Laser Fusion Research at NRL

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Opening Remarks (ICF)

- NIF has encountered multiple physics challenges at high laser energy (MJ) for indirect drive that need to be resolved.
- Polar direct drive spearheaded by LLE offers a near term alternative.
- Symmetric direct drive is simpler and has potential for greater performance than the above two mainline options – it needs to be on the table.
- ICF requires precision – in targets, in the driver and in knowledge of the physics.

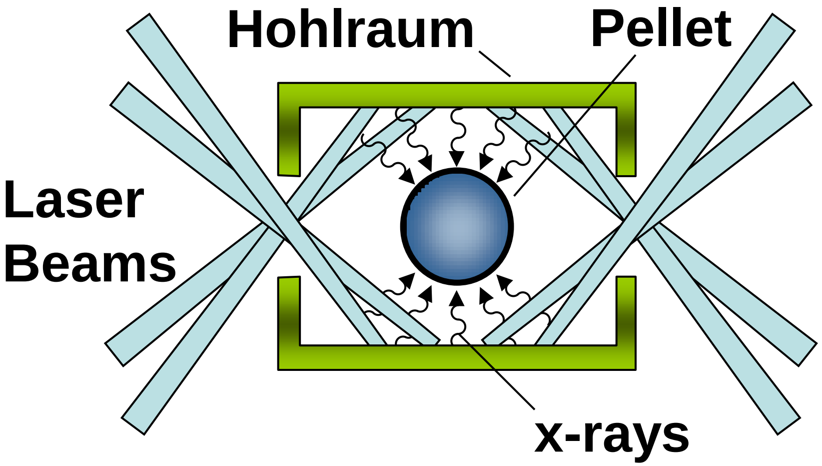
- Use of KrF light would help mitigate physics challenges of laser fusion and would increase target performance.

Opening Remarks (Fusion Energy)

- We need to invest in fusion energy technologies – a physics first (and only) program will not lead to IFE or MFE.
- There needs to be support for new ideas and alternate approaches.

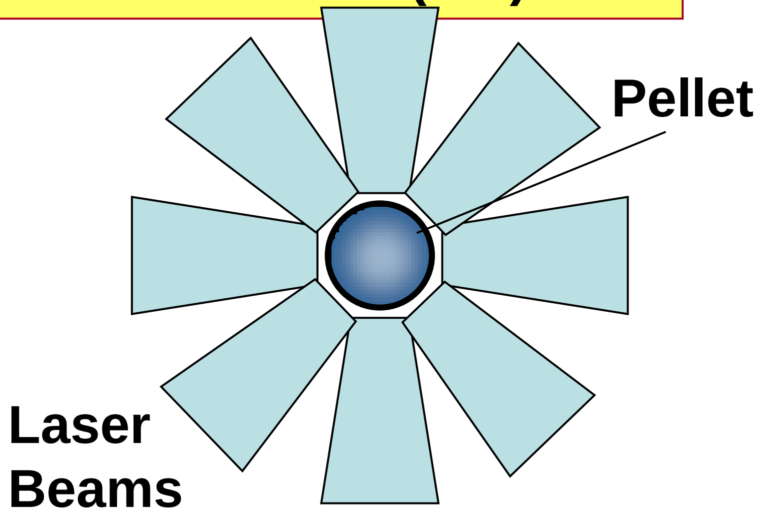
Direct Drive has advantages for the Energy Application (Research in US by NRL and LLE)

Indirect (path chosen for NIF)



