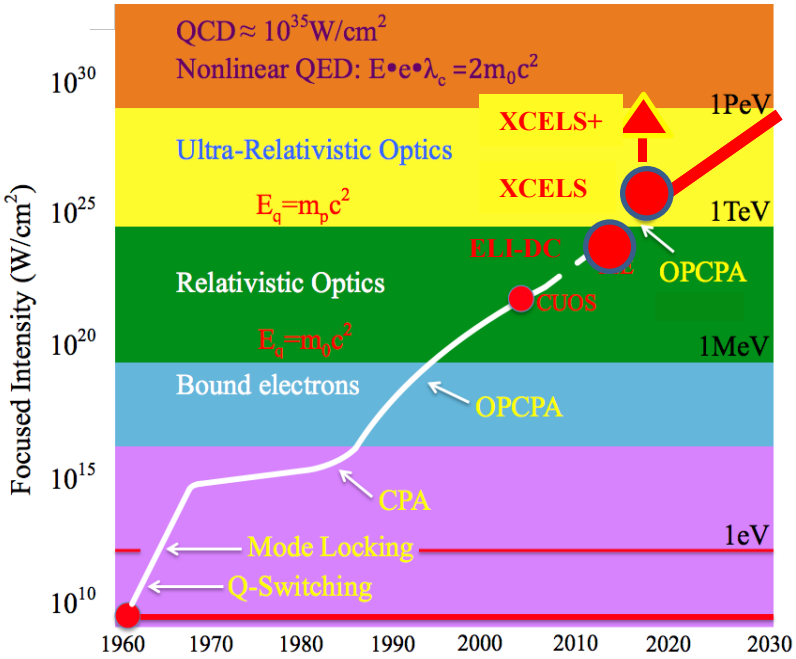
Megaproject XCELS

XCELS - world most powerful laser infrastructure that will be built at

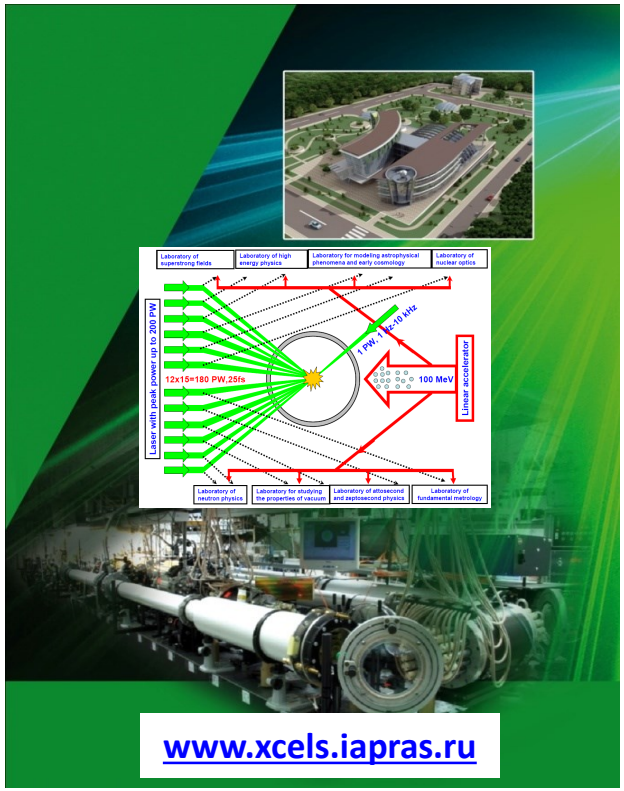
the Institute of Applied Physics in Nizhny Novgorod

to study the properties of matter and vacuum in the presence of extreme light



Ascent to the highest intensity of light,

"the Extreme Light"



