Status of High-Gain Target Designs

presented by:

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including results of:
Denis Colombant, John Gardner, Nathan Metzler, Sasha Velikovich,
J. Perkins, J. Lindl, R. Betti, K. Anderson, etc.

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Outline

What's New?

Foam Target status

- 100 mg/cm^3 outside-foam high-gain design exists in 1D; 2D stability analysis is underway.

Gains are insensitive to initial temperatures below the DT freezing point

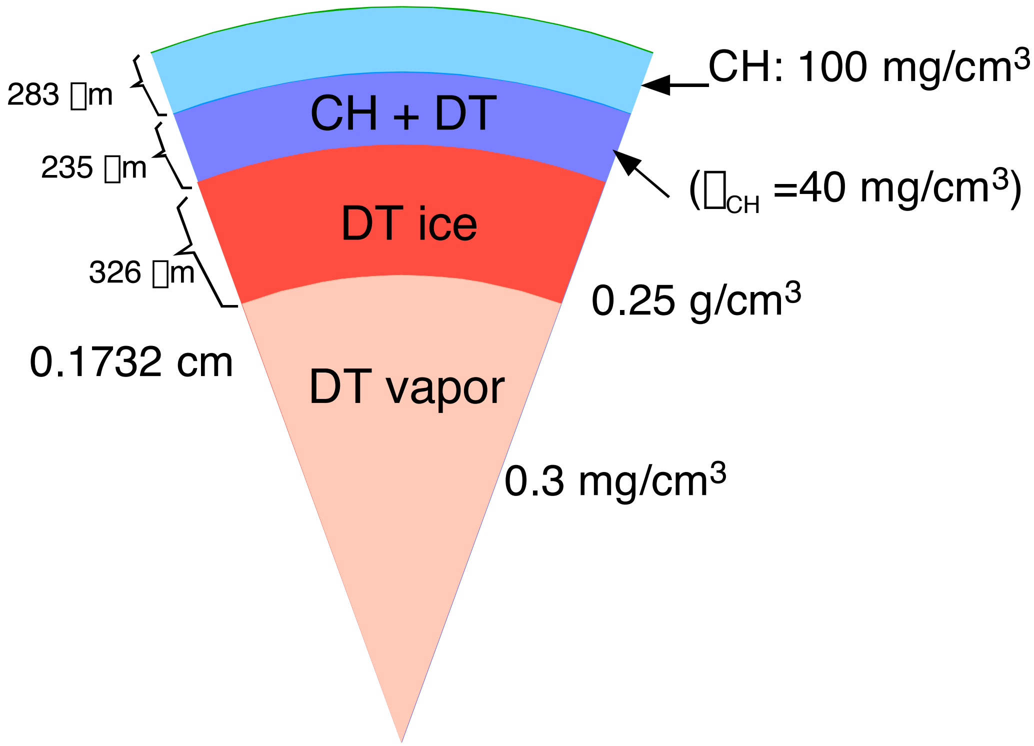
What's the status of target designs?

The high gain KrF pellet of last year remains a "standard" design.

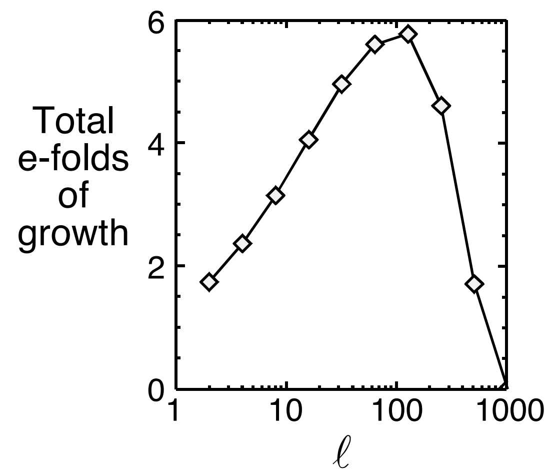
Spikes on laser pulse are becoming quite popular

Wetted foam designs for ablator are also popular

There now exists a high-gain foam design with 100 mg/cc foam (outside) & 2.5MJ KrF