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

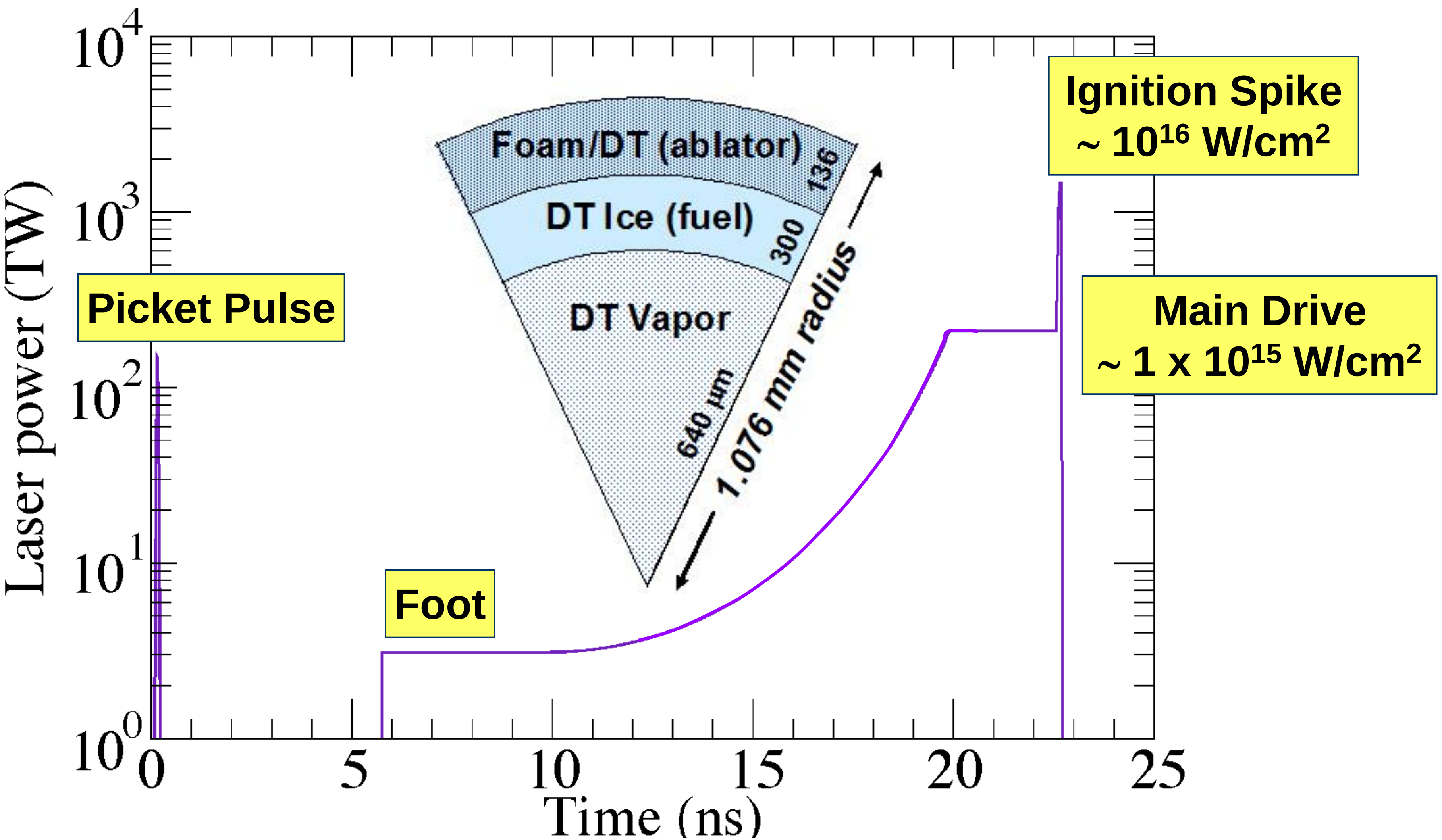
Direct Drive (IFE)