www.xcels.iapras.ru

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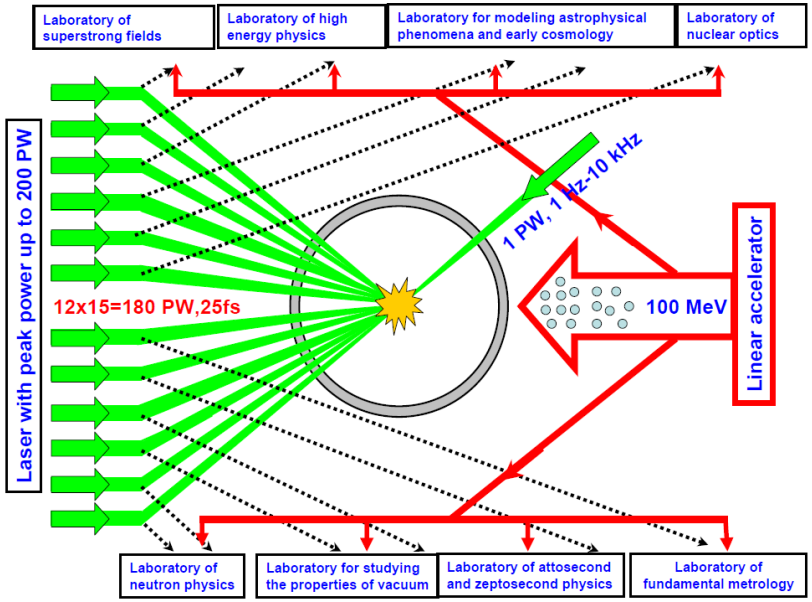
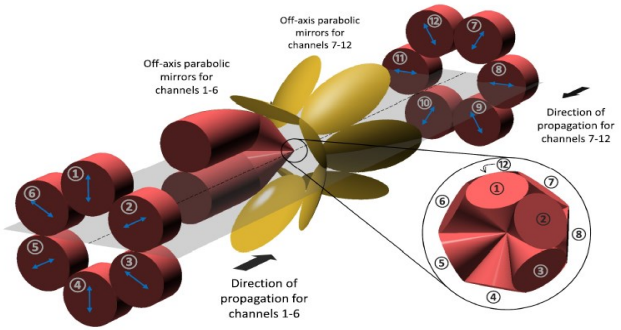
Laser source for XCELS



XCELS is based on the 200 Petawatt (2×10^{17} Watt) laser facility that exceeds the current record power level by 100 times. It comprises 12 amplification channels, each producing a laser pulse with 400 J energy and 25 femtosecond pulse duration.

A specially designed focusing system provides the ascent to the highest intensity level of 10^{25} - 10^{26} W/cm^2 by combining 12 laser beams. The resulting energy density in the focal area attains 10^{12} J/cm^3, several orders of magnitude higher than in the center of the Sun.