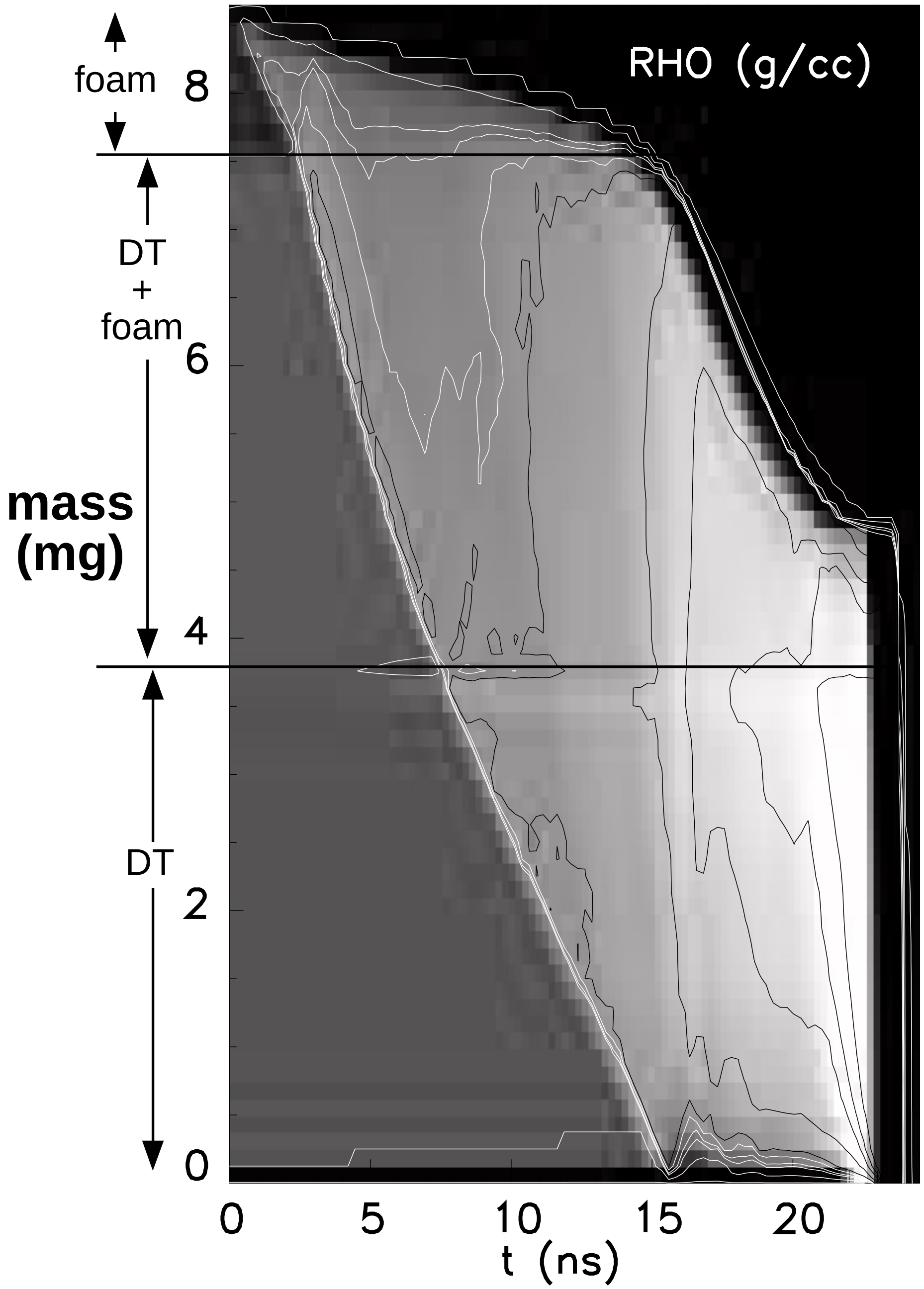
projected RT growth from 1D stability formula



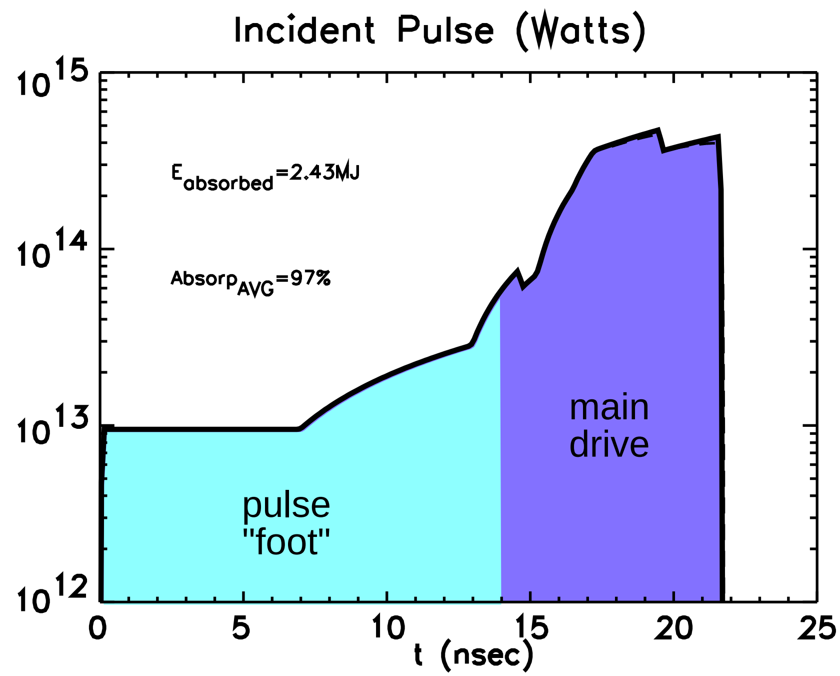
Foam Covered KrF target	
E_{laser}	2.5MJ
Gain	170
η_{eff}	9.6%

Stability is currently untested in 2D simulations, (*testing underway by Perkins @ LLNL*). There is some reason to hope that the foam may help the stability of the pellet, [*Bodner et al., Phys. Plasmas* **5**, *1901 (1998).*] if the interface RM instability can be avoided.

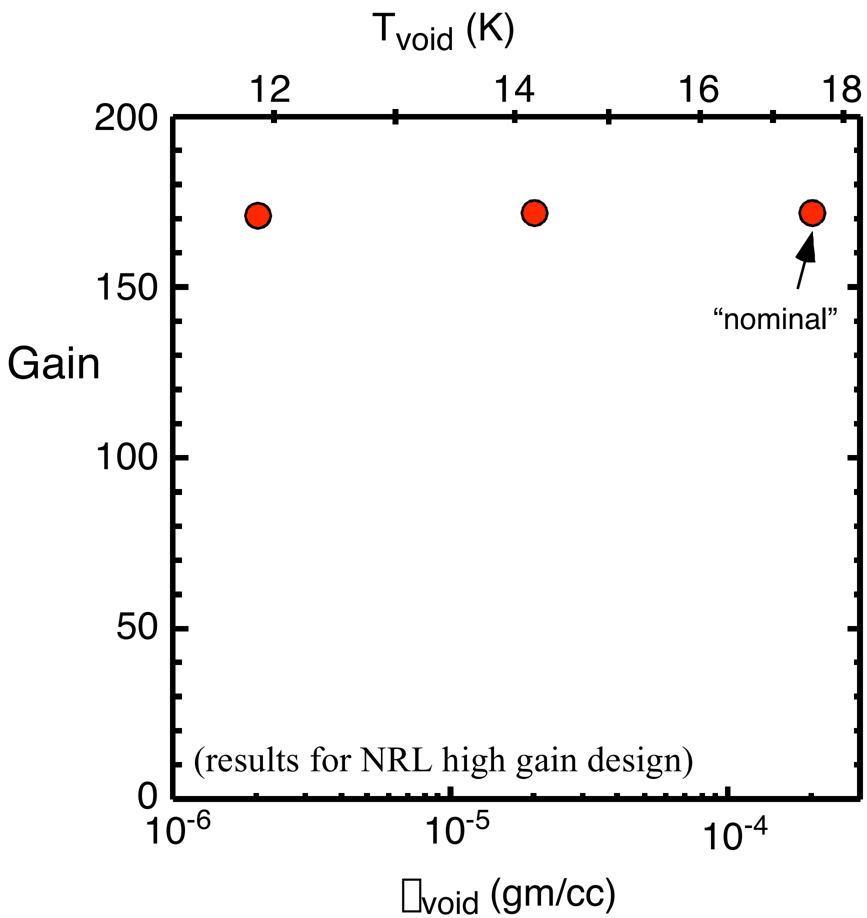
The foam layer mostly ablates off before the main pulse arrives



