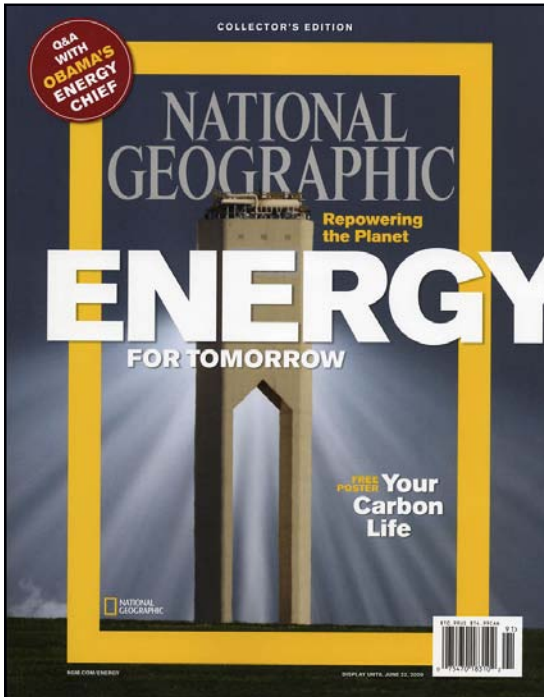
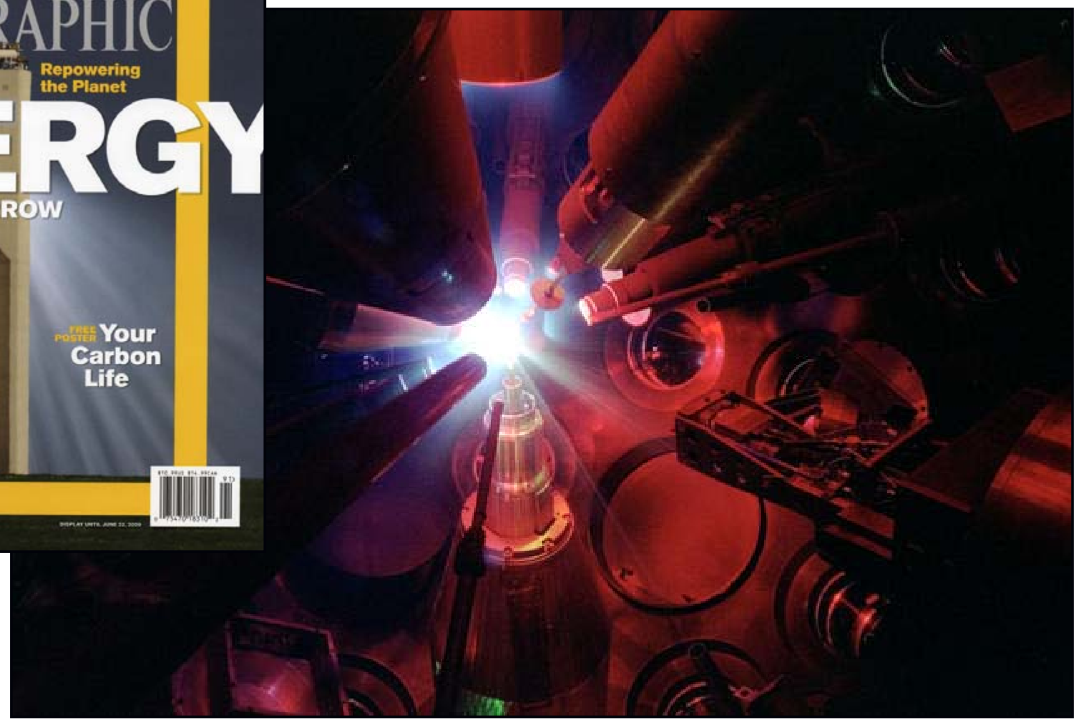
Thoughts on Inertial Fusion Energy





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LIFE got one thing right!

