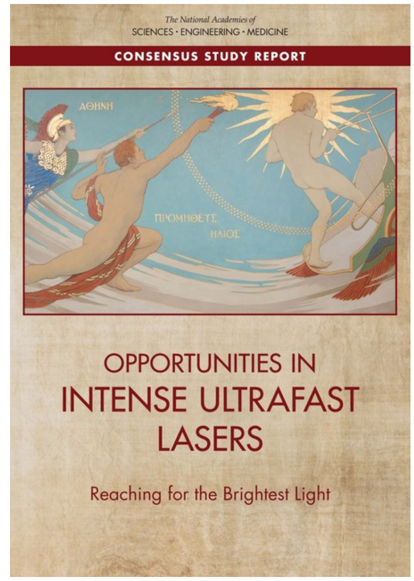
Consensus Study Report

December 2017

HIGHLIGHTS

Opportunities in Intense Ultrafast Lasers: Reaching for the Brightest Light

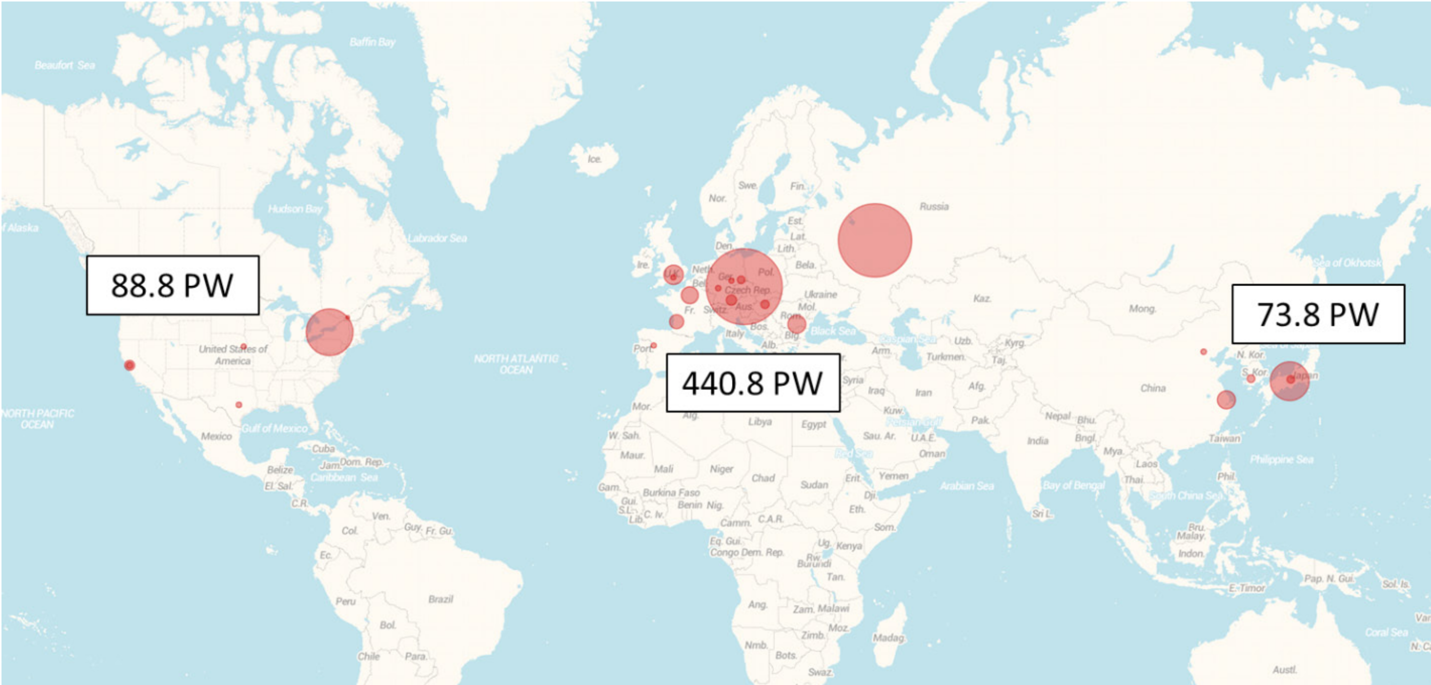


The laser has revolutionized many areas of science and society, transforming the ways we investigate science and enabling trillions of dollars of commerce. Now a second laser revolution is underway with pulsed petawatt-class lasers (1 petawatt: 1 million billion watts) that deliver nearly 100 times the world's total power consumption in less than one-trillionth of a second. Such light sources create unique, extreme laboratory 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. They also deliver applications beyond scientific discovery, in medicine, industry, and the stewardship of the nuclear weapons stockpile. Very powerful lasers were originally developed in the United States, and their successes prompted funding agencies in Europe and Asia over the last decade to invest heavily in new facilities that will employ these high-intensity lasers for fundamental and applied science. No similar investment has occurred in the United States, so the vast majority of high-intensity laser systems are located overseas.

