drive and more general geometries [5][6]. The HB11 reaction energy in the alpha particles (helium) is converted by electrostatic fields with nearly no heat losses into electric power with standard Million-Volt technology. Economically profitable power generation without nuclear radiation problem appears to be possible including socio-economic aspects.
*Collaboration with G. Korn, S. Eliezer, N.Noaz, P. Lalousis, P. Moustaizis, G.H. Miley, G.J. Kirchhoff, G. Mourou, C.P.J. Barty, D.H.H. Hoffmann et al.
[1] Rubbia Carlo, Laser and Particle Beams 11, 391 (1993)
[2] Hora Heinrich, Korn G. et al., Laser and Particle Beams 33, 607 (2015)
[3] Eliezer Shalom, Hora H., Korn G. et al. Physics of Plasmas 23, 050704 (2016)
[4] Hora H. and Kirchhoff G.J. PCT world patent WO 2015/144190 A1 (23 March 2014)
[5] Hora H. Chapter 10 of Laser Plasma Physics, Second Edition, SPIE Press, Bellingham WA, 2016
[6] Hora H. et al Conference Abstract 3rd ICHDP 23-25 SEP 2016, ShenZhen/China

Socio-Economic Impacts / 4

Laser-Driven High Energy Alpha Beam Interaction with Solid p11B to Achieve Fusion Ignition by Alpha Heating

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Laser-Driven High Energy Alpha Beam Interaction with Solid p11B to Achieve Fusion Ignition by Alpha Heating

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ABSTRACT

We present for the first time numerical results on fusion ignition process produced by laser-driven high energy alpha beam interaction with compressed solid p11B fuel. Relevant results on alpha measurements from nuclear reactions, induced by laser-driven proton beam interaction with 11B plasma [1, 2], justify extensive numerical investigations on fusion burning feasibility of pB11 fuel using a multi-fluid code [3, 4, 5, 6]. The consideration of a new physical process, termed as alpha avalanche effect [7, 8] contribute to enhance the alpha heating effect and consequently the reaction rate of the fusion process. The p11B nuclear fusion reaction is attractive not only because is an aneutronic reaction but because have the advantages to produce three alphas with total energy 8.9 MeV. But the main difficulty for fusion ignition in solid density p11B targets is that the cross section for nuclear fusion reactions is efficient for energies higher than 250 keV. The proposed concept, to overcome this difficulty, is to inject an energetic alpha beam in the compressed target and simulate the temporal evolution of the temperature and the reaction rate of the p11B fuel due to alpha heating effect. The initial high energy alpha beam could be produced by ultra-short and high intensity laser beam interaction with thin DT solid targets (see fig.3 of ref.9). The high energy alpha beam interact with a p11B plasma compressed 4-10 times the initial solid density and with low initial temperaturature. The numerical results show that the maximum of the reaction rate is achieved tens of nsec after the injection of the alpha beam. After this time interval the reaction rate decreases due to the depletion of the plasma ion density. The temperature corresponding to the maximum of the reaction rate is about 200 keV. The time corresponding to the maximum reaction rate depend strongly on the density of the injected alpha beam, the initial plasma temperature and the compression factor of the p11B fuel. In the near future Petawatt or Exawatt – Zetawatt laser systems [10, 11] and especially the IZEST project and the fiber based laser system investigate for the ICAN project, will be able to attain intensities up to 1025 W/cm2 and 1029 W/cm2 with pulse duration of the order of attoseconds or zettaseconds. These projects will enable unique applications on laser-driven ion beam acceleration with high current [12, 13, 14]. The numerical results of this work promote the development of new high efficiency and high power fibre laser systems like ICAN in order to generate high density alpha beams.