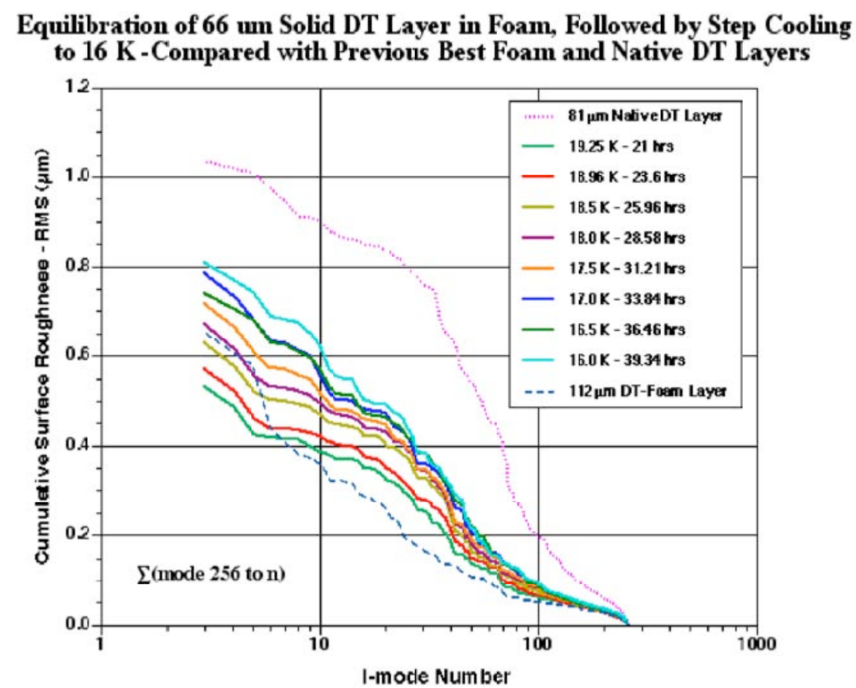
... so the foam does not significantly degrade the hydro efficiency (~9.9%)



The gain is insensitive to the initial DT vapor pressure (starting temperature)



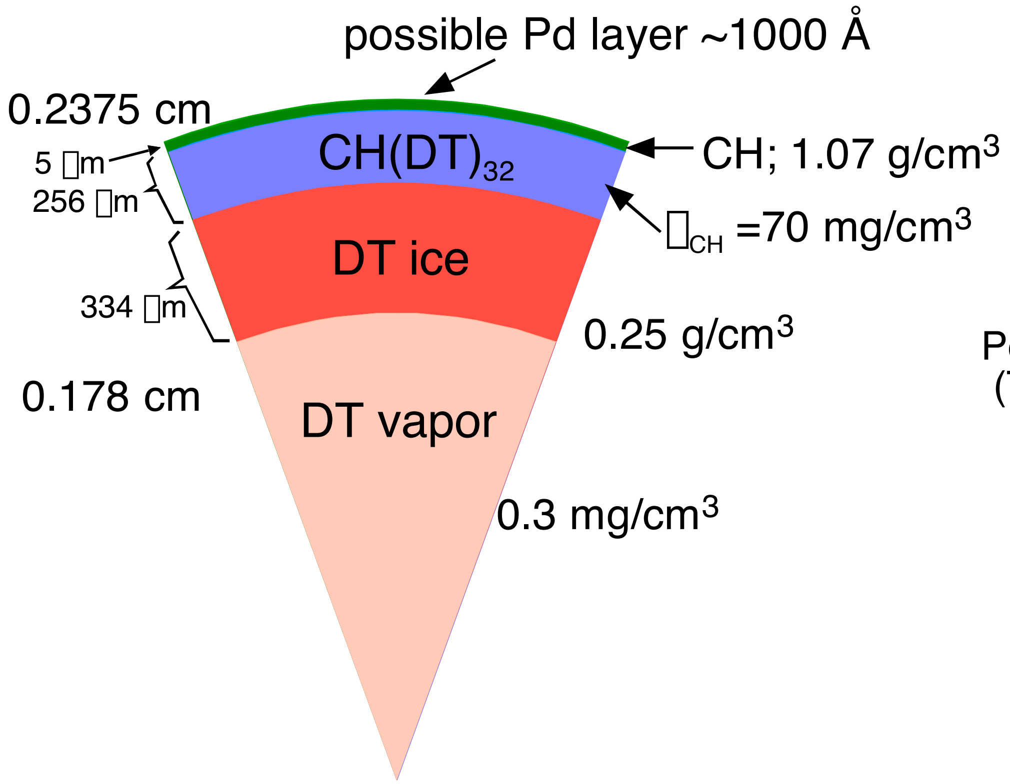
and the projected inner surface
is reasonable at lower temperatures (?)

