Director's Remarks

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The Laboratory for Laser Energetics (LLE) is funded primarily by the U.S. Department of Energy (DOE) National Nuclear Security Administration's (NNSA's) Office of Experimental Sciences Inertial Confinement Fusion (ICF) Program through a five-year Cooperative Agreement. The fiscal year ending September 2022 (FY22) comprised the fourth year of work under DOE/NNSA Cooperative Agreement No. DE-NA0003856. The Laboratory is also sponsored by the New York State Energy Research Development Authority and other federal agencies such as the DOE Office of Science and the National Science Foundation. I was honored to become the fifth Director of LLE, succeeding Dr. E. Michael Campbell who retired in March 2022.

The year 2022 was exciting for the National ICF Program and LLE. Ignition was achieved at the National Ignition Facility for the first time, producing more energy out of the implosion than the input laser energy to the target. LLE has made many contributions to the pursuit of ignition, including laser technologies, diagnostics, simulation capabilities, physics understanding, and student education. Groundbreaking for the construction of a new $42M addition to the LLE Complex (funded by the University of Rochester) occurred in August 2022. LLE submitted a proposal to renew the Cooperative Agreement with DOE/NNSA for FY24–FY28.

This report summarizes work conducted at LLE during FY22 that includes research on the ICF and High-Energy-Density (HED) science campaigns; laser, optical materials and advanced technology development; operation of the Omega Laser Facility for the ICF and HED campaigns, the National Laser Users' Facility, Laboratory Basic Science Program, and other external users, including the newly established LaserNetUS supported by the DOE Office of Fusion Energy Sciences; and programs focusing on the education of high school, undergraduate, and graduate students.

- The Omega Laser Facility conducted 2110 target shots in FY22, close to the average annual number of shots since FY14 with nearly 60% of the shots performed for external users. These experiments are critical to LLE and the national community achieving progress in the ICF/HED Physics mission, in advancing science, and in training students.

- Mission Impact: All of the completion criteria for the 15 NNSA Level II milestones were achieved.

- Scientific Output: One hundred and one technical manuscripts were published in peer-reviewed scientific journals during FY22.

- Sixteen Ph.D. degrees were conferred on graduate students during 2022 whose primary research was performed at the Laboratory either as students of the University of Rochester or as students of other collaborating user institutions who performed experiments or worked with scientists at the Omega Laser Facility.

- One University of Rochester Ph.D. graduate (Alison Christopherson) won the American Physical Society Division of Plasma Physics Marshall N. Rosenbluth Outstanding Doctoral Thesis Award.

- Radha Bahukutumbi, a Distinguished Scientist in the Theory Division, received the Leadership Award at the annual meeting of the Fusion Power Associates.

- Steve Ivancic, head of the Diagnostic Development and Integration Group, received a Defense Programs Award of Excellence from Lawrence Livermore National Laboratory.

Key technical highlights included:

- A series of high in-flight aspect ratio and high-velocity implosions on OMEGA produced yields between 2.6×10^{14} and 3.1×10^{14}, all above the previous yield record. The highest yield implosion, when corrected for ^{3}He buildup using statistical modeling, would have produced a yield of nearly 1 kJ, roughly the same as the shell kinetic energy. These direct-drive implosions enable Ph.D. research on ICF and open opportunities for future ICF optimization.

- Layered DT implosions with silicon dopants performed significantly better (higher yields) than comparable targets without dopants, confirming that the dopant suppresses imprint while only modestly increasing the shell adiabat via x-ray preheat.

- The Lawrence Livermore National Laboratory (LLNL)/LLE Neutron Sources collaboration conducted a polar-direct-drive exploding-pusher experiment at the National Ignition Facility that produced a record laser-direct-drive (LDD) yield of 1.6×10^{16} with a laser pulse of 1.6 MJ.

- The proof-of-concept for the LLE dynamic-shell ignition design, where pulse shaping dynamically creates a high-density shell with a DT wetted-foam target, was demonstrated using 3-D–printed foam capsules.

- Constrained by integrated implosion measurements, spectroscopic observables revealed that a density functional theory (DFT)-based kinetic model developed by LLE scientists (*VERITAS*) reproduces a majority of the emission and absorption features observed in experiments, while the traditional collisional-radiative-equilibrium treatment with *ad hoc* continuum lowering does not, suggesting that self-consistent treatment of dense plasma effects is needed at very high pressures.

- In collaboration with LLNL, LLE scientists showed that diamond can precipitate from twice-shocked CH polymers (e.g., ICF ablators) in the presence of oxygen, nitrogen, and chlorine.

- An LLE–LLNL team conclusively demonstrated species separation in the release of strongly shocked CH, finding that the hydrogen ions carry 10 to 100$\times$ more mass than the carbon ions to large distances, confirming a hypothesis developed to understand the seeds of instability growth in plastic ICF ablators.

- Based on x-ray diffraction measurements of sevenfold compressed sodium, a team from LLE and LLNL observed the *hP4* electride phase at a pressure of 480 GPa and a temperature of 3000 K (a regime where core electron overlap was thought to stabilize against this phase), indicating that electride formation is possible on nanosecond time scales at high temperatures.

- A decades-old discrepancy between theory and measurement on the shock-induced metallization of polystyrene was resolved using a new exchange correlation functional that properly captures the shock-induced dissociation of carbon and correctly predicts the band-gap closing behavior at 1 to 2 Mbar.

- New DFT calculations of Fe and Cr opacity at stellar interior densities and temperatures did not resolve the iron opacity "mystery" identified some time ago at Sandia National Laboratories' Z Pulsed Power Facility. The new calculations showed good agreement with the measured Cr opacity but did not agree with Z's measurements of the Fe opacity.

- Recent experiments showed that micron-scale x-ray radiography is possible for a wide range of flow visualizations at ultrahigh pressures using a new LLE-developed Fresnel zone plate imaging diagnostic.

- The first electron radiographs of a test object were acquired (in collaboration with Los Alamos National Laboratory) using a laser-plasma accelerator platform on OMEGA EP.

- The 13th Omega Laser Facility Users Group (OLUG) Workshop, held 27–29 April 2022 at LLE, attracted nearly 200 researchers from around the world.

- The 24th Topical Conference on High-Temperature Plasma Diagnostics (HTPD), hosted by LLE in Rochester, NY, attracted 370 registered participants. The HTPD conference showcased the latest in advanced instrumentation in the fields of magnetic confinement fusion, inertial confinement fusion, high-energy-density plasmas, space plasmas, astrophysics, and industrial applications.

- The 50th Anomalous Absorption Conference 2022 hosted and organized by LLE was held 5–10 June in Skytop, PA. Conference topics included theoretical and experimental studies in parametric instabilities, radiation hydrodynamics, particle acceleration, HED physics, short-pulse laser–matter interactions, and ICF.

- A classified report on the scope of applications within the Stockpile Stewardship Program for platforms that rely on LDD was submitted to the NNSA Office of Experimental Science, completing one of the milestones in the ICF five-year plan.

As the fifth Director working with the senior leadership team, we have set our vision to be "the leading academic institution advancing laser technologies, inertial confinement fusion, and high-energy-density science at scale." I hope you agree that FY22 met this vision.