EXTREME LIGHT INFRASTRUCTURE NUCLEAR PHYSICS (ELI-NP)

V. Zamfir, K. Tanaka, C. Ur – DOI: https://doi.org/10.1051/epn/2019204

Extreme Light Infrastructure – Nuclear Physics (ELI-NP), "Horia Hulubei" – National Institute for Physics and Nuclear Engineering (IFIN-HH) – 30 Reactorului Street – 077125 Bucharest-Magurele, Romania

ELI - Extreme Light Infrastructure, a project to build an international research infrastructure "dedicated to the investigation and applications of laser matter interaction at the highest intensity level" is one of the 35 projects in the first Roadmap, in 2006, of the European Strategy Forum on Research Infrastructures (ESFRI) [1]. "ELI will comprise three branches: ultra high field science that will explore laser matter interaction up to the nonlinear QED limit including the investigation of pair creation and vacuum structure; attosecond laser science designed to conduct temporal investigation at the attosecond scale of electron dynamics in atoms, molecules, plasmas, and solids; lastly, the highenergy beam facility devoted to the development of dedicated beam lines of ultra short pulses of high energy radiation and particles up to 100GeV for users."

The project was initiated by the European laser community lead by Gerard Mourou, the co-inventor, back in 1985, of the Chirp Pulse Amplification (CPA) method to generate ultrashort optical pulses. In 2018, Mourou and Donna Strickland were awarded Nobel Prize in Physics for this accomplishment.

Supported by the European Commission through a DG-Research Preparatory Phase Project (2008-2010) [2],the construction of the distributed facility among three European countries (the Czech Republic - secondary sources, Hungary – attosecond pulses and Romania – nuclear physics) is funded by European Commission through Structural Funds.

The Extreme Light Infrastructure – Nuclear Physics (ELI-NP) facility [3] is being built near Bucharest, at the Magurele Physics research campus. Following Mourou's vision, ELI-NP will enable the exploration of a novel field of science at the frontier between laser, plasma, and nuclear physics. At ELI–NP, two well–established scientific communities, high-power lasers and nuclear physics, have joined their efforts to build a new interdisciplinary facility and to define its research program.

The implementation of the ELI-NP project, valued at 311 MEuro, is financed by Structural Funds and the Romanian national budget. The project began in January 2013 and the new facility will be operational by the end of 2019. The construction, finished in 2016, consists of innovative buildings assuring stability in temperature, humidity, pressure, and against floor vibration, covering a total area 33,000 m^2 and with a Geothermal system providing 6 MW.

The main equipment is a high-power laser system consisting of two 10 PW ultra-short pulse lasers based on CPA method. The center will also have a brilliant energy tunable gamma-ray beam machine. The ELI-NP high-power laser system was constructed by an association between Thales Optronique SA France and Thales Romania. It consists of two parallel Chirped Pulse Amplification systems at about 820 nm central wavelength, with a dual front-end architecture, designed to minimize down-time for the laser facility. Each of the two parallel chains includes Ti:Sapphire amplifiers to bring the final output energy to the level of a few hundreds of Joule. Subsequently, the pulses are compressed to around a 20 fs pulse duration that implies a peak power of 10 PW at a repetition rate of 1 shot per min for each of the two arms. Along the two amplification chains, additional outputs with corresponding optical compressors have been installed. Their corresponding power levels are 0.1 PW and 1 PW at repetition rates of 10 Hz and 1 Hz, respectively.

The commissioning of this equipment is under way, and with 10 PW power level recently achieved, is the most powerful laser in the world.

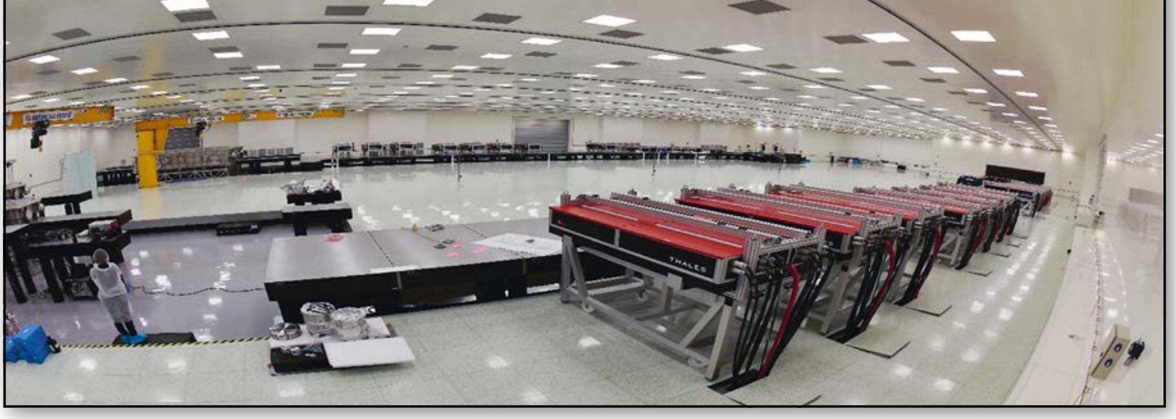
The mission of the ELI-NP center covers scientific research involving laser-matter interaction experiments related to nuclear physics and strong-field quantum electrodynamics. The main research topics are:

Investigation of the high-power laser-matter interactions using nuclear physics methods in order to study the possibilities of obtaining electron, proton, and heavy ion accelerated beams using lasers.