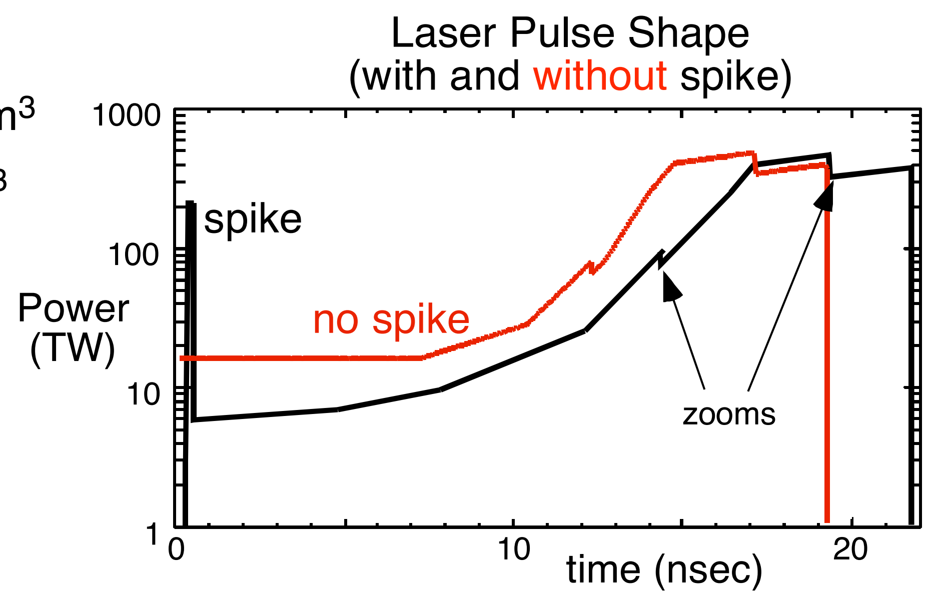


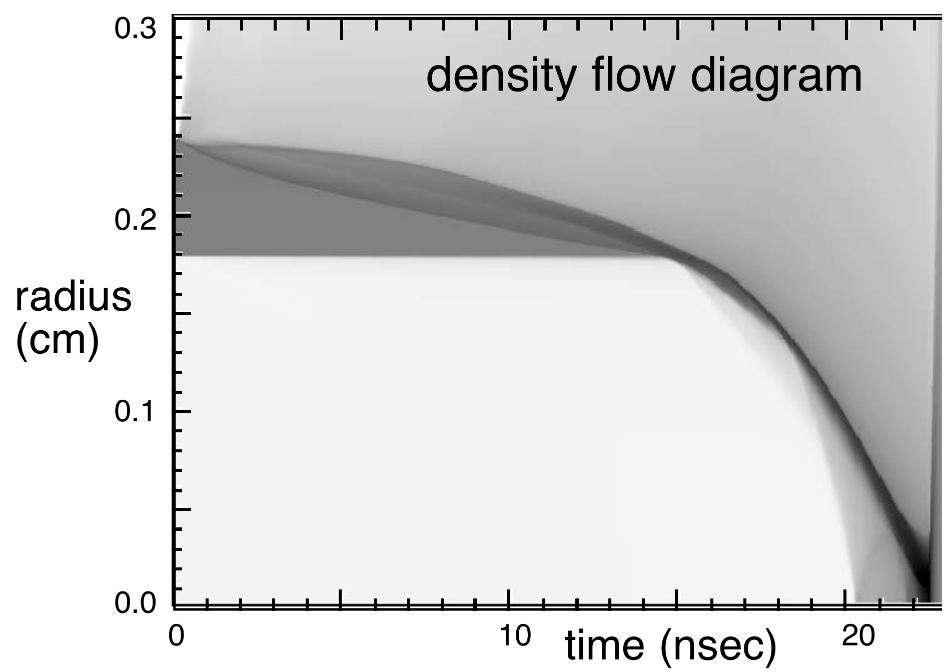
(stolen from J. Hoffer)

... do we *need* the foam outer ablator?