[1]*Labaune, C., S. Deprieraux, S. Goyon, C. Loisel, G. Yahia & J. Rafelski Nature Communications 4, 2506 (2013).*
[2] G. Korn, D. Margarone, A. Picciotto, Boron-Proton Nuclear-Fusion Enhancement induced inBoron-dopped Silicon Targets by low Contrast Pulsed Laser Lecture at the IZEST conference, Paris, Romanian Embassy, 19 September 2014.
A. Picciotto et al. Physical Review X 4, 031030 (2014).
[3]*P. Lalousis, H. Hora and S. Moustaizis, Laser and Particle Beams 32, 409 (2014).*
[4_H. Hora, G. Miley, P. Lalousis, S. Moustaizis, K. Clayton and D. Jonas. Efficient Generation of Fusion Flames Using PW-ps Laser Pulses for Ultrahigh Acceleration of Plasma Blocks by Nonlinear (Ponderomotive) Forces, IEEE Transaction of Plasma Science 42, 640-644 (2014).
[5] H. Hora, P. Lalousis, Shalom Eliezer, G. H. Miley, S. Moustaizis, G. Mourou. 10 kilotesla magnetic field confinement combined with ultra-fast laser accelerated plasma blocks for initiating fusion flames. Abstract of an oral presentation at the Physics-Congress Canberra/Australia, see arXiv 1412.4190. (11 December 2014).
[6]*P. Lalousis, S. Moustaizis, H. Hora and G.H. Miley, Kilotesla Magnetic Assisted Fast Laser Ignited Boron-11 Hydrogen Fusion with Nonlinear Force Driven Ultrahigh Accelerated Plasma Blocks, Journal of Fusion Energy, 34 62-67 (2015).*
[7]_H. Hora et al,.Petawatt laser pulses for proton-boron high gain fusion with avalanche reactions excluding problems of nuclear radiation. SPIE Conf. Proceedings No. 9515, paper 9515-44 (2015).
[8] S. Eliezer, H. Hora, G. Korn, N. Nissin and J. M. Martinez Val, "Avalance proton-boron fusion based on elastic nuclear collisions", Physics of Plasmas 23, 050704, 2016
[9]_ R. Banati, H. Hora, P. Lalousis, S. Moustaizis.. "Ultrahigh laser acceleration of plasma blocks with ultrahigh ion density for fusion and hadron therapy", Jour. Intense Pulsed Lasers & Application in Adv. Physics 4, No. 1, 11-16 (2014).
[10]_T. Tajima and G. Mourou, "Zettawatt-exawatt lasers and their applications in ultrastrong field physics", Physical Review Special Topics – Accelerators and Beams, Vol 5, 0310301, 2002
[11]_G. Mourou, T. Tajima and S. Bulanov, Reviews of Modern Physics 78, 309 (2006)
[12]_G. Mourou, T. Tajima and Jens Limpert, " The future is fibre accelerators", Nature Photonics, Vol. 7, April 2013.
[13] _ T. Esirkepov, M. Borgesi, S. V. Bulanov, G. Mourou and T. Tajima, "High Efficiency Relativistic-

Ion Generation in Laser-Piston Regime", Phys. Rev. Lett. Vol.92, no 17, 175003-2, April 2004.
[14]_T. Tajima, G. Mourou and S. Gals, "Arrangement for generating a proton beam and an installation for transmutation of nuclear wastes", European Patent Application, EP 2 709 429 A1, 2012.

Short Pulses and Quantum Beams / 11

Control of temporal intensity profile for PW laser pulses

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We present theoretical and experimental results on enhancement of temporal intensity profile of PW laser pulses. Techniques of peak power increasing based on self-phase modulation, second harmonic generation and cascaded quadratic nonlinearity effects will be discussed. The specific of its implementation for modern powerful laser facilities is investigated and results will be demonstrated.

Short Pulses and Quantum Beams / 7

Twisted Photons at DESY

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Vortex light with orbital angular momentum (OAM) have successfully been generated in many laboratories. So far, however, energies of the particles with OAM, called twisted photons or electrons, remain below 0.1 keV. Here we report on the first high energy vortex photon beam obtained via Compton scattering of the topologically charged (OAM=2) 2.3eV laser photons on the PETRA 6 GeV electrons. According to angular momentum conservation, the scattered twisted photons have topological charge 2 near their maximal energy of 588 MeV. This opens up an unprecedented possibility for direct quadrupole excitation of nuclei with evenly-charged twisted photons. After modifying the laser entrance pipe, we plan to expand the energy range of twisted photons from 10 MeV to 1.1 GeV. That will allow exploring multipole resonances in nuclei at MeV, as well in quark matter inside the nucleons at GeV energies. The latter could pave a way towards quark gamma laser with twisted photon pumping and cold nuclear fusion with altered charge distributions in deuteron and tritium. The PETRA twisted photon setup allows for fast flipping of the topological charge between ±2 or ±1 states, which could be used for the quarks' orbital angular momentum measurements, by twisted photons' scattering asymmetry; this could solve the long standing nucleon spin puzzle. Employing the twisted Compton scattering at FLASH and E-XFEL will expand the energy range of the twisted particles from keV to few GeV energies, along with some possible applications. In perspective, extreme power

lasers will be required for the transition from proof of principle vortex beam experiments to novel field of science and technology with twisted particles.

