Pathways to Inertial Fusion Energy
Laser Direct Drive

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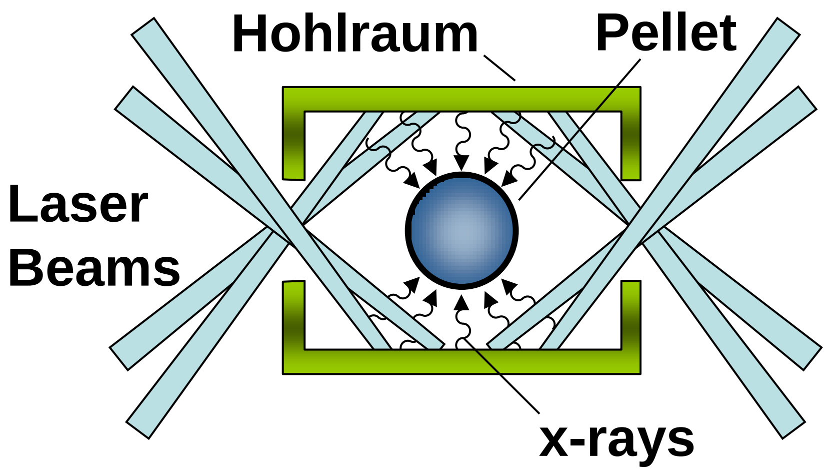
Opening Remarks

- Direct drive with shock ignition looks very promising for IFE.
- Both KrF and frequency tripled DPSSL are have the potential to meet the IFE requirements (energy, durability, efficiency).
- Use of KrF's deeper UV light increases the gain and reduces the risks from hydro and laser plasma instabilities.
- Path forward for IFE should be settled by competition in a phased IFE program.

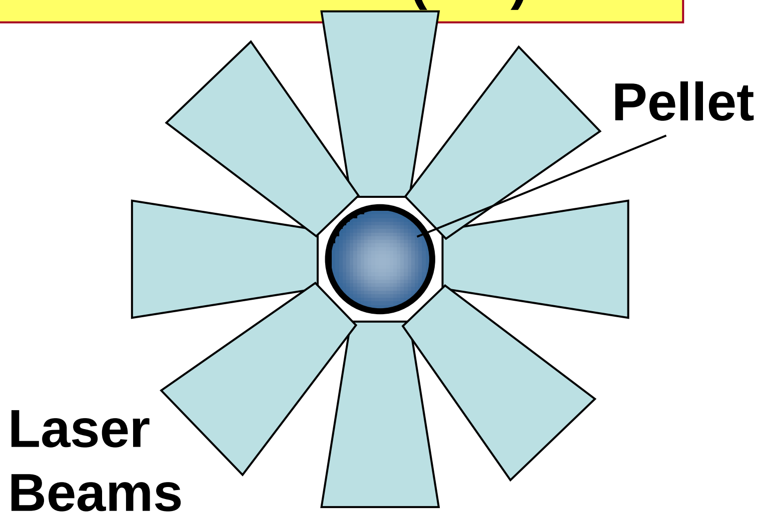
We chose Direct Drive for the Energy Application (Research in US by NRL and LLE)

Indirect (path chosen for NIF)



- Less efficient illumination of target
- More complex physics
- Relaxed laser uniformity requirements

Direct Drive (IFE)

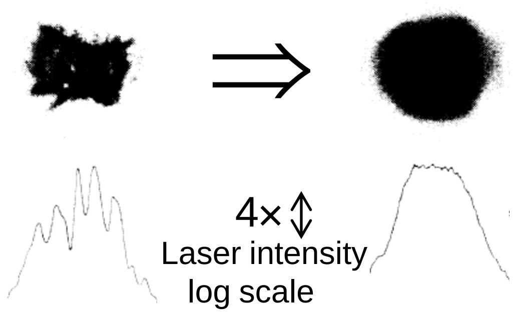


- Efficient illumination
- Simpler physics
- Much higher predicted performance (gain)
- Simpler target fabrication
- Little target material to recycle
- Advances in lasers and target designs have overcome uniformity requirements

