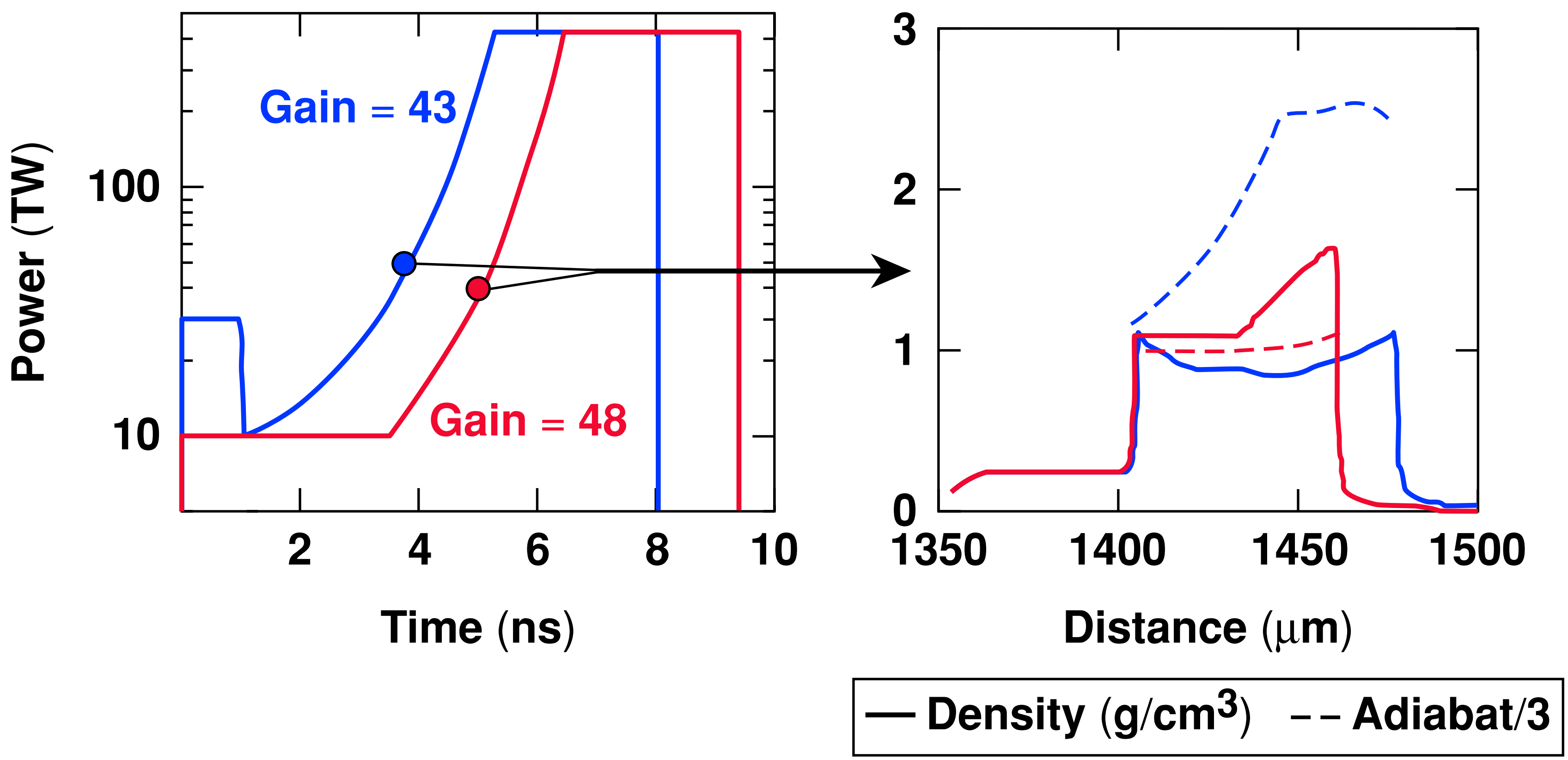
Optimization of Direct-Drive Target Designs for the NIF