Orbital Debris / 18

Deorbiting of Space Debris by Laser Ablation

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Recent years deorbiting by the laser ablation attracts increasing attentions as almost unique effective method to remediate cm-sized space debris. According to Ebisuzaki et al. 2014, the deorbiting operation is divided into three steps. First, a super-wide field telescope detects the reflection signal of the solar light by a space debris and roughly determine its position and moving direction. Second, laser beams are ejected to the directions of the debris to determine the position and velocity precisely as well as its distance. Finally, a high intensity laser beam is focused onto the debris surface to induce laser ablation on the surface. The reaction force of the ablation leads the debris to the deorbiting to the Earth's atmosphere. In this talk, we will propose the step-by-step approach for the technical demonstration of the mission and present the concept of a possible space mission dedicated to deorbiting cm-sized space debris by laser ablation technology.

[1] Ebisuzaki et al., Demonstration designs for the remediation of space debris from the International Space Station, Acta Astronautica, 112 (2015), 102-113.

Orbital Debris / 2

Update on XCAN, Ecole Polytechnique-Thales Coherent Beam Combination joint laser program

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Ecole Polytechnique and Thales are engaged into the development of a femtosecond laser system based on the coherent combination of laser beams produced through a network of 61 amplifying optical fibers [1] known as XCAN [2].
Designing, integrating and operating efficiently a laser system based on such an innovative architecture is clearly a challenge. But major key issues have already been studied as part of Thales previous activities in this field [3] but also within the ICAN (International Amplifying Coherent Network) project [4] of the European Commission. This consortium included scientists from the communities of particle accelerators (International Committee for Future Accelerators) and ultra-intense lasers (International Committee on Ultra-High Intensity Lasers). Together, they defined the key lasers parameters required for a prototype wake field based laser particle accelerator. ICAN helped to combine the expertise of high-energy and laser/fiber physicists, while ensuring a close connection with relevant industry experts in this field.
X-CAN relies on the coherent beam combination of fiber chirped-pulse amplifiers operating at 50 kHz repetition rate. Sub µJ energy pulses of 300 fs duration will be temporally stretched up to 2 to 5 ns and spatially demultiplexed in 61 channels. Parallel amplification will be performed through successive amplifying stages, the main one based on large mode area fibers. The output beams will be bundled into one single beam, and a small fraction will be used for collective phase measurement. A

feedback loop relying on individual phase control devices implemented in each channel will ensure maximum, stable combination efficiency. Followed by pulse compression, the coherent addition of all individual phased beams is expected to provide ultrashort pulses of several mJ energy, and will pave the way for large-scale fiber-based coherent amplifying networks in the femtosecond regime.

[1] G. A. Mourou, D. Hulin and A. Galvanauskas, "The road to High Peak Power and HighAverage Power Laser: Coherent Amplification Network (CAN)", AIP Conference Proceedings, Third International Conference on Superstrong Fields in Plasmas, vol. 827, Dimitri Batani and Maurizio Lontano, 152-163 (2006).
[2] L. Daniault, S. Bellanger, J. Le Dortz, J. Bourderionnet, É. Lallier, C. Larat, M. Antier-Murgey, J.-C. Chanteloup, A. Brignon, C. Simon-Boisson et G. Mourou, "XCAN—A coherent amplification network of femtosecond fiber chirped-pulse amplifiers." The European Physical Journal Special Topics 224, no. 13 (2015): 2609-2613.
[3] J. Bourderionnet, C. Bellanger, J. Primot, A. Brignon, "Collective coherent phase combining of 64 fibers", Opt. Express. 19 (18), (2011).
[4] G. Mourou, B. Brocklesby, T. Tajima, J. Limpert, "The future is laser accelerator," Nature Photonics, 7, 258-261 (2013).

