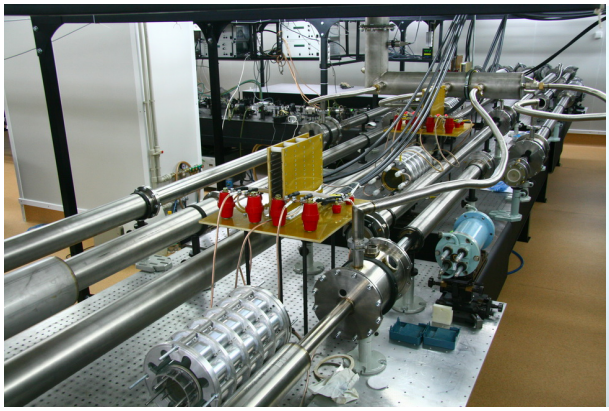
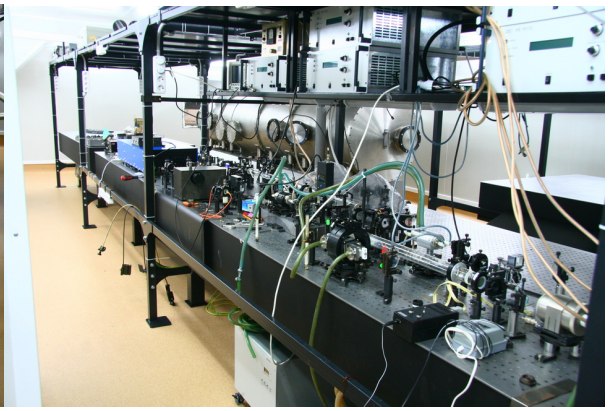
PASSPORT

Location: Institute of Applied Physics of the Russian Academy of Sciences, Nizhny Novgorod, Russia (IAP RAS)
Initiating organization: IAP RAS
Contact: Efim Khazanov, IAP RAS Deputy Director (khazanov@appl.sci-nnov.ru)
Project web-site: http://www.xcels.iapras.ru/
Period of project implementation: 2012-2025
Cost of the mega-science project: The estimated costs of the architectural design, construction, equipment, and furniture for XCELS as well as the implementation of the S&T program are about 12 billion rbls.

Brief description, the primary purpose of the construction

The goal of the Project is establishing a large research infrastructure – the Exawatt Center for Extreme Light Studies (XCELS) using sources of laser radiation with unprecedented giant (Exawatt) peak power. The Project rests upon the considerable advance made in the recent years in Russia and worldwide on creating Petawatt lasers (1 Petawatt = 10^{15} W) with intensity up to 10^{22} W/cm^2 and ultrashort pulse duration (< 100 femtoseconds = 10^{-13} s).





XCELS addresses a pressing global research challenge: reaching new frontiers in the strength of the electromagnetic fields, exploration of the states of matter in such fields, probing QED vacuum structure in extremely strong electromagnetic fields, developing compact particle and radiation sources with record parameters, modeling astrophysical phenomena in laboratory conditions, etc.

Unique character (advantages)

The core of the planned infrastructure will be a new unique source of light having the power of about 200 Petawatt with a further prospect to increase it up to 1 Exawatt (1 Exawatt = 10^{18} W) and beyond.

The fundamental processes of such laser-matter interaction belong to an absolutely new branch of science that will be the principal research task of the infrastructure. There will open up opportunities for studying the space-time structure of vacuum and unknown phenomena at the interface of the high-energy physics and the physics of high fields. The envisaged applications of results of these studies will include among others development of compact charged-particle accelerators with sizes hundreds times less that the available ones, creation of sources of ultrashort pulses of hard X-ray and gamma radiation for diagnosing materials with unprecedented spatial and temporal resolution, elaboration of new sources of radiation and particles for clinical applications,

Scientific and practical importance

The research program of XCELS is essentially multifunctional. A considerable amount of research will be carried out at the junction with other areas of knowledge – high energy physics, nuclear physics, astrophysics, and biomedicine. Once completed, XCELS will be a world-class S&T facility with the subexawatt laser significantly exceeding the level of radiation power inherent in the most powerful available, constructed or projected laser systems worldwide. The resulting radiation at the output of the laser complex will have a power of 200 PW. The complex will comprise 12 identical channels based on the technique of optical parametric chirped pulse amplification (OPCPA) to a Petawatt power developed at the Institute of Applied Physics RAS. Along with the subexawatt laser, the XCELS complex will house unique laboratories for experiments on the physics of strong fields, high-energy physics, laboratory astrophysics and cosmology, nuclear optics, neutron physics, laboratories for studying the properties of vacuum, attosecond and zeptosecond physics, and fundamental metrology. XCELS will also comprise a powerful center for data processing and computer modeling of the interactions of extreme light fields.

