New report: US has lost dominance in highly intense, ultrafast laser technology to Europe and Asia

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The U.S. is losing ground in a second laser revolution of highly intense, ultrafast lasers that have broad applications in manufacturing, medicine, and national security, says a new report from the National Academies of Sciences, Engineering, and Medicine. Currently, 80 percent to 90 percent of the high-intensity laser systems are overseas, and all of the highest power research lasers currently in construction or already built are overseas as well. The report makes five recommendations that would improve the nation's position in the field, including for the U.S. Department of Energy (DOE) to create a broad network to support science, applications, and technology of these lasers, as well as for DOE to plan for at least one large-scale, open-access high-intensity laser facility that leverages other major science infrastructures in the DOE complex.

The report focuses on highly intense pulsed petawatt-class lasers (1 petawatt is equal to 1 million billion watts) that deliver nearly 100 times the total world's energy consumption rate concentrated into a pulse that lasts less than one picosecond, or one-trillionth of a second. To illustrate the timescale, a picosecond is to one second as one second is to more than 31,000 years. Such laser sources create conditions that can accelerate and collide intense beams of elementary particles, drive nuclear reactions, heat matter to conditions found in stars, or even create matter out of the empty vacuum. These powerful lasers originated in the U.S.; however, research-funding agencies in Europe and Asia began in the last decade to invest heavily in new collaborations and facilities that will employ these high-intensity lasers for broad areas of science.

The committee that carried out the study and wrote the report concluded that intense, ultrafast lasers have broad applicability beyond science to nuclear weapons stockpile stewardship, industry, and medicine. The main application of high-intensity lasers to the science of DOE's Stockpile Stewardship Program is to produce bright, penetrating, high-energy X-rays for radiography of high-energy matter. These lasers can deposit a large amount of energy on a picosecond timescale, and this makes them a unique tool to probe inertially-confined nuclear fusion experiments and high-energy-density physics occurring on a much longer time scale. In manufacturing, high-intensity lasers can be used for precision cutting, mainly due to minimal heat transfer to the materials, resulting in negligible collateral damage. This can also allow for the ability to drill clean, small, deep holes in materials without damaging the surrounding material. For instance, the technology is now commonly used in the medical industry for fabricating high-quality surgical stents that need micron size features, such as 1 micron diameter holes with large lengths. Ultrahigh intensity lasers also show promise for both medical imaging and as the source of intense particle beams for cancer therapies.

The committee also concluded that high-intensity lasers enable a significant and important body of science, which has a large and talented technical community already, but it is fragmented across different disciplines. Coordination between industry and government is limited and often inadequate, the committee said. Scientists and engineers trained in intense, ultrafast lasers contribute to the workforce for applications in photonics and optics, including high-energy lasers for defense and stockpile stewardship. Therefore, the committee recommended that DOE create a broad national network—that includes universities, industry, and government laboratories, in coordination with the Office of Science and Technology Policy, the research arms of the Department of Defense, National Science Foundation, and other federal research organizations—as the cornerstone of a national strategy to support science, applications, and technology of intense and ultrafast lasers.

No single federal agency currently acts as the steward for high-intensity laser-based research, nor does cross-agency stewardship exist in the U.S. Programs are carried out under sponsorship of several different federal agencies according to their various missions and without the overall coordination that exists in Europe. To increase integration and coordination in this field, the committee recommended that research agencies—including the U.S. Department of Defense, DOE, National Science Foundation, and others—engage the scientific stakeholders within the network to define what facilities and laser parameters will best serve research needs, emphasizing parameters beyond the current state of the art in areas critical to frontier science, such as peak power, repetition rate, pulse duration, wavelength, and focusable intensity.

The committee also called for the DOE to lead the development of a comprehensive, interagency national strategy for high-intensity lasers that includes a program for both developing and operating large-scale laboratory projects; midscale projects such as those hosted at universities; and a technology development program with technology transfer among universities, U.S. industry, and national laboratories.

Co-location of high-intensity lasers with existing infrastructure, such as particle accelerators, has been recognized as a key advantage of the U.S. laboratories over the Extreme Light Infrastructure concept in Europe. Based on this, the committee recommended that the DOE plan for at least one large-scale, open-access, high-intensity laser facility that leverages other major science infrastructure in the DOE complex. Furthermore, cooperation among universities, laboratories, and industry is necessary to retain and renew the talent base, and cooperation among these sectors in the past has proved essential. The current situation could be improved to develop a robust national talent pool and a strong technology base for this fast growing area. The committee's final recommendation called for agencies to create programs for U.S. scientists and engineers that include midscale infrastructure, project operations in high-intensity laser science in the United States, development of key underpinning technologies, and engagement in research at international facilities, such as Europe's Extreme Light Infrastructure.

Provided by National Academies of Sciences, Engineering, and Medicine

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