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Orbital Debris / 48

Mini-Euso, a pathfinder on the ISS to detect [2 - 10 cm] debris

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Mini-Euso is a small telescope to be installed inside the ISS in 2017. It is a small pathfinder of the main Jem-Euso mission in which a large UV telescope is to be set outside the ISS to capture the most energetic cosmic rays by detecting the [300-400 nm] fluorescence light from nitrogen struck by the shower charged particles.. Mini-Euso looks at earth through a UV window on the Russian segment, with two 25 cm Fresnel lenses. As a Jem-Euso pathfinder, it is primarily dedicated to assess the technology and look during the night at luminous events like storms, meteors, etc. It detects single photo-electrons with large dynamics [from 0.1 to 10ˆ6 pe par time gate (2.5 μs)]. At ISS sunset and sunrise, the earth is in the dark for 5 mn, while ISS is sun illuminated. During these 10 mn every 90 mn, we will observe debris under the ISS (at 300 to 400 km altitude) by their brightness. They will look as a slow moving track on the focal surface (48 x 48 pixels, recorded every 2.5 μs). It is the first step to observe the [2-10 cm] debris, before using a satellite big enough to install a CAN laser which would shoot at it to ablate and recoil it to earth. Some 50 such debris could be detected that way during a year of observation.

Basic Science / 5

Gamma beams generation with high intensity lasers for the study of two photon Breit-Wheeler pair production

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Direct production of electron-positron pairs in photon collisions is one of the basic processes in the Universe. The linear Breit-Wheeler (BW) pair creation process (γ+γ to e^{+}+e^{-}), is the lowest threshold process in photon-photon interaction, controlling the energy release in Gamma Ray Bursts and Active Galactic Nuclei [1]. It is also responsible for the TeV cutoff in the photon energy spectrum of extra-galactic sources. The linear BW process has never been clearly observed in laboratory with important probability of matter creation [2]. Using MeV photon sources a new experimental set-up based on numerical simulations with QED effects has recently been proposed [3]. This scheme offers a possibility of conducting a multi-shot experiment with a reliable statistics on laser systems with pulse energies on the level of a few joules to tens of joules, and in a low noise environment without heavy elements. This scheme relies on a collision of relatively low energy (few MeV), intense photon beams. By colliding two of them in vacuum, one would be able to produce a significant number of electron-positron pairs in a controllable way.

To prepare future experiments using this scheme, we have performed an optimization study on collimated gamma sources generation with high intensity lasers using numerical simulations with QED effects for different possible ways of creation of the MeV photons with solid foils or dense gas jets. At ultra high intensities, higher than $10^{23}W/cm^2$, most of the energetic photons are generated in the synchrotron-like radiation dominated regime, but for intermediate intensities, between a few 10^{21} and $10^{23}W/cm^2$, a competition between the Bremsstrahlung and the synchrotron-like processes arise. For intensities lower than $10^{21}W/cm^2$, Bremsstrahlung dominates. This optimization study has been performed using the parameters of soon to be available laser facilities like Apollon at Université Paris Saclay, the ultra high intensity upgrade of the INRS laser in Canada, the Texas Petawatt in the US, and PETAL on the LMJ facility in France.

The possibility to study two-photon Breit-Wheeler pair production in the laboratory would allow to test new concepts of pair plasma production and to explore this pair creation process in the ultra high field regime with important potential applications in astrophysics. Moreover, the obtained optimized gamma sources could also have promising applications as radiography sources.

References: [1] Ruffini, R. et al. Physics Reports 487, 1-140 (2010). [2] Bamber C. et al. Phys. Rev. D, 60, 092004 (1999). [3] Ribeyre, X. et al., Phys. Rev. E, 93, 013201 (2016).

Basic Science / **6**

Electron-positron pairs beaming in the Breit-Wheeler process

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Direct production of electron-position pairs in photon collisions is one of the basic processes in the Universe. The electron-positron production $\gamma + \gamma$ to e^{+} +e^{-} (linear Breit-Wheeler process) is the lowest threshold process in photon-photon interaction, controlling the energy release in Gamma Ray Bursts, Active Galactic Nuclei, black holes and other explosive phenomena [1]. It is also responsible for the TeV cutoff in the photon energy spectrum of extra-galactic sources. The linear Breit-Wheeler process has never been clearly observed in laboratory with important probability of matter creation [2].

Thanks to the recent progress in high-power laser sources it will be possible to create compact sources of intense γ-ray beams (few MeV) and to use them in new experiments allowing to observe and study the BW process in laboratory [3]. In this presentation, based on the kinematics of two photon collisions, we study the $e^{+} - e^{-}$ beam properties. In particular, we demonstrate a possibility for beaming of $e^{+} - e^{-}$ pairs in one particular direction, which may strongly facilitate the observation of the BW process [4]. We show that the pair beaming effect depends on the angle between photon beams and the energy of each beam. Moreover, the numerical simulations with the photon collision code TriLens [5] are in good agreement with the analytical model. Simulation results obtained with TriLens using optimized gamma beams to prepare experiments on future ultra-high intensities lasers like Apollon will be presented. With higher photon beam energies (>100 MeV) the beaming effect can be observed also for muon-pairs creation.

