Cremlin Connecting Russian and European Measures for Large-scale Research Infrastructures

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Deliverable D6.1: Report on workshops dedicated to common technological challenges on the way towards 100PW class lasers.

This deliverable is essentially related to the Task 6.1: “Key high-power laser technologies for ultrahigh intensity physics” but also, to a lesser extent, to Task 6.2 “Identification of novel applications of Exawatt laser sources”.

To identify and map the research interests and needs of EU and Russian partners for scientific cooperation in the XCELS project, it is clearly obvious that communication between scientists must be strengthen. To do so, the Institute of Applied Physics RAS organized a meeting which took place on board the river ship cruising from Nizhny Novgorod to St.Petersburg from July 17 to July 23, 2016, as part of the International Conference "Frontiers of Nonlinear Physics". 34 participants from different countries took part in the Workshop.

For the second workshop, organized by the CEA-LIDYL, and object of the present deliverable, we took advantage of the organization in France (Cassis Convention Center) of the fourteen edition of the “International Symposium on Ultrafast Intense Laser Science”. This well know and high level conference gathered 80 high-level scientists directly concerned with ultra-fast and ultra-high-intensity physics, both topics at the heart of the XCELS scientific program.

Sponsors as Newport Spectra-Physics GmbH and Spectra-Physics K.K., Thales Optronique SA, Amplitude Technologies, FASTLITE, TRUMPF Scientific Lasers, Imagine Optic, Coherent, JAPAN LASER CORPORATION, ARDoP SAS, Optima Corporation, Tokyo Instruments, Inc., Springer, Asahi business, QB Systems, Co. LTD, International Academic Publishing Co., Ltd were also present and took this opportunity to approach our Russian colleagues.

The workshop was organized as follows, including five talks and a sponsor session (7 talks)

- Philippe Martin, introduction and objective of CREMLIN
- Catalin Miron, “ELI - a distributed user facility for high-power laser research and applications”
- Alexander Sergeev, “Main scientific objectives of XCELS”
- Patrick Audebert, “How Apollon laser is conceived and present status”
- Efim Khazanov, “How XCELS laser is conceived and expected performances”
- Sponsors’ Session I (CREMLIN sponsors)
- Discussion

Introduction and objectives

Ph. Martin introduced the session with an introduction to CREMLIN and its goals namely “improve and strengthen the relations and networks between European and the six Russian mega-science research infrastructures both at a scientific level and at a research policy level”.

He then introduced the WP6 dedicated to XCELS, a project aiming at the construction and exploitation of a 200 PW laser facility. He then addressed to the speakers and to the audience the following questions:

- Who are the Competitors if any?
- What unique science and applications could be done?
- What is the required technology and is it mature?
- What is the necessary staff and budget for the construction?
- What is the necessary staff and budget for the running cost?

ELI - a distributed user facility for high-power laser research and applications

C. Miron presented the extreme richness of the ELI scientific case going from Particle acceleration, Ultrafast-laser driven X-ray sources, Attoscience & ultrafast dynamics, Laser-based nuclear physics, Investigation of vacuum structure, Physics of dense plasmas to Laboratory astrophysics.

He presented in a few slides, the scientific mission of each ELI pillar:

- ELI-ALPS: Visualizing ultrafast structural dynamics in new regimes of space and time resolution
- ELI BL: Fundamental & applied research with ultrashort pulses of charged particles and high-energy radiation serving users of different fields
- ELI-NP: Explore matter and its constituents from nuclei and atoms to vacuum

He presented also, the ELI laser portfolio to be made available by 2018 which is quite impressive: two coupled 10PW lasers (ELI-NP), a 1-2PW laser @ 10-20Hz (ELI-Beamlines), a 1PW laser (OPCPA, <20fs) @ 10Hz (ELI-Beamlines), a 10PW laser (1.5kJ, 150fs) (ELI Beamlines) and a multi-PW laser @ 10Hz (ELI-ALPS).

These lasers rely on well-established technology and most of them are bought from renowned international companies.

The implementation of the three pillars of ELI is nearing completion. Scientists and engineers are now in the process to design and order the first experimental chambers.
ELI will be operated as an international user facility by a European Research Infrastructure Consortium (ELI-ERIC) to be created by the European Commission in 2017.