State of the Art

The XCELS road map features three main goals:

Goal 1. Establishment and operation of mega-project infrastructure.
Goal 2. Carrying out fundamental research in the established infrastructure.
Goal 3. Implementation of innovative developments using the infrastructure.

Each goal includes specific objectives and activities, e.g. creating prototypes of laser modules, constructing buildings and utilities, establishing and equipping research laboratories, creating new sources of radiation, carrying out goal-oriented experiments, experimental simulation of different phenomena, design and prototyping of diagnostic and metrological systems, and so on. Some of the objectives have been successfully reached. The currently solved tasks include the following:

- A high-voltage electronics building at the IAP RAS experimental site was commissioned. It will be used to operate the XCELS parametric amplification pump lasers.
- A target chamber with diagnostic equipment for experiments on the interaction of Petawatt optical pulses with solid targets was created.
- A unique magnetic system that allows modeling a wide range of astrophysical problems was created.
- A new technological line for growing and processing large-aperture KDP crystals intended for manufacturing critical components of kilojoule nanosecond pump lasers of parametric amplifiers of

Petawatt pulses was commissioned. Samples for manufacturing critical components of kilojoule nanosecond pump lasers of parametric amplifiers of Petawatt pulses are currently grown.
- Works on the creation of an assembly section for manufacturing components for controlling the radiation of a kilojoule nanosecond pump laser (plasma electrode Pockels cell system) were completed.
- A large-aperture profilometer for surface quality control of precision optical elements was developed. The profilometer was delivered to RFNC-VNIIEF, where it will be tested and further used for the construction of kilojoule pump lasers of XCELS parametric amplifiers.
- An engineering building intended for processing and quality control of crystals for the XCELS facility was constructed. Balancing and commissioning are currently under way.

Future status

XCELS is expected to be a user-oriented international infrastructure. The intention to participate in the creation and operation of XCELS was shown by the major foreign scientific laboratories, agencies and companies, including Commissariat of Atomic Energy of France, Nuclear Energy Agency of Japan, High Energy Accelerator Research Organization KEK (Japan), Extreme Light Infrastructure - ELI (Europe), Center for Antiproton and Ion Research FAIR (Germany), Lawrence Livermore National Laboratory (USA), Los Alamos National Laboratory (USA), Fermi National Accelerator Laboratory (USA), Rutherford Appleton Laboratory (UK), John Adams Institute for Accelerator Science (UK), Thales Optronique (Europe), Academy of Opto-electronics (China).

XCELS is a promising project for international collaboration. It is of particular interest to the European Community in connection with the European research infrastructure ELI that is one of the major projects on the ESFRI roadmap. ELI is intended for construction of 4 research centers dedicated to different trends, including producing laser fields of extreme intensity for studying new states of matter and vacuum. Construction of the first three centers on the basis of lasers with a peak power of up to 10 PW is conducted in the Czech Republic, Hungary and Romania. XCELS has characteristics that are comparable or even superior to those planned by the European colleagues for the fourth ELI. Combined efforts of EC and Russia may enable constructing a unified pan-European infrastructure, with ELI+XCELS functioning on the basis of coordinated activity of 4 centers. This cooperation will open up a unique opportunity for the EC countries to implement in full the ELI project and for Russia to become an equitable partner of the All-European scientific community.

XCELS welcomes contacts with interested organizations. XCELS has expressed interest in learning more about potential opportunities for collaboration with the following research infrastructures/organizations through the GSO. These include Deutsches Elektronen-Synchrotron (DESY), Japanese High Energy Accelerator Research Organization (KEK), and International Facility for Antiproton and Ion Research (FAIR).