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[1] Ruffini, R. et al. Physics Reports, 487, 1-140 (2010).

[2] Bamber C. et al. Phys. Rev. D, 60, 092004 (1999).

[3] Ribeyre X. et al. Phys. Rev. E, 93 013201 (2016).

[4] Ribeyre X. et al., PPCF 59, 014024 (2017).

[5] Jansen O. et al., Submitted to JCP, arXiv:1608.01125 (2016).

Basic Science / **52**

Potential to search for Dark Matter with multi-wavelengths light sources

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Nambu and Goldstone have predicted emergence of massless boson (NGB) as a result of spontaneous symmetry breaking of a global symmetry. Originally the lightness of the pion mass was explained because pion is NGB as a result of chiral symmetry breaking. This guiding principle can be applied to any kinds of global symmetries. There are theoretically predicted NGBs which can be dark components in the universe if their couplings to matter are very weak. However, these masses cannot be exactly zero due to complicated quantum corrections and these theories cannot exactly predict where these masses physically appear. Therefore, it is important to perform searches for such Dark Matter candidates over a wide range of the mass scale. I would like to discuss how we can extend the search window by introducing laser fields from sub-eV to 10 keV.

Basic Science / **65**

Ultra-Intense X-Ray Radiation of Relativistic Laser Plasma Inducing Radiation-Dominated Matter Kinetics

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The energy of petawatt optical laser pulses of pico- and femto-second duration and relativistic intensities exceeding 1021 W/cm2 is efficiently converted to X-ray radiation, which is emitted by hot electron component in collision-less processes and heats the solid density plasma periphery. In turn,

the intense X-ray radiation effectively ionizes the matter inside out, providing a large population of exotic states called hollow ions, i.e. ions with empty inner and populated outer electron shells. Hollow-ion emission from radiation-dominated hot, dense plasmas provides a new opportunity for diagnosing high-intensity x-ray radiation fields. However, constructing adequate non-LTE atomic models remains a challenge, since configuration interaction plays a significant role in the structure of the emission, and multiply excited states with many holes in both valence and inner shells can lead to enormous structural and computational complexity. Currently, the process of hollow ion production by X-rays is of particular importance due to the advent of multiple high-power X-ray lasers such as: transient–collisional, based on plasma pumping by visible lasers and the free-electron lasers.
Direct high-resolution spectroscopic measurements demonstrate that X-ray radiation from plasma periphery exhibits unusual non-linear growth ˜E4–5 of its power. The non-linear power growth occurs far earlier than the known regime when the radiation reaction dominates particle motion (RDR). Nevertheless, the radiation is shown to dominate the kinetics of the plasma periphery, changing in this regime the physical picture of the laser plasma interaction. Although in the experiments reported here we demonstrated by observation of KK hollow ions that X-ray intensities in the keV range exceeds 1018 W/cm2, there is no theoretical limit of the radiation power.
Therefore, such powerful X-ray sources can produce and probe exotic material states with high densities and multiple inner-shell electron excitations even for higher Z elements. Relativistic laser-produced plasmas may thus provide unique ultra-bright polychromatic X-ray source for future studies of matter in extreme conditions and radiography applications.

POSTER SESSION / 14

High Peak Power Laser System for ELI NP

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High peak power lasers for Ultra High Intensity (UHI) physics have been developed for almost two decades. The first generation of such lasers has been essentially built with Nd:Glass Chirped Pulse Amplifiers (CPA) operating at very low repetition rates (few shots per day).

The last decade has seen the tremendous development of CPA based on Titanium Sapphire crystals pumped by the second harmonic of a Nd:YAG or a Nd:Glass laser. Several groups have recently reported up to 2 PW whereas entirely commercial systems have achieved PW output at a repetition rate of Hz based on Nd:YAG pump laser technology as well as the shortest pulse ever produced by a PW laser, below 25fs. Such systems have already produced outstanding results such as laser-plasma acceleration of electrons up to the record value of 4.25GeV.

The next generation will be based on lasers delivering more peak power than currently including ELI (Extreme Light Infrastructure) Nuclear Physics (ELI-NP) in Romania involving two laser beams of 10PW each (HPLS - High Power Laser System) awarded in July 2013 to Thales by the Romanian Nuclear Physics Institute IFIN-HH.