This report was commissioned by four U.S. agencies—the Office of Naval Research (ONR), the Air Force Office of Scientific Research (AFOSR), and the Department of Energy's Office of Science (DOE-SC) and National Nuclear Security Administration (NNSA)—to assess the opportunities. The final report surveys high-intensity laser science, assesses U.S. technical capabilities, evaluates the impact of applications, and compares U.S. efforts with those in Europe. Most importantly, the report recommends a path forward for possible U.S. investments in this field. This roadmap for action was formulated after the study committee spent a year gathering thousands of pages of information, attending seminars from experts, and visiting major laser laboratories in the United States and Europe.

Download the full report at nap.edu/24939

The National Academies of
SCIENCES · ENGINEERING · MEDICINE



Bubblechart of total peak power for operational, under construction, and proposed high power laser facilities. SOURCE: J. Collier, Rutherford Central Laser Facility.

ROADMAP FOR FUTURE U.S. INVESTMENT IN INTENSE, ULTRAFAST LASERS

The report finds that the case for high-intensity laser research is strong and recommends that U.S. funding agencies strengthen the U.S. position in the field by taking several actions for high-intensity laser science and technology: (1) develop a stewardship strategy, (2) form a network, (3) engage the community, (4) plan for one or more major facilities, and (5) coordinate the talent base. Taken together, these recommendations constitute a national strategy for high-intensity laser science and technology, and lay out a roadmap for implementing this strategy.

1. Develop a National Stewardship Strategy

The US has lost its previous dominance. The United States was the leading innovator and dominant user of high-intensity laser technology when it was developed in the 1990s, but Europe and Asia have now grown to dominate this sector through coordinated national and regional research and infrastructure programs. In Europe, this has stimulated the emergence of the Extreme Light Infrastructure (ELI) program. At present, 80 to 90 percent of the high-intensity laser systems are overseas, and all of the highest power (multi-petawatt) research lasers currently in construction or already built are overseas.

RECOMMENDATION: The Department of Energy should 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.

2. Form a Network

Despite the importance of high-intensity laser research, ***the large technical community is fragmented across different disciplines***. Coordination between industry and government, as well as among federal agencies, is also limited and often inadequate. The 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.

RECOMMENDATION: The Department of Energy should create a broad national network, including 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.

3. Engage the Community

No cross-agency stewardship exists. No single agency currently acts as the steward for high-intensity laser-based research in the United States. Programs are carried out under sponsorship of several different federal agencies, including DOE-SC, NNSA, AFOSR, ONR, the Defense Advanced Research Projects Agency (DARPA), and the National Science Foundation (NSF), according to their various missions and without the overall coordination that exists in Europe.

RECOMMENDATION: To increase integration and coordination in this field, the research agencies (Department of Defense, Department of Energy, National Science Foundation, and others) should 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.

