LA-UR-24-25789

Approved for public release; distribution is unlimited.

Title:	LANL ICF Historical Overview
Author(s):	Johnson, Lizabeth Jean
Intended for:	LANL ICF History Day, 2024-06-17 (Los Alamos, New Mexico, UNITED STATES)
Issued:	2024-10-11 (rev.1)

LANL ICF Historical Overview

NATIONAL SECURITY RESEARCH CENTER

Lizabeth Johnson,
NSRC Mission Support

June 17, 2024

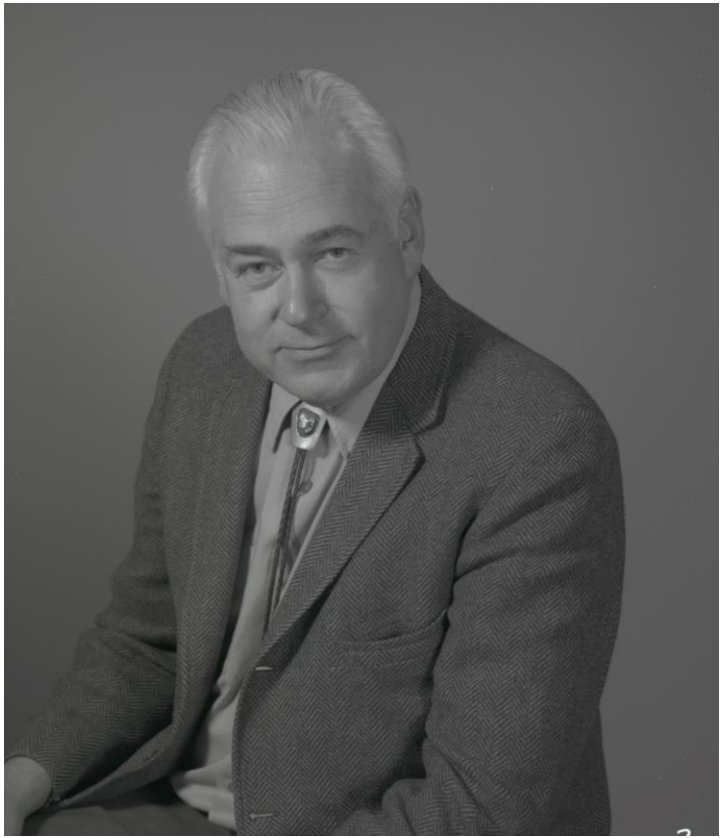
Managed by Triad National Security, LLC for the U.S. Department of Energy's NNSA