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

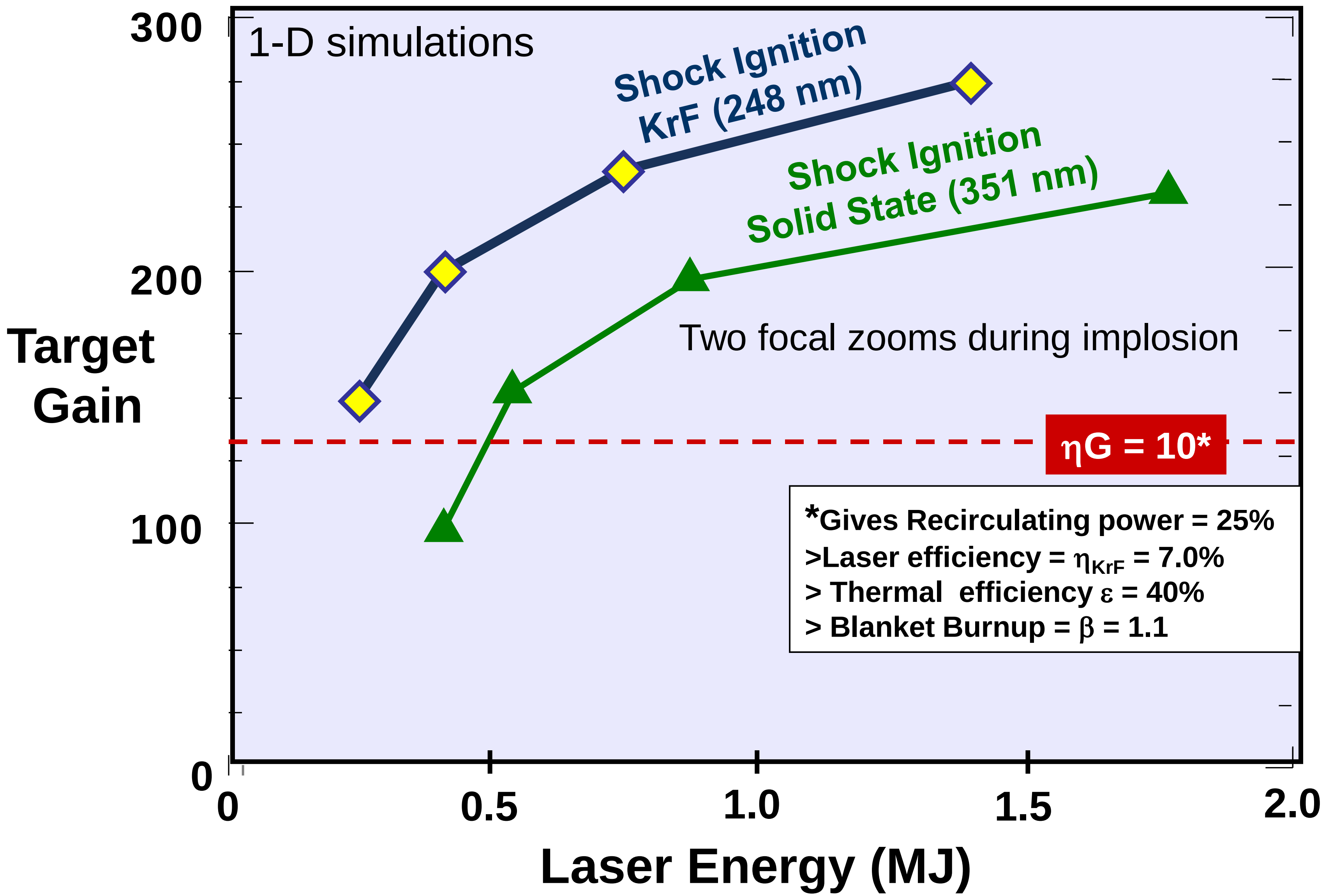
Shock Ignition:

Shell accelerated to sub-ignition velocity (<300 km/sec),
Ignited by converging shock produced by high intensity spike