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Summary

A model has been developed to optimize NIF DD target designs

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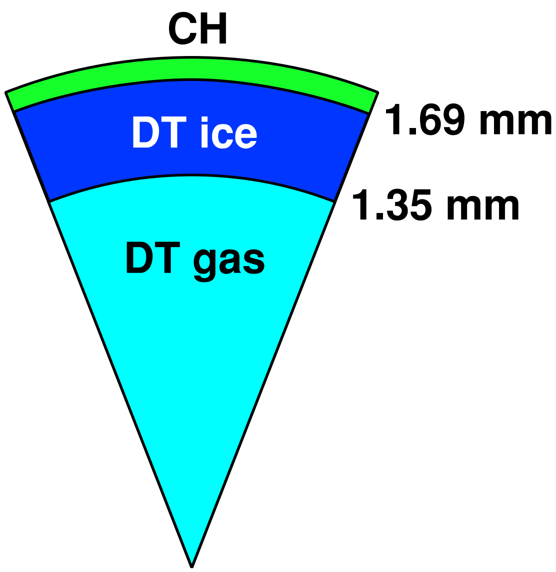
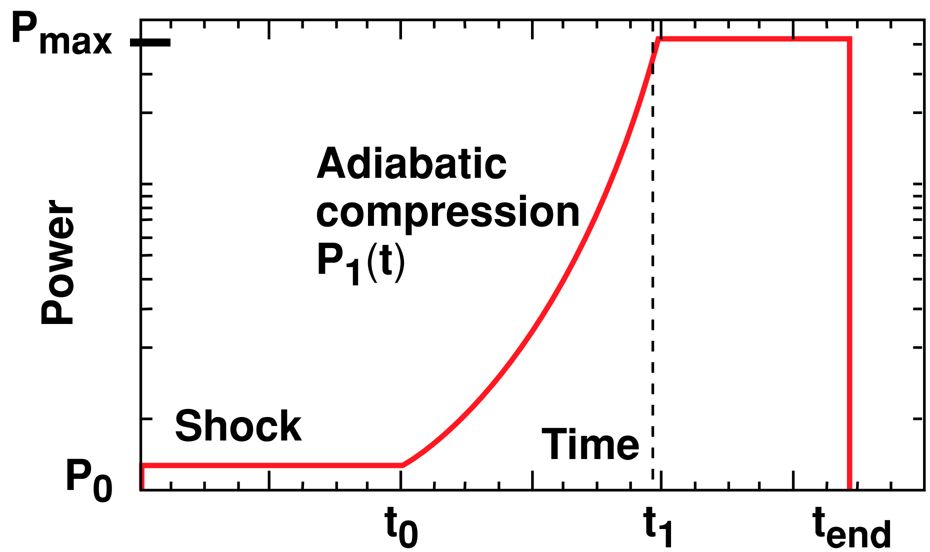
- A model has been developed to optimize target gain.
  - The model uses results of a stability postprocessor to calculate shell integrity during the acceleration phase and mode spectrum at shell stagnation.
  - Target gain is calculated by using the obtained mode spectrum and results of 1-D simulations with reduced implosion velocities.
- The model was applied to predict stability and gains for "all-DT" moderate-gain and high-gain foam target designs.
- The results of the model suggest that the maximum gain for the "all-DT" targets can be achieved for $\alpha = 3$ to $\alpha = 4$ designs.

The model consists of three main steps

Step	**Instability seeding**	**Acceleration, coasting, and deceleration phases**	**Target gain**
Physical phenomena	**Imprinting, RMI, feedout**	**Ablative RTI, Bell-Plesset instability**	**Burn-wave propagation**
Calculated by	**Analytic theory, *ORCHID* simulations**	**Stability postprocessor**	**1-D simulations with reduced implosion velocity**

"All-DT" DD NIF targets driven on adiabat up to 7 were considered





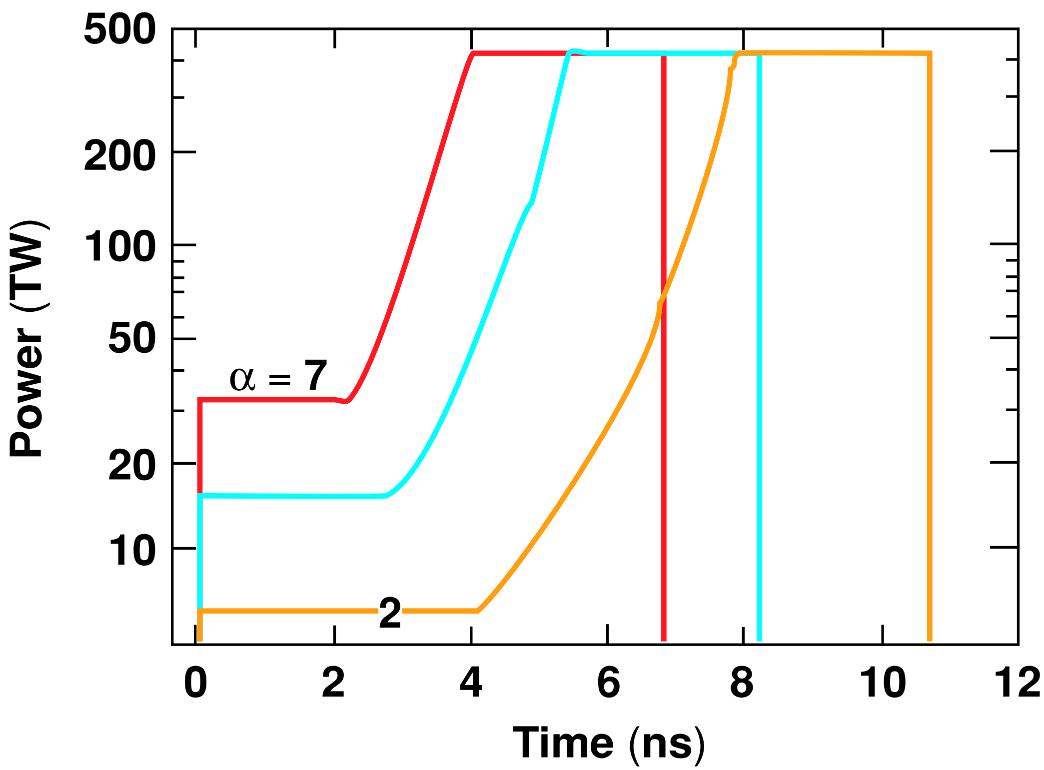
Pressure $p_{kidder} = \dfrac{p_0}{\left[1-(t/\tau)^2\right]^{5/2}}$