LA-UR-24-25789

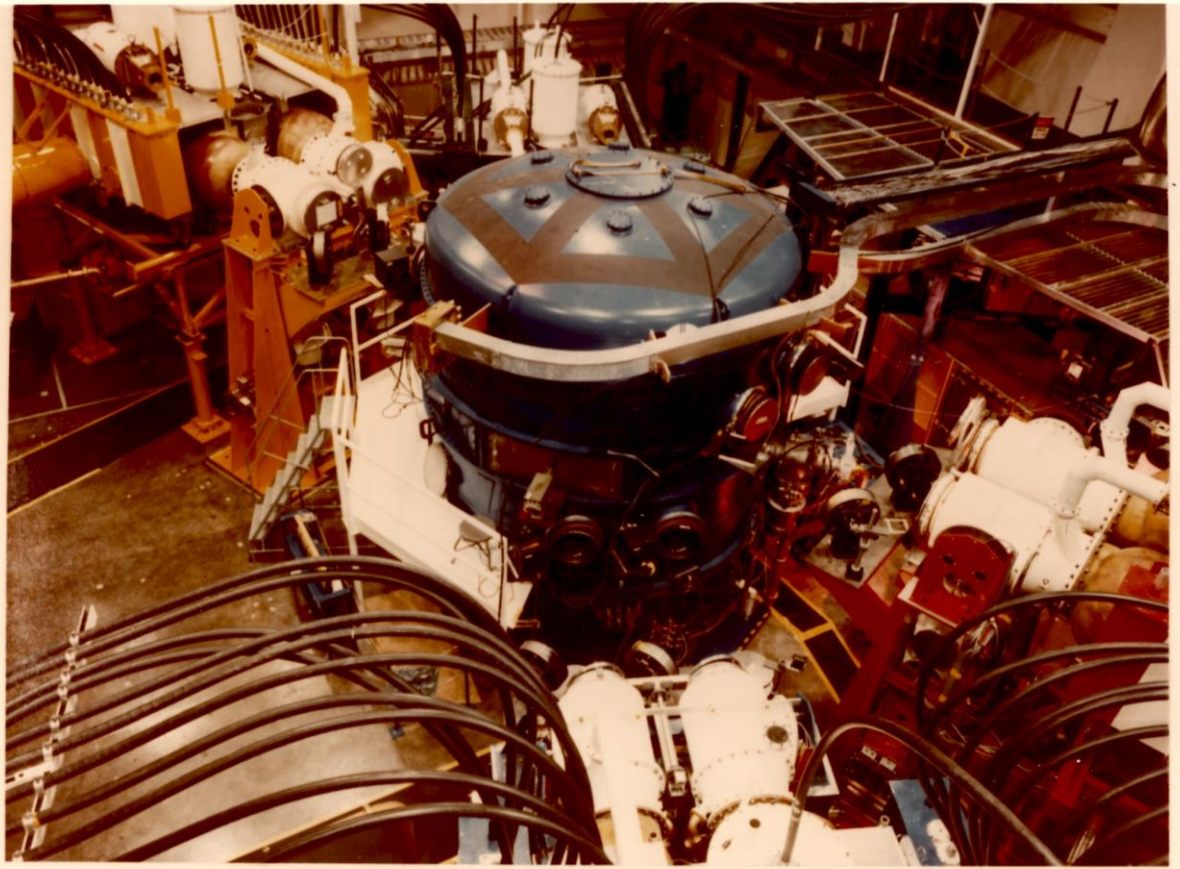
LASL's Laser Division, 1972-1981

LASL Portrait of Keith Boyer

- L-Division created in 1972 by director Harold Agnew
  - Keith Boyer served as the first division leader (1972-1976)
    - Boyer had worked on the Rover Program and was interested in laser-initiated fusion for propulsion
  - Focus was on gas lasers, specifically CO2
    - Gemini
      - A dual-beam, 1 kJ laser
    - Helios
      - An eight-beam, 10 kJ laser, operational by 1978
    - Antares
      - Designed as a 72-beam, 100 kJ laser

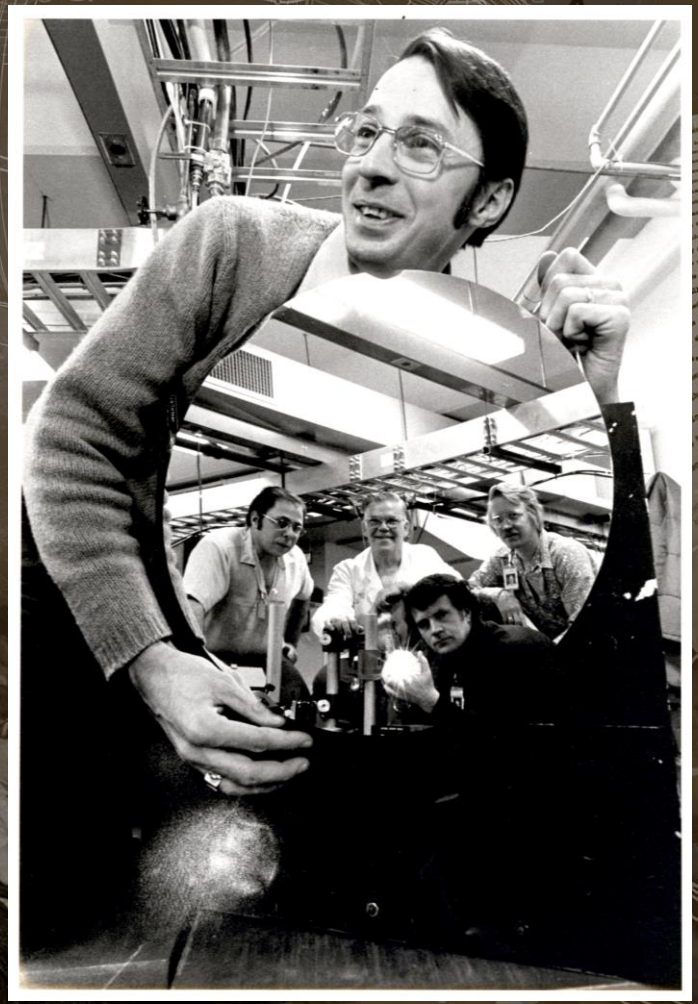


Helios target chamber



THE HELIOS TARGET CHAMBER SURROUNDED BY
THE FOUR DOUBLE-BEAM LASER MODULES.