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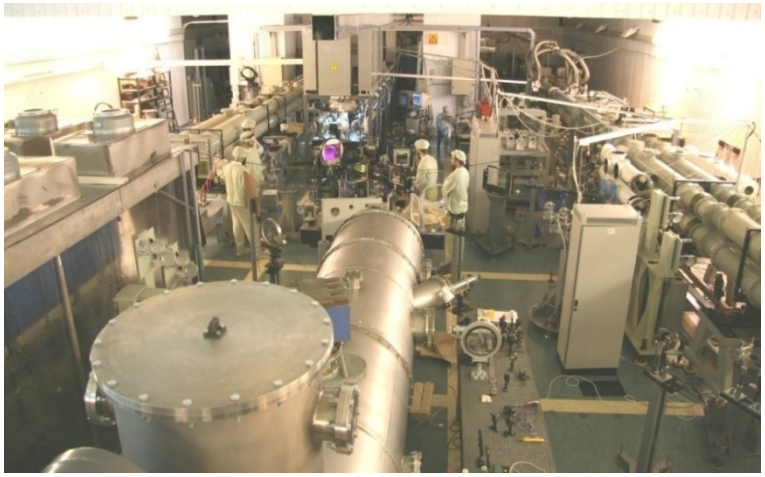
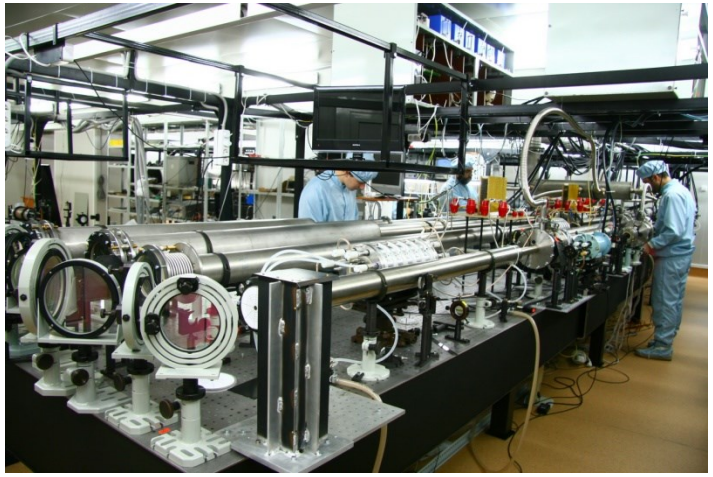
Key technologies behind XCELS laser facility

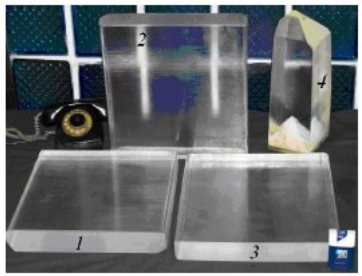
The XCELS laser facility is based on the technologies developed at the Institute of Applied Physics in Nizhny Novgorod and the Russian Federal Nuclear Center in Sarov and implemented in PEARL and FEMTA, the world's first petawatt parametric lasers

FEMTA

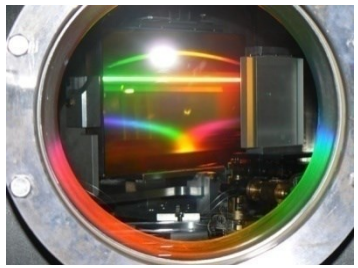


PEARL-10





Large aperture nonlinear crystals and optical gratings provide amplification and compression of laser pulses to multipetawatt level