- The extremely high intensity of the laser beam will allow the study of fundamental physics phenomena anticipated by theory, such as vacuum birefringence, dark matter,and pair creation in intense electric fields.
- Investigation of nuclear structure and reactions cross sections of interest for astrophysics using photonuclear reactions.
- New methods of identification and remote characterisation of nuclear materials with application for homeland security and nuclear material management.
- New ways of producing more efficiently radioisotopes currently used in medicine and the producing of newly proposed ones.

At full power, the ELI-NP lasers will reach intensities at the 10^{23} W/cm^2 level, never obtained before, allowing for the exploration of ion acceleration regimes with key features, such as quasi monoenergetic distribution or solid state density (~10^{22} ions/cm^3), many orders of magnitude higher than the ion bunches provided by "classical" accelerators. Such very intense laser pulses will radically change the paradigm of particle acceleration and will lead to an extreme shrinking of the dimensions of particle accelerators.

FIG. 1: ELI–NP experimental building.



◂ FIG. 2: The 40m × 70 m clean room for ELI-NP High Power Laser System.

ELI-NP is a world-leading research infrastructure in the newly emerging field of science, Nuclear Photonics. Nuclear Photonics is a cross-disciplinary field where nuclear physics, laser physics, material science, accelerator science, andlife sciences are converging to establish new directions of fundamental and applied research and to develop unique societal benefits.

A broad biomedical research program, anchored in the unique ELI-NP capabilities, is currently being developed at ELI–NP and addresses topicsuch as: production of radiotherapy relevant nuclear beams, radiobiological effects of laser and gamma nuclear beams, medical imaging research with laser X-ray sources and medical isotope production research with laser nuclear beams. Research efforts aim to enhance the spatial resolution of medical imaging by using laser driven X-ray sources as well as improving the biological effectiveness of charged particle therapy by using ultra–short/ultra–intense laser accelerated charge particle pulses. Production of radioisotopes with medical relevance via nuclear reactions driven by laser and gamma beams is also considered.

Highly-penetrating gamma beams of high energy, with very small energy dispersion, are the perfect tools for active interrogation of special nuclear materials, industrial radiography and tomography and cultural heritage studies. Nuclear resonance fluorescence (NRF) can be combined with computed tomography (CT) to yield 2D/3D maps of elemental/isotopic distributions in a large variety of objects. CT–NRF mapping done with quasi–monoenergetic gamma beams can be successfully employed in the detection of special nuclear material, assay of spent fuel or elemental analysis of work of arts.

ELI-NP will perform innovative research in the field of materials behavior in extreme environments and radiobiology, with direct application in the development of accelerator components, new materials for next generation fusion and fission reactors, shielding solutions for equipment and human crew in long term space missions, and new biomedical technologies.

Benefiting from the collaborations of more than 100 scientists from 30 countries, the ELI-NP facility is on track with the implementation of the Technical Design Reports [4] and construction of the experimental set-ups and their commissioning will start in 2019.

ELI–NP is going to be the most advanced research infrastructure in the world focusing on photonuclear physics studies and applications. As the first large-scale European research facility in Romania, the project is likely to become the flagship of the national scientific research, covering frontier fundamental physics, new nuclear physics and astrophysics, as well as applications in nuclear materials management, materials science and life sciences. ■

About the Author

Victor Zamfir is Scientific Researcher in Experimental Nuclear Physics, co-author of more than 300 articles in ISI journals with more than 6500 citations (Hirsch index 40), member of the Romanian Academy. He is Director General of the "Horia Hulubei" National Institute for Physics and Nuclear Engineering (IFIN-HH), Bucharest-Magurele, Romania and Director of the ELI-NP Project. He was member of Nuclear Physics European Committee (NuPECC) of European Science Foundation (2005-2008) and member of Nuclear Physics Board of EPS (2007-2013, 2012-2013 Chairman). Since 2016 is a member of the Executive Committee of EPS.

References

[1] European Strategy Forum on Research Infrastructures (ESFRI): European Roadmap for Research Infrastructures Report 2006.

[2] Gérard A. Mourou, Georg Korn, Wolfgang Sandner, John L. Collier (eds.) *ELI – Extreme Light Infrastructure: Science and Technology with Ultra-Intense Lasers Whitebook*, (THOSS Media GmbH, 2011).

[3] www.eli-np.ro

[4] Romanian Reports in Physics vol. 68 Supplement I,II (2016) (online: www.rrp.infim.ro)

▾ FIG. 3: ELI-NP Target Laboratory.