Power $P_1 = \dfrac{P_0}{\left[1-(t/\tau)^2\right]^4}$

Parameter	Determined by
P_0	Shell adiabat
P_{max}	Damage threshold, shell stability
t_0	Timing of compression wave and first shock
t_1	Target gain
t_{end}	Laser energy

TC5632

"All-DT" DD NIF targets driven on adiabat up to 7 were considered (continued)



α	ρR_{peak} (g/cm^2)	V_{imp} ($\times 10^7$ cm/s)	Gain
2	1.5	4.17	55
3	1.3	4.27	48
4	1.2	4.34	41
5	1.1	4.42	29
6	1.0	4.42	22
7	0.9	4.45	9

A stability postprocessor[1] was applied to study perturbation evolution of imploding targets during the acceleration, coasting, and deceleration phases

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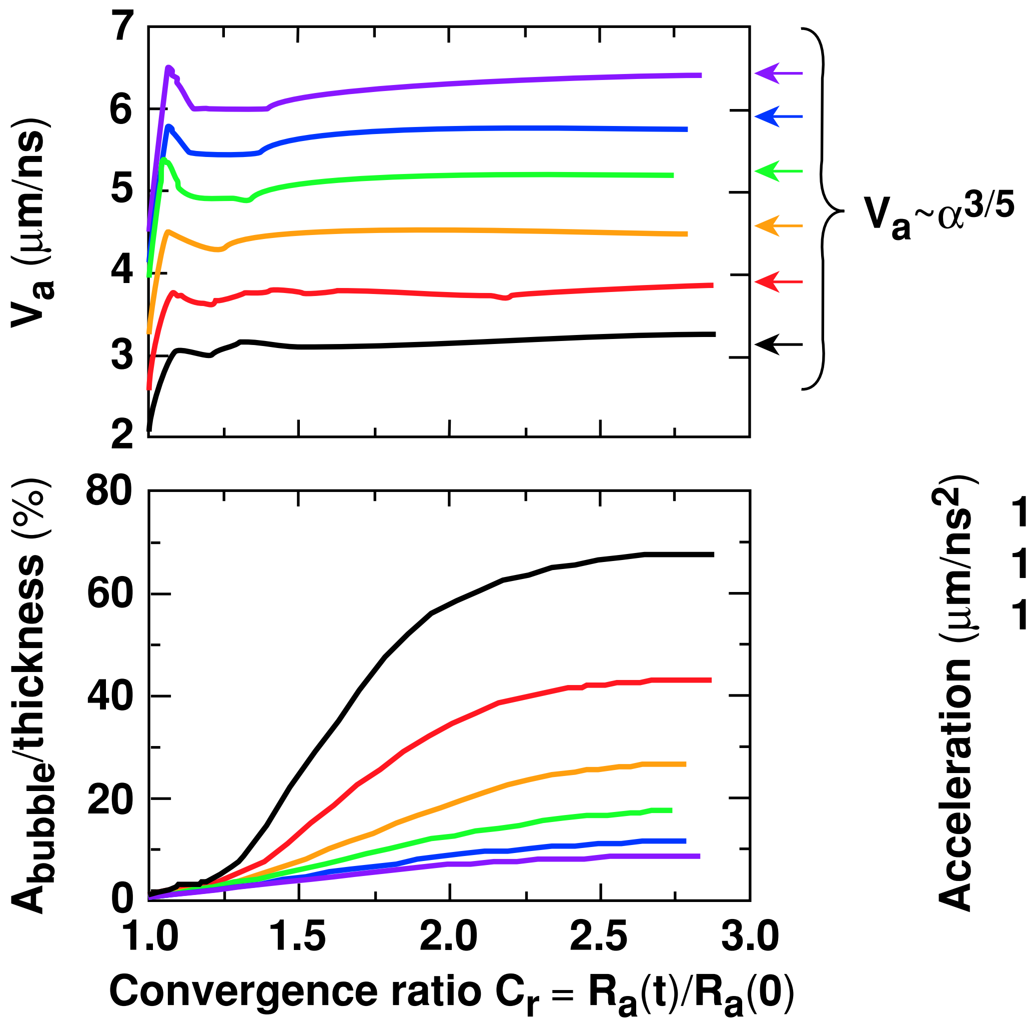
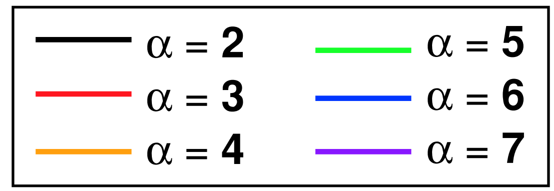
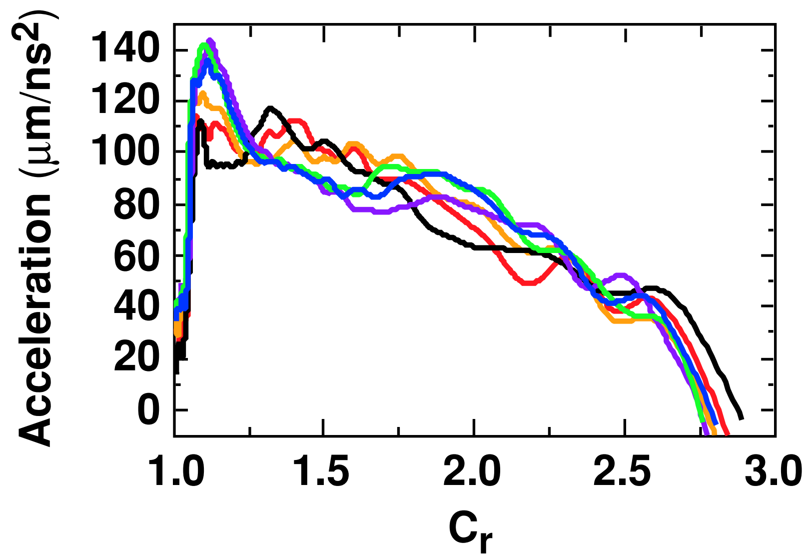




