Preprint
UCRL-JC-143964

Army Solid State Laser Program: Design, Operation, and Mission Analysis for a Heat-Capacity Laser

C. B. Dane, L. Flath, M. Rotter, S. Fochs, J. Brase and K. Bretney

This article was submitted to
Solid State and Diode Laser Technology Review 2001
Albuquerque, New Mexico
May 21-25, 2001

U.S. Department of Energy

Lawrence Livermore National Laboratory

May 18, 2001

UCRL-JC-143964

Army Solid State Laser Program: Design, Operation, and Mission Analysis for a Heat-Capacity Laser

C. Brent Dane, Laurence Flath, Mark Rotter, Scott Fochs, and Jim Brase

Lawrence Livermore National Laboratory
P.O. Box 808, L-477, Livermore, CA 94550

Kirk Bretney

Raytheon Electronic Systems
PO Box 902, El Segundo, CA 90245

Solid-state lasers have held great promise for the generation of high-average-power, high-quality output beams for a number of decades. However, the inherent difficulty of scaling the active solid-state gain media while continuing to provide efficient cooling has limited demonstrated powers to <5kW. Even at the maximum demonstrated average powers, the output is most often delivered as continuous wave (CW) or as small energy pulses at high pulse repetition frequency (PRF) and the beam divergence is typically >10X the diffraction limit. Challenges posed by optical distortions and depolarization arising from internal temperature gradients in the gain medium of a continuously cooled system are only increased for laser designs that would attempt to deliver the high average power in the form of high energy pulses (>25J) from a single coherent optical aperture. Although demonstrated phase-locking of multiple laser apertures may hold significant promise for the future scaling of solid-state laser systems,[1] the continuing need for additional technical development and innovation coupled with the anticipated complexity of these systems effectively limits this approach for near-term multi-kW laser operation outside of a laboratory setting.

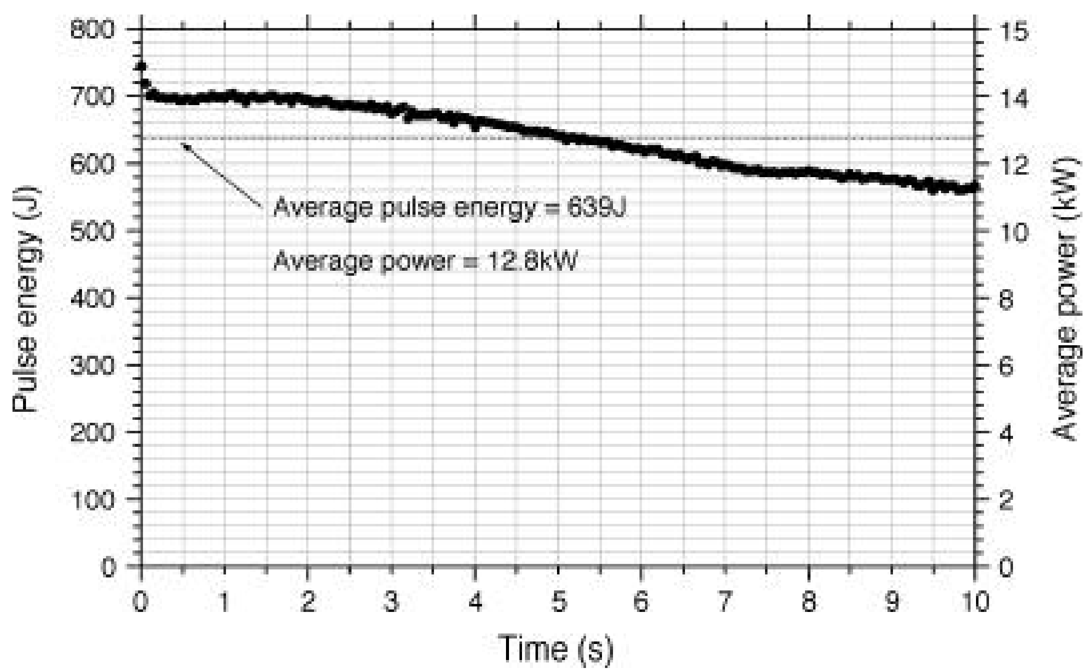
We have developed and demonstrated a new operational mode for solid-state laser systems in which the cooling of the gain medium is separated in time from the lasing cycle. In “heat-capacity” operation, no cooling takes place during lasing. The gain medium is pumped very uniformly and the waste heat from the excitation process is stored in the solid-state gain medium. By depositing the heat on time scales that are short compared to thermal diffusion across the optical aperture, very high average power operation is possible while maintaining low optical distortions. After a lasing cycle, aggressive cooling can then take place in the absence of lasing, limited only by

[1] C. B. Dane, J. Wintemute, B. Bhachu, and L. Hackel, "Diffraction limited high average power phase-locking of four 30J beams from discrete Nd:glass zig-zag amplifiers," post-deadline paper CPD27, Conference on Lasers and Electro-Optics (CLEO '97), May 22, 1997, Baltimore, MD.

the fracture limit of the solid-state medium. This mode of operation is ideally suited for applications that require 1-30s engagements at very high average power. If necessary, multiple laser apertures can provide continuous operation.

Land Combat mission analysis of a stressing air defense scenario including a dense attack of rockets, mortars, and artillery has indicated that multiple HEL weapon systems, based on the solid state, heat capacity laser concept, can provide significantly improved protection of high value battlefield assets. We will present EADSIM results for two government-supplied scenarios, one with temporally high threat density over a fairly large defended area, and one with fewer threats concentrating on a single defended asset. Implications for weapon system requirements will be presented.

In order to demonstrate the operation of a high average power heat-capacity laser system, we have developed a flashlamp-pumped Nd:glass laser with output energies in the range of 500-1000J/pulse in a 10x10cm^2 beam. With a repetition frequency of 20Hz, an average power of 13kW has been demonstrated for operational periods of up to 10s using a stable optical resonator (see enclosed figure). Using an M=1.4 unstable resonator, a beam divergence of 5X diffraction-limited has been measured with no active wavefront correction. An adaptively corrected unstable resonator that incorporates an intracavity deformable mirror controlled by feedback from an external wavefront sensor will provide <2X diffraction-limited output integrated over an entire 10s run at an average power of 10kW.



A very similar laser architecture in which the Nd:glass is replaced by Nd:GGG and the flashlamps are replaced by large diode-laser arrays will enable the scaling of the output average power from the demonstrated 10kW to 100kW (500J/pulse at 200Hz). Risk reduction experiments for diode-pumped Nd:GGG, the fabrication of large Nd:GGG amplifier slabs, as well as the progress toward a sub-scale amplifier testbed pumped by diode arrays with total of 1MW peak power will also be presented.

*Work done under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.