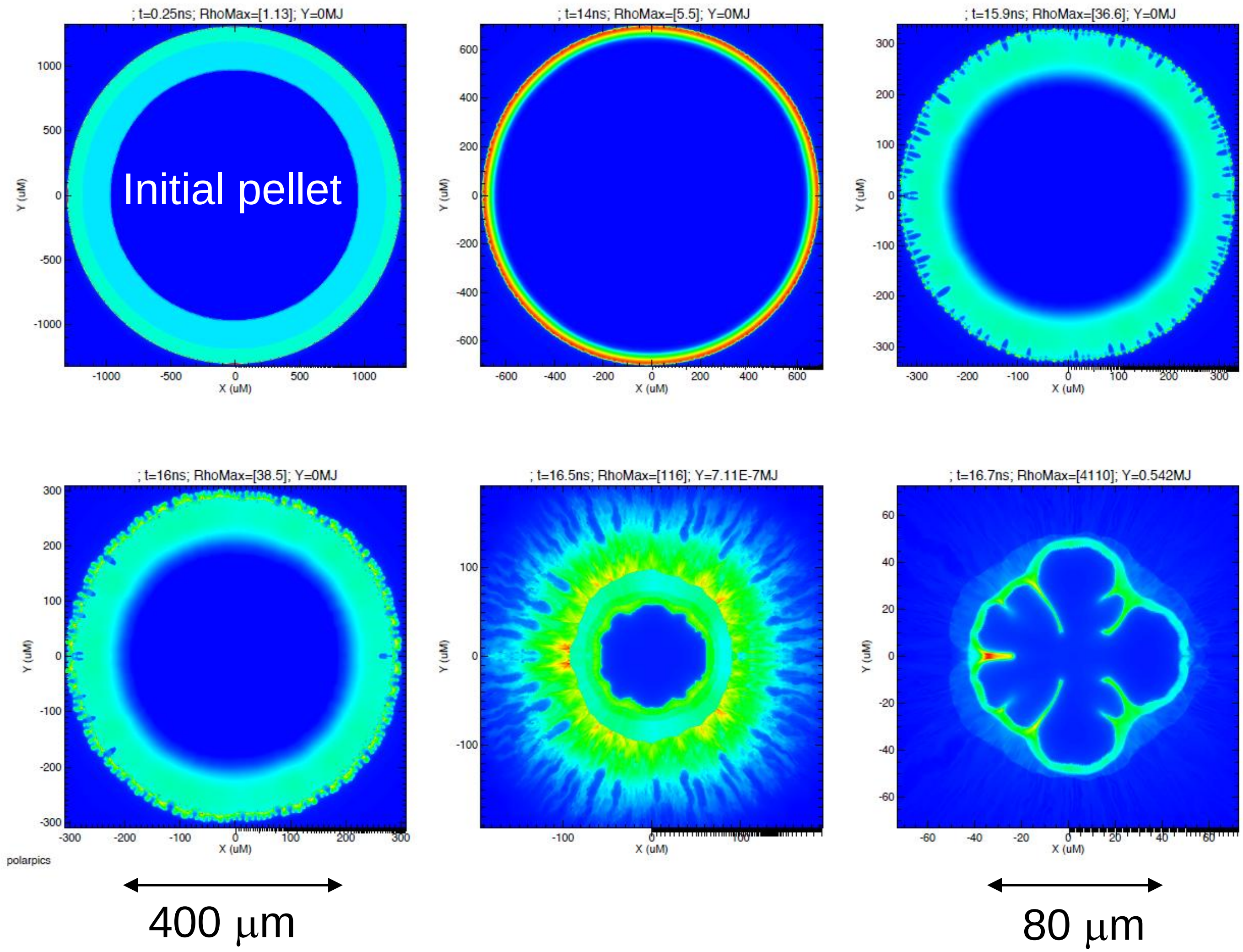
First Shock Ignition Theory: Betti et al, Phys. Rev. Lett. 98, 155001 (2007).

High enough gains for energy predicted at laser energies <1 MJ with direct-drive shock ignition.



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

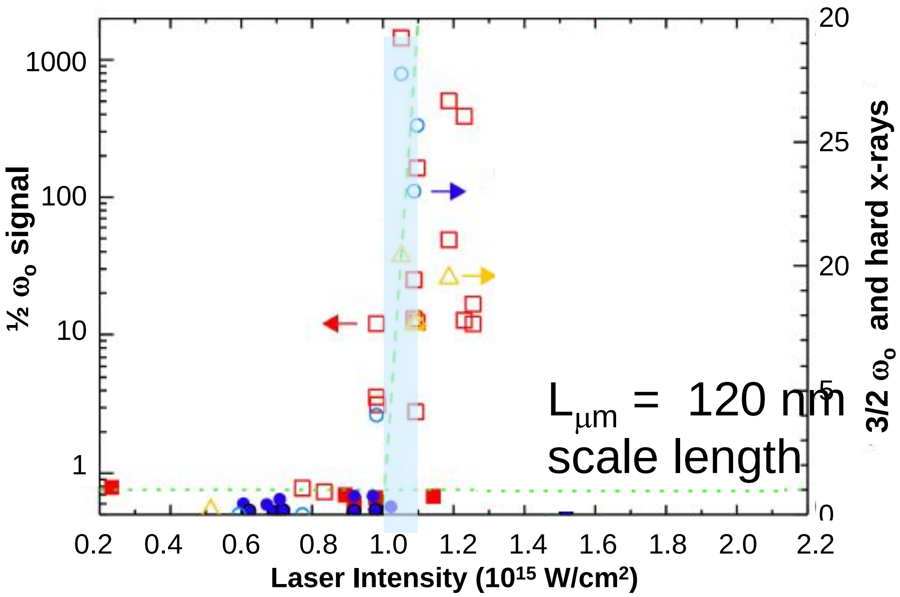
Imploded pellet (magnified scale)

In addition to higher target performance, use of KrF's shorter wavelength light reduces the risk from laser plasma instability.

