Advances in High Gain Target Design

Laser IFE Meeting

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Stephen Bodner (NRL consultant),

Denis Colombant, John Gardner, Andrew Schmitt (NRL)

Advances in high gain target design

1 **Review the 1999 direct-drive target design for fusion energy**

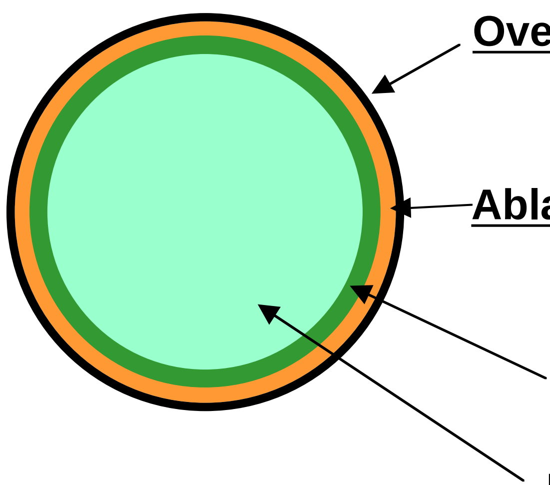
2 **Challenges and Problems**
   - **Partial solutions**

3 **Questions and Uncertainties**
   - **Partial answers**

1999 high gain target design*

First laser fusion target design with <u>both</u> energy gain > 100 and possibly sufficient control of plasma and fluid instabilities.

E_L ~ 1.3 MJ and Gain ~ 127
(*using KrF laser and zooming*)



*** Bodner et al, Phys. Plasmas, 7, 2298 (2000)**

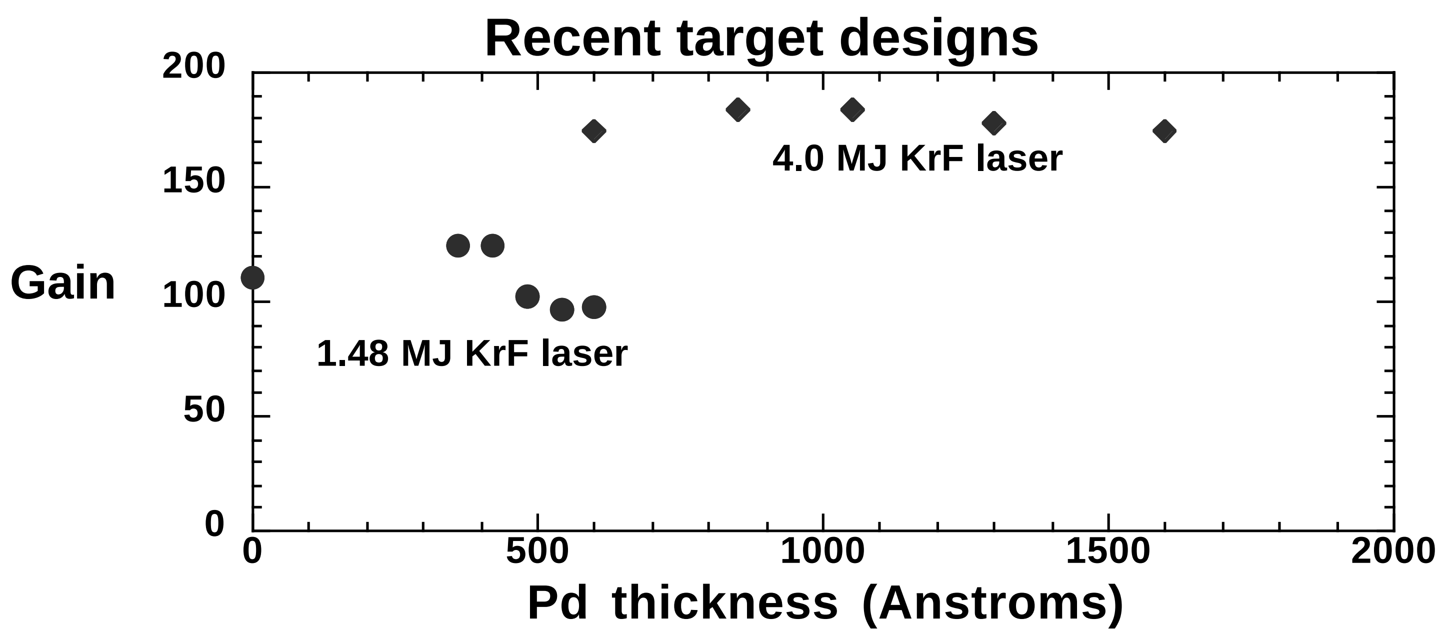
Foam density may be too low to be fabricated

- Foam density can be raised from 10 mg/cc to ~ 100 mg/cc with minor penalty in target performance.