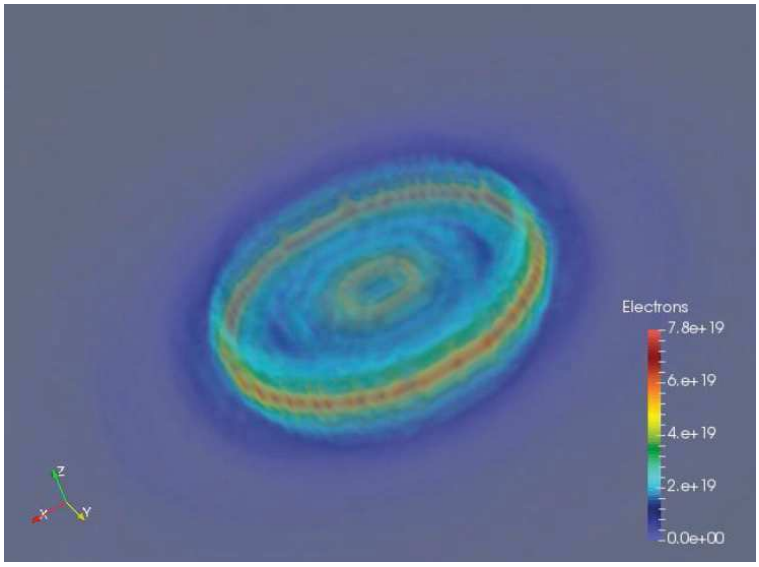
Main scientific objectives of XCELS

Alexander Sergeev focused his presentation on the unic opportunities that XECELS could bring to science considering a priori that the max intensity it could reach is a least one order of magnitude higher than ELI.

To make it brief, the objective is to study new physics of matter and vacuum at intensity 10^{23}-10^{25} W/cm2 and beyond.

Topics which has been discussed are the following: Amazing particle dynamics in Radiation dominated regime, Ultrarelativistic ultradense e-e+ plasma, Gamma-Ray sources with extreme brilliance, Giant magnetic fields and currents, Probing nonlinear vacuum, Approaching Schwinger field intensity 10^{29} W/cm^2.

Interesting simulations concerning QED cascades and generation of giant magnetic fields, time-space structure of genuine physical vacuum, generation and Focusing of giant Attosecond Pulses and pair production,…have been presented.



Simulation of a thin disk e^-e^+ plasma formation in m-dipole wave

How Apollon laser is conceived and present status

After a short introduction of the funding and geographical context, Patrick Audebert described in detail the status of the so-called "Apollon" facility. It will comprise a 10 PW and two fully protected radio protected areas hosted in l'Orme des merisiers at the university Paris-Saclay. The overall infrastructure (finalized) is about 2500 m^2.

To perform the experiments, which cover in essence the topics proposed by ELI, the laser has been design with 4 independent beams

- main beam : 15fs-few ps / 150J possible
- secondary beam : 15 fs-few ps / 15J max
- ns beam : uncompressed up to 200J
- probe beam : <20fs / 0.2J

Laser key features (1000m2)

Hybrid architecture: OPCPA + Ti:Sap phire ➔ Contrast + Bandwidth
Unique Material: Φ10-175mm Ti:Sapphire crystals, Meter size gold gratings, state-of-the-art optics
High energy pump sources: up to 700 Joules/min
Adaptive control: spatial (Deformable mirrors) and spectral phase (Dazzler)

Experimental areas:

*Short focal area (300m^2): e*xperimental equipments dedicated to ultra-high intensity physics thanks to f/2.5 focussing allowing for intensities higher than 10^{22} W/cm^2.

Long focal area (600 m^2): experimental equipments dedicated to electron acceleration and X ray generation using ultra-long focal lengths (up to 30m).

Operation of the facility

- Facility will be open to national and international scientists
  - The experimental programs on APOLLON will be decided, on an annual basis, by the Steering Committee, taking into account suggestions from an independent Program Committee.
- Beam time allocation per year
  - The goal is 140 days for users
  - Maintenance and configuration changes 60 days
  - Laser development 50 days
- Experiments
  - Each experimental area will perform one after the other.
  - Experimental campaigns will be defined on 4 weeks basis
  - The laser will deliver pulse sequences on demand for users 5 hours per day.
  - At the beginning, 2 days will be used for changing configuration between experimental areas
- The experiment should use as much as possible every laser shots