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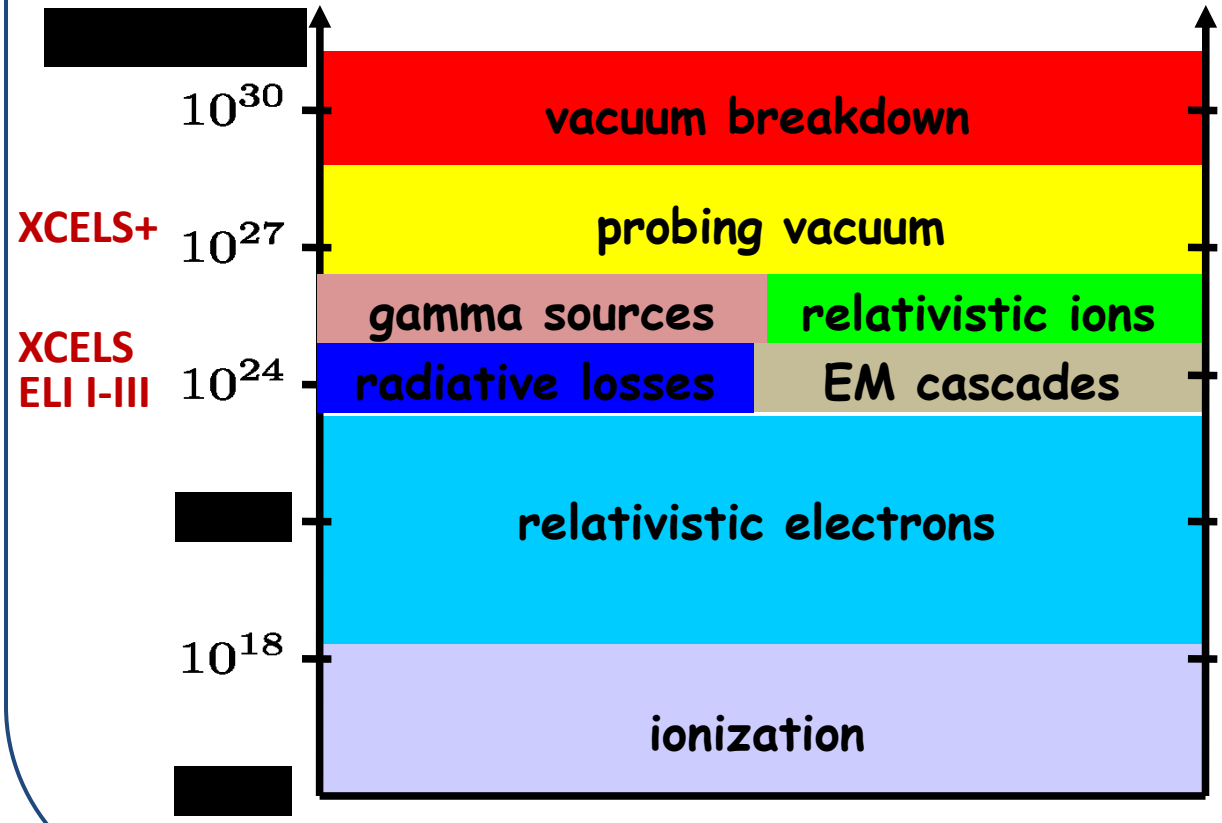
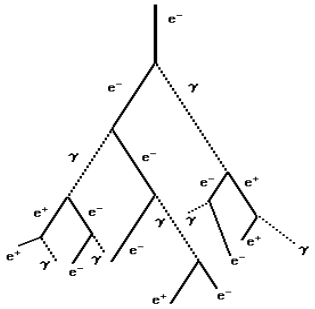
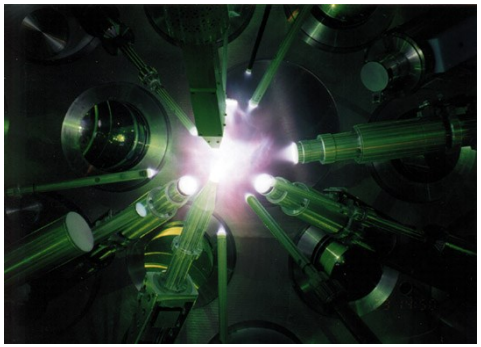
New science with XCELS

The main goal of XCELS is to study new science and applications at the emerging interface between high-field physics and high-energy physics







Electromagnetic cascades in vacuum can be produced by laser light

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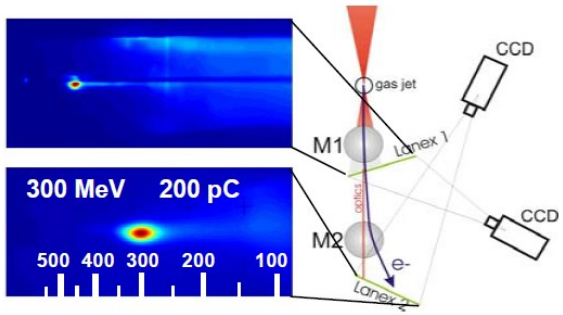
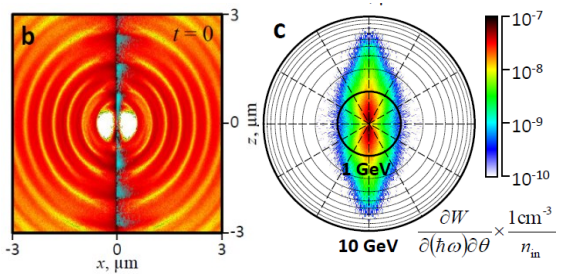
Prospects for fundamental research and applications