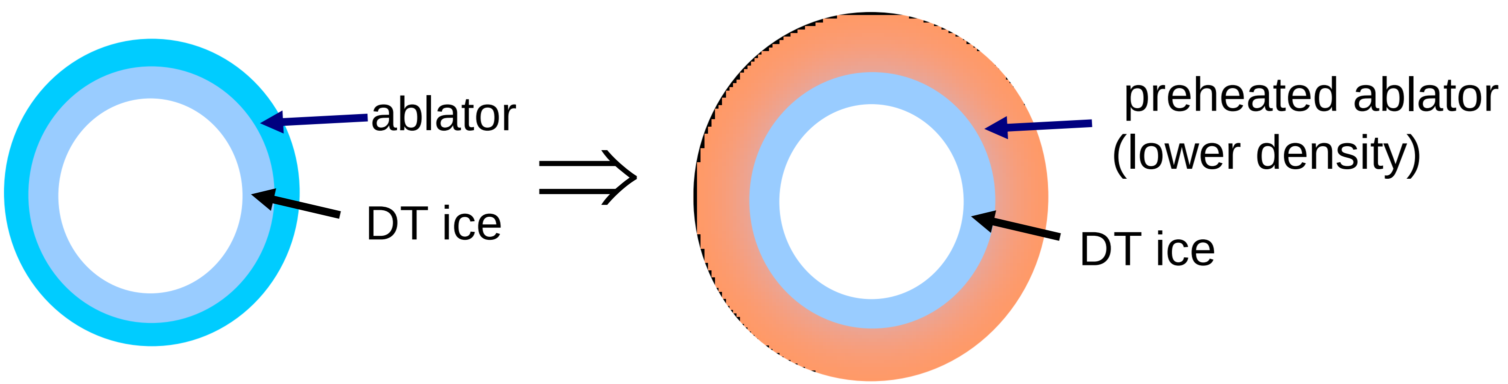
Two developments that help enable symmetric direct drive implosions.

1980's Development of controlled laser incoherence to achieve time-averaged smooth laser profiles on target.

Random Phase Plates – RPP (ILE, Japan)
Induced Spatial Incoherence – ISI (NRL)
Smoothing by Spectral Dispersion – SSD (LLE)



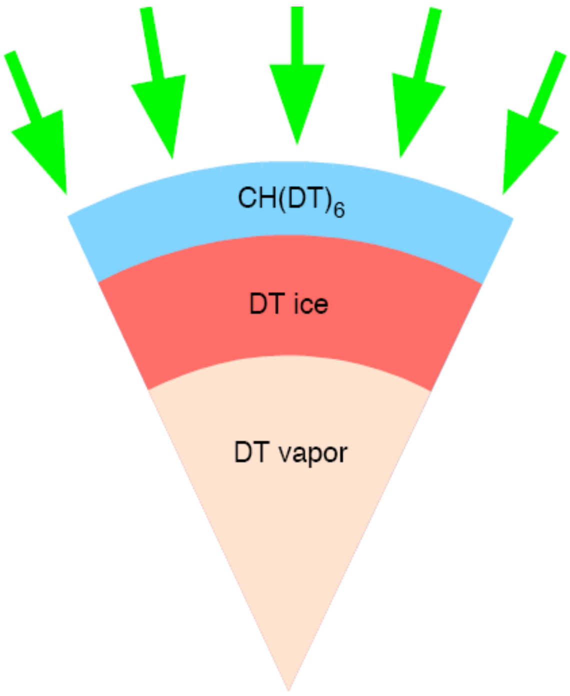
Late 1990's – Development of tailored adiabats to reduce Rayleigh Taylor instability while maintaining gain.

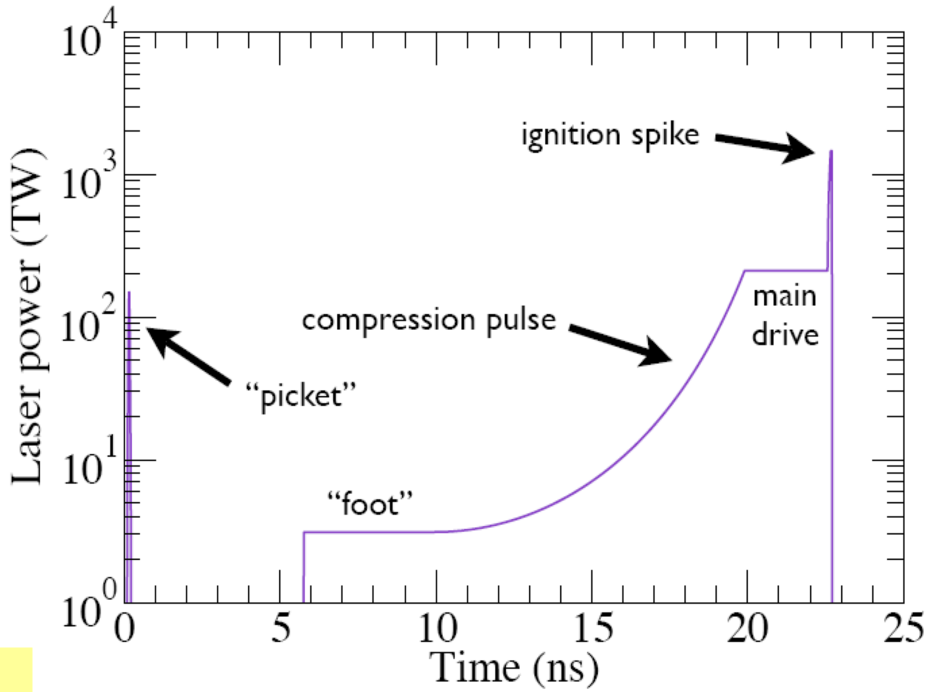


- Larger ablation velocity (V_A= {mass ablation rate}/ρ) suppresses RT instability.
- Can be accomplished via decaying shocks or soft x-ray preheat.

