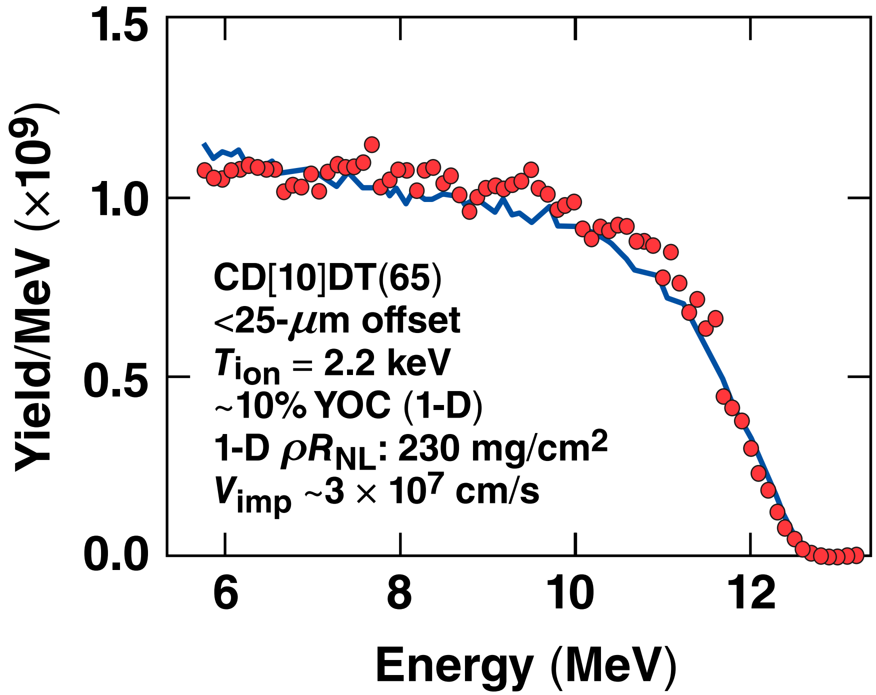
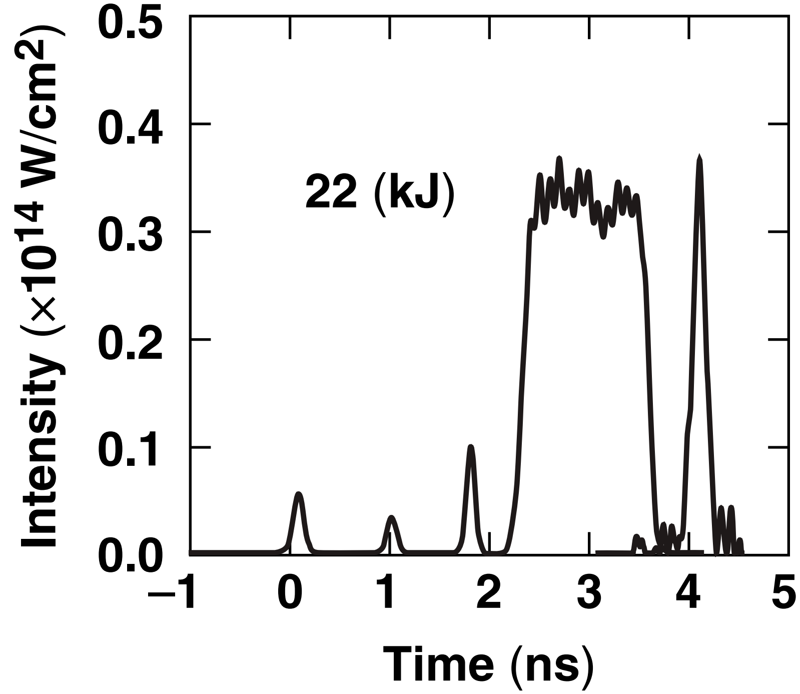
Overview of Inertial Fusion Research at the University of Rochester

KO-D data from the MRS gives 200±20 mg/cm²



Triple-picket drive* pulse with neutron burn history



John M. Soures
Manager, NLUF
Laboratory for Laser Energetics
University of Rochester

Fusion Power Associates
Annual Meeting and Symposium
Livermore, CA
3–4 December 2008

Summary

LLE's focus is on the National Ignition Campaign

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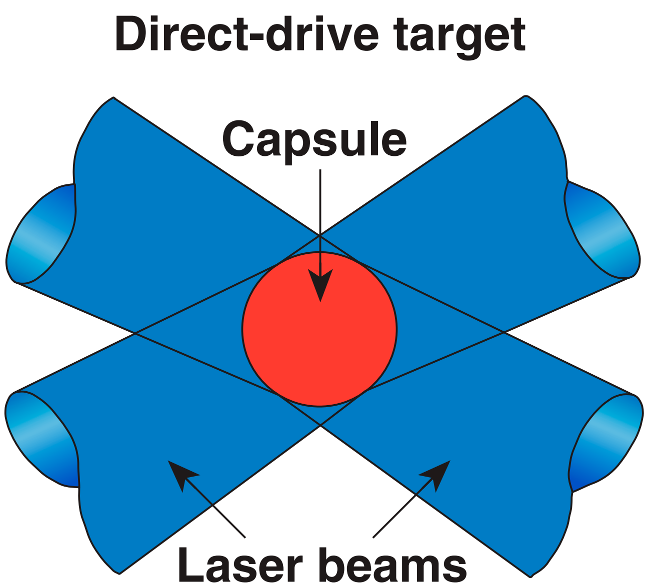
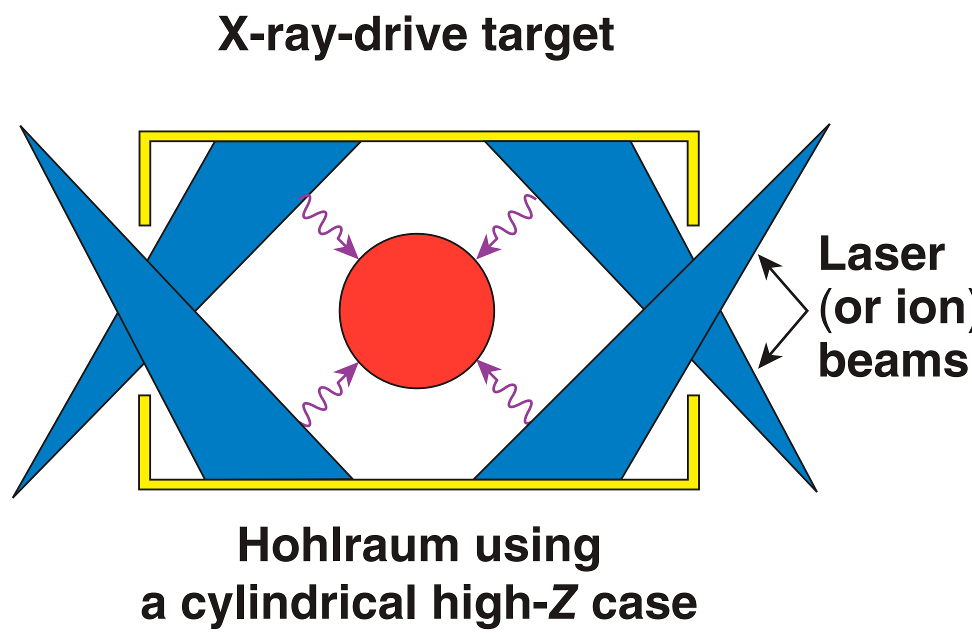
- Cryogenic implosions—only facility performing ignition-scaled cryogenic implosions
- Development of NIF cryogenic target system
- Shock timing (direct and indirect drive)
- Hohlraum energetics
- EOS of target constituents
- Diagnostic development (neutronics, backlighting, etc)
- Exploration of advanced ignition concepts (fast and shock ignition)
- Optical fabrication and coating technology for the NIF and beyond