High gain target uses KrF laser with zooming and optional "spike" prepulse



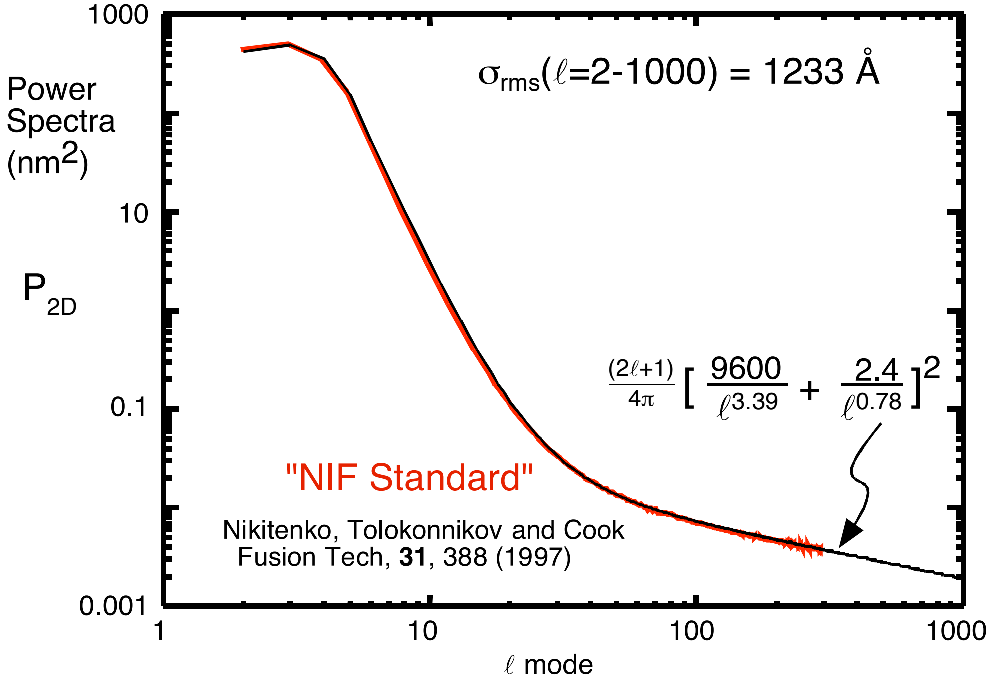




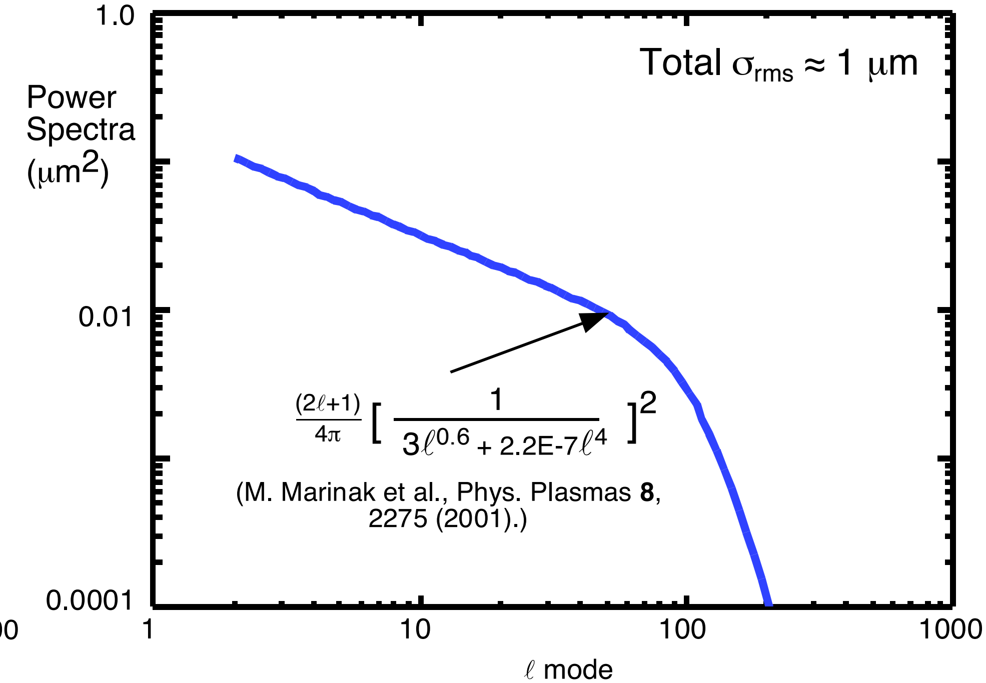
High Gain KrF target	
E_{laser}	2.6 MJ
Gain	150-170
Margin:	52%

“Standard NIF surface finish” spectra is used in the simulations

Outer Surface finish



Inner Surface finish



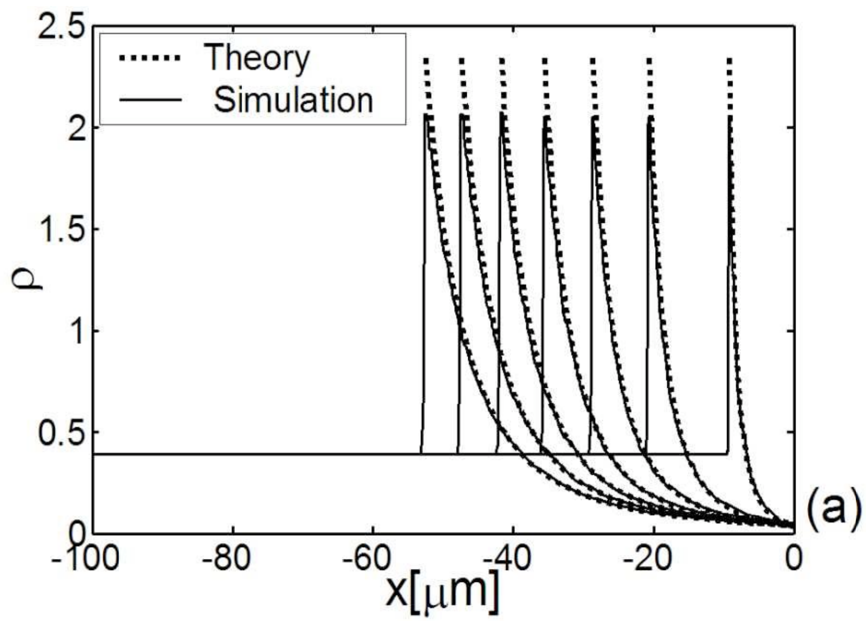
Other sources of nonuniformity:

- Imprint from optically smoothed laser
- Low-mode contributions from beam geometry, misalignment, and power imbalance

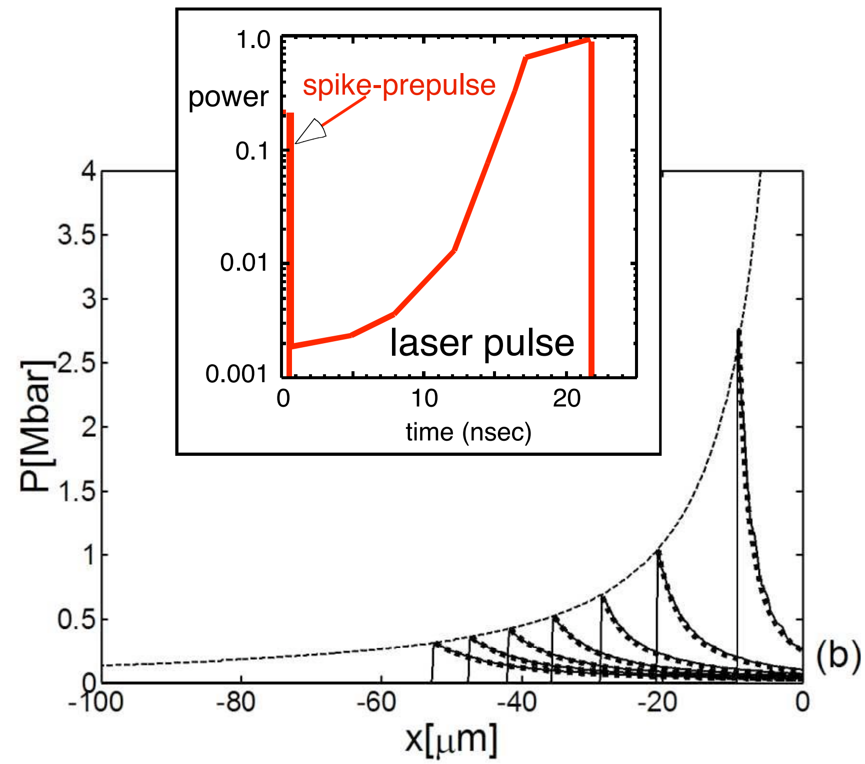
A spiked prepulse can be used to control instability during compression (early drive) and acceleration (late drive)