- Pore size and uniformity of foam is critical (need very uniform density for scale lengths > 10 microns). Still need 2D implosion studies for quantitative specifications.

Au overcoat not permeable to DT

- **Changed to Pd overcoat with minor change in target performance.**
- **Pd thickness can be increased to 1000 Å (even higher for higher-laser-energy targets)**



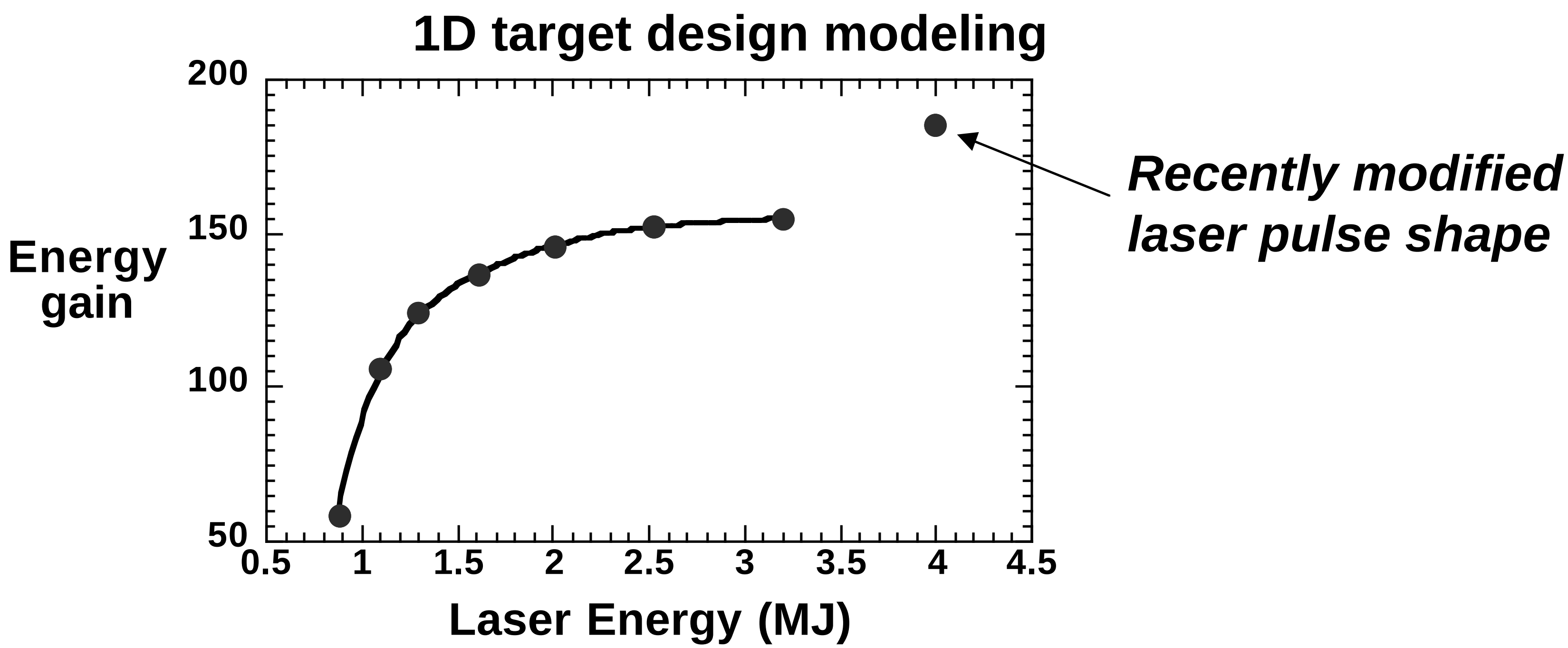
Excessive viscous & IR heating during target injection into the chamber

- **Viscous heating**
  - Must lower gas density in reactor chamber, compared to Sombrero concept.
- **IR heating**
  - Lower chamber wall temperature, or
  - Maintain high IR reflectivity of metal overcoating (cocktail mixture of Pd + … ?)