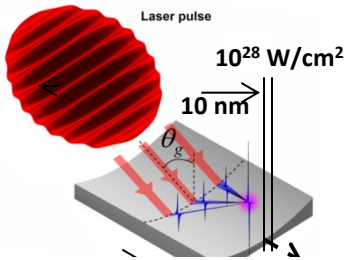
- Ultrarelativisitic laser-matter interaction
- Exotic states of matter with ultrahigh energy density, laboratory astrophysics
- Phenomena of nonlinear quantum electrodynamics in the presence of ultraintense laser fields; ultradense electron-positron plasma
- Study of space-time structure of vacuum
- Nuclear optics



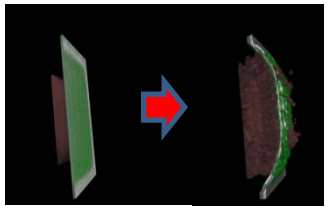
Electron acceleration with rate 1 GeV/cm



Directed Γ-ray source with 10 GeV quanta

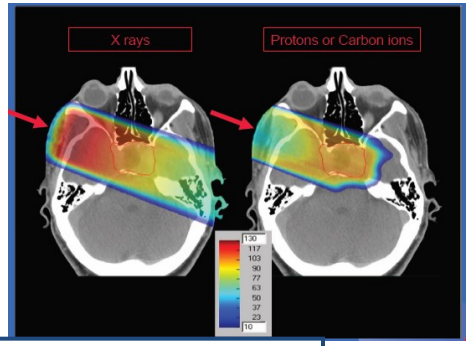


Generation of giant attosecond pulses for probing of quantum vacuum



300 MeV protons from thin foils for hadron therapy

- Ultracompact particle acceleration
- Directed brilliant gamma-ray sources
- Material diagnostics and metrology with picometer spatial and subfemtosecond temporal resolution
- Advanced particle and radiation sources for medicine, pharmacology, radiography, nuclear inspection and processing



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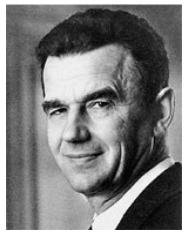
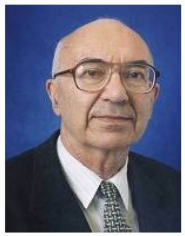
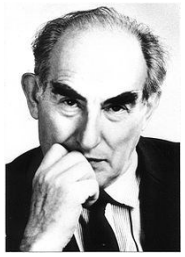
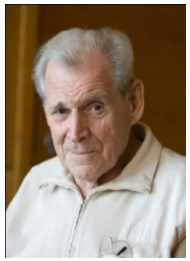
World Renown Scientific Schools


- **Lasers**
  (A.M. Prokhorov, N.G. Basov)

- **Nonlinear Optics**
  (R.V. Khokhlov, V.I. Talanov)

- **Plasma Physics**
  (V.L. Ginzburg, A.V. Gaponov-Grekhov)


- **Theory of Extreme Light Interactions**
  (L.V. Keldysh, N.B. Narozhny)

Megaproject XCELS

International Collaboration

The main contribution of foreign partners is supposed in the form of high-tech research equipment for the laser complex and research laboratories

Interest to collaborate from:

- The Ministry of Education and Science of France
- The Commissariat of Atomic Energy of France
- Thales (France)
- The Nuclear Energy Agency of Japan
- High Energy Accelerator Research Organization KEK (Japan)
- Center for Antiproton and Ion Research- FAIR (Germany)
- Extreme Light Infrastructure - ELI (Europe)
- Lawrence Livermore National Laboratory (USA)
- Los Alamos National Laboratory (USA)
- Fermi National Accelerator Laboratory (USA)
- Rutherford Appleton Laboratory (UK)
- The John Adams Institute for Accelerator Science (UK)

