editorial

Extreme light

The Extreme Light Infrastructure (ELI) project is dedicated to the investigation of light–matter interactions at high laser intensities and on short timescales.

The first operational laser, built in 1960 at the Hughes Research Laboratory was only capable of emitting a series of irregular spikes within each pump pulse. Lasers have come a long way since then. The method of chirped-pulse amplification (CPA) in the mid-80s managed to drive lasers from terawatt to petawatt powers (D. Strickland & G. Mourou *Opt. Commun.* **56,** 219–221; 1985). A number of facilities around the world are hosting this class of powerful lasers: notably, the Petawatt Aquitaine Laser (PETAL) at the Laser Megajoule facility in France (1.2 PW; http://go.nature.com/TufsxS) and the Laser for Fast Ignition Experiments (LFEX) at Osaka University in Japan (2 PW peak power with picosecond pulses; http://go.nature.com/Pvy1dn). However, most of the current facilities are at the low multi-petawatts level with repetition rates — with some exceptions — significantly below 1 Hz.

The ELI project is expected to push those limits even further. Considered by many as the most ambitious research effort for laser technology in recent years, the project began in 2005 and was approved by the European Strategy Forum on Scientific Research Infrastructures (ESFRI) the following year (http://www.eli-beams.eu/about/milestones/). This pan-European effort will outperform existing laser facilities by at least a factor of ten with regard to laser peak and average powers. According to Wolfgang Sandner, who served as Director General and CEO of the ELI Delivery Consortium International Association (http://www.eli-laser.eu/), ELI marks the onset of the next generation of high-peak and high-average-power systems, through a combination of new disruptive technologies: high-power optical parametric chirped pulse amplification, all-diode-pumped systems, coherent beam coupling, advanced active materials, optical surfaces and grating technologies.

The ELI project consists of four large-scale laser facilities, each targeting a different area of research. The ELI Beamlines facility, built in the Czech Republic and inaugurated in October 2015 (http://go.nature.com/MZq7ar), will provide ultrashort laser pulses of a few femtoseconds (10–15 fs) duration and performances up to 10 PW. The lasers in the second pillar will produce even shorter radiation pulses, in the attosecond range. The ELI Attosecond Light Pulse Source (ELI-ALPS; http://www.eli-hu.hu/) is currently under construction in an old Soviet military base in Hungary and its central aim will be the study of ultrafast electron dynamics in atoms, molecules, plasmas and solids. The third facility will focus on nuclear physics. Built in Romania, the ELI Nuclear Physics (ELI-NP) facility will host two 10 PW lasers, coherently added to deliver intensities of the order of 10^{23}–10^{24} W cm^{-2} and an intense source of gamma radiation (www.eli-np.ro). Among others, it is expected to have a significant impact on nuclear waste processing, radio-medicine and isotope production.


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The recently inaugurated ELI Beamlines facility in the Czech Republic.

Finally, the Ultrahigh Field Facility will be tailored for the study of relativistic physics and is expected to be the most expensive and challenging of the facilities as it will outperform the others, providing the highest peak power (100 PW) and intensities beyond 10^{25} W cm^{-2}. Such values approach the Schwinger intensity range, above which vacuum breaks down and light is materialized into pairs of electrons and positrons (http://go.nature.com/Wdpocq). The first three pillars are expected to be fully operational and open to external users by 2018. A decision about ELI's fourth pillar (technology, finances and site) will be made by the ELI European Research Infrastructure Consortium that will govern ELI's operation.

These ultra-intense lasers will not only provide high electromagnetic fields but will also make possible the generation of ultrashort and ultrahigh energy beams of particles and radiations up to the TeV range. As such, they are expected to primarily impact fundamental physics; Gérard Mourou, initiator of ELI and coordinator of the preparatory phase, comments that these facilities will permit studies of cosmos acceleration, vacuum nonlinearities, dark matter and dark energy, nonlinear quantum electrodynamic and chromodynamic fields, and radiation physics in the vicinity of the Schwinger field (http://go.nature.com/v7GyTg). However, ELI is expected to affect other disciplines, including materials research (for example, the dynamics of reactions such as protein activity and protein folding, radiolysis, monitoring of chemical bonds and catalysis processes, as well as the investigation of defect creation and materials aging in nuclear reactors) and medical applications (such as, the production of new medical isotopes relevant to cancer chemotherapy).

ELI was the first ESFRI project funded by European regional structural funds and national contributions from the host countries, with the total cost for the first three sites approaching €1 billion (http://go.nature.com/BhSQQG). ELI constitutes a bold move towards a more balanced distribution of research capacities in the EU, at the same time placing the European Research Area at the forefront of laser technology worldwide and opening exciting possibilities for fundamental science. ❐