Almost all of LLE's research program supports the NIC and provides a strong base of support for LIFE.

The fundamental physics of direct- and indirect-drive ICF implosions is the same





Key physics issues are common to both

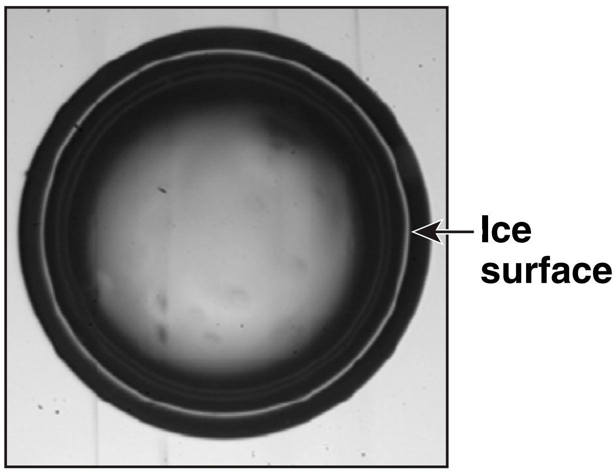
- Energy coupling
- Drive uniformity
- Hydrodynamic instabilities
- Compressibility

Direct-drive cryogenic implosions provide essential information for ICF physics.

E6426o

The fuel areal density and hot-spot ion temperature determine cryogenic target performance

Shadowgraph image of a cryogenic DT target (~100-μm-thick layer)



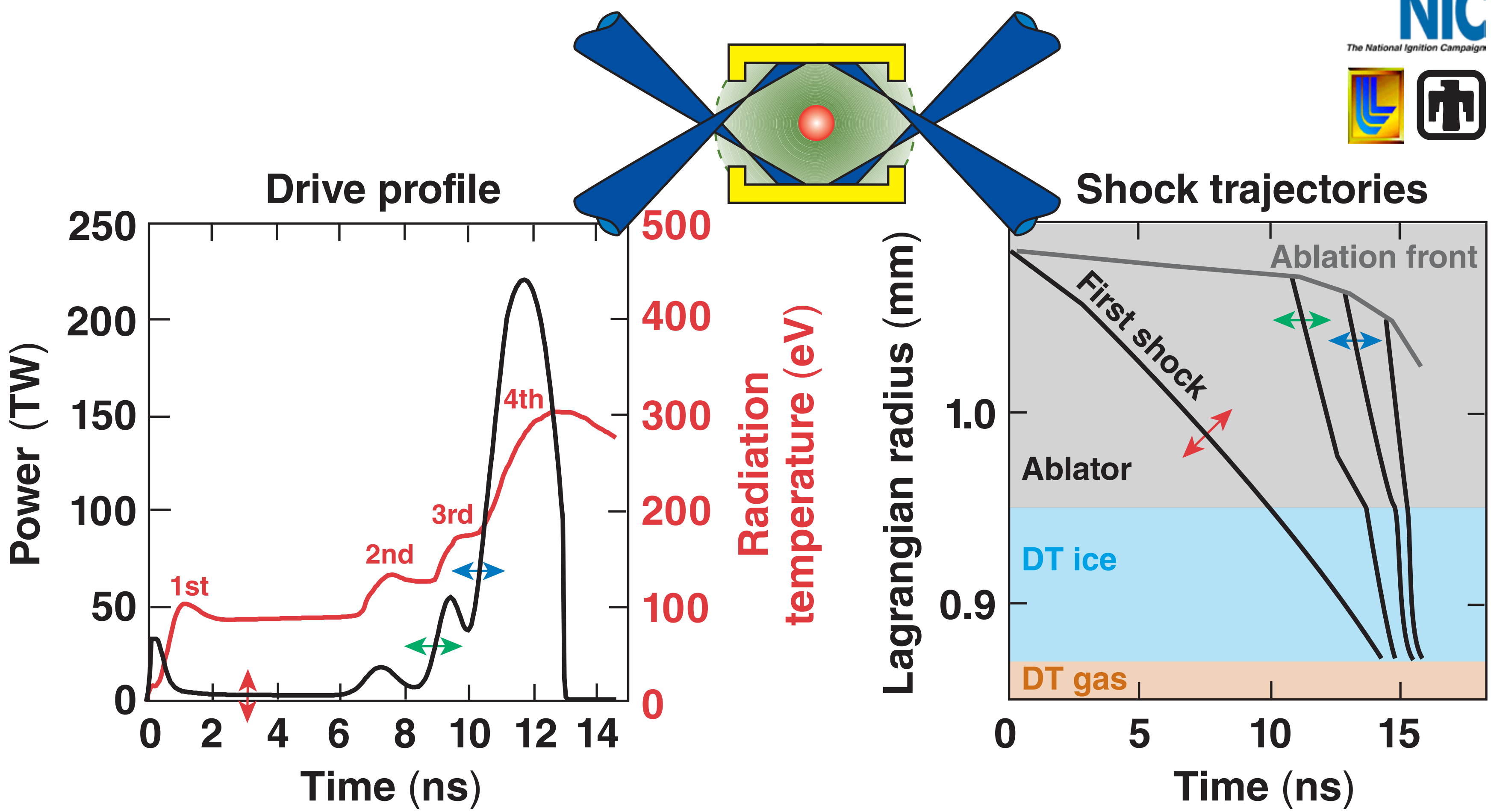
Ice-surface roughness: 0.47-μm rms in a single view