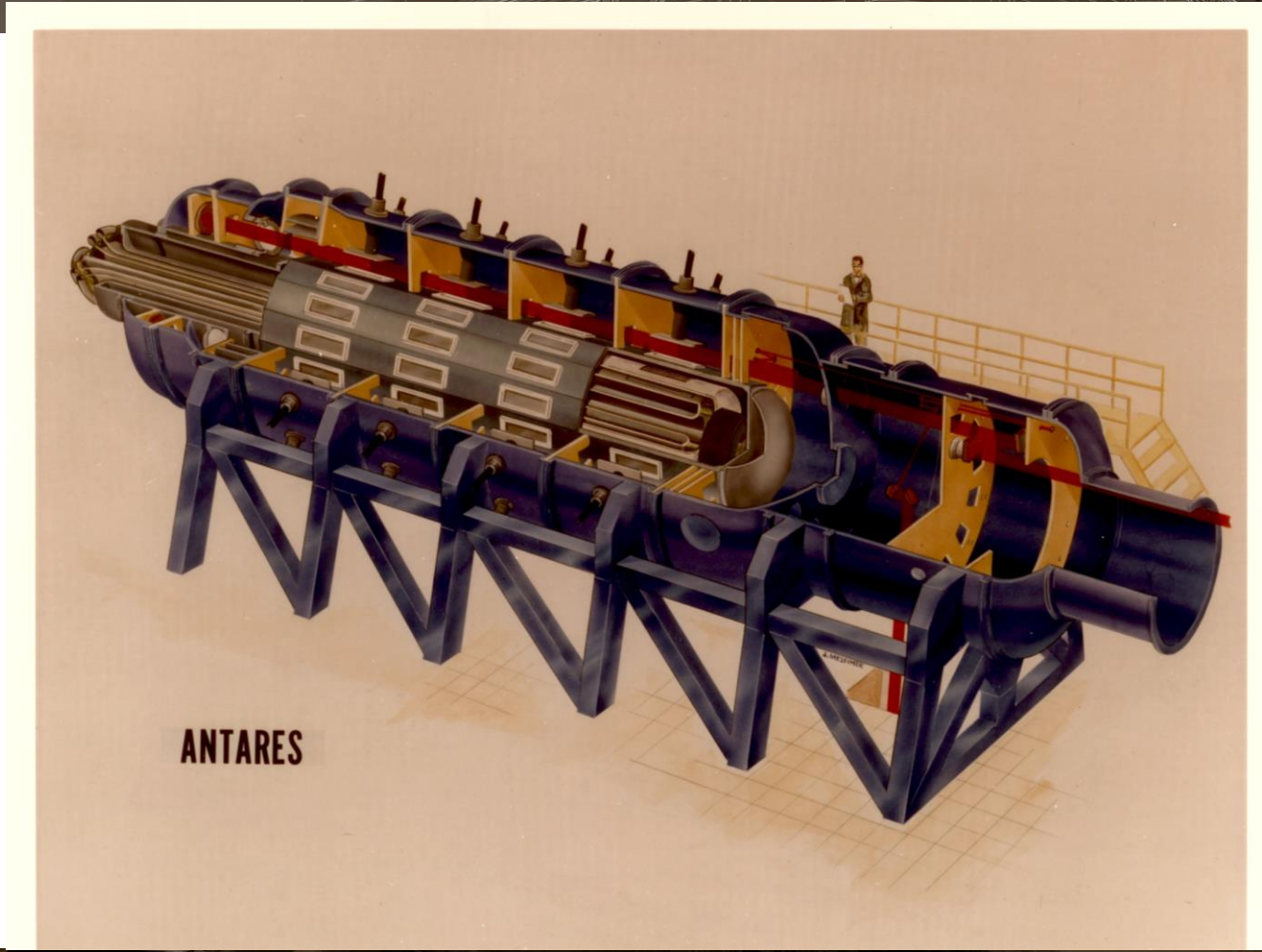
Left—L-1 staff with Germanium crystal; right—L-DO staff with 2- and 8-beam laser.



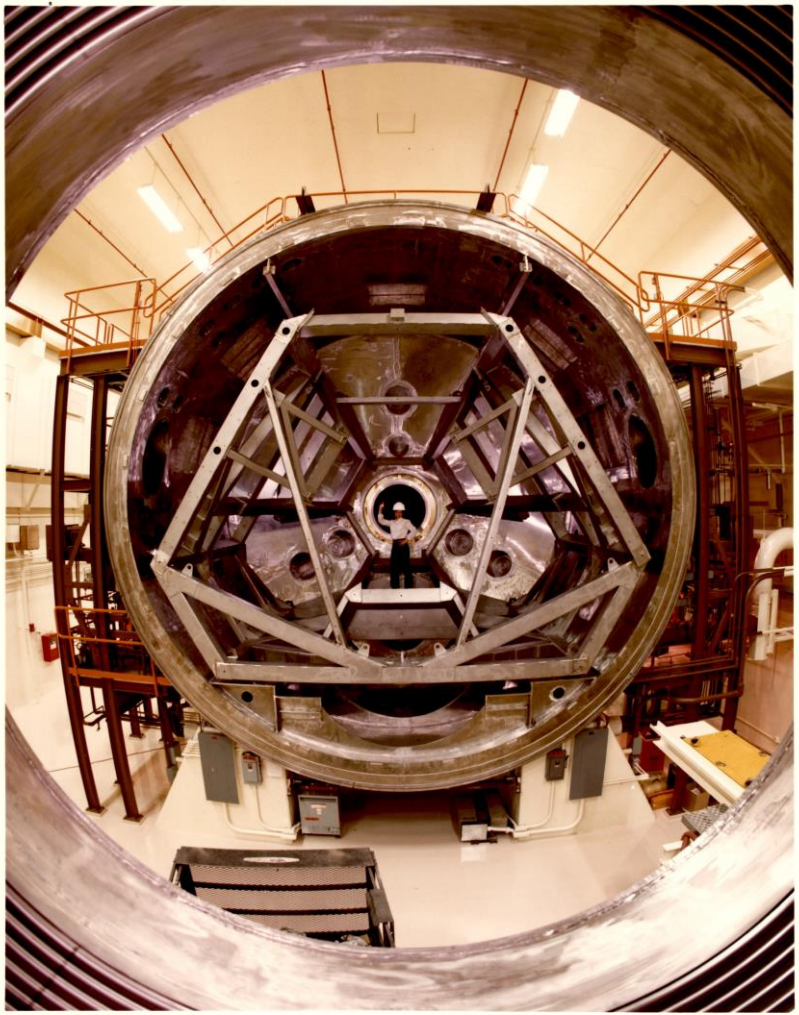
Investing in Antares and HEGLF

- The High Energy Gas Laser Facility (HEGLF) was under construction by 1977
- In 1981, L-Division merged with P-Division
  - The Antares Project became P-DO-ABO
    - Hansjorg Jansen
  - Antares was redesigned in 1983 (24-beam, 40 kJ), but ultimately was retired in 1985
    - Long wavelength lasers (10 μm) caused fusion targets to preheat