$$GF_{\text{classical}} \sim e^{\sqrt{2\ell}\,\text{arc sin}\,\sqrt{1-C_r^{-1}}}$$

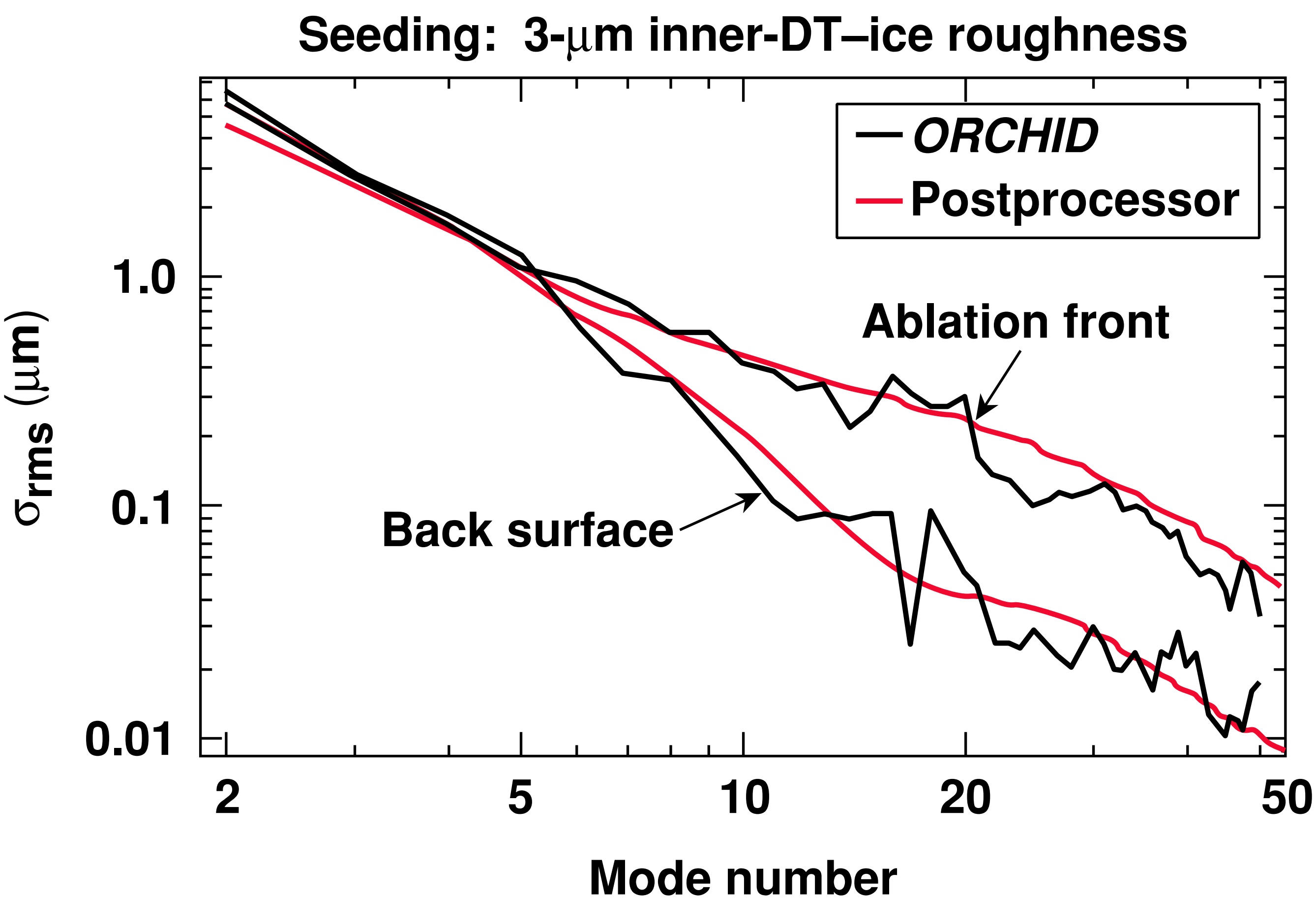


TC5634

[1]V. Goncharov *et al.*, Phys. Plasmas 7, 5118 (2000).