- Areal density (ρR)
  - shock timing and strength
  - preheat
  - compressibility
  - hydrodynamic instabilities
- Ion temperature (T_i)
  - implosion velocity
  - hydrodynamic instabilities
  - absorption/drive coupling

Our strategy is to first increase ρR and then T_i

I1776

Indirect-drive-ignition capsules use four shocks to achieve ignition

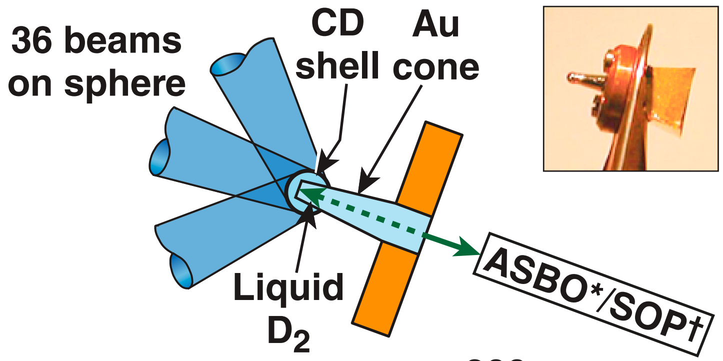


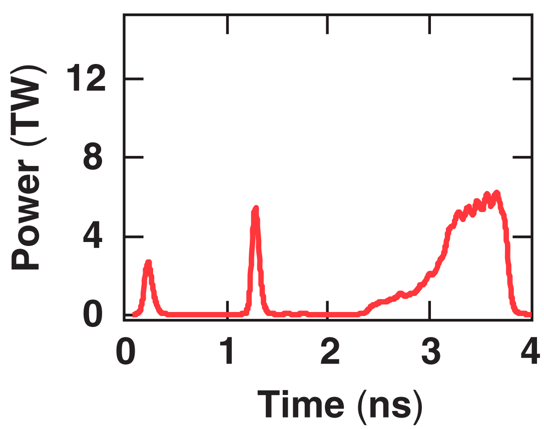
- First three shocks ±50 ps
- Fourth shock ±100 ps

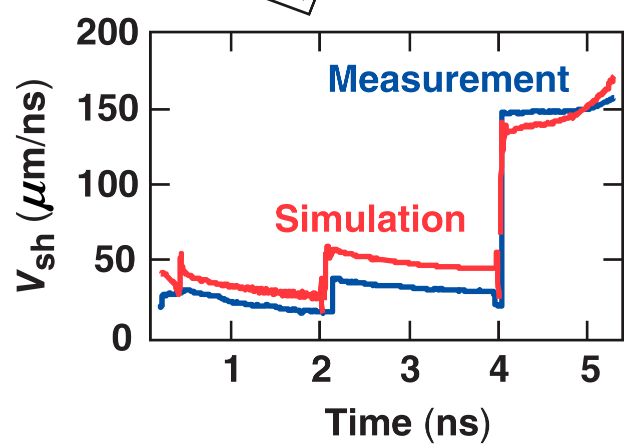
E14087a

A multiple-shock-wave target design makes accurate timing possible

- A technique to time multiple shock waves was developed (National Ignition Campaign)







- Indirect-drive target designs use multiple shock waves‡
- We are moving to a four-shock (triple-picket) design

* P. Celliers *et al*., Rev. Sci. Instrum. 75, 4916 (2004).
† J. Oertel *et al*., Rev. Sci. Instrum. 70, 803 (1999).
‡ S. Haan *et al*., Fusion. Sci. Tech. 49, 553 (2006).

A recent cryogenic DT implosion (65-μm ice) produced a yield of ~6 × 10^{12} and an areal density of ~200 mg/cm^2

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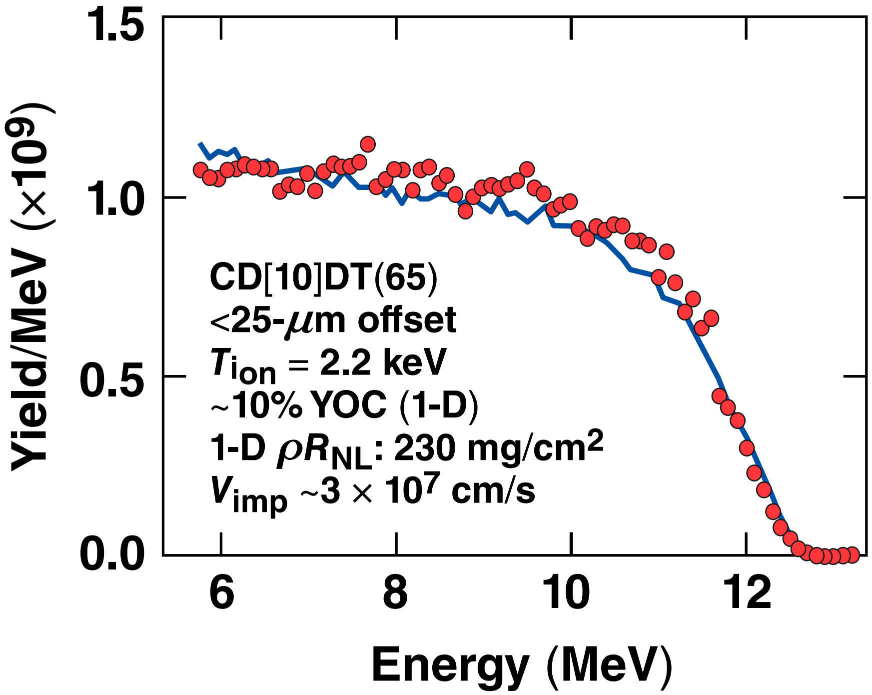
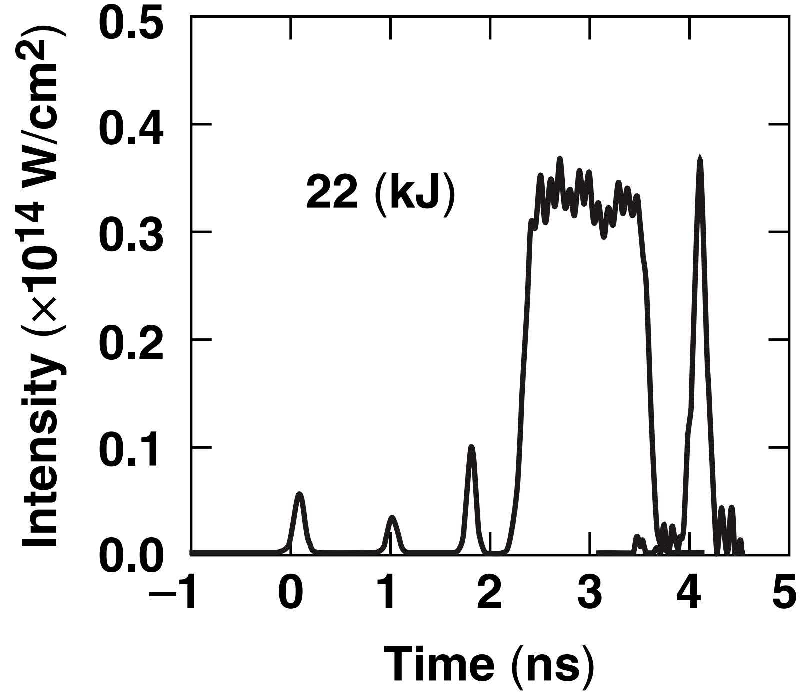
KO-D data from the MRS gives 200±20 mg/cm^2