Shock Ignited (SI) direct drive targets

Pellet shell is accelerated to sub-ignition velocity (<300 km/sec), and ignited by a converging shock produced by high intensity spike in the laser pulse.





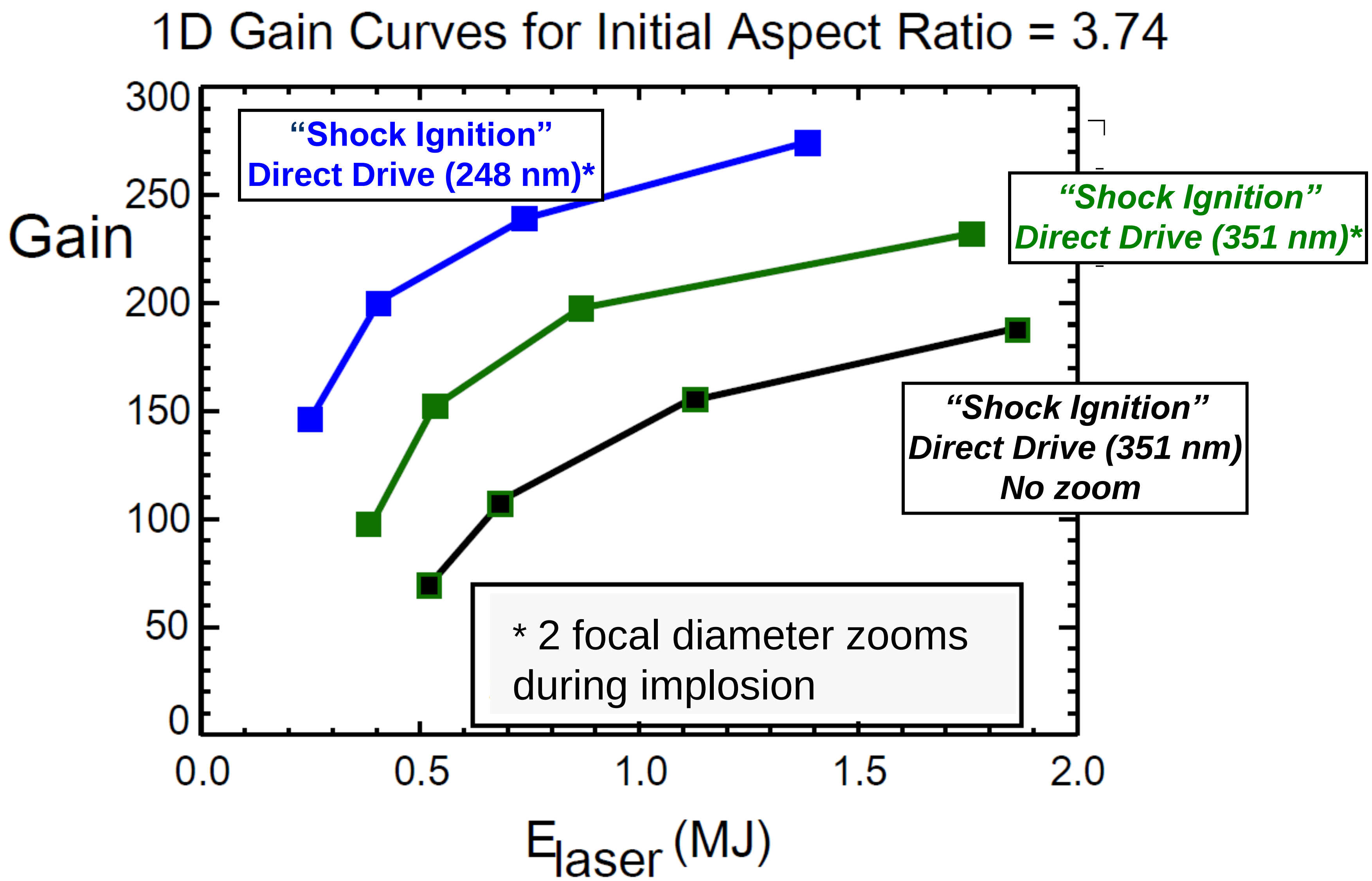
Low aspect ratio pellet helps mitigate hydro instability