- Diode-pumped, solid-state lasers are the most-likely IFE driver, but……
- Indirect drive has inherently lower gains than direct drive
  - gain does matter unless you over-constrain the problem
    - LIFE laser diodes are 60% of capital cost[1]
    - doubling the gain from a LIFE design reduces the recirculating power fraction[2] ~ 2×
  - target fabrication for direct drive will be significantly simpler
- The proposed 15 years to demonstrate LIFE continuous high-yield operations and a 20-year timeline to begin electricity supply defies imagination
  - indirect-drive ignition is proving difficult
  - the LIFE claims may damage the credibility of all fusion options

It is much too early for a down-select to indirect drive!

[1] M. Dunne, presented to the NAS IFE panel, January 2011.
[2] T. Anklam, presented to the NAS IFE panel, January 2011.

Direct drive is the only true alternative to indirect drive

- Direct drive couples more energy to the capsule (~6% versus ~1%)
  - provides significantly higher margins
- The concept has been validated through decades of research, primarily by LLE on OMEGA, with contributions from NRL
- Shock ignition provides an additional direct-drive option with the possibility of significantly higher gain
  - less validated to date
- There is no credible, experimentally demonstrated basis for 2ω indirect drive
  - 2ω indirect drive provides, at best, ~2× more kinetic energy for ignition

Direct drive exhibits ample margins for ignition on the NIF

- Direct drive couples up to 6% of the laser energy to the target kinetic energy
  - for a 1.5-MJ UV laser pulse: $E_{kin}^{direct\ drive} \approx 90\ kJ$

- The minimum kinetic energy for ignition*

$$E_{kin}^{min}(kJ) = 9.3\,\alpha^{1.9}\left(\frac{400}{V_{ign}^{km/s}}\right)^{5.9}\left(\frac{100}{P_A^{Mb}}\right)^{0.77}$$

- Two possible direct-drive designs with similar margins

$P_A = 100,\ \alpha = 2,\ V_{ign} = 420 \longrightarrow$ $E_{kin}^{min} \approx 26\ kJ$

$P_A = 100,\ \alpha = 1,\ V_{ign} = 330 \longrightarrow$ $E_{kin}^{min} \approx 29\ kJ$

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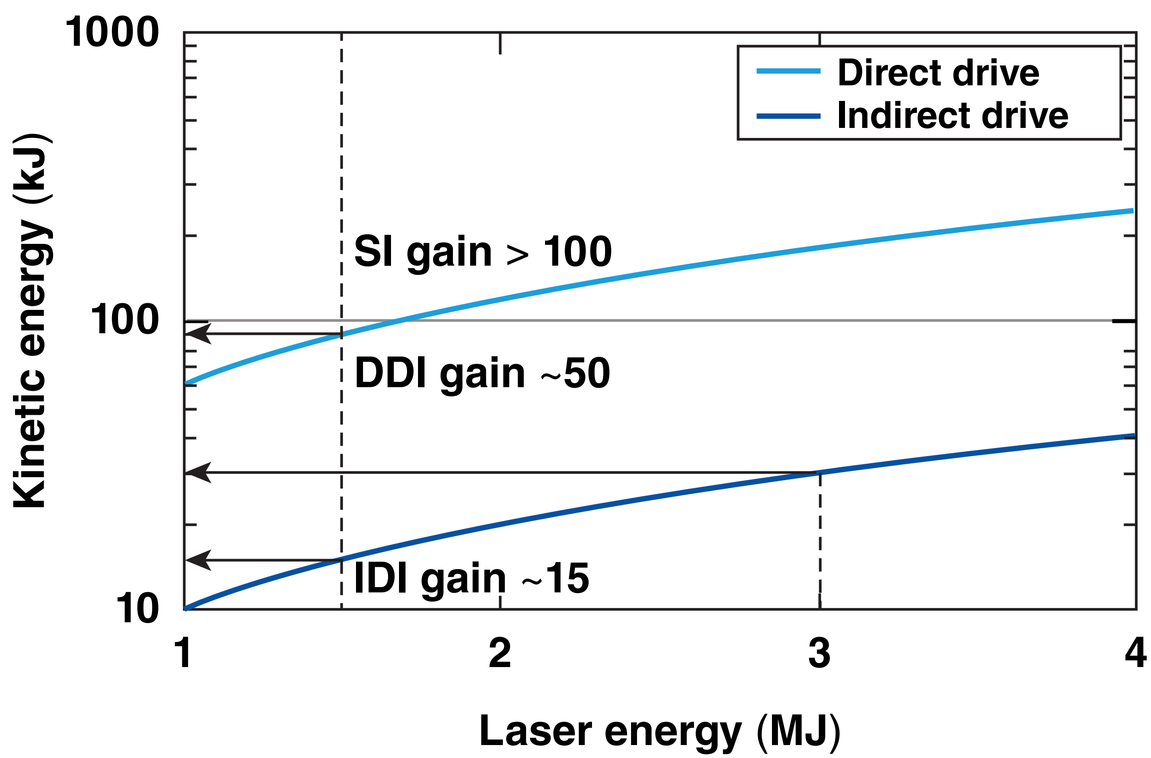
* M. C. Herrmann, M. Tabak, and J. D. Lindl, Phys. Plasmas 8, 2296 (2001).