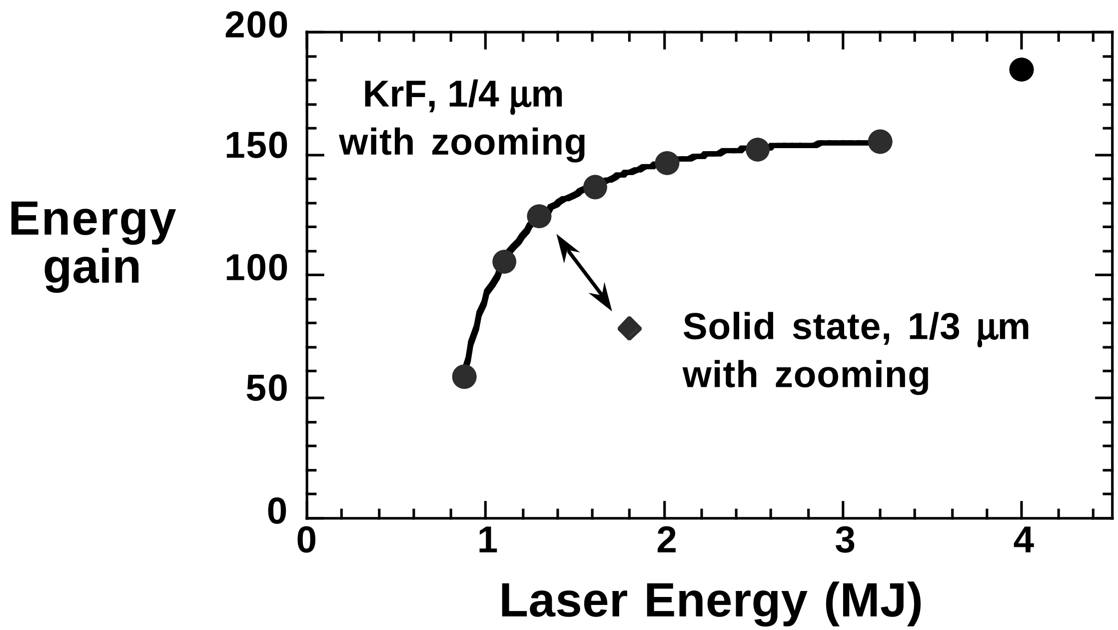
Can N and O be added to the CH foam?

- **Preliminary survey (limited class of target designs) indicates that N and O must be limited to less than a few percent.**

Scaling of target performance with laser energy?

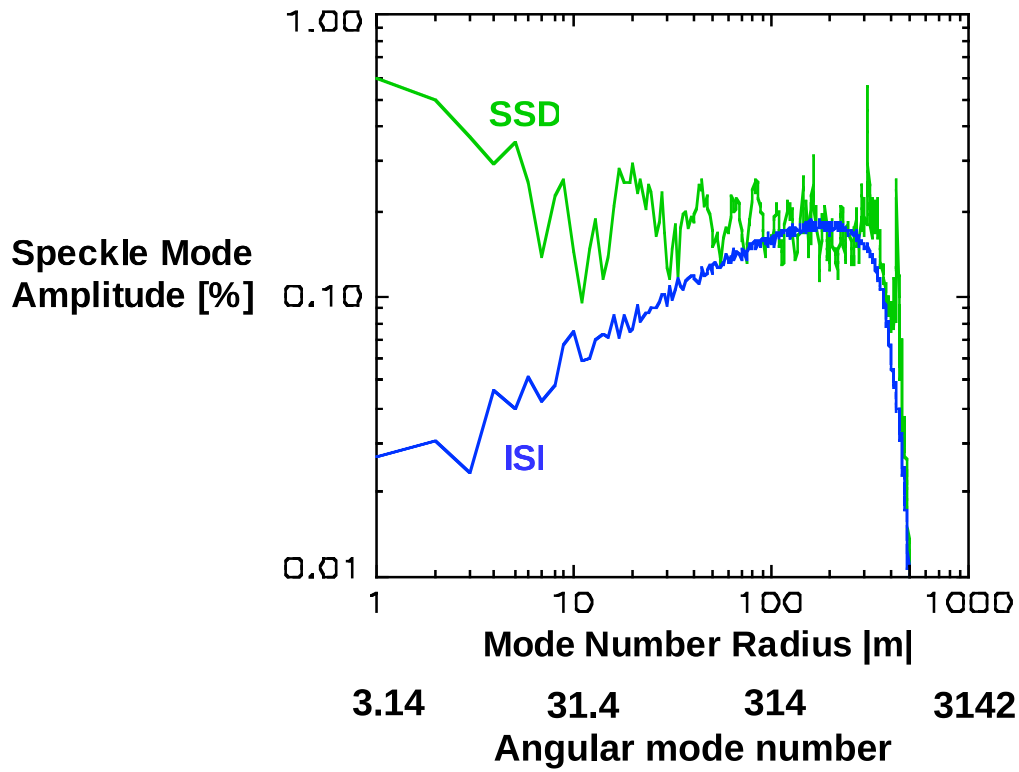


Target performance using solid-state laser light?