Triple-picket drive* pulse with neutron burn history



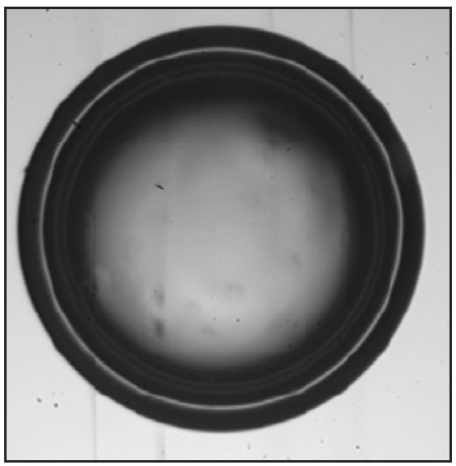
E17451a

*V. N. Goncharov (TO5.00006)

Ignition requires smooth cryogenic DT targets

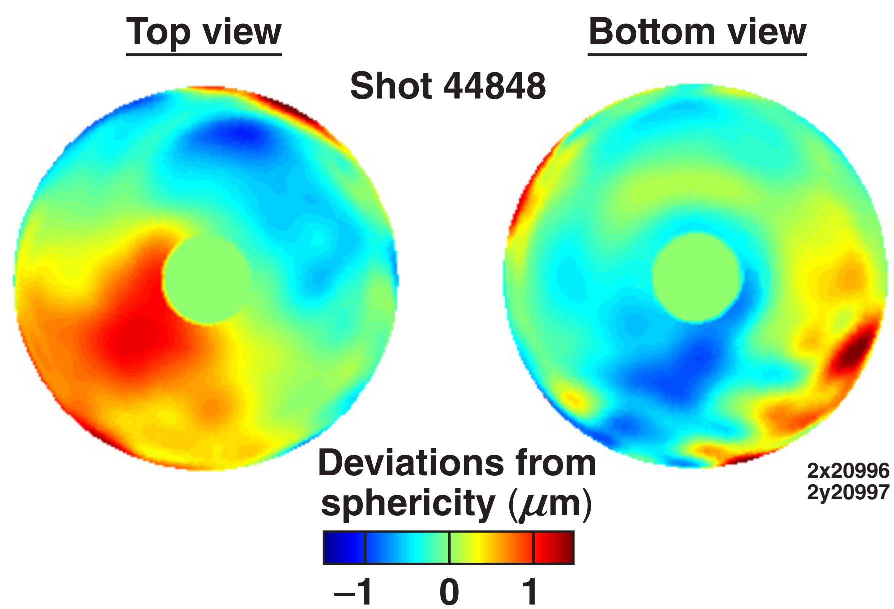
- Thick (>50 μm) DT-ice layers are required for ignition.
- β-layered 50:50 DT cryogenic targets have measured ice-roughness nonuniformities <1-μm rms, meeting ignition specifications.

Shadowgraph image of a cryogenic DT target (~100-μm-thick layer)



Ice-surface roughness: 0.47-μm rms in a single view

Ice-surface reconstruction showing 0.72-μm rms (48 views)



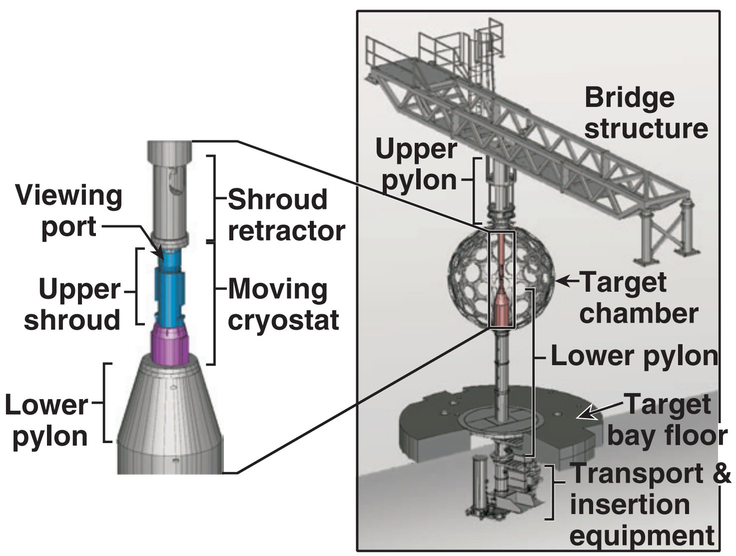
~80% of the DT cryogenic ice layers have sub-μm roughness.