XCELS International Advisory Committee was founded in December 2011

T.Tajima, Chair of ICUIL

Gérard Mourou – Chair, Ecole Polytechnique, France
Christian Barty – Lawrence Livermore National Laboratory ,USA
Paul Bolton – Kansai Photon Science Institute, Japan
Maria Douka – European Commission
Bjorn Manuel Hegelich – University of Texas at Austin, USA
Dino Jaroszynski – SCAPA ,University of Strathclyde, UK
Kazuoshi Koyama – KEK, Japan
Thomas Kuehl – GSI Helmholtzzentrum, Germany
Thierry Massard – Commissariat of Atomic Energy, France
Wolfgang Sandner – Director General of ELI
Toshiki Tajima – International Committee for Ultraintense Lasers, ICUIL

W.Sandner, Director General of ELI

G.Mourou, Chair of XCELS IAC

Megaproject XCELS

International Expertise

Report on XCELS
by the
International Advisory Committee

Gérard Mourou, Paul Bolton, Maria Douka, Dino Jaroszynski, Bjorn Manuel Hegelich, Thierry Massard, Wolfgang Sandner, Toshiki Tajima, Thomas Kuehl, Kazuoshi Koyama

Conclusion

Based on the description of the conceptual design, the scientific committee is convinced of the quality and timeliness of the XCELS project. XCELS is ambitious and designed to introduce a new paradigm in High Energy Physics where high-energy particles are replaced by an ultrahigh laser field. XCELS could be the premiere laser-based High Energy Physics platform in the world occupying a prominent scientific position. The committee is of the opinion that the XCELS conceptual design phase has been completed and recommends advancement to the prototyping phase. The appropriate funding should be allocated. During this phase, which would last two to three years, we recommend that the current team works in concert with the international community as early as possible. This, includes, in particular the ELI Consortium.

During this phase the design will be finalized. It should include specification of the laser, the beamline configuration and experimental halls. An early integration with the international community will facilitate and encourage other countries to join and help to fund the project.

Gérard Mourou
Chair of the International Advisory Committee

EUROPEAN COMMISSION

DIRECTORATE-GENERAL FOR RESEARCH & INNOVATION

REPORT OF THE EXPERT GROUP ON THE ASSESSMENT OF EU COOPERATION WITH SIX RUSSIAN FEDERATION MEGASCIENCE PROJECTS

"The expert group encourages the Russian authorities to timely implement the first stages of the XCELS project, in order to demonstrate the feasibility of the project to the potential partners and to keep up with the dynamic international evolution of high-power lasers. "
Dec. 20, 2013

Megaproject XCELS

MoUs with European Partners

Memorandum of Understanding

between

THE ELI DELIVERY CONSORTIUM INTERNATIONAL ASSOCIATION, an international non-profit association founded and existing under Belgian law (AISBL), having its registered office at 23, rue Montoyer, 1000 Brussels, Belgium, represented by Wolfgang Sandner, acting in his capacity of Director General and CEO of ELI Delivery Consortium International Association (hereinafter referred to as "**ELI-DC**"),

and

THE FEDERAL AGENCY FOR SCIENTIFIC ORGANIZATIONS, a federal executive body founded and existing under the laws of the Russian Federation, having its registered office at 32a Leninsky Prospect, 119334 Moscow, Russia, represented by Alexey Medvedev, acting in his capacity of First Vice-Head of Federal Agency for Scientific Organizations (hereinafter referred to as "**FANO**")

1. Background

ELI is a new research infrastructure of pan-European interest and a part of the European ESFRI Roadmap. It is a laser facility that aims to host some of the most intense lasers worldwide, develop new interdisciplinary research opportunities with light from these lasers and secondary radiation derived from them, and make them available to an international scientific user community. The facility will be based on four sites. Three of them are presently being implemented in the Czech Republic, Hungary and Romania. Their scientific profile will be complementary, while the operation, starting in 2018, will be unified under one single legal umbrella of a European Research Infrastructure Consortium ELI-ERIC. The present implementation phase is coordinated by the ELI-DC.