Conclusion/agenda

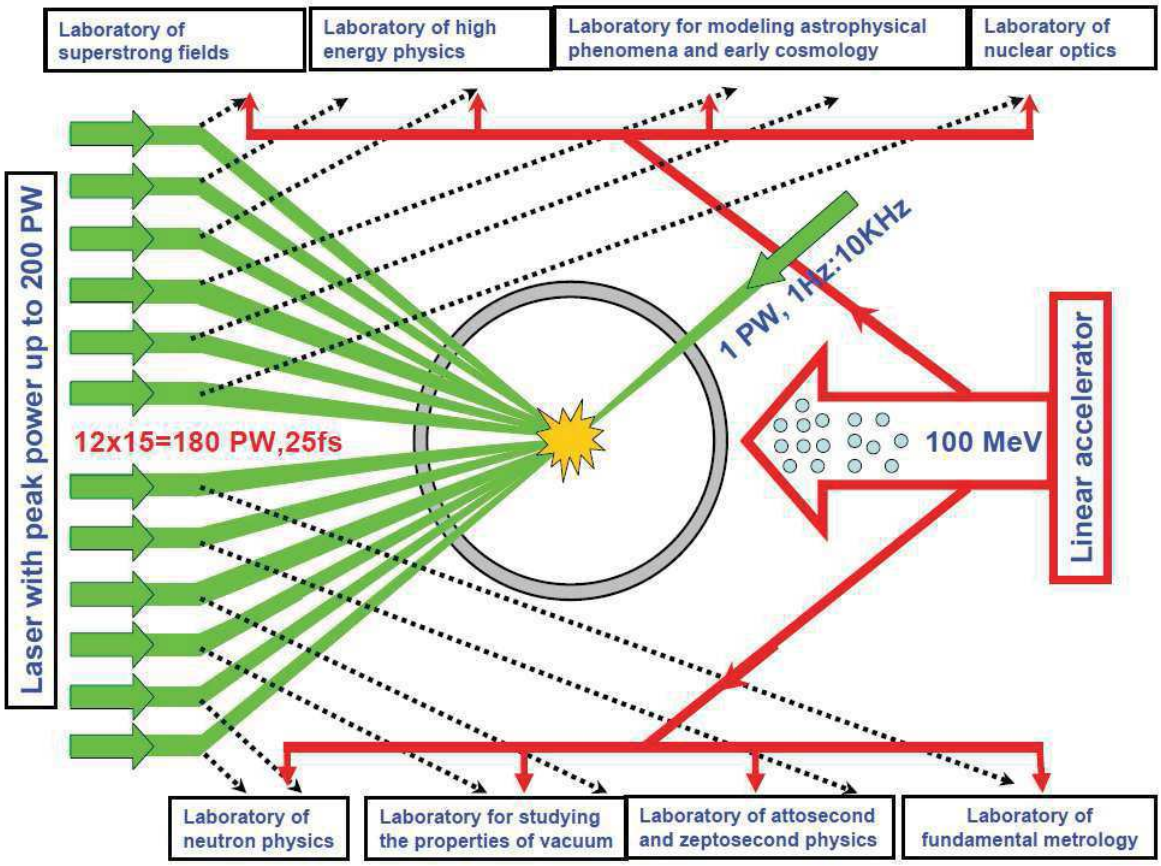
- Apollon is based on state-of-the-art laser systems, material and technology and will provide unique laser performances
- High Contrast/Large bandwidth Front End in the final commission phase
- High energy amplification: demonstration of 32 Joules
- Critical material reception and integration
- Demonstration of PW level capacity (2016)➔ PW level experiments (2017), multi-PW operation (2018)

<u>How XCELS laser is conceived and expected performances</u>

Efim Kazanov presented the XCELS laser. Its power is supposed to exceed the level of the most powerful available, constructed or projected laser systems worldwide. It will be based the so-called optical parametric chirped pulse amplification (OPCPA) technics which is developed at the Institute of Applied Physics RAS. The laser will comprise 12 identical channels, each of which will generate a pulse with the energy of 300-400 J, duration of 20-30 fs, maximum intensity at focusing more than 10^{23} W/cm^2.
The channels operate by the scheme of parametric amplification in KD*P crystals with the aperture of final cascades of 30×30 cm2. It is supposed that optical pulses in laser modules of

the subexawatt complex will be phased to an accuracy of hundredths fractions of a light wave period (10^{-16}s).

The first phase of the Project will be creation at IAP RAS of two such modules (PEARL) with the power of 15 PW each based on parametric amplification in KD*P crystals. This will not only allow creating a reliable prototype of an XCELS module, but will also enable solving fundamental problems associated with phasing of channels, as well as completing diagnostic equipment for applications. In addition, final corrections will be made in the architecture and component base of the XCELS facility. Further, 12 channels of the main XCELS laser complex will be assembled by the proven technology in a newly constructed building.



The resulting radiation at the output of the laser complex will have the following parameters: power 200 PW, pulse duration 25 fs, wavelength 910 nm, divergence not more than 3 times the diffraction limit.