I1740f

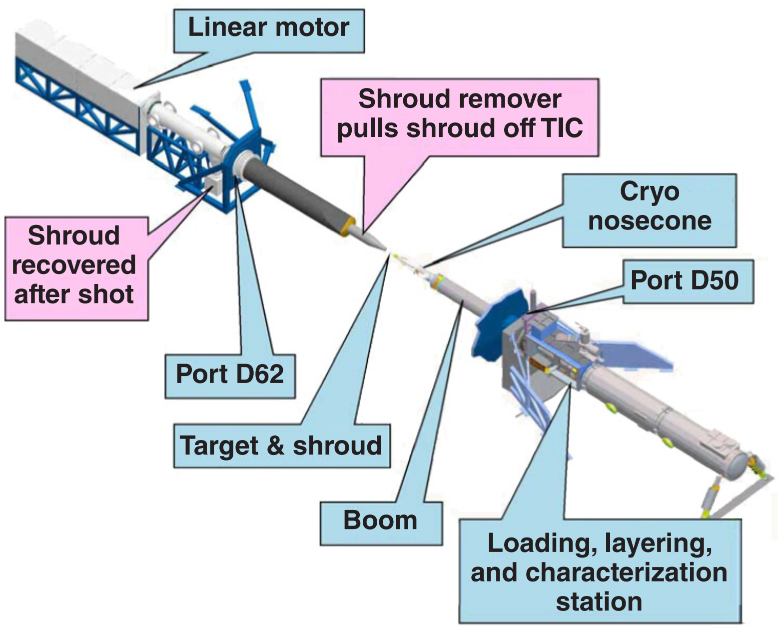
LLE has lead the development of cryogenic target systems that are required for ignition

- The OMEGA Cryogenic Target Handling System was completed as an engineering prototype for the NIF
  - over 200 cryogenic targets shot
  - DT introduced in 2006
- LLE's cryogenic system experience supports the NIF cryogenic target system

LLE



NIF



I1739c

The NIC hohlraum energetics campaign investigates key areas of target physics for the NIF ignition design

- Laser-beam smoothing with multicone geometry
  - phase plates
  - polarization smoothing (PS)
  - smoothing by spectral dispersion (SSD)
- Laser-to-x-ray energy coupling
  - cone-dependent laser scattering losses (SRS, SBS)
  - radiation temperatures
  - hohlraum wall materials (e.g., Au, Au/U)
- Implosion symmetry
  - inner-cone beam propagation
  - beam-to-beam energy transfer
  - beam bending
- Suprathermal electron generation (hot electrons)
  - preheat of ignition capsule
  - sources (two plasmon decay, SRS)
  - mitigation techniques
  - LEH liners

NIC experiments on OMEGA are dynamic and well diagnosed.

ρR diagnostics are being developed for high performance cryogenic DT implosions

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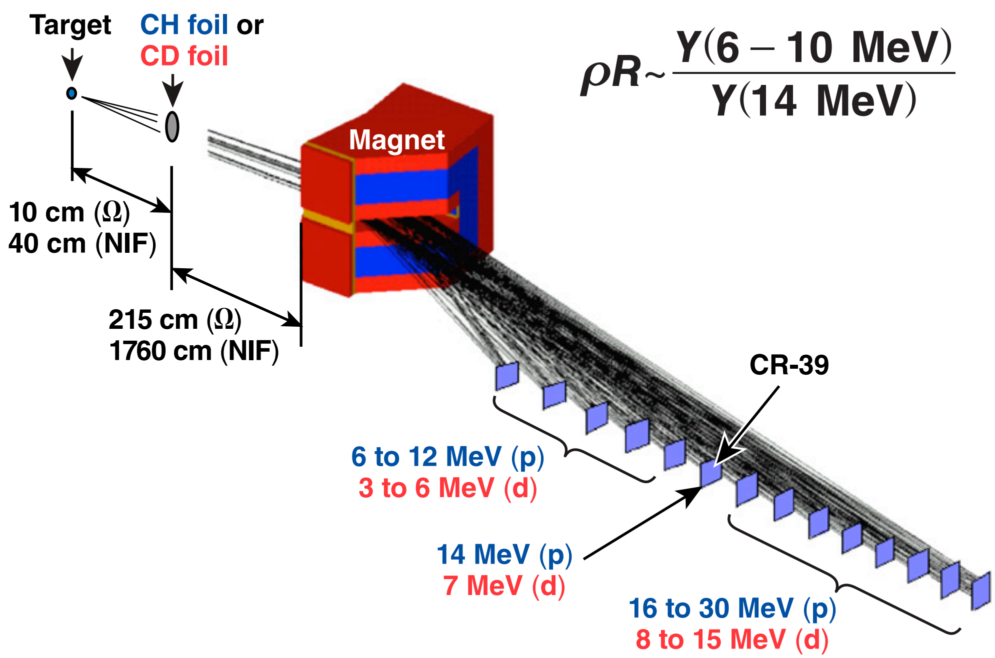
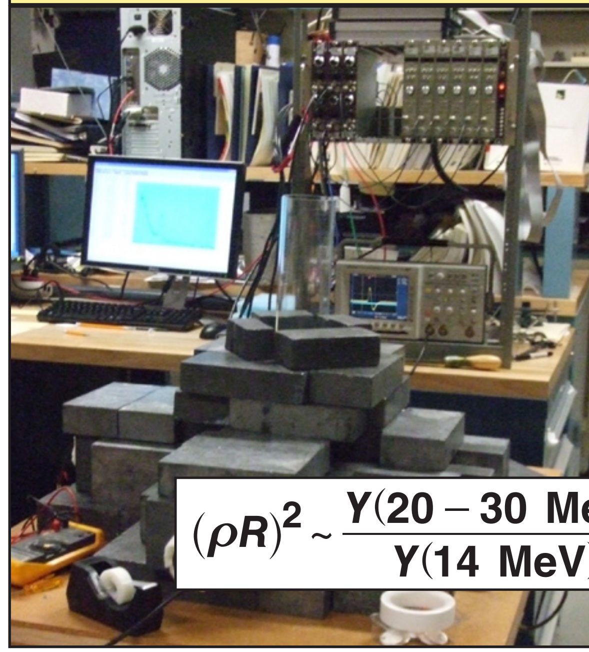
MIT

Magnetic Recoil Spectrometer (MRS)



$$\rho R \sim \frac{Y(6-10\ \text{MeV})}{Y(14\ \text{MeV})}$$

Multi-Channel Carbon Counting System (MC3)