Peak main drive is 1 to 2 × 10^{15} W/cm^2

Igniter pulse is ~10^{16} W/cm^2

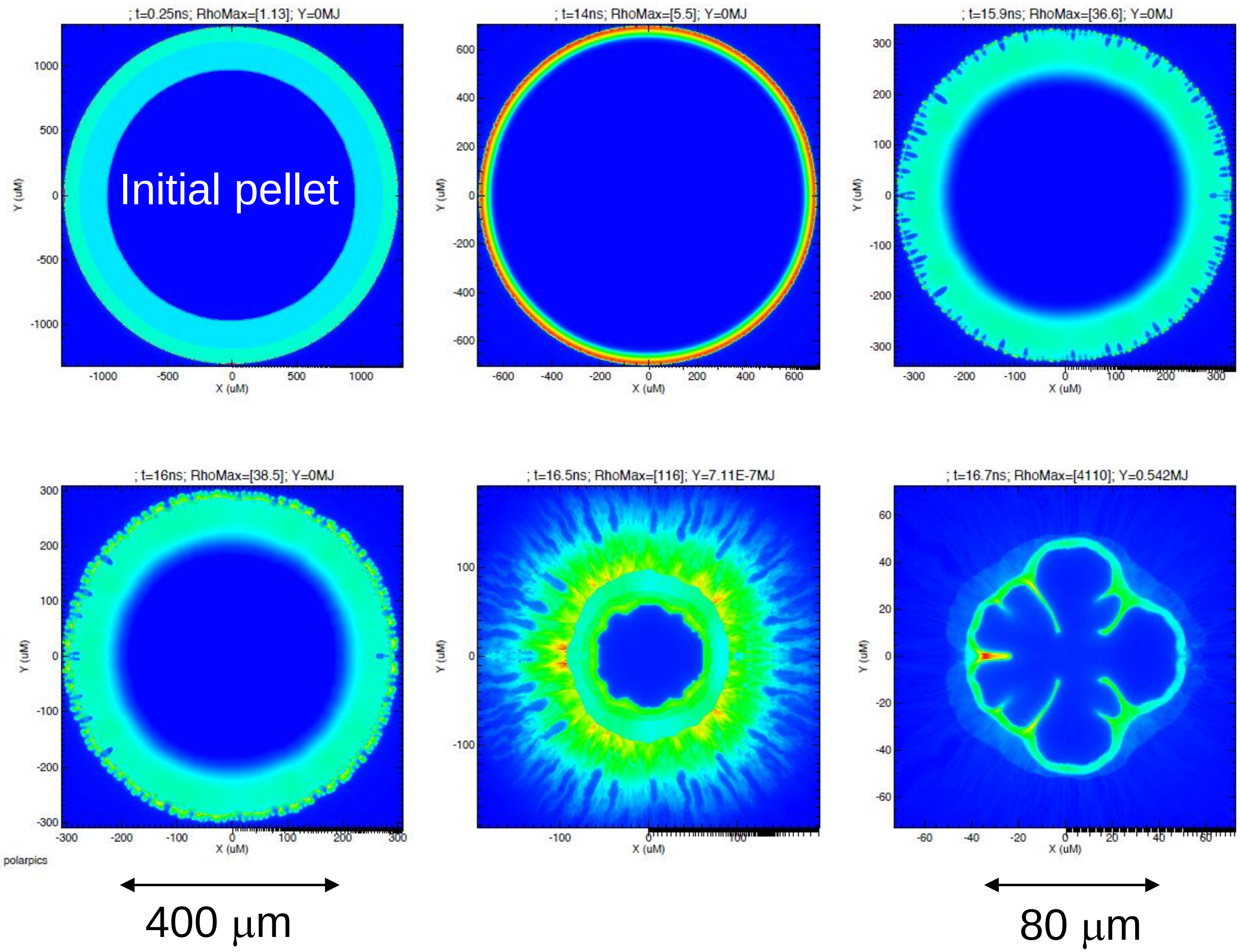
* *R. Betti et al., Phys.Rev.Lett.* ***98****, 155001 (2007)*

High gain is obtained with both KrF (λ=248 nm) and frequency tripled Nd:glass (λ=351 nm) lasers utilizing direct drive shock ignited targets with focal zoom.



Simulations predict enough gain for a power plant with only a 529 kJ. KrF driver (<1/3 of NIF's design energy)

High resolution 2-D simulation accounts for laser and target imperfections.