Antares laser design



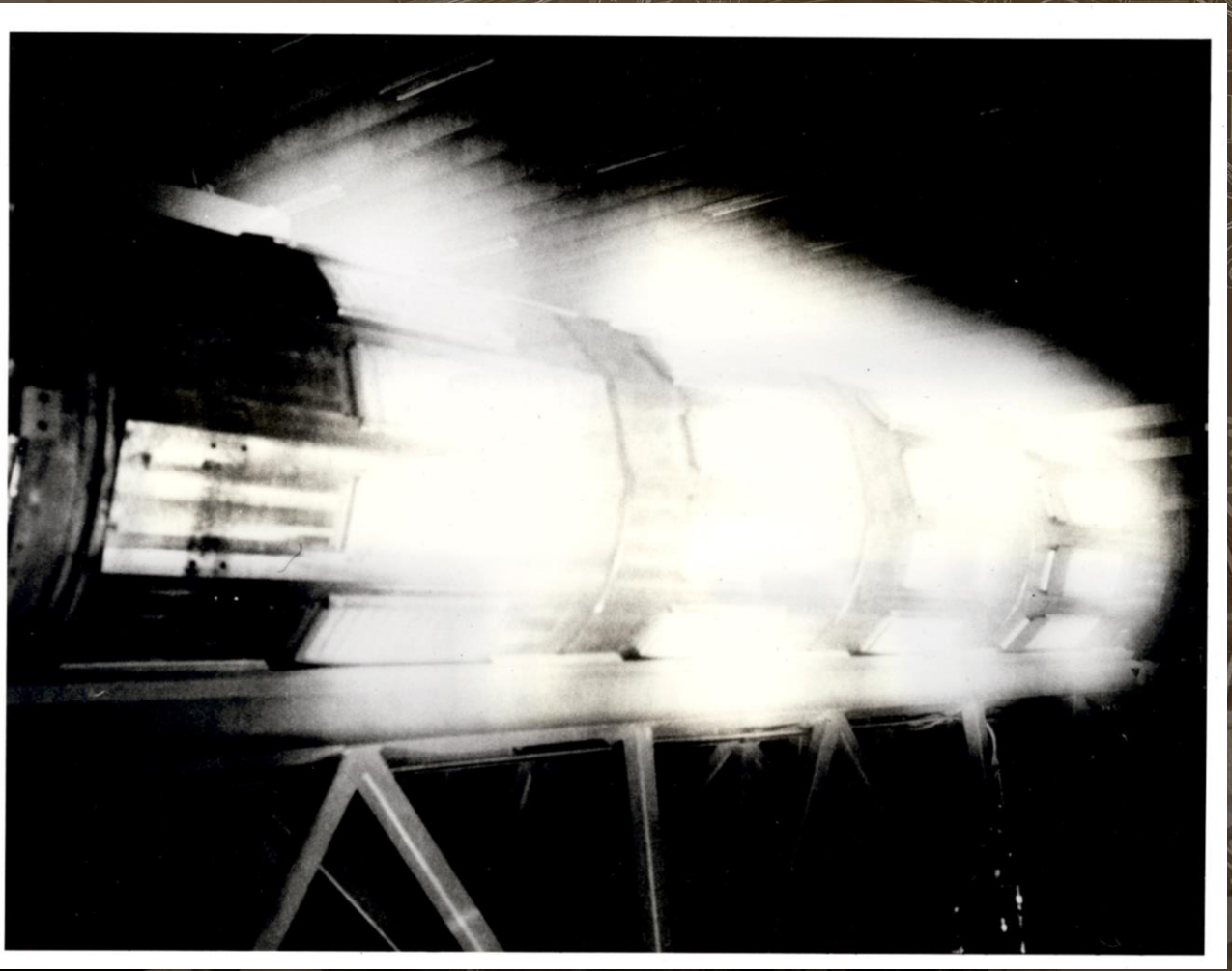
Antares target chamber



Antares staff with “hair dryers”

Antares staff with an award for best use of materials and fabrication processes for a calorimeter