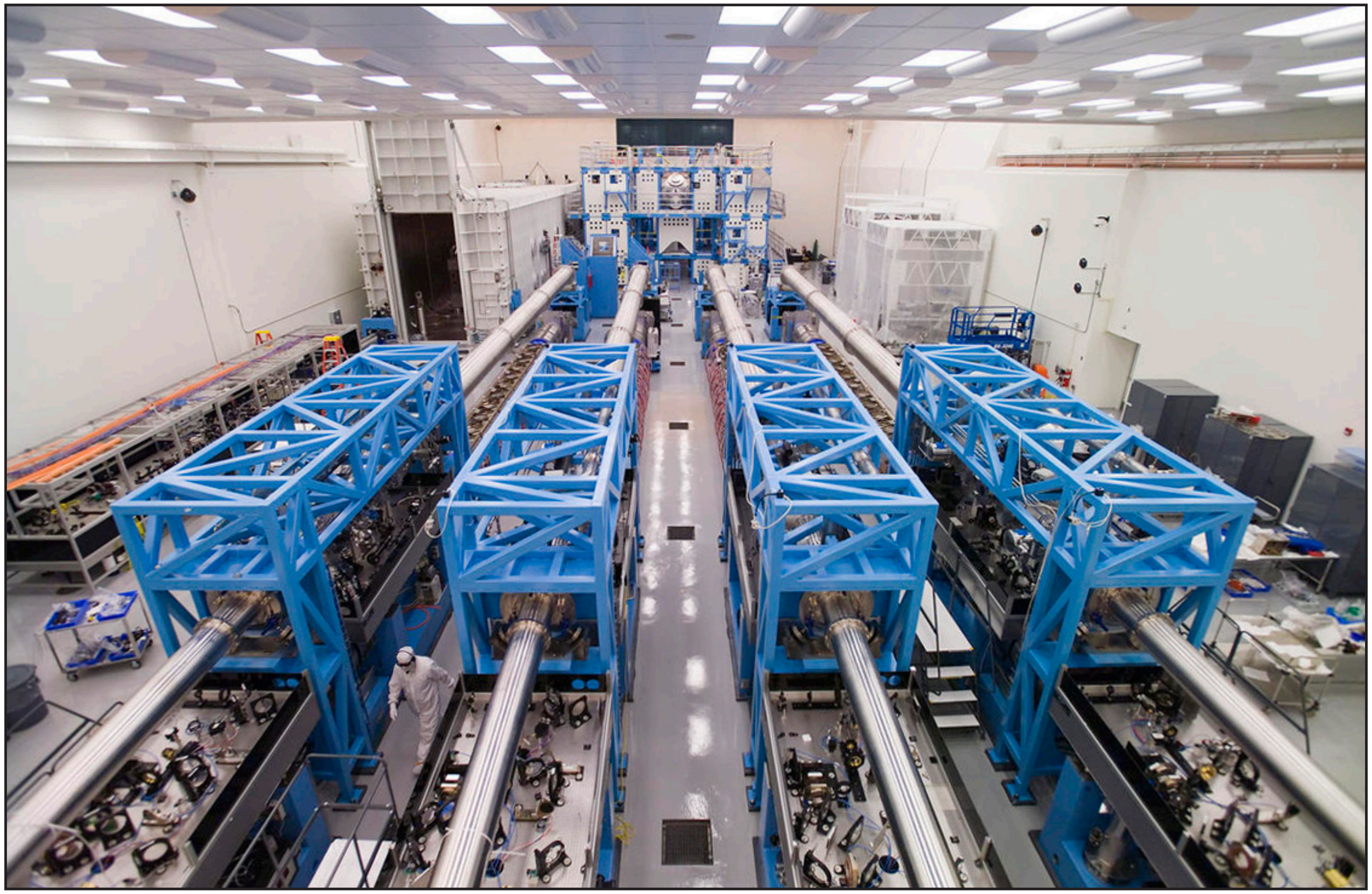
$$(\rho R)^2 \sim \frac{Y(20-30\ \text{MeV})}{Y(14\ \text{MeV})}$$

Both techniques require cryogenic DT yields in excess of 10^{12} to infer areal densities to ~10% (so thinner ice and higher V_{imp}).

J. A. Frenje (UO3.00003); D. T. Casey (YP6.00012).

E14482d

OMEGA EP was completed on 25 April 2008—on schedule and on budget



OMEGA EP significantly advances NNSA's User Facility capabilities.

G8272

The OMEGA EP system was dedicated 16 May 2008

NNSA Administrator D'Agostino speaking

Seated from left to right:
Representative Reynolds,
Senator Schumer,
Representative Kuhl,
and LLE Director McCrory

Senator Schumer speaking

Seated from left to right:
University of Rochester President Seligman,
Representative Reynolds,
LLE Director McCrory,
Representative Kuhl,
and NNSA Administrator D'Agostino

The OMEGA EP Laser System will provide backlighting of cryogenic implosions and tests of the fast-ignition concept

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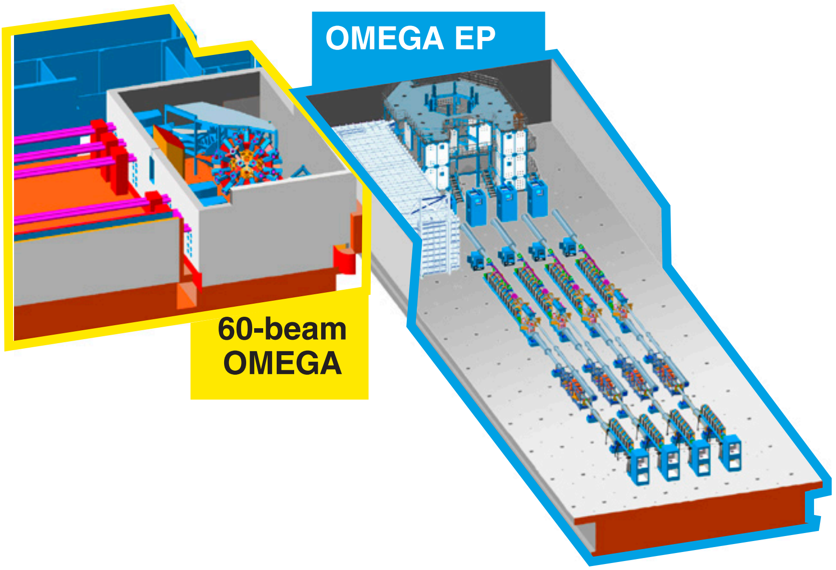
OMEGA EP (2008)