Lower target coupling efficiency requires more laser energy, higher laser efficiency, and lower laser capital cost (*than KrF*). Zooming is important; it raises absorption from ~ 65% to ~ 90%.

SSD optical smoothing has a worrisome residual in the intermediate modes



t_{av} = 500 ps, $\Delta\nu$ = 1 THz

SSD angular divergence: $\Delta\theta_x$ = 100 XDL, $\Delta\theta_y$ = 50 XDL + 50 XDL from DPP

Status of 2D & 3D integrated implosion calculations?

- **Simplified modeling, with 2D piggybacking on 1D code, predicted sufficient control of fluid instabilities.**

- **Until recently, <u>no</u> ICF code could simultaneously, calculate 2D implosions with *nonlinear multi-mode* coupling, in the *higher* modes.**

- **New NRL FAST code can reach these goals simultaneously, but is still in preliminary evaluation phase.**

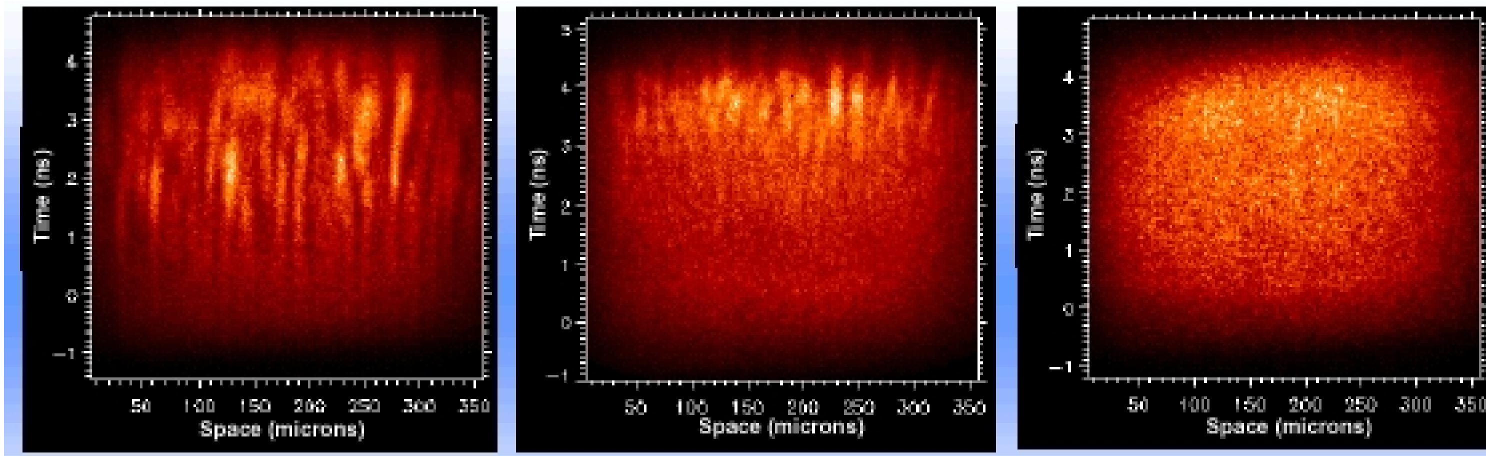
Realistic comparison of design codes with experiment?

- Excellent comparison in many experiments through years between FAST1D, FAST2D, and FAST3D and Nike low-isentrope CH planar acceleration targets.

- Recent Nike experiments with Pd coated-CH again demonstrate that metal coatings provide a significant reduction in laser imprinting. Metal coating probably necessary for robust direct-drive target performance.

- However NRL FAST2D code still incorrectly predicts that a thin metal coating enhances the laser nonuniformities, in contradiction to Nike experiments. Possible reasons for discrepancy still under investigation.

Acceleration of CH/Pd foils using Nike



1 beam foot pulse
Bare CH

40 beam foot pulse
Bare CH

1 beam foot pulse
120-nm Pd layer

Summary

- The IFE target design so far:
  - Robust to the changes needed for fabrication.
  - Near or below threshold for laser-plasma instabilities.
  - Metal overcoat required to control laser-imprinting, and probably required to prevent IR preheating.
  - Major advances in FAST 2D implosion modeling capabilities, but still challenging:
    - modeling the early-time behavior of metal overcoat
    - simultaneous modeling of large spectrum of modes
    - Magnitude of inner surface DT roughness

- Overall, we may have a successful IFE target for a fusion reactor, but it is not yet provable to a reasonable skeptic.