NRL

The spike drives a decaying shock through the pellet. The rarefaction behind it gives a density gradient that decreases imprint and surface growth (*Velikovich et al., Phys. Plasmas* ***10****, 3270 (2003)*.)



density at successive times after spike prepulse

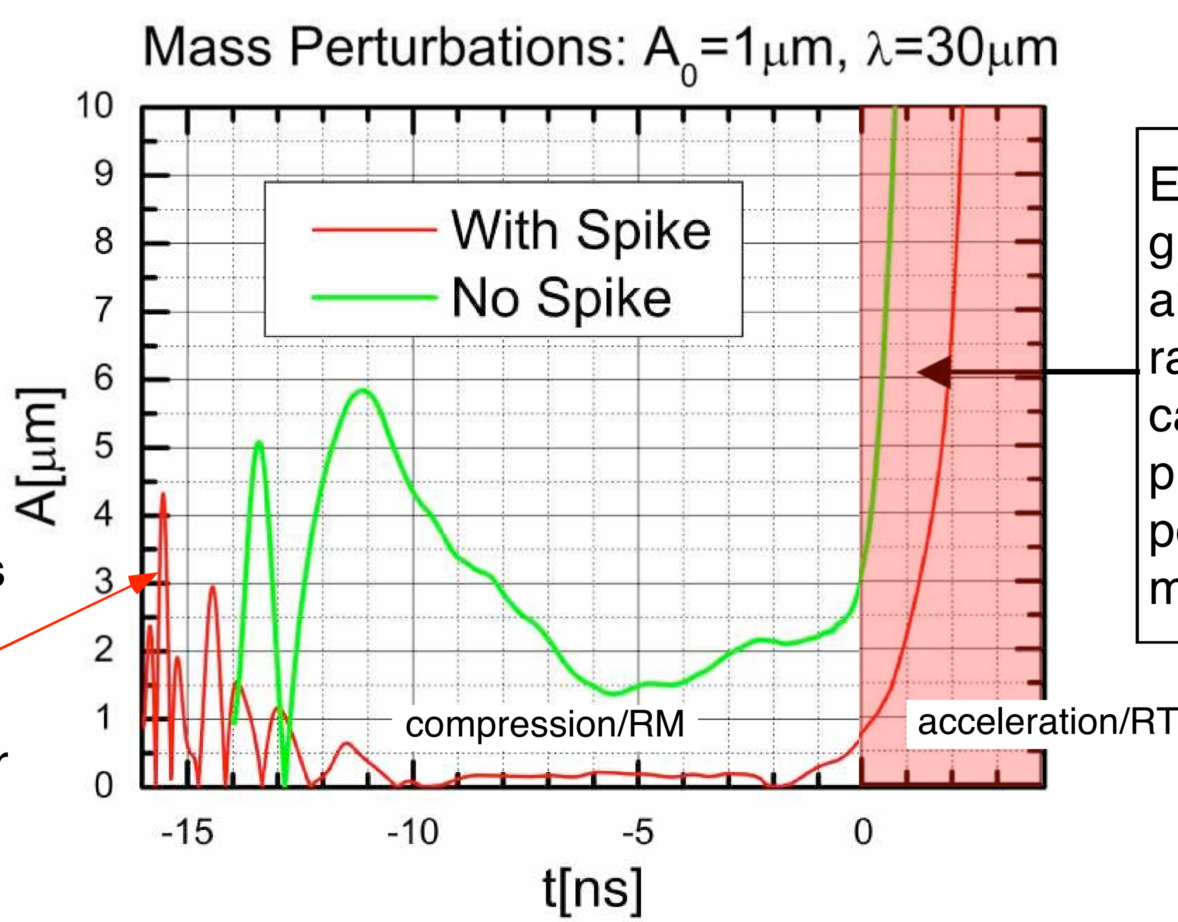


pressure at successive times after spike prepulse

If the rarefaction wave is significantly shocked again, the ablation velocity will increase during the main drive, and RT growth rates are decreased.

Laser pulse spike: imprint mitigation

When the spike is relatively “small”, and subsequent shocking during the foot of the pulse is mild, the spike primarily acts during the pellet compression phase.
The spike can then decrease the growth of the surface perturbations / laser imprint, but the RT growth (and gain) during the main pulse is unaffected.
(*This is how the spike works in the NRL high-gain target*)