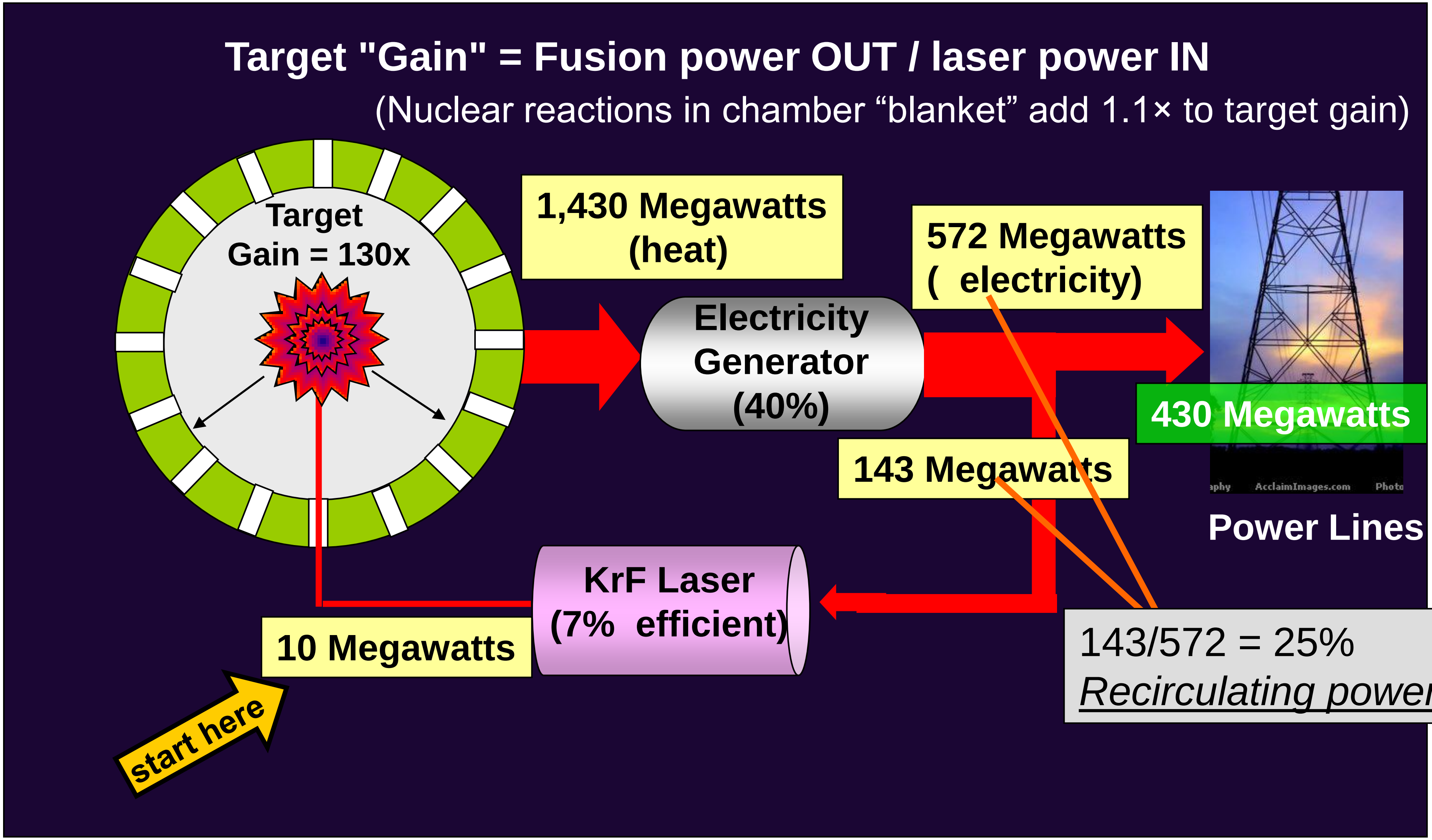


Shock ignited target

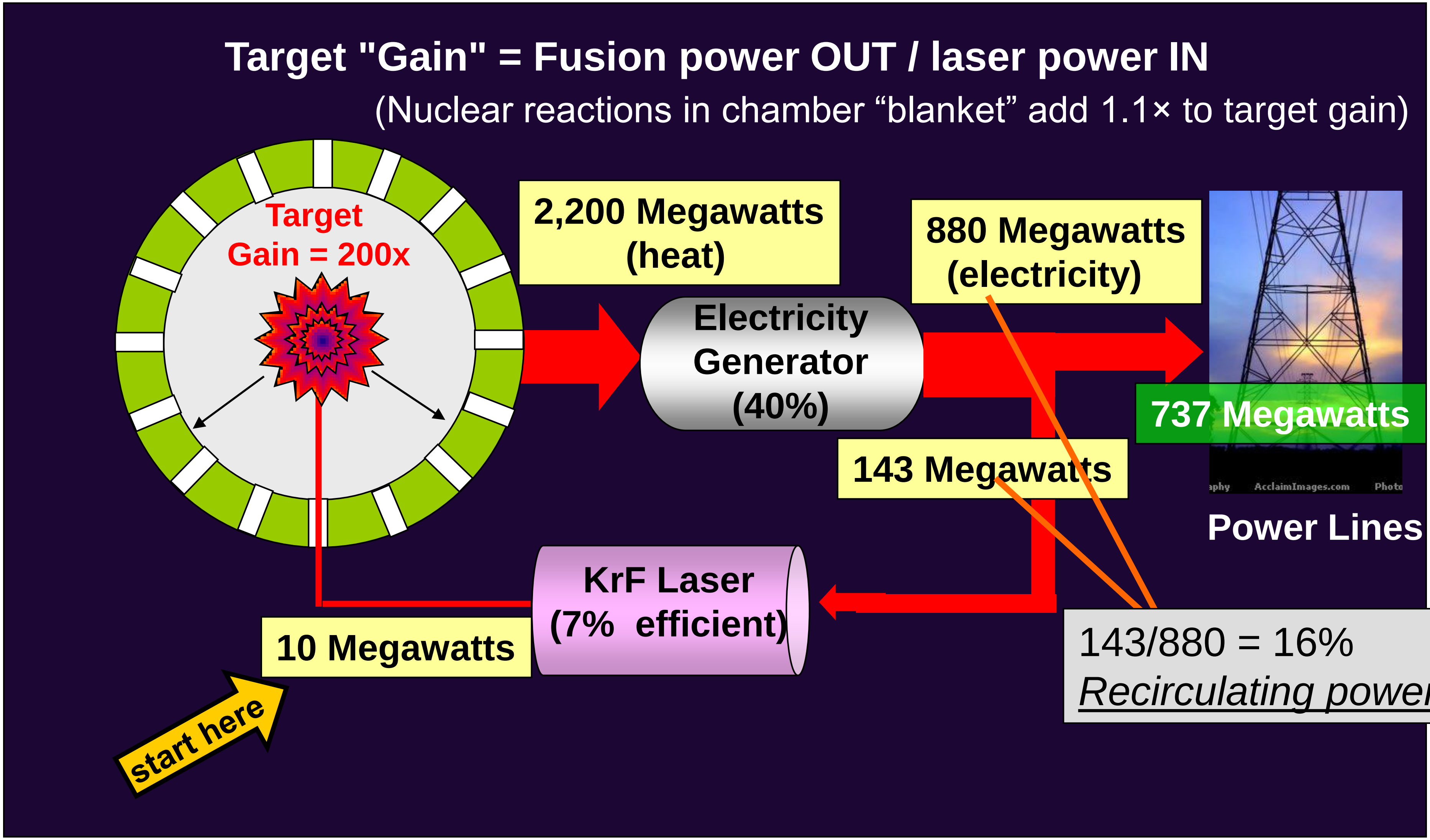
138 x gain

Imploded pellet (magnified scale)

The target has to release enough energy to power the reactor… AND produce electricity for the grid



Higher target gain increases power to grid and reduces % of power needed to operate the reactor.