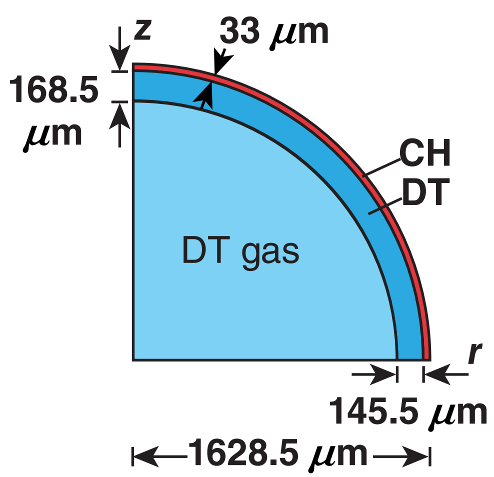
Direct drive couples more energy to the capsule than indirect drive for a fixed laser energy

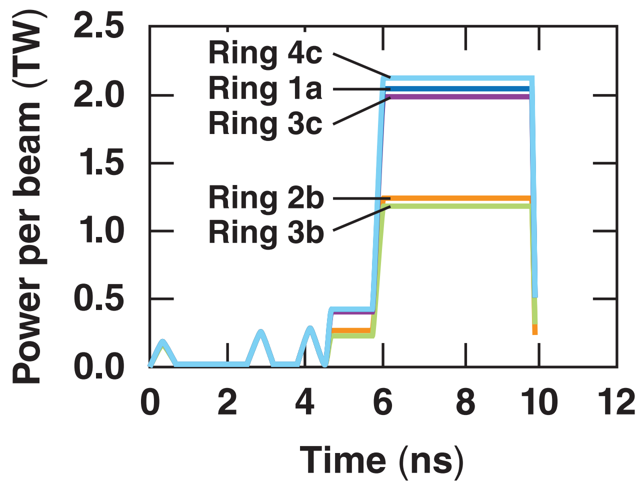
- Higher kinetic energy means more design flexibility
- Shock ignition (SI) has the same kinetic energy as hot-spot direct drive
  - lower velocity allows more massive shells and higher gain



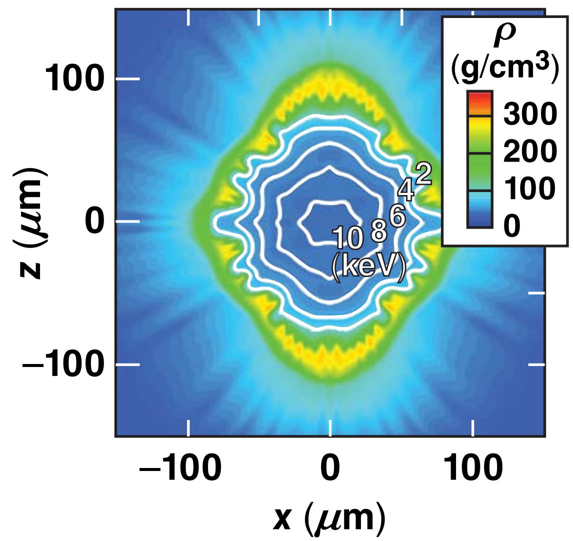
Direct drive offers great flexibility of ignition target options