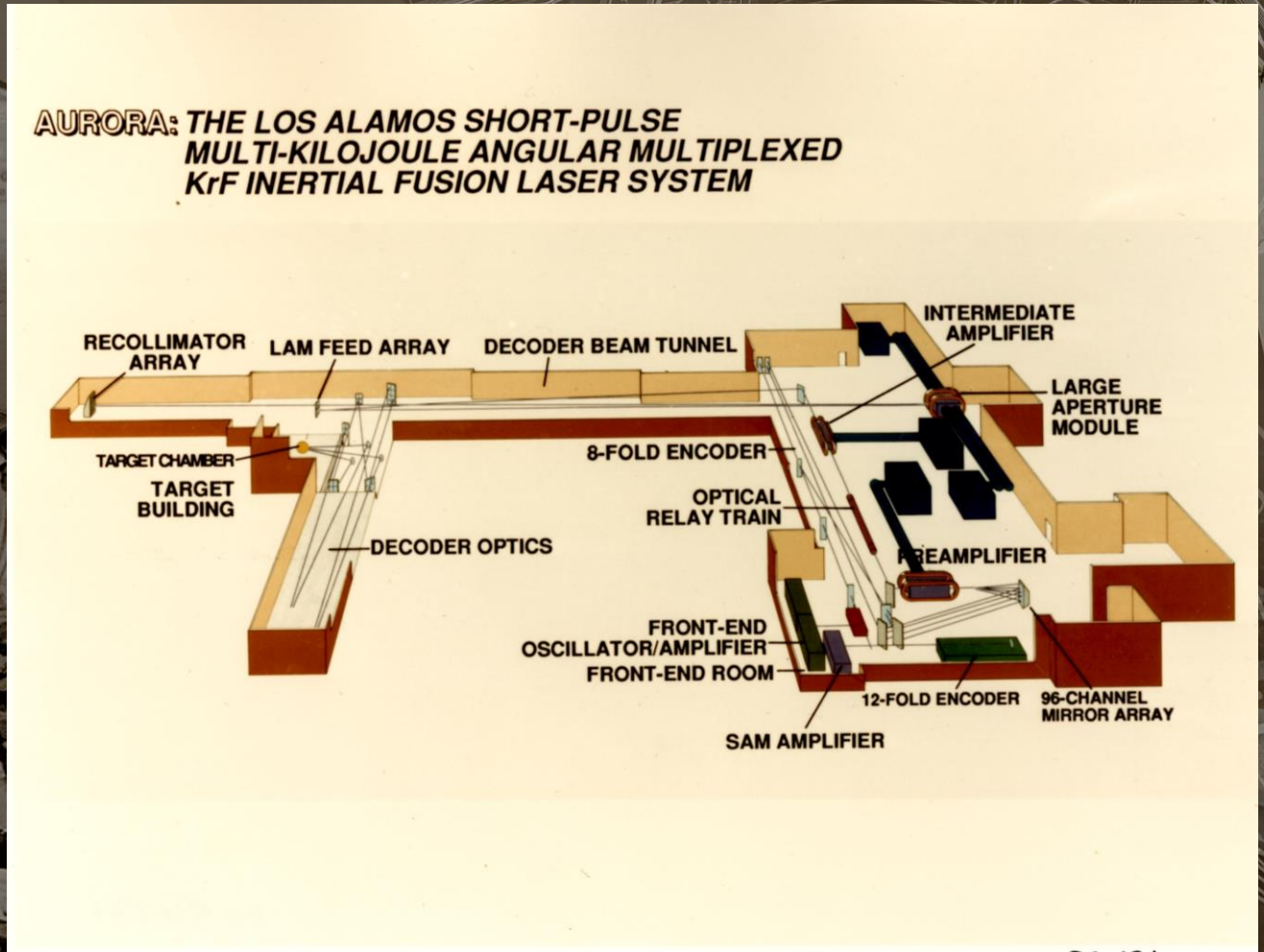
Antares electron gun



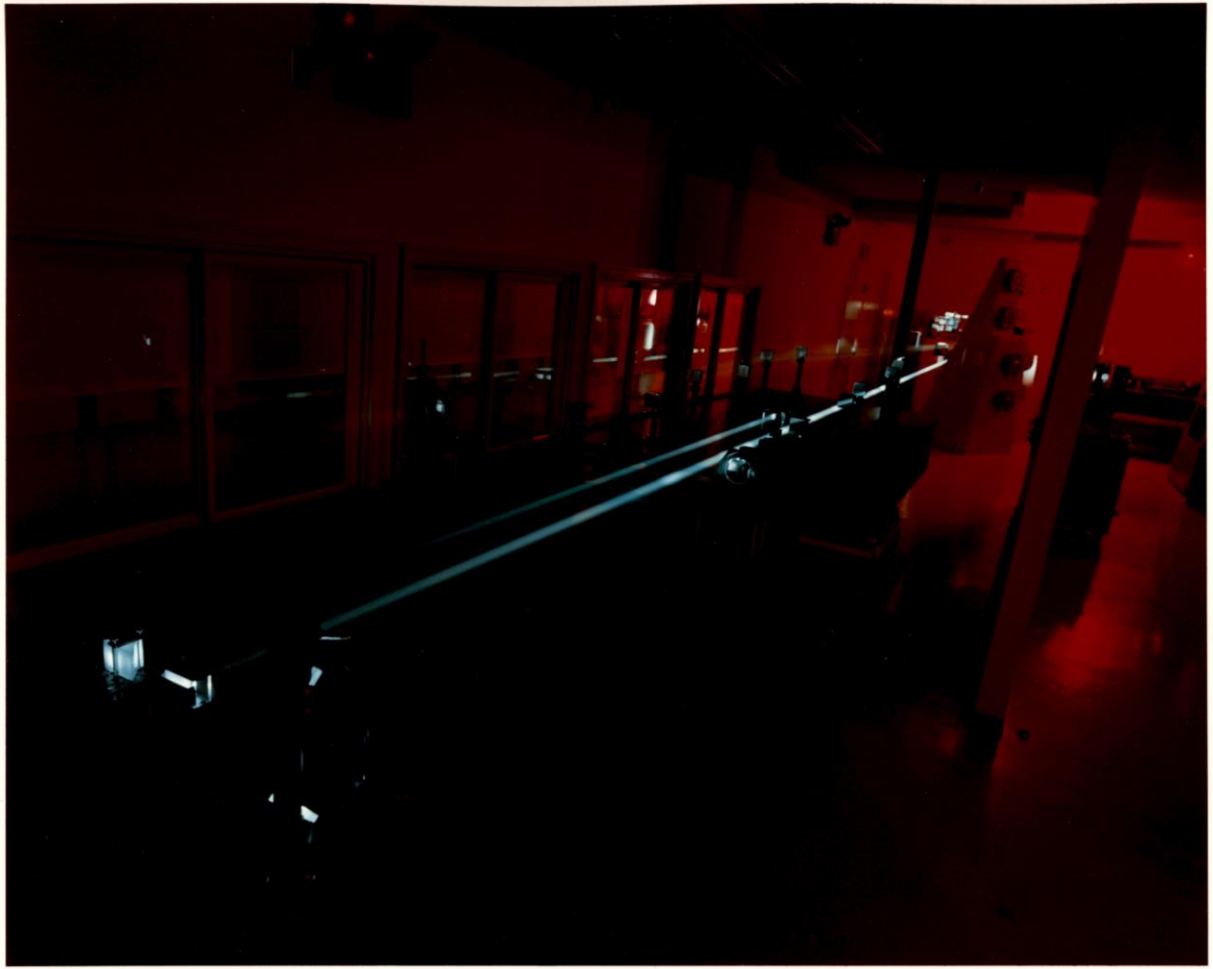
Krypton Fluoride (KrF) laser systems

- KrF laser research had begun in 1976, but it became the focus of LANL's program in 1985
  - Aurora was a first generation KrF laser
    - Shorter wavelength (0.25 µm)
    - First fired in 1988
      - Final amplifier produced a 96-beam pulse train of 2.5 kJ; target chamber received 48 beams and 780 J
      - Later experiments produced 1.2 kJ from 36 beams
    - Affordability was an issue, leading to the shuttering of Aurora in 1991
      - Driver costs in the vicinity of several thousand dollars per joule (the goal for commercial energy production was $200 per joule)