Result of the model was compared against *ORCHID* simulations

- **End of acceleration phase**



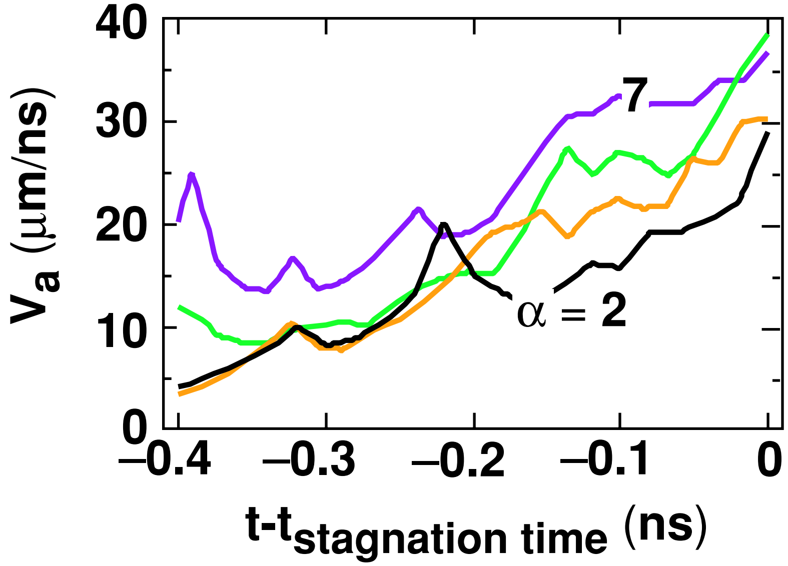
TC5757

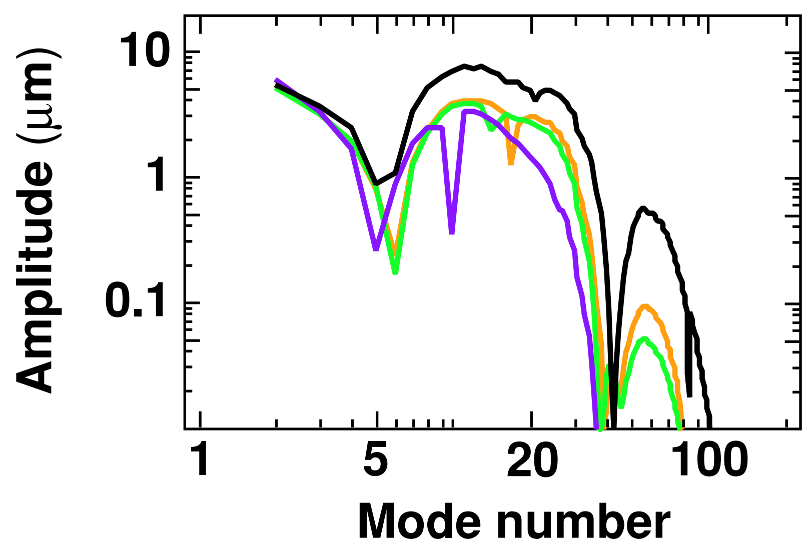
The postprocessor was used to calculate mode spectrum at stagnation

- V_a in decel phase is calculated by using theory of R. Betti[1] *et al.*

$$V_a \propto \frac{(T_{hs})^{5/2}}{R_{hs}\,\rho_{shell}}$$

- Mode spectrum at the back surface of cold fuel at stagnation (1 THz SSD, 1 μm DT ice roughness, 800Å outer surface finish)





[1]V. Lobatchev and R. Betti, Phys. Rev. Lett., 85, 4522 (2000).

TC5635

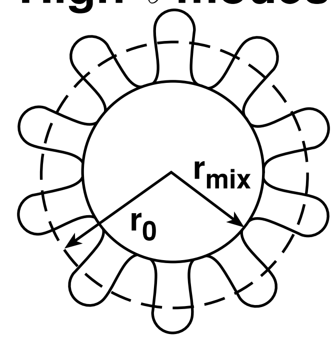
The mode spectrum at stagnation is related to the gain reduction

- According to Levedahl and Lindl[1]

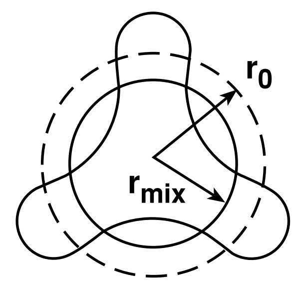
$$\frac{V_{mix}}{V_0} = \left(\frac{r_0}{r_{mix}}\right)^{2/5} \qquad r_{mix} = r_0 - \eta$$