The pump lasers will be developed in collaboration with the UFL-2M facility in Sarov (9 KJ). This has the advantage to significantly decrease the budget but the drawback is a strong decrease of the repetition rate which is anticipate to a few shots per day.

IAP contributed about 18.5 M€

- Engineering infrastructure of the “out of campus” experimental facility – XCELS’ site(3.5 M€)
- REAPL laser – prototype of XCELS’ channel (3.5 M€)
- Facility with irradiative shielding for multy-petawatt laser for PEARL-X (2.5 M€)

- Developing technology and installations for growing large-aperture nonlinear optical crystal KDP and DKDP (5 M€)
- Developing technologies of laser generation, amplification, and characterization of femtosecond pulses (4 M€)

Sponsors' Session

The following industrial partners had the opportunity to present their last products and research to the audience

Imagine Optic : Xavier Levecq

"New adaptive optics strategy to optimize the focalization spot of ultra intense laser"

Newport Spectra-Physics: Catalin Neacsu

"Recent progress in ultrafast laser systems for high-field and attosecond science"

Thales Optronique : Christophe Simon-Boisson

"Thales new developments in mid-infrared lasers"

Amplitude Technologies : Franck Falcoz

"Latest development on ultra-intense lasers at Amplitude Technologies"

Fastlite : Nicolas Forget

"Few-cycle, CEP-stable, MIR OPCPA front-end delivering 3W at 100 kHz"

Coherent : Marco Arrigoni

"Improving reliability, compliance and lifetime of ultrafast lasers with the adoption of industrial testing protocols"

Japan Laser Corporation : Jun Sasaki

"High power high repetition rate diode-pumped ultrafast laser"

TRUMPF Scientific Lasers : Thomas Metzger

"High power ultrafast thin-disk amplifiers"

Discussion

ELI is definitively opens remarkable scientific opportunities for the users.

It is clear that if such intensities can be achieved in XCELS with the appropriate experimental set-up, it would open the door to a quite fascinating and unknown dimension in science.

The question of the associated budgets for constructing and operation of EXCELS is still an open question.

Cremlin session in Cassis gathering 80 renewed scientists in the world

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Program

[October 2nd (Sun.)]

17:00 Arrival and registration

18:00 **Welcome Reception** at Cassis Convention Center ("Rotonde" hall)

[October 3rd (Mon.)]

8:30 - 9:00 Opening Session: *Tribute to the Honorary Chair*
Awarding of the Young Researcher Awards

9:00 - 11:30 **Session I: Molecules in intense laser fields I**

Discussion Leader:
Markus Kitzler (Vienna University of Technology)
Invited Speakers:
Tomoya Okino (RIKEN)
Jian Wu (East China Normal University)
Andre Bandrauk (University of Sherbrooke)

11:45 - 12:45 Lunch at restaurant *La Vieille Auberge*

13:00 - 15:00 **Session II: Medical applications for high intensity lasers**

Discussion Leader:
Kenneth Ledingham (University of Strathclyde)
Invited Speakers:
Ulrich Schramm (HZDR)
Victor Malka (LOA, ENSTA)

15:00 - 16:00 **Short presentations of poster papers**
List of poster presentations

16:00 - 16:30 Coffee break

16:30 - 19:00 **Session III: Quantum phononics in condensed matter**

Discussion Leader:
Kazutaka Nakamura (Tokyo Tech)
Invited Speakers:
Duncan England (NRC, Canada)
Yutaka Shikano (IMS)
Daniele Fausti (University of Trieste)

[October 4th (Tue.)]

8:30 - 10:30 **Session IV: Physics at extreme intensities - Toward exawatt laser systems?**

(CREMLIN session:Key high-power laser technologies for ultrahigh intensity physics)
Philippe Martin, *introduction and objective of the CREMLIN session*
Catalin Miron, "*ELI - a distributed user facility for high-power laser research and applications*"
Alexander Sergeev, "*Main scientific objectives of XCELS*"
Patrick Audebert, "*How Apollon laser is conceived and present status*"
Efim Khazanov, "*How XCELS laser is conceived and expected performances*"

10:30 - 11:30 **Sponsors' Session I**

11:30 - 12:30 **Sponsors' Session II**
Program

12:30 - 13:30 Lunch at restaurant *La Vieille Auberge*

14:00 - 16:00 Visit to the vineyard and Perfume Museum

17:00 - 19:00 **Poster Session I**

[October 5th (Wed.)]