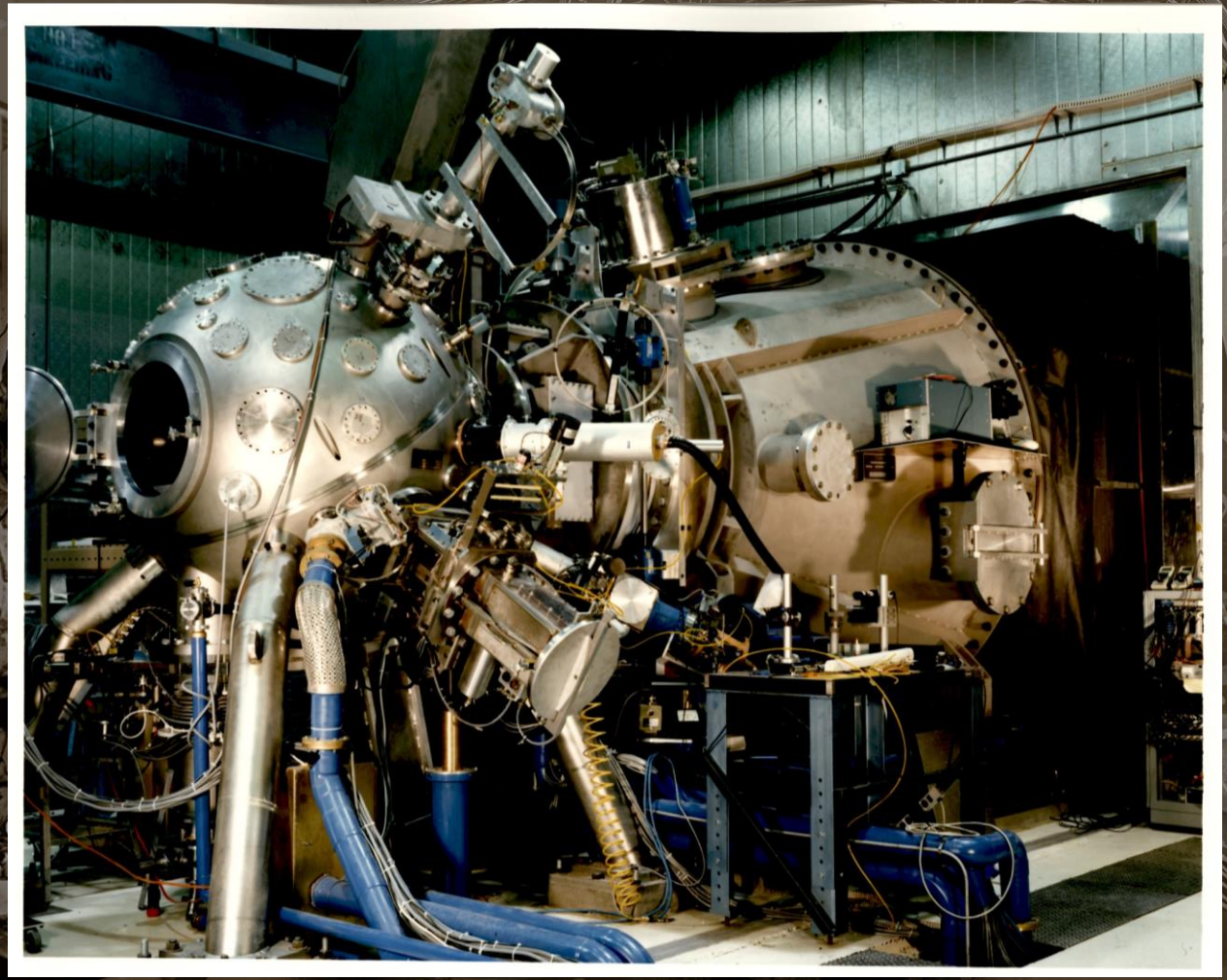
Aurora laser design



Aurora laser alignment



Aurora target chamber



Krypton Fluoride (KrF) laser systems

- KrF laser research in addition to and after Aurora
  - Los Alamos Bright Source Lasers (LABS I and II)
    - Ultrashort pulse lasers developed in 1986
      - LABS I operated at 248 nm KrF wavelength and produced 35 mJ at 5 Hz with pulse lengths of 0.7 psec
      - LABS II operated at 308 nm XeCl wavelength and produced up to 250 mJ at 1 Hz with pulse lengths of 335 fsec
  - Mercury was designed in 1991 and utilized some of Aurora's parts
    - 48 beamlets expected to deliver 500 to 1000 J