$$\frac{V_{mix}}{V_0} = (1-\xi)^{-2/5} \qquad \xi = \eta/r_0$$

High-ℓ modes



Low-ℓ modes



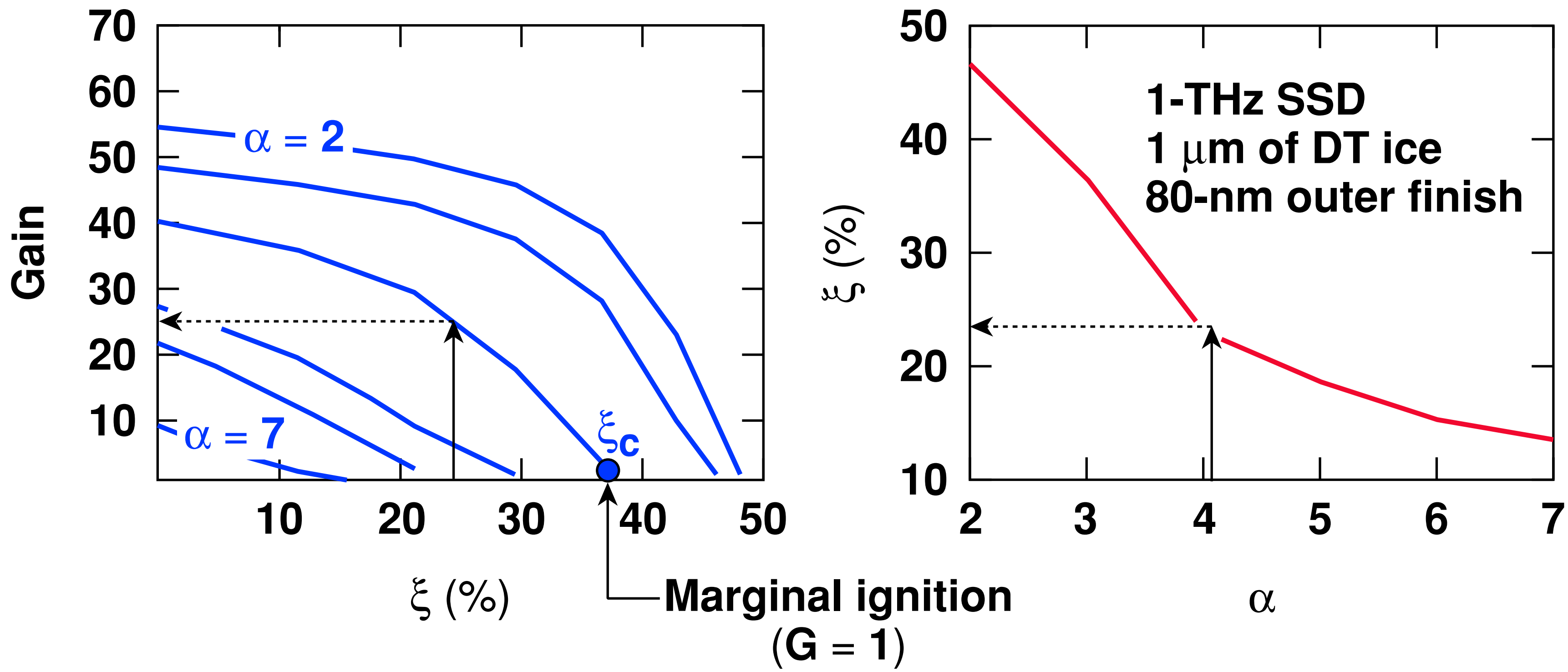
- Perturbation is equivalent to a reduction in 1-D implosion velocity:[2]

$$\xi = 1 - \left(\frac{V_0 - \Delta V}{V_0}\right)^{5/2}$$

[1]W. Levedahl and J. Lindl, Nuc. Fusion 37, 165 (1997).
[2]Roy Kishony, Ph.D. thesis, 1999.