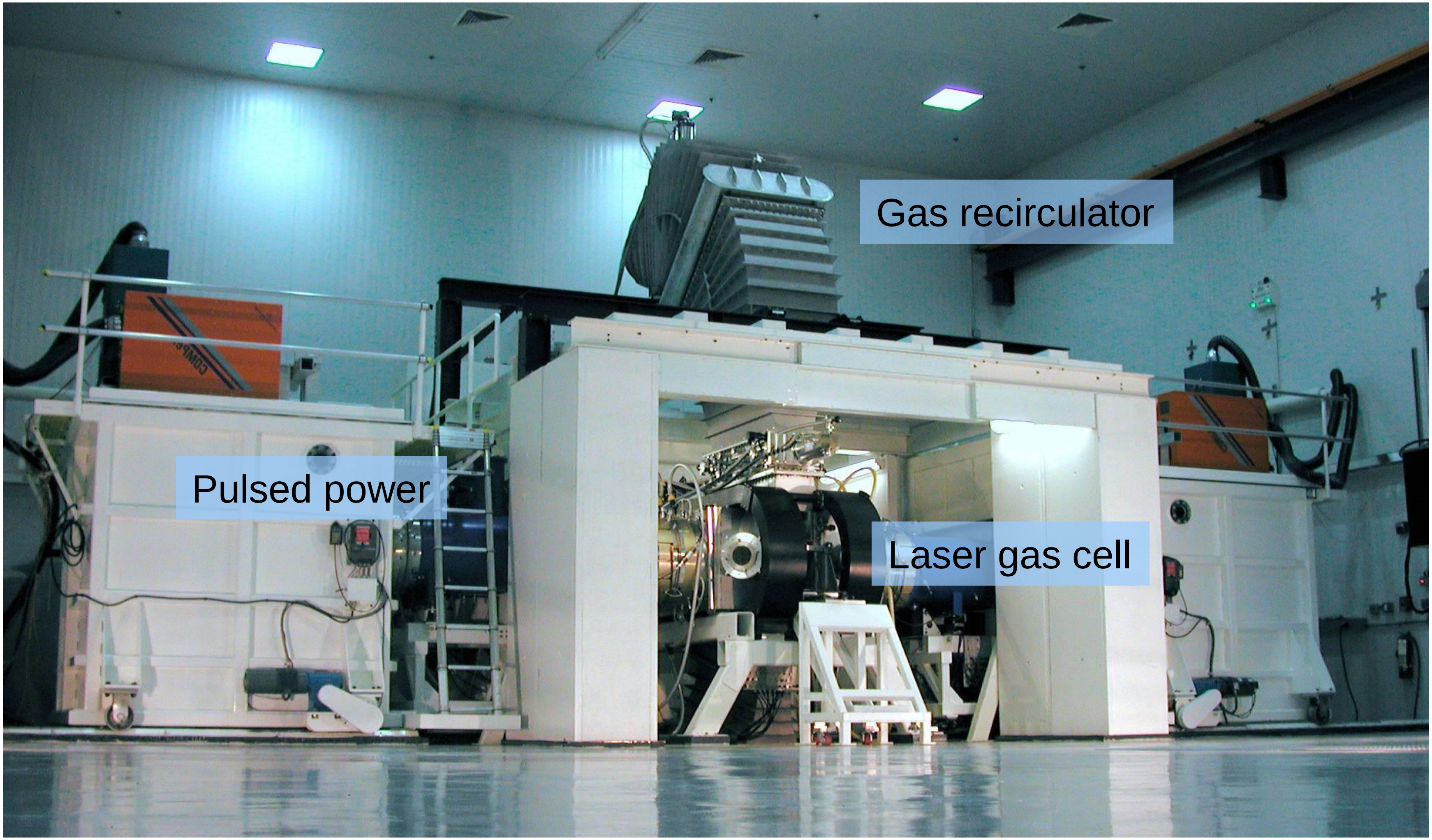


Electra Krypton Fluoride (KrF) Laser

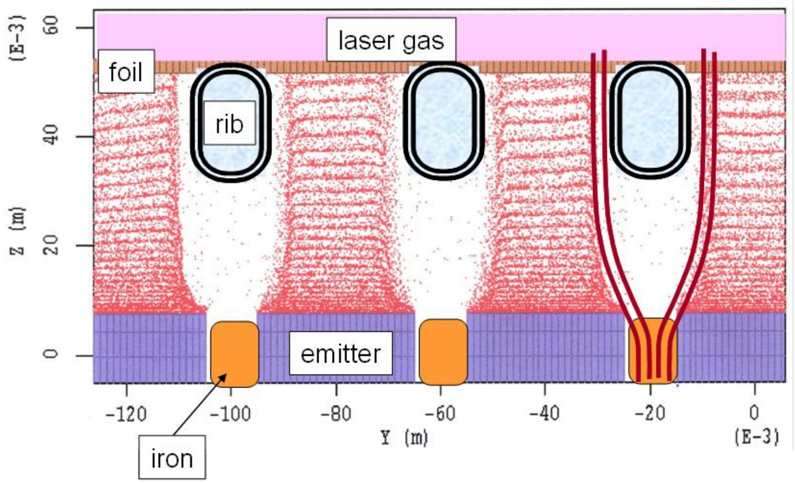
Laser Energy: 300 to 700 Joules

Repetition rate: up to 5 pulses per second

Continuous Runs: 10 hrs at 2.5 Hz (90,000 shots)



Path forward established for efficient and durable KrF laser systems for IFE. .



Electra diode provides >75% E-beam transmission into laser gas

Compact 200 kV, 4.5 kA Solid State Pulse Generator Integrated Test of Components

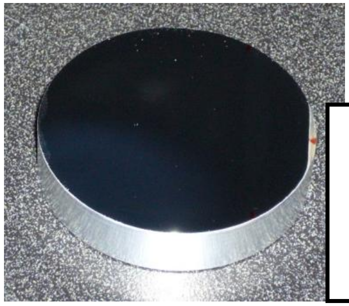
This system has run for 11,500,000 shots continuously at 10 Hz (319 hours)

Components tested to 300M shots.

KrF IFE systems using high-efficiency E-beam diodes and solid-state switched pulse power are predicted to have >7% wall-plug efficiency..