Conventional polar drive (multiple designs are possible for the NIF)

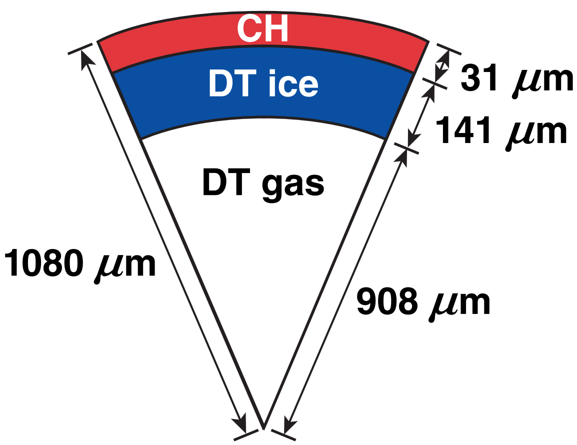


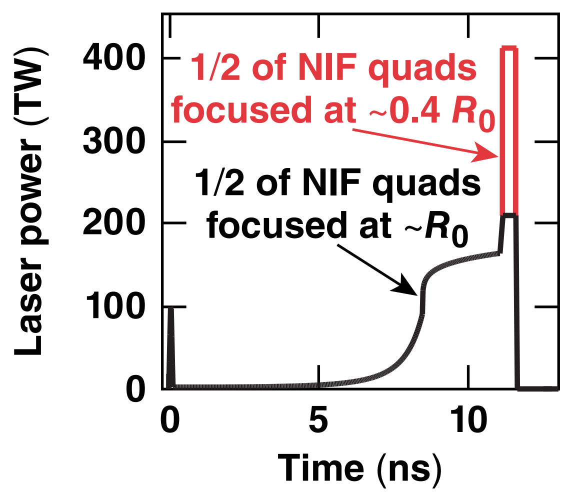


E = 1.5 MJ, 2-D gain = 32

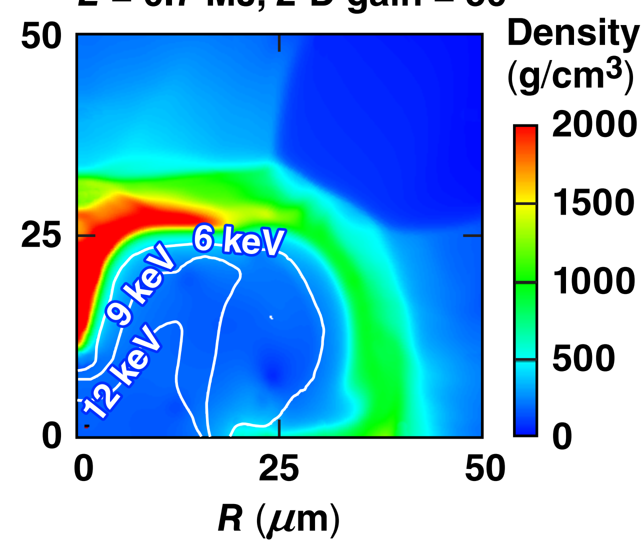


Polar-drive shock ignition (multiple designs are possible for the NIF)





E = 0.7 MJ, 2-D gain = 50



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Substantial IFE technology development will be required after the demonstration of ignition

- Fusion researchers have too often made claims about energy production that are not supported by demonstrated technology
- Any energy demonstration must be cost effective and reliable
- The path to a prototype power plant demonstration is long and slower than most fusion researchers would like
- An aggressive technology program is required after the demonstration of ignition

The community must not "over-promise."