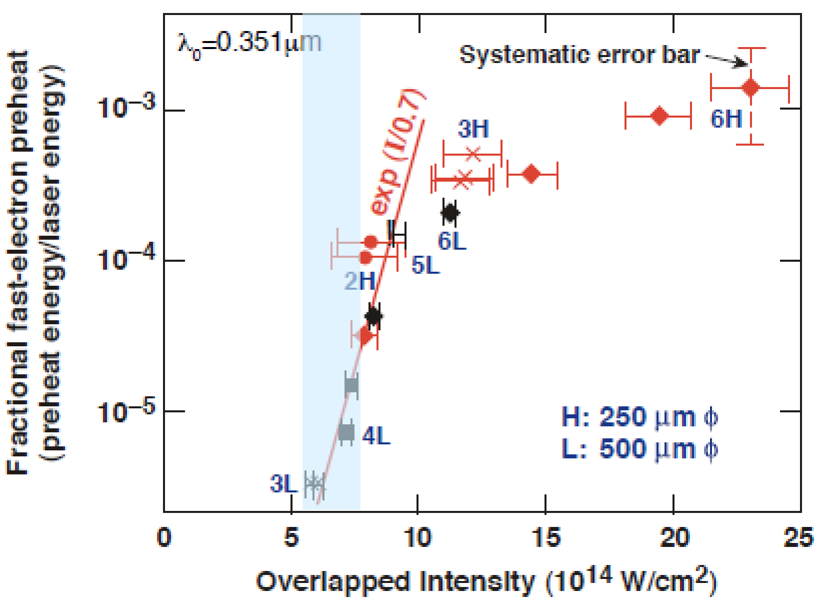
Predicted threshold for two plasmon decay instability (EM plane wave analysis):

$$I_{threshold}(2\omega_{pe}) \sim \mathbf{80\ T_{keV}/(\lambda_{\mu m} \times L_{\mu m})} \times 10^{15}\ \mathrm{W/cm^2}$$

LLE and NRL experiments agree with this prediction.



J. Weaver, Bull. Amer. Physics Soc. , 54 No. 15, JO5.8 (2009).



Stoeckl, et al., Phys. Rev. Lett. 90 235002 (2003),

Basic experiments on laser plasma interaction and hydrodynamics are conducted on the Nike KrF facility

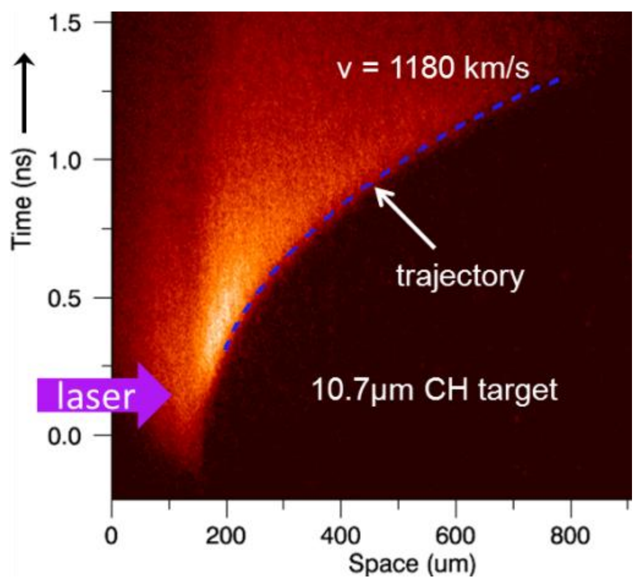
- Nike is operated by 3 technicians
- Nike's angularly multiplexed optical system has operated 17 years with many thousands of high energy shots on the optics

Recent experiments with Nike facility

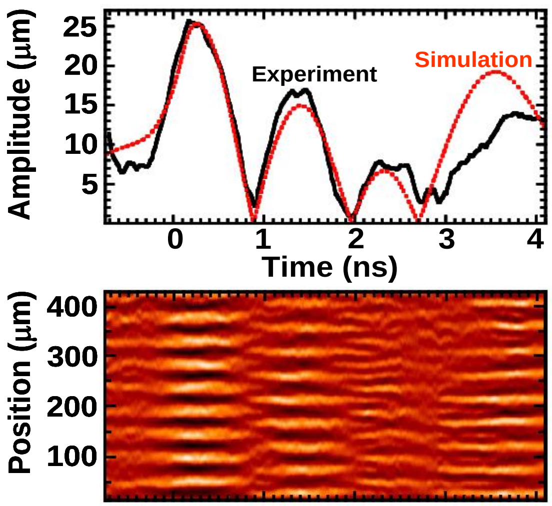
Success with inertial fusion requires a precise understanding of the underlying physics.