HAPL generated, and in many cases, “bench tested” solutions for most key components

Final Optics:
High Laser Damage Threshold Grazing Incidence Metal Mirror

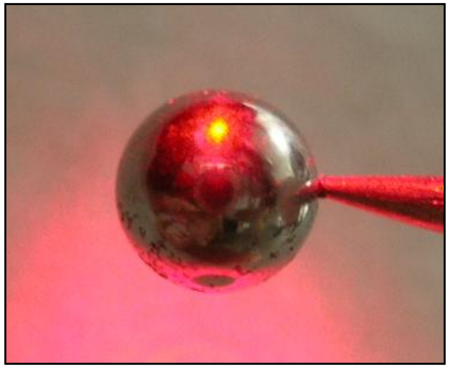


10 M shots at 3.5 J/cm^2 *(not a limit!)*

Target Fabrication:
Mass Produced Foam Shells

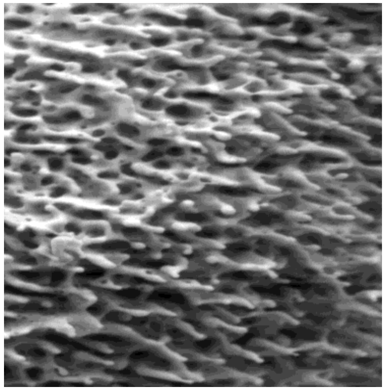
Estimate Target Cost 16 c each

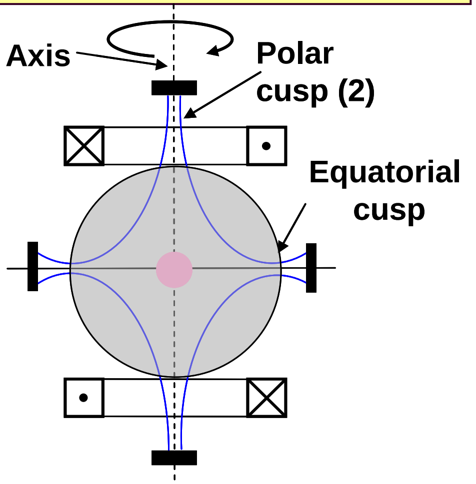
Target Engagement:
Glint system: accuracy 28 microns



Developing two chamber concepts

Engineered Wall | *Magnetic Intervention*



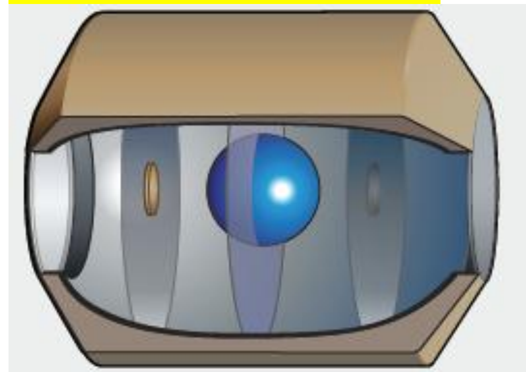


Direct Drive targets should be much easier to make at low cost and at a rate of 500,000 per day

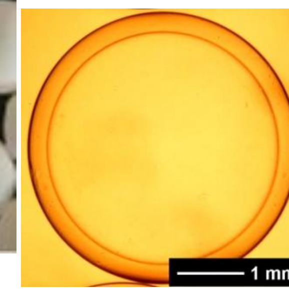
1. Simpler Target Fabrication

L. Latkowski, NAS Panel Presentation, 29 Jan, 2011

Concept for Indirect Drive IFE



Foam shells, mass produced for Direct Drive IFE target



Schafer Corp/GA

2. Lowest estimated cost

IFE Concept	Target Design	Target Yield (MJ)	Est'd Cost/target for 1000 MW(e)	% of E-value
Laser Fusion	Direct drive foam capsule	~400	$0.17	~6
HIF	Indirect drive distributed radiator	~400	$0.41	~14
ZFE	Dynamic hohlraum	~3000	$2.90	~13
LIFE	Indirect drive Pb rugby hohlraum	~132	~$0.30	~30

Chart from D.T. Goodin, NAS Panel Presentation, 30 Jan, 2011

Closing Remarks

- Direct drive with shock ignition looks very promising for IFE.
- Both KrF and frequency tripled DPSSL are have the potential to meet the IFE requirements (energy, durability, efficiency).
- Use of KrF’s deeper UV light increases the gain and reduces the risks from hydro and laser plasma instabilities.
- Path forward for IFE should be settled by competition in a phased program.
- ***Without feedback from the IFE technologies, it is impossible to make optimum choices in the inertial fusion approach and target designs.***