HPLS is made of two beamlines which will deliver each a main beam of 10PW peak power at 1 shot per minute, with intermediate outputs at 100TW/10Hz and 1PW/1Hz. The two beamlines will be seeded by a common 10mJ Front End.

The 10PW beamline is based on an hybrid scheme involving a first TiSa based kHz CPA of mJ level, a XPW filter for temporal contrast enhancement, an optically synchronized 532nm-pumped OPCPA stage delivering 10mJ at 10Hz capable to enlarge the bandwidth and enhance the temporal contrast and a second TiSa based CPA. Design has taken benefit from a technology transfer agreement with CNRS leading to technical discussion and exchange on the Apollon laser design.

The gain narrowing and wavelength red-shifting effects in TiSa amplifiers is compensated through the insertion of properly designed spectral filters between amplifying stages. In order to reach around 300J of energy per pulse before compression, final amplifier stage between 1 PW intermediate output and 10 PW compressor will be pumped by 800J at 527nm provided by 8 pump lasers (ATLAS-100) delivering each 100J per pulse at 1 shot per minute.

Two Front End beam have been entirely built and characterized. Energy per pulse of more than 10.5mJ has been demonstrated for less than 55mJ pump available at OPCPA BBO crystals showing therefore an overall optical efficiency close to 20% for the OPCPA without any temporal and spatial shaping of the pump beam. The spectral bandwidth is of about 100nm which is more than sufficient in order to seed the following chain of amplifiers. The temporal contrast has been measured and has confirmed the enhancement by at least three orders thanks to the OPCPA.

The Front End beam was used to seed the amplifiers stages corresponding to level required for the 100TW output and the 1PW output with demonstration of the expected performances in term of spectral bandwidth and energy level.The two beams were sent through the compressor with demonstration of a pulse compression at 21fs leading to a peak power of 1.3PW at 1Hz.

Fourteen ATLAS 100 pump lasers (out of sixteen) have been also built and the delivery of more than 100J per pulse with a near flat-top spatial profile has been confirmed for all the units with a pulse energy stability better than 1.5% rms over 8 hours of continuous operation.

Initial results obtained with the system integrated up to the 1PW level within Thales facilities at Elancourt, France, have confirmed the expectations from the design of the HPLS for ELI NP. The final performances are now expected in Romania where the HPLS installation has started in the new facility dedicated to the ELI NP project.

POSTER SESSION / 1

HHG Beamline, a unique turnkey system for the generation of a brilliant XUV beam

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Over the past years, the ultra-intense laser field has continued to flourish as demonstrated by a growing number of scientific and technological projects. In particular, Europe's commitment towards ultra-high intensity physics is exemplified by the involvement of several European countries pooling research, network resources and experience to succeed in the completion of different state of the art laser facilities.
ELI consortium represents the core of the European effort to create unique laser facilities that can explore new regimes of laser-matter interaction as has never done before. It is divided into three facilities, ELI-Beamlines in Czech Republic, ELI-NP in Romania and ELI-ALPS in Hungary, each one equipped with unique laser systems and dedicated to a particular type of physics that will be studied. Most of the laser system will be used to generate secondary sources, like electron beams, Xray beams, gamma beams etc. In particular, ELI-Beamlines facility has been designed in order to let interact beams of different nature in unique pump-probe experiments. One of the beamlines – a High Harmonic Generation Beamline - will be designed, delivered and installed by a French company ARDOP as a turn-key system generating a broadband XUV beam.

The HHG beamline has been designed to accept two driving 1 kHz laser beams with pulse duration <20 fs and energy up to 100 mJ and, to superpose and focus them on a gas cell, to filter-out the residual laser beams and to characterize the generated XUV beam. The system can generate a very broadband radiation in the XUV region (from 5nm to 120), thanks to its modular design that allows to work at different focusing geometries (focal lengths from 1 m to 20 m), the gas cell that has a variable length and the choice of different rare gases.

The beamline is composed of four meter-size vessels, a complete IR rejection system done of grazing incidence mirrors and thin metallic filters, and a diagnostic system including a focusing flat-field spectrometer, a wavefront sensor and a calibrated photodiode for photon flux measurements.

The HHG Beamline has been designed also to accommodate two parallel driving lasers, generating two parallel XUV beams. To our knowledge, this is the only HHG beamline that can generate such a broad spectrum at such high intensities.

The HHG Beamline installation in Czech Republic should start in september and will be operational by the end of 2016.