8:30 - 10:30 **Session V: Sub-femtosecond isolated electron/XUV pulses**

Discussion Leader:
Luis Roso (CLPU)
Invited Speakers:
Kyung Taec Kim (Gwangju Institute of Science and Technology)
Jéróme Faure (LOA, ENSTA)

10:30 - 13:00 **Session VI: Exploration of ultrafast dynamics in atoms, molecules, and solids**

Discussion Leader:
Chang Hee Nam (Gwangju Institute of Science and Technology)
Invited Speakers:
Katsuya Oguri (NTT Basic Research Laboratory)
Mauro Nisoli (Politecnico di Milano)
Johan Mauritsson (Lund University)

13:00 - 14:00 Lunch at restaurant *La Vieille Auberge*

14:15 - **Free Discussion**

[October 6th (Thu.)]

9:00 - 11:30 **Session VII: Laser induced filamentation**

Discussion Leader:
Huailiang Xu (Jilin University)
Invited Speakers:
Ruxin Li (SIOM)
André Mysyrowicz (ENSTA)
Jean-Pierre Wolf (University of Geneva)

11:45 - 12:45 Lunch at restaurant *La Vieille Auberge*

13:00 - 15:30 **Session VIII: High-order harmonic generation from solid**

Discussion Leader:
Gerhard Paulus (Friedrich Schiller University Jena)
Invited Speakers:
Thomas Brabec (University of Ottawa)
Fabien Quéré (CEA Saclay)
Eleftherios Goulielmakis (MPQ)

15:30 - 16:30 Coffee break and Poster Session II

16:30 - 19:00 **Session IX: Molecules in intense laser fields II**

Discussion Leader:
Hirohiko Kono (Tohoku University)
Invited Speakers:
Tamás Szidarovszky (The University of Tokyo)
Wendell T. Hill, III (University of Maryland)
Deepak Mathur (Tata Institute of Fundamental Research)

20:00 - Banquet at *La Presqu'ile*

[October 7th (Fri.)]

Departure

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Name	Participant type	Department/Organization
Prof. Philippe MARTIN	ISp	CEA
Prof. See Leang Chin	R	Laval University
Prof. Kyung Taec Kim	ISp	IBS / GIST
Prof. Chang Hee Nam	DL	IBS / GIST
Dr. Markus Kitzler	DL	Photonics Institute, TU Wien
Prof. Jean-Pierre Wolf	ISp	Universite de Geneve
Prof. Ulrich Schramm	ISp	Helmholtz-Zentrum Dresden-Rossendorf HZDR
Dr. Eleftherios Goulielmakis	ISp	Max Planck Institute of Quantum Optics
Dr. Johan Mauritsson	ISp	Lund University
Dr. Tomoya Okino	ISp	RIKEN
Prof. Yutaka Shikano	ISp	Institute for Molecular Science, National Institutes of Natural Sciences
Dr. Andre D. Bandrauk	ISp	Universite de Sherbrooke
Dr. Tamás Szidarovszky	ISp	The University of Tokyo
Dr. Claus E. Ascheron	Spons	Springer
Prof. Gerhard G. Paulus	DL	Friedrich-Schiller-University
Prof. Kaoru Yamanouchi	R	The University of Tokyo
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Dr. Catalin MIRON	ISp	ELI-DC AISBL
Dr. Kazutaka Nakamura	DL	Tokyo Institute of Technology
Prof. Jerome Faure	ISp	LOA, Ecole Polytechnique
Prof. Deepak Mathur	ISp	Tata Institute of Fundamental Research
Dr. Reika Kanya	R	The University of Tokyo
Prof. Alfred Maquet	R	Université Pierre et Marie Curie
Prof. Howard Reiss	R	Max Born Institute
Prof. Wendell T. Hill, III	ISp	University of Maryland
Mr. Thomas Brabec	ISp	University of Ottawa
Prof. Yosuke Kayanuma	R	Tokyo Institute of Technology
Prof. Jian Wu	ISp	East China Normal University
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Dr. Erik Lötstedt	R	The University of Tokyo
Dr. Toshiaki Ando	R	University of Tokyo
Mr. Oleg Meshkov	S	Institute of Applied Physics, Russian Academy of Sciences
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Dr. Daniele Fausti	ISp	University of Trieste
Dr. Bernd Schütte	R	Max-Born-Institut
Dr. Yuya Morimoto	R	Ludwig-Maximilians-Universität München and Max-Planck-Institute of Quantum Optics
Mr. Jun Sasaki	Spons	Japan Laser Corporation

Dr. Yasushi Shinohara	R	The University of Tokyo
Dr. Tom Metzger	Spons	TRUMPF Scientific Lasers GmbH + Co. KG
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Mr. David B. Foote	S	University of Maryland
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