

# Optical Engineering

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## **High-Energy Laser Systems and Components**

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**SPIE**

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Almost every adult today holds some concept of a laser weapon and many children have at least one toy laser among their possessions. Fascination with these ideas reaches as far back as Archimedes' legendary defense of Syracuse with solar reflectors in 212 BC. Other examples include the Martian invaders of Earth who used "heat rays" with chilling efficiency in H. G. Well's 1898 *War of the Worlds* and the now-classic *Star Wars* movie series. While most fictional depictions of laser weapons (and some news stories) are without sound basis, these devices do offer the potential for a whole new class of weapons and capabilities that complement (but do not replace) existing kinetic energy weapons and electronic warfare.

Prokhorov and Basov (USSR) first described the physics behind lasers in 1952, quickly followed by Townes (U.S.) who demonstrated a 24-GHz MASER in 1953. The trio received the 1964 Nobel Prize in physics for advances in quantum electronics. The first optical MASER (or laser) was a subwatt flash-lamp-pumped ruby device. It was demonstrated barely 50 years ago and was soon followed by combustion-driven gas lasers. Average power rose rapidly in the 1960s while the imagination and expectations of the U.S., Soviet, and other militaries around the world grew even faster. The Cold War led to large investments, some timely and some premature, by the U.S. and the Soviet Union. There were major advances in high-energy lasers, beam control, and other related optical component technologies that led to demonstrations of ever larger laser systems on both sides of the Iron Curtain. Despite substantial investments, technological advances, and successful demonstrations, issues of size, weight, cost, and capability versus expectation continued to inhibit deployment. This frustrated the developers and generated many skeptical observations such as "laser weapons are only a few years away and have been for a few decades." Today's global emphasis on tactical and counterinsurgent warfare, combined with recent advances in high-average-power solid-state lasers, may provide the simultaneous "user pull" and "technology push" needed to bring these weapons to fruition.

This special section attempts a survey of high-energy laser (HEL) weapons development, with articles written by technical leaders in relevant fields.

The following group of papers provides historical perspective on parallel HEL weapon developments in the U.S. and in the Soviet Union. The paper "Basov and the Soviet development of lasers for missile defense" by P. Zarubin offers a fascinating first-hand history of Soviet strategic laser weapon development led by Basov and the author during the height of the Cold War. In the paper "High-energy laser weapons since the early 1960s," J. Cook provides a detailed review

of parallel efforts in the U.S. and the Soviet Union along with a close look at the limitations that inhibited deployment. In "United States army tactical HEL program," J. Wachs and G. Wilson describe the development of the army's tactical HEL (THEL) system, which was designed, built, and successfully tested. The paper "High-energy laser-summator based on the Raman scattering principle" by E. Zemskov, translated by P. Zarubin and J. Cook, details the development of Raman conversion in the Soviet Union to combine and improve quality of very-high-power laser beams in a then-secret antimissile weapon development program. In "Electroionization lasers: on the way to gigawatt," V. Danilychev describes the Soviet approach to megawatt CO<sub>2</sub> and kilowatt CO lasers using electric discharge ionization instead of combustion.

This special section also includes a number of survey papers that discuss the background and the current state of the art in key HEL weapon areas. In the paper "High-power diode-pumped solid state lasers," S. Bowman explains the materials properties that have enabled today's capabilities in high-average-power bulk lasers. The paper "High average power free electron lasers" by J. Blau, K. Cohn, and B. Colson discusses the physics behind free-electron lasers, the unique problems encountered when increasing average power, and the current state of the art. In "Beam control for high energy laser systems," P. Merritt and J. Albertine describe the optical and pointing requirements placed on an HEL beam control system and then outline the evolution in performance and approaches used to meet their needs. The paper "Adaptive optics compensation for propagation through deep turbulence" by G. Tyler explores the problems that tactical laser systems encounter when scintillation and anisoplanatism complicate the wavefront measurement process. In the paper "Review of alkali laser research and development," B. Zhdanov and R. Knize describe the properties of this family of lasing atoms that has led to the interest in scaling to high power. Some of the challenges are also addressed. The paper "Ceramic windows and gain media for high energy lasers" by W. Kim et al. provides an overview of recent development of the many ceramic materials that are candidates for HEL windows and advanced gain materials.

If this journal were a newspaper, it would have an editorial section containing the paper "Is this the time for a high energy laser weapon program?" by D. H. Kiel, which offers the thoughts of a prior U.S. Navy HEL weapons development program manager on the utility of HEL weapons.

There were additional topics that I very much wanted to include in this special section. Some were precluded by the lack of available time by the authors who knew the topics best and some were precluded by classification restrictions. Current research (both classified and unclassified) in the

fields of HEL and high-power-microwave weapon development is available to those with the proper clearances through the Directed Energy Professional Society ([www.deps.org](http://www.deps.org)).

I would like to thank each of the authors and translators for the time and effort invested in these excellent first-person histories and technology surveys. Finally, I would like to thank the Directed Energy Professional Society, the HEL Joint Technology Office, and SPIE for their support and assistance in preparing this special section.



**John Albertine** has a BS in physics from Rose Polytechnic Institute and a Master's degree in applied physics from Johns Hopkins University with research in satellite navigation. He began working with precision tracking, optical propagation, and high-power lasers in the early 1970s while at the Space Division of Johns Hopkins Applied Physics Laboratory. In 1976, he joined the Navy's High Energy Laser Program Office where he led the development, integration,

and test of the first megawatt-class laser system in the U.S. He retired from government service in 1997 and began independent technical consulting for the defense department. He has been a technical advisor to the high-energy laser joint technology office for over 10 years and chaired the independent review team for the AirBorne Laser Program. He was a member of the National Academy of Sciences study on free-electron laser technology and a member of the Air Force Scientific Advisory Board. He is a DEPS Fellow.