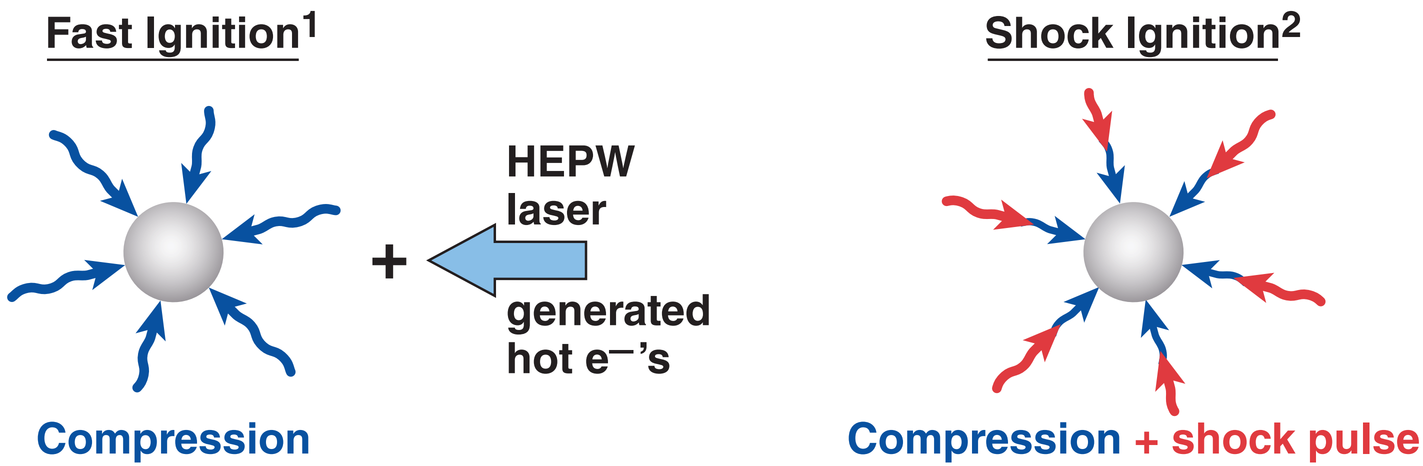
2 HEPW beamlines
2.6 kJ_{IR} each in 10 ps

- The OMEGA EP Laser System was completed 25 April 2008
- The performance of the system is being ramped to design goals
- On 16 September, OMEGA EP produced >1.4 kJ in a single 10-ps beam
- This is 2× higher energy than any other short-pulse laser has ever produced

Integrated OMEGA/OMEGA EP experiments began in October 2008.

New ignition concepts separate compression (ρR) and heating (T_i)—two-step ignition

- In the current hot-spot ignition, the driver provides both compression (ρR) and heating (T_i).
- Both fast ignition and shock ignition use a second drive to provide heating (T_i).



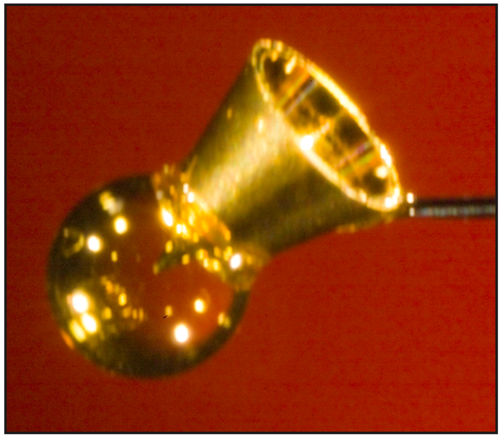
- Measured cryogenic target areal densities are relevant to these schemes.

Two-step ignition offers lower driver energies with the possibility of higher gain.

I1784b

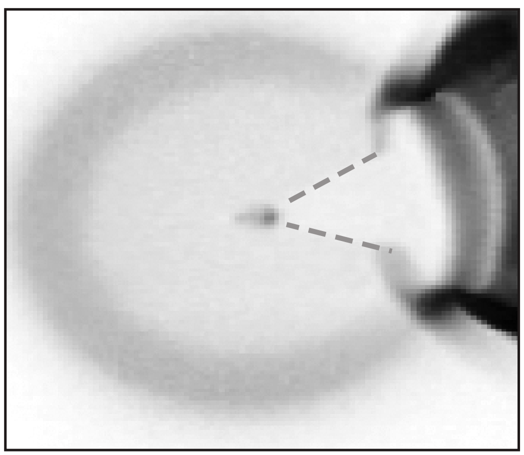
[1]M. Tabak *et al*., Phys. Plasmas 1, 1626 (1994).
[2]R. Betti *et al*., Phys. Rev. Lett. 98, 155001 (2007).

Integrated FI experiments with cone-in-shell targets have started on OMEGA

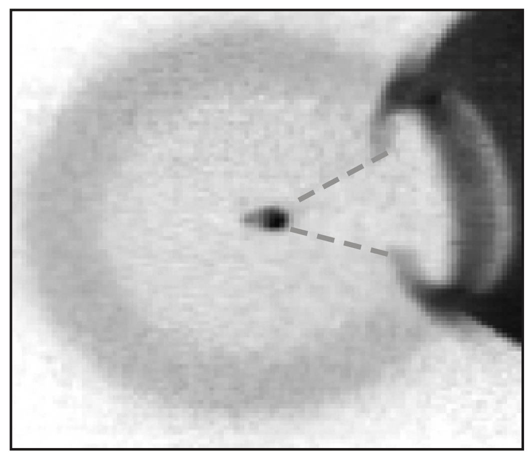


CD shell	~870-μm diam
Driver energy	~18 kJ
Short pulse	~1.3 kJ
Pulse duration	~10 ps
Focus	~40-μm diam