The Laser Microfusion Facility (LMF) era

- DOE wanted to invest in an LMF for civilian energy production
  - The idea grew out of the Centurion and Halite experiments at NNSS, 1978-1988
  - LANL and LLNL drew up proposals for an LMF
    - LANL's based on KrF laser technology; LLNL's based on glass laser technology
  - In 1991, the DOE's National Research Council of Inertial Confinement Fusion (ICF) decided to invest in glass laser technology
    - LLNL's Nova facility would be the benefactor
    - LANL's KrF research was to be reduced, with LANL staff becoming involved in target design and fabrication
      - The Naval Research Laboratory's Nike KrF laser remained as a backup, with LANL support
    - KMS Fusion, a DOE contractor, lost its contract and closed
      - LANL purchased parts from KMS's glass laser (Chroma), which became the 3-beam Trident laser

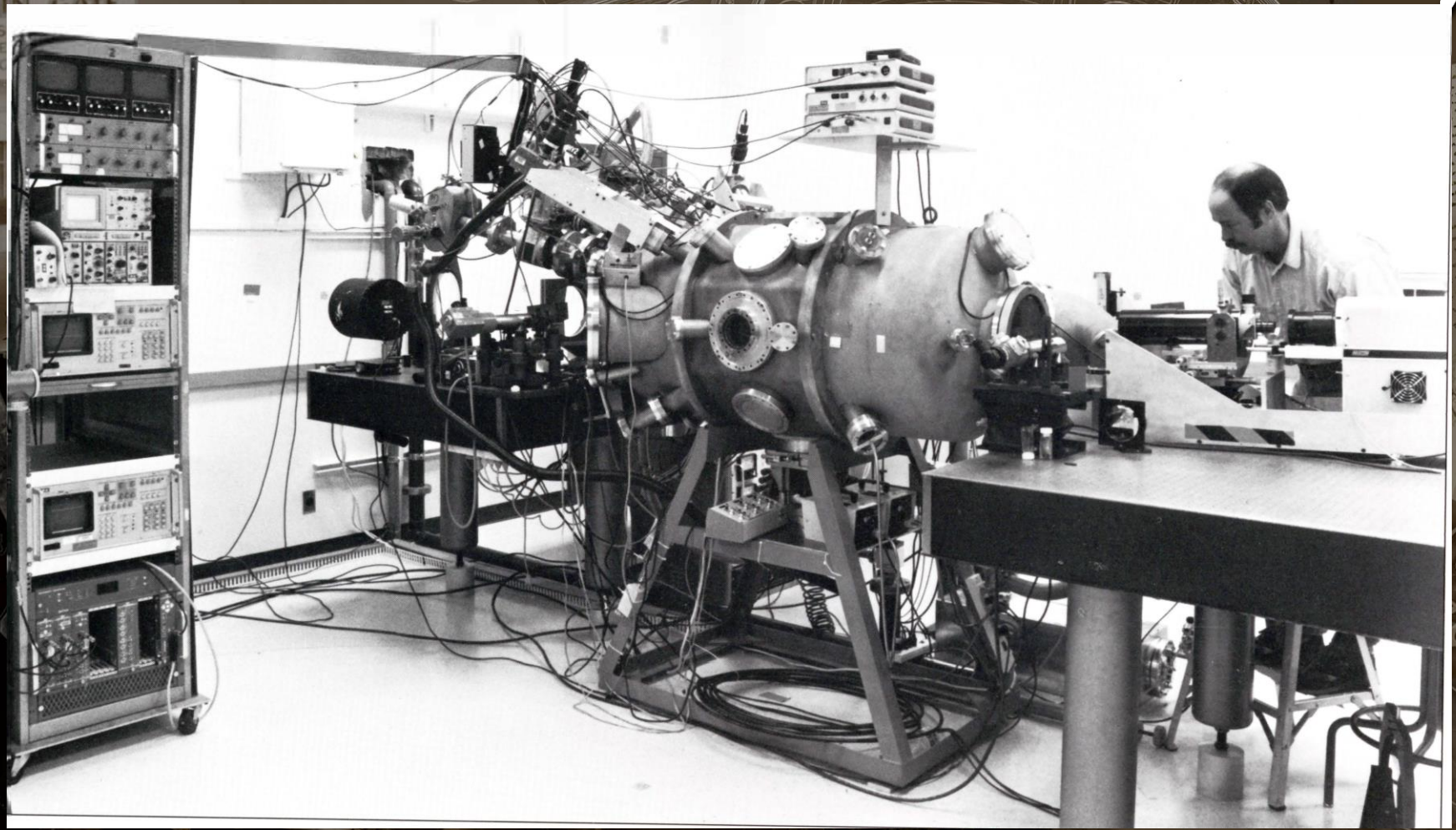
The Cold War ends; LMF becomes NIF

- DOE announced plans to build the National Ignition Facility (NIF) in January 1993
  - ICF viewed as a means of continuing weapons development and testing as well as maintaining stockpile stewardship
  - LANL staff had been using Nova for weapons physics research and ICF and didn't view Trident as a potential candidate for the NIF
  - LLNL's proposal to build the NIF at the Nova facility was approved
    - Original plan was for 192 beams to focus 1.8 MJ on a target; building was to begin in 1994 and be finished by 2002 (actually completed in 2009)
  - LANL staff performed research to help develop the NIF
    - Testing of measurement concepts, developing nonlinear optics theory and code, beryllium capsule studies, laser plasma instability (LPI) studies