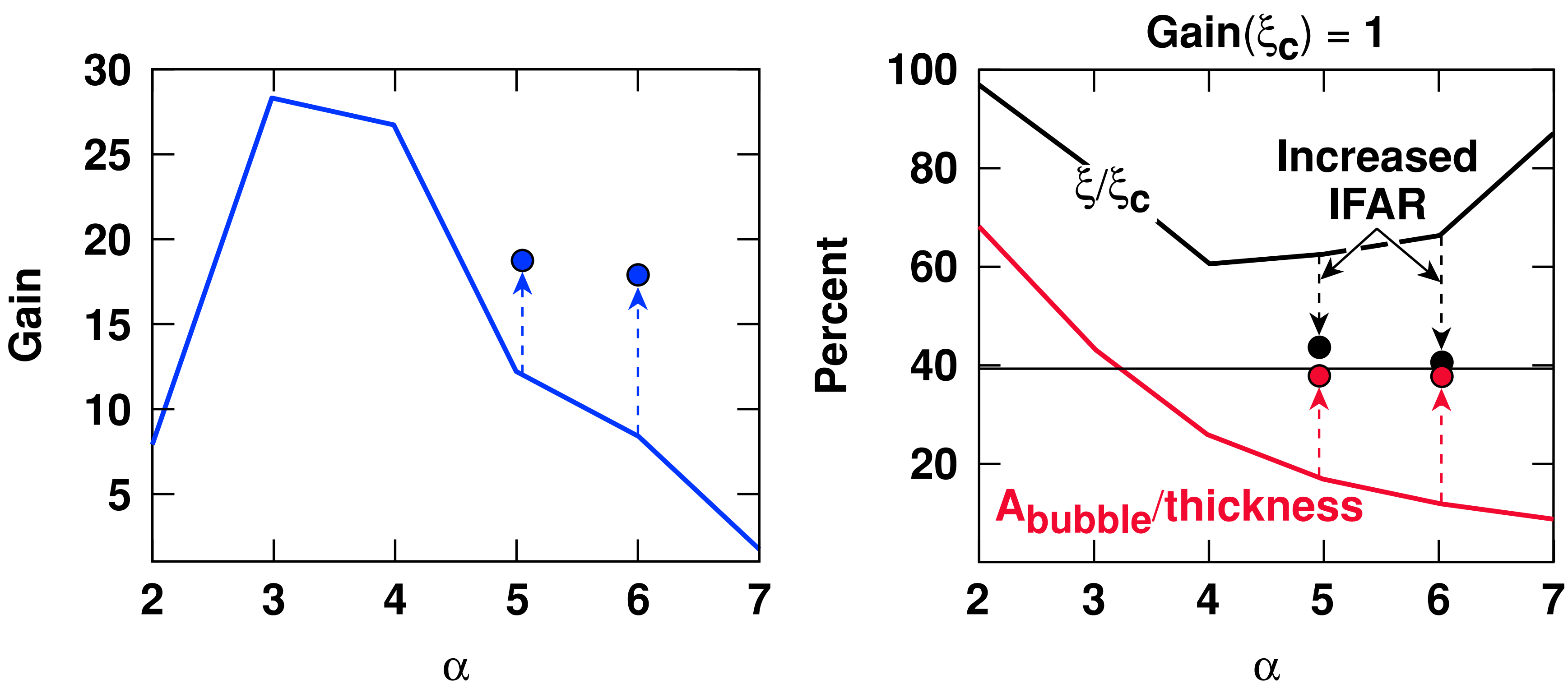
TC5636

Gain is calculated by using the results of 1-D simulations with reduced V_{imp}



TC5752

Target designs with 3 < α < 4 have the highest 2-D gain



- Target gain is calculated assuming 1-THz, 2-D SSD; 1-μm ice–DT gas roughness, and 800-Å outer surface finish.
- Imprint spectrum is assumed to be the same for different α's.

Change in EOS results in a small variation in target gain

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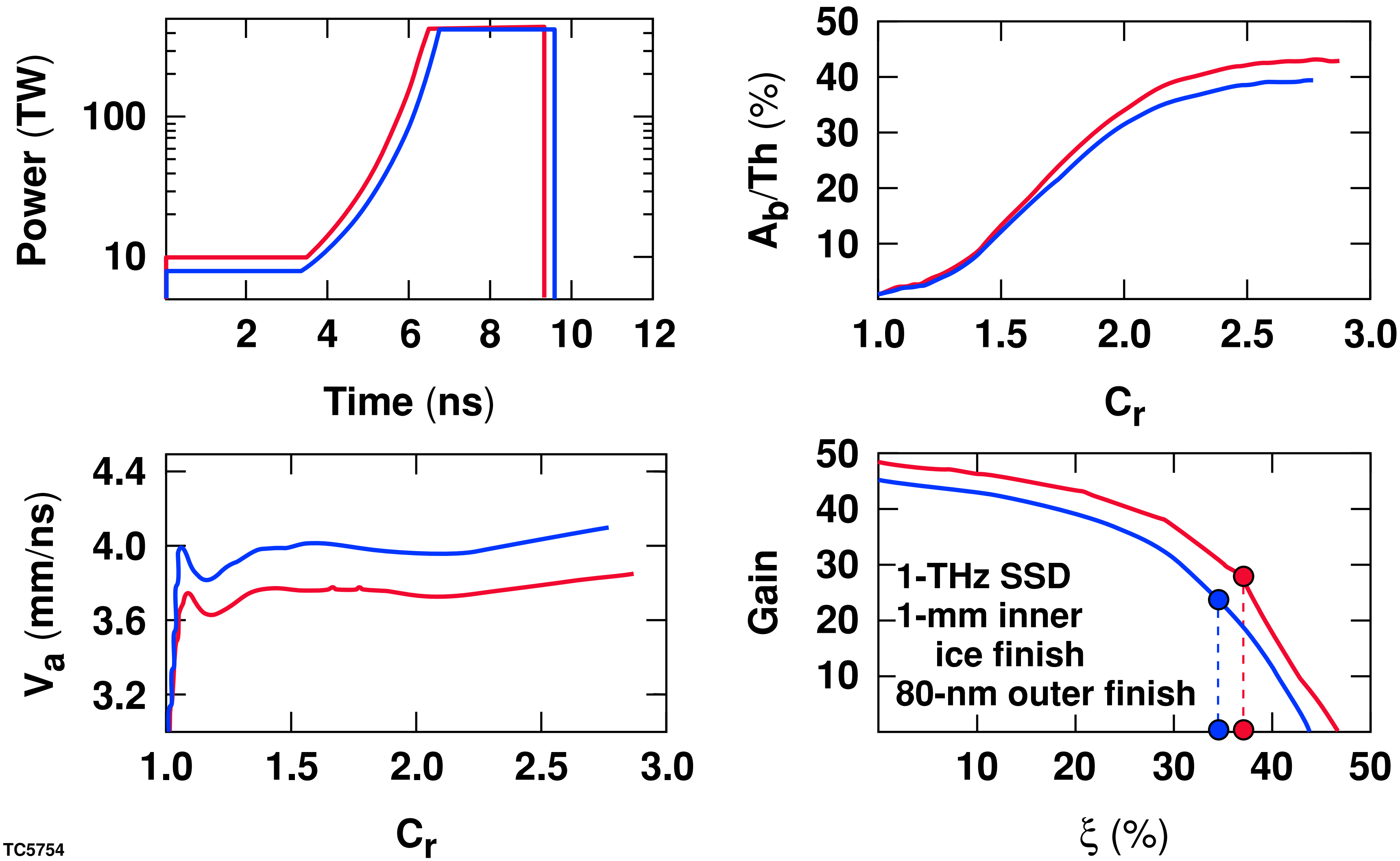
α = 3 design *SESAME* (G = 48) TF (G = 45)