FANO is responsible at the federal level for operation of academic scientific organizations, for implementation of the State program of fundamental studies, for development of new research programs and research infrastructures. FANO promotes the sustainable development of Exawatt Center for Extreme Light Studies (XCELS) as a research infrastructure selected by the Government of Russian Federation among six Russian mega-science projects. The XCELS project aims at creating a laser system with the sub-Exawatt peak power and at using it by the international scientific user community to study new physical phenomena at the interface of strong-field physics and high-energy physics. The XCELS laser parameters are similar to those planned for the forth site of ELI which makes two infrastructures complementary. The XCELS project will be implemented by a consortium of Russian scientific organizations within the jurisdiction of FANO and headed by the Institute of Applied Physics in Nizhny Novgorod.

MEMORANDUM OF UNDERSTANDING

(hereinafter referred to as the "**MOU**")

THALES OPTRONIQUE S.A.S., a company organized and existing under the laws of France, having its registered office at 2, avenue Gay Lussac, 78990 Elancourt – France, represented by Jean-Pascal ARROU-VIGNOD, acting in his capacity of President of THALES (hereinafter referred to as "**TOSA**"),

On the first part,

AND,

FEDERAL RESEARCH CENTER INSTITUTE OF APPLIED PHYSICS OF THE RUSSIAN ACADEMY OF SCIENCES, a company organized and existing under the laws of the Russian Federation, having its registered office at 46 Ulianov street, 603950 Nizhny Novgorod, Russia, represented by Alexander SERGEEV, acting as Director (hereinafter referred to as "**IAP**"),

On the second part,

TOSA and IAP being hereafter individually or collectively referred to as "**Party**" or "**Parties**".

WHEREAS:

(A) TOSA is engaged in the business of manufacturing and supplying for sale, on a world-wide basis, ultra high peak power (Petawatt-class) solid-state lasers (hereinafter referred to as the "**Product**"); and

(B) IAP has significant experience in research, development and construction of ultra high peak power (Petawatt-class) lasers; and

(C) The Parties entered into a memorandum of understanding dated 22nd October 2012, renewed annually since then , under which they started exploratory discussions related to a potential cooperation related to the development of ultra-high peak power laser technology for infrastructures dedicated to scientific applications, including the Russian mega-science project XCELS, the Exawatt Centre for Extreme Light Studies, (hereinafter referred to as the "**Project**"); and

(D) The current memorandum is due to expire on the 20th of November 2015; and

(E) The Parties intend to expand their discussions to possible coordination regarding international programs, and modify the scope of the Project accordingly. The Parties are willing to carry on their exploratory discussions related to the Project according to the conditions set forth in

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Megaproject XCELS

ELI + XCELS = Joint Pan-European Infrastructure ?

ELI will comprise 4 branches:

- **Attosecond Laser Science**, which will capitalize on new regimes of time resolution (*ELI-ALPS*, Szeged, HU)

- **High-Energy Beam Facility**, responsible for development and use of ultra-short pulses of high-energy particles and radiation stemming from the ultra-relativistic interaction (*ELI-Beamlines*, Prague, CZ)

- **Nuclear Physics Facility** with ultra-intense laser and brilliant gamma beams (up to 19 MeV) enabling also brilliant neutron beam generation with a largely controlled variety of energies (*ELI-NP*, Magurele, RO)

- **Ultra-High-Field Science** centred on direct physics of the unprecedented laser field strength (*ELI 4*, to be decided)

W. Sandner, ELI 2013-01

XCELS – 4th Pillar of ELI ?

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