Ongoing research with Trident

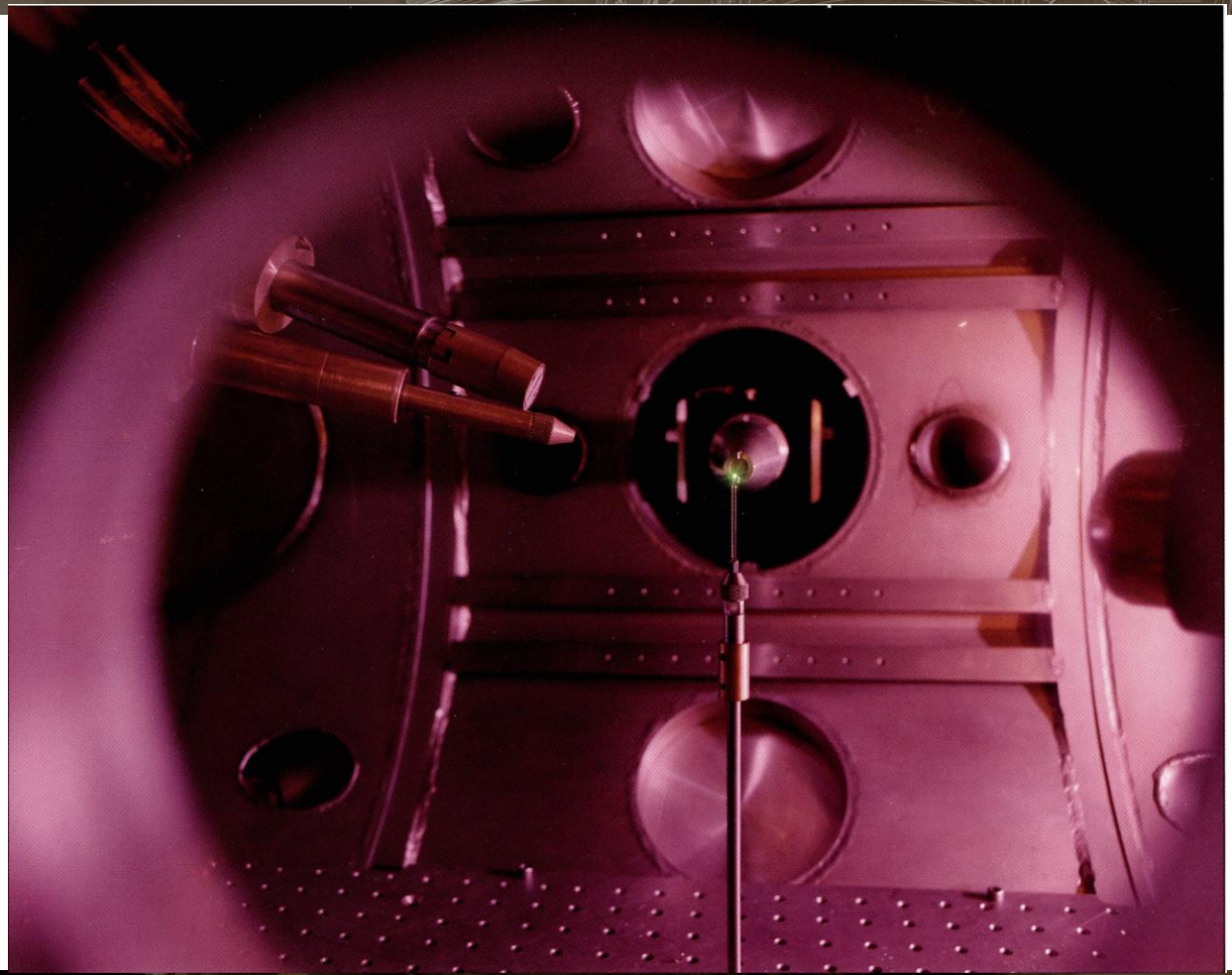
- Trident continued in use at LANL
  - Diagnostics development, plasma instability studies, characterization of direct and indirect drive targets
  - LANL staff performed research at Nova and the Laboratory for Laser Energetics' (LLE) Omega as well
  - Troubleshooting for the NIF, particularly regarding hohlraum behavior and LPI
  - Upgrades led to capabilities exceeding 200 TW
  - In 2008, opened up to users from the wider NSE
    - In 2009, 66 users, 21 institutions (including AWE), and 7 foreign universities
  - By 2016, it was decided to close Trident because of the expense of upgrades

Trident target chamber



Trident two-power amplifier chains

Trident experimental chamber



After Trident and success with the NIF

- LANL staff continued to focus on ICF research, including improvements to hohlraum geometry and implosion symmetry control
- In August 2021, the NIF delivered 1.93 MJ and generated 1.35 MJ, 70% of the input energy
- In December 2022, the NIF delivered 2.05 MJ and generated 3.15 MJ, 154% of the input energy

Acknowledgements

- Thanks to Steve Batha for this opportunity!
- Thanks also to Albert Hsu, Matthew Hopkins, John Moore, Julie Miller, and the Knowledge Management team for their assistance in helping with this project.