4. Plan for a Major Facility (or Facilities)

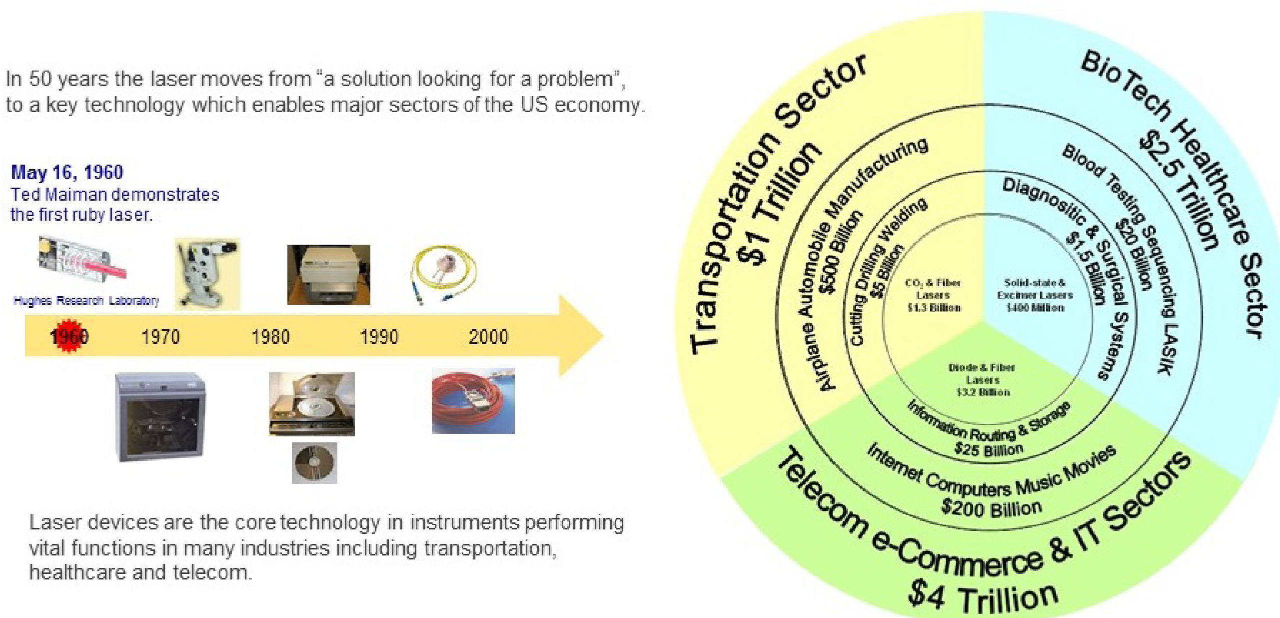
Co-location with existing infrastructure is essential. Co-location of high-intensity lasers with existing infrastructure such as particle accelerators would provide the U.S. with an advantage not found within the ELI program.

RECOMMENDATION: The Department of Energy should plan for at least one large-scale open-access high-intensity laser facility that leverages other major science infrastructure in the Department of Energy complex.

5. Coordinate the Talent Base

University/Laboratory/Industry cooperation is necessary to retain and renew the talent base. Cooperation among all sectors—private industry, research universities, and government laboratories—in the past has proved essential, and the current situation could be improved to develop a robust national talent pool and a strong technology base for this fast growing area.

RECOMMENDATION: Agencies should create programs for U.S. scientists and engineers that include mid-scale 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 Extreme Light Infrastructure.



Lasers play a key role in driving the U.S. economy to produce direct societal benefits. SOURCE: T. Baer and F. Schlachter, 2010, "Lasers in Science and Industry: A Report to OSTP on the Contribution of Lasers to American Jobs and the American Economy," presented at LaserFest 2010.

COMMITTEE ON OPPORTUNITIES IN THE SCIENCE, APPLICATIONS, AND TECHNOLOGY OF INTENSE ULTRAFAST LASERS: Philip Bucksbaum, Stanford University, *Chair*; Riccardo Betti, University of Rochester; John Collier, Rutherford Appleton Laboratory; Louis F. Dimauro, The Ohio State University; Elsa Garmire, Dartmouth College; Jacqueline Gish, Northrop Grumman Aerospace Systems; Ernie Glover, Gordon and Betty Moore Foundation; Marshall Jones, General Electric Global Research; Henry C. Kapteyn, University of Colorado, Boulder; Andrew Lankford, University of California at Irvine; Howard Milchberg, University of Maryland; Stephen Milton, Los Alamos National Laboratory; Peter Moulton, MIT Lincoln Laboratory; C. Kumar Patel, Pranalytica, Inc. (resigned September 2016)

STAFF: James C. Lancaster, Director, Board on Physics and Astronomy; David Lang, Senior Program Officer, *Study Director*; Neeraj P. Gorkhaly, Associate Program Officer; Henry Ko, Research Assistant; Linda Walker, Program Coordinator; Beth Dolan, Financial Associate

This Consensus Study Report Highlights was prepared by the Board on Physics and Astronomy based on *Opportunities in Intense Ultrafast Lasers: Reaching for the Brightest Light* (2017). The study was sponsored by the Department of Energy, the Department of the Air Force, and the Department of the Navy. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of the sponsors. Download the report at **nap.edu** and learn more about the board at **nas.edu/bpa**.

Division on Engineering and Physical Sciences

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

The nation turns to the National Academies of Sciences, Engineering, and Medicine for independent, objective advice on issues that affect people's lives worldwide.
www.national-academies.org