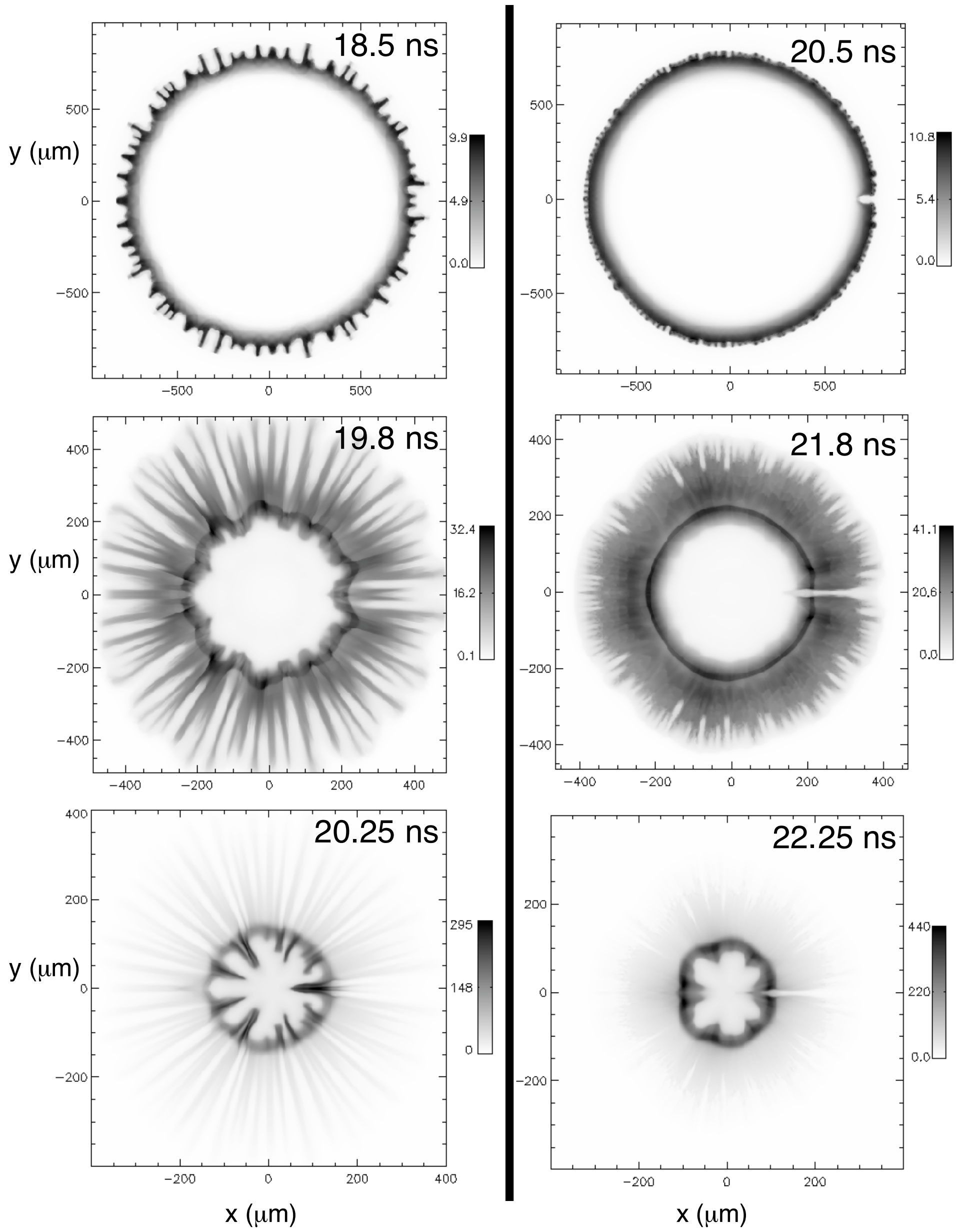
Spike oscillations reach almost the same peak amplitude (~4x) but have a higher frequency and decay faster

Exponential RT growth occurs at about the same rate in both cases. The spike-produced perturbations are much smaller

(c.f. N. Metzer, A. Velikovich, et al., Phys Plasmas **10**, 1897(2003).

The result of the spike is that the perturbations at stagnation are smaller, and the gain is much larger

Without a spike
Gain = 0.5

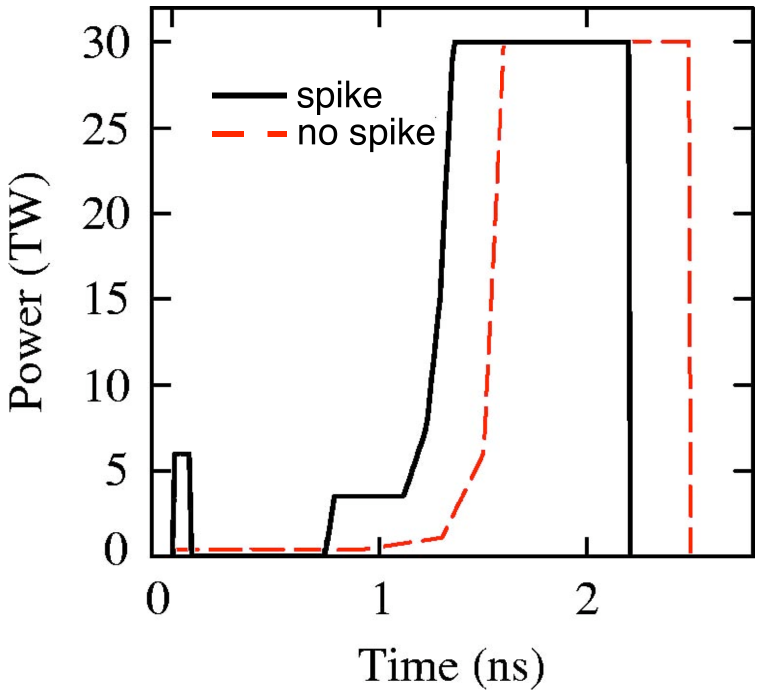


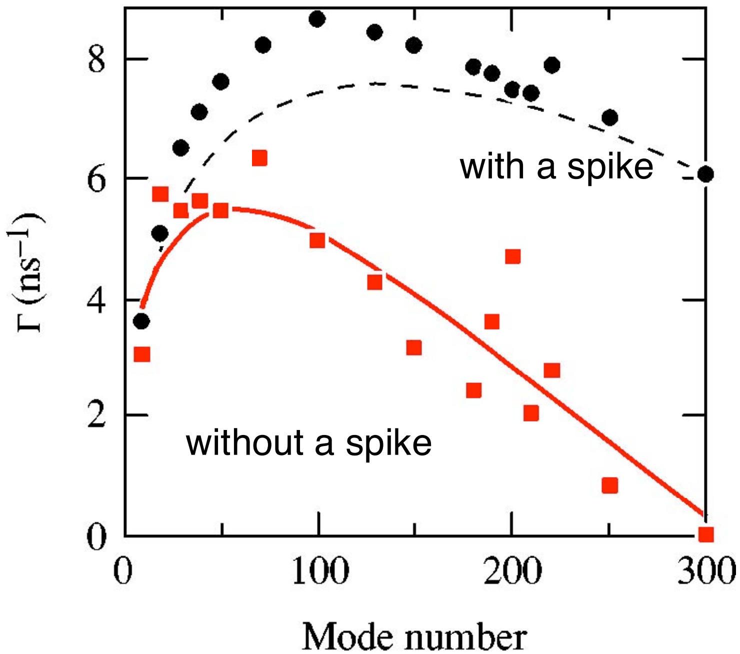
With a spike
Gain = 160

In both cases:
"NIF standard" inner (1μm) and outer (0.125μm) surface finishes;
1THz optically smoothed light

If the spike is large enough (or otherwise properly configured) the explosive RT growth is decreased

Figures stolen directly from:
K. Anderson & R. Betti
Phys. Plasmas 11(1), **5** (2004).

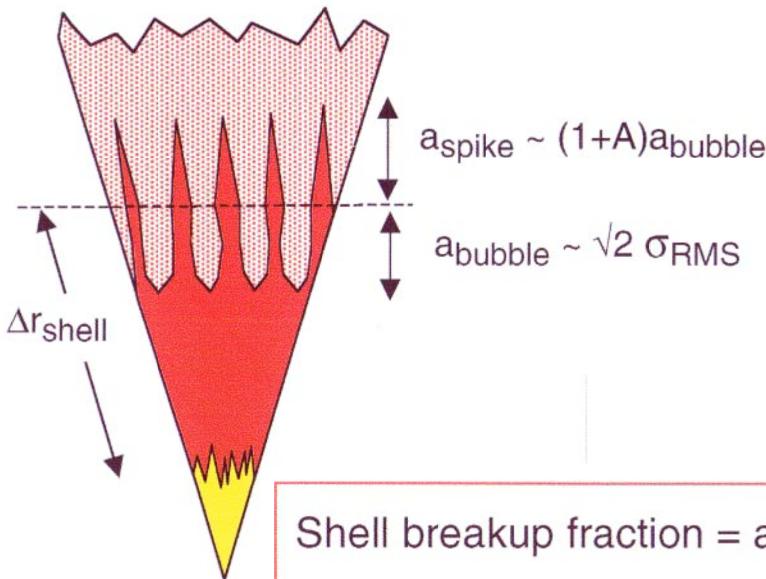


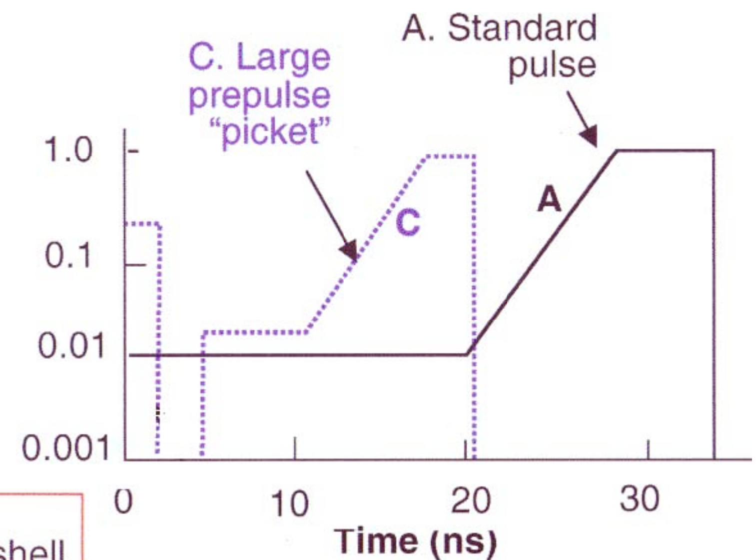


The spike and succeeding pulse can shock the outside ablator enough to raise the ablation velocity during the main drive (acceleration).
Doing so will stabilize the exponential RT growth of perturbations, although care must be taken not to cause a significant gain reduction.

Using spikes for RT suppression offers more flexibility in direct-drive pellet designs.

Resulting Shell Breakup Fraction at Late Time is Modest for the Tailored Adiabat Case





Shell breakup fraction = $a_{bubble} / \Delta r_{shell}$

(Require $\leq 30\%$)

Pulse Shape	Laser (MJ)	Yield (MJ)	Gain	Max Shell Breakup Fraction	
				Roughness Only	Roughness + Imprint
A. Standard	2.4	430	180	0.83	1.83
C. Large prepulse (large "picket")	3.1	360	110	0.015	0.15

slide from John Perkins, LLNL

Summary

Foam Target status
- 100 mg/cm^3 outside-foam high-gain design exists in 1D
  2D stability analysis and "threat" spectrum analysis is underway.
  (is it important to match interior/exterior foam density?)

Gains insensitive to initial temperatures (what does this say about foam?)

Target designs status

The high gain KrF pellet of last year remains a "standard" design.
Understanding its performance characteristics and improving the simulation accuracy is a top priority

Spikes on laser pulse are becoming quite popular because of the flexibility they offer in target design.
- can mitigate initial (relatively mild) imprint-type growth, with minimal gain degradation
- can mitigate later (relatively strong) Rayleigh-Taylor growth, with some gain degradation

Wetted foam designs for ablator also popular.
- high absorption & hydro efficiency

Whatever happened to thin high-Z layers on outside of pellet?
- (We still like them. And, they appear to be compatible with all these concepts.)