The NRL program helps develop the basic physics of ICF using its Nike laser facility, theory and advanced simulation codes.

Nike accelerates target to record velocity 1100 km/sec (2.5 million miles per hour)



Simulation accurately predicts evolution of early-time (RM) hydro-instability in Nike accelerated target.



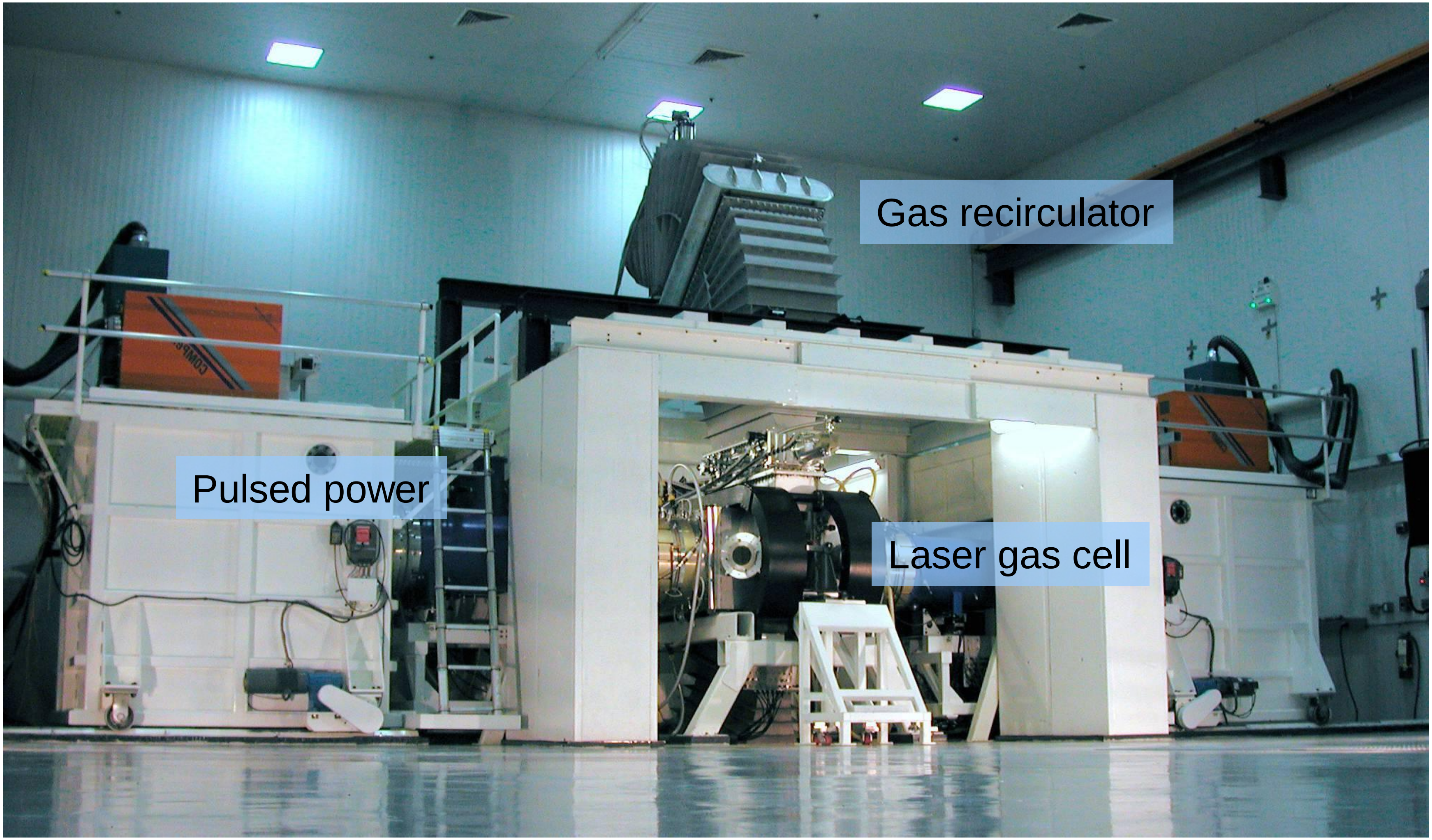
Precise understanding of hydro-instability is important for both indirect and drive ignition designs.

Electra Krypton Fluoride (KrF) Laser

Laser Energy: 300 to 700 Joules

Repetition rate: up to 5 pulses per second