TC5754

ξ/ξ_c of $\alpha = 5$ and $\alpha = 6$ can be reduced by increasing the in-flight aspect ratio

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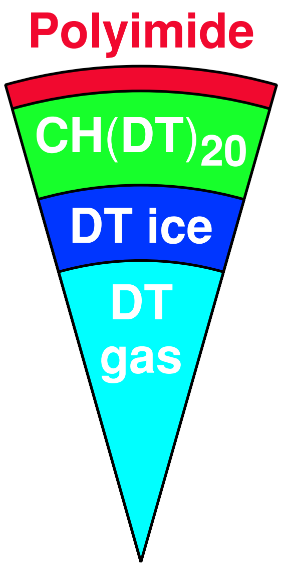
$\alpha = 5$

IFAR	46	56
A_{bubble}/Th (%)	17	40
ξ/ξ_c	62	47
1-D gain	27	27
2-D gain	12	18

TC5755

Three high-gain “wetted foam” designs have been considered

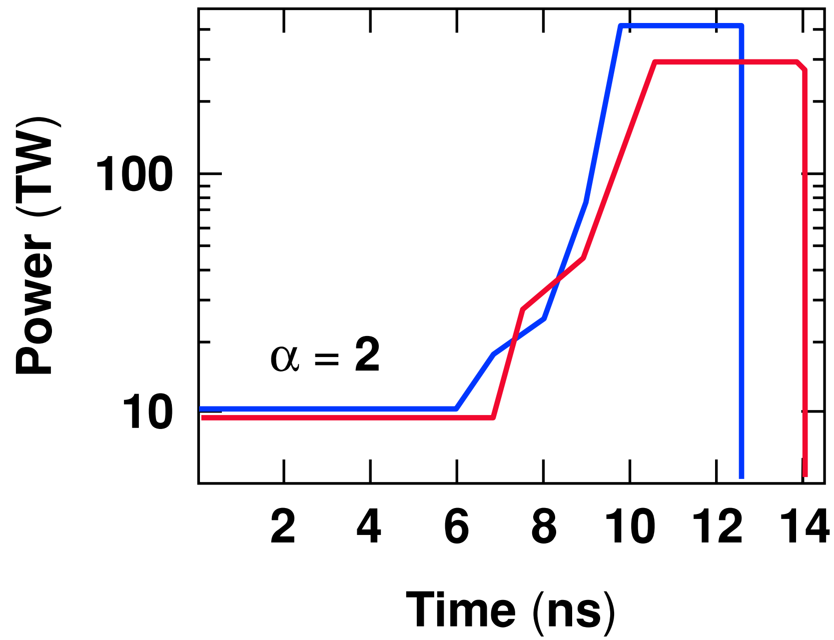


Design 1:

$G = 124$

$V_{imp} = 3 \times 10^7$ cm/s

$\rho R_m = 1.7$ g/cm^2

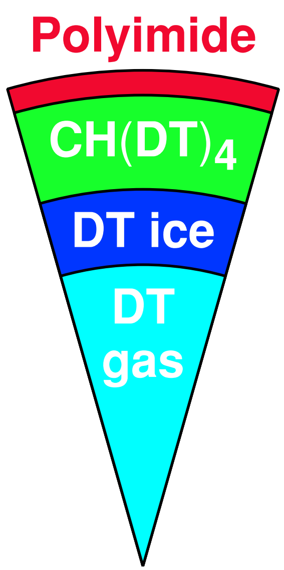


Design 2:

$G = 81$

$V_{imp} = 3.9 \times 10^7$ cm/s

$\rho R_m = 1.4$ g/cm^2



TC5758

Target stability and gain are calculated by using a developed model

Design	1	2
A_{bubble}/Th (%)	22	52
ξ/ξ_c (%)	200	72
1-D gain	124	81
2-D gain	0	55

Assumptions:
(1) imprint is the same for "all-DT" designs
(2) perfect power balance
(3) 1-μm DT-ice roughness and 80-nm outer surface finish

TC5759

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