No short pulse



With short pulse



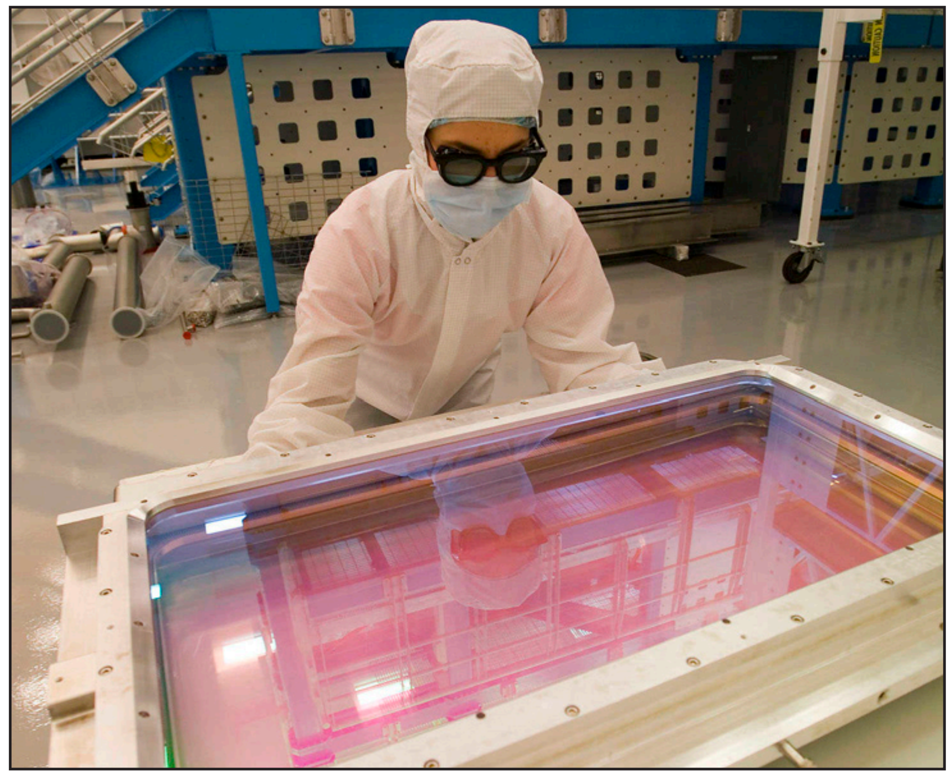
- **The hard x-rays produced by the short-pulse interaction saturate the current neutron detectors.**

E17408

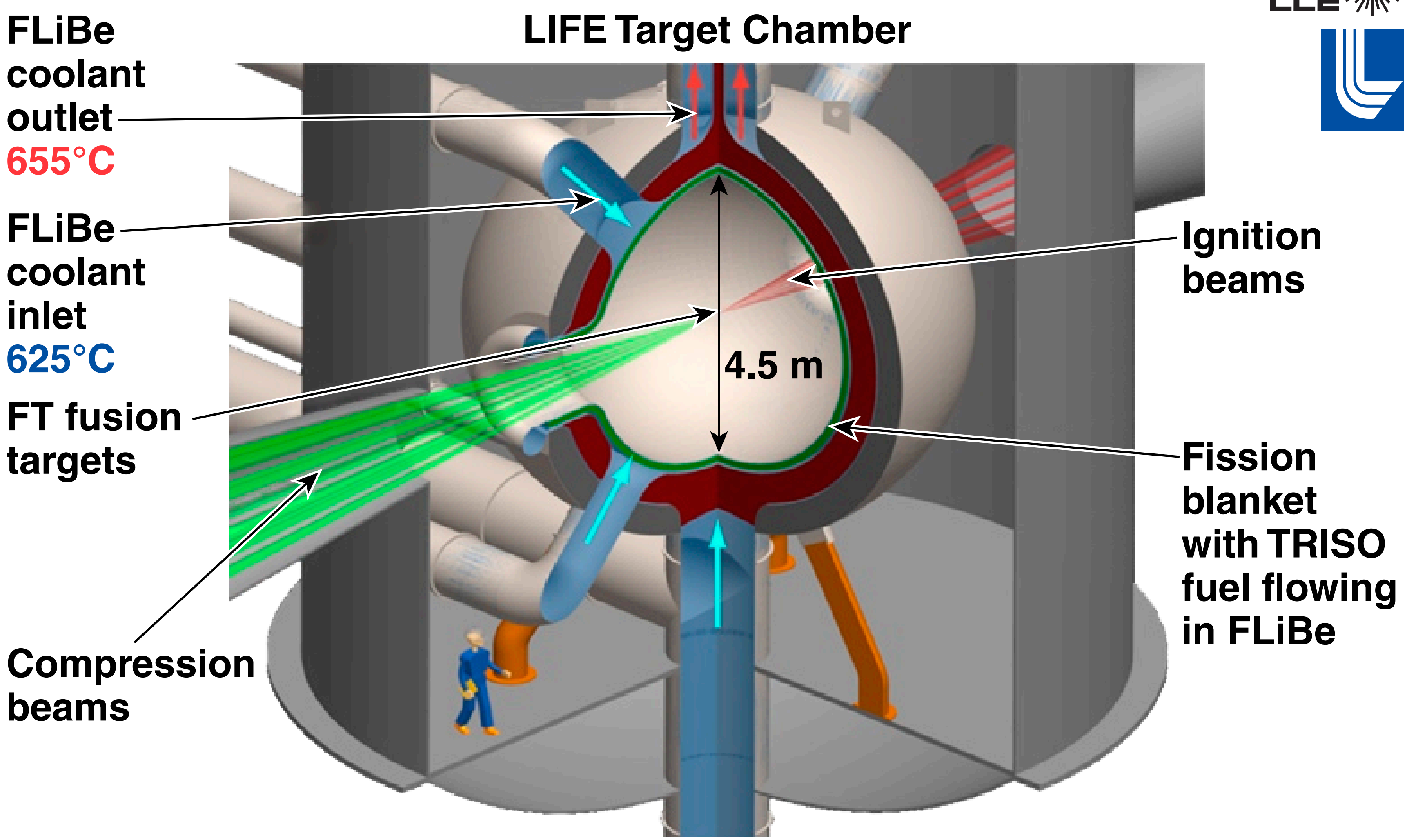
The Optical Manufacturing (OMAN) Group provides high-quality optics for the NIF, OMEGA, OMEGA EP and many others

- Develops and manufactures high laser-damage-threshold optical coatings, liquid-crystal devices, and ion-etched DPP's and diffraction gratings
- Performs metrology, mounts, and replaces optics
- Inspects optics and maintains inventories
- Produces half of the optical coatings for NIF large optics
- Has supplied coatings to many other laboratories in the U.S. and Europe

Cavity polarizer



LLE is a partner with LLNL on the Laser Inertial Fusion-Fission Energy (LIFE) project



~500 MW_{th} of fusion power generates 2000 to 3000 MW_{th} in the fission blanket with a total energy gain of ~200.

U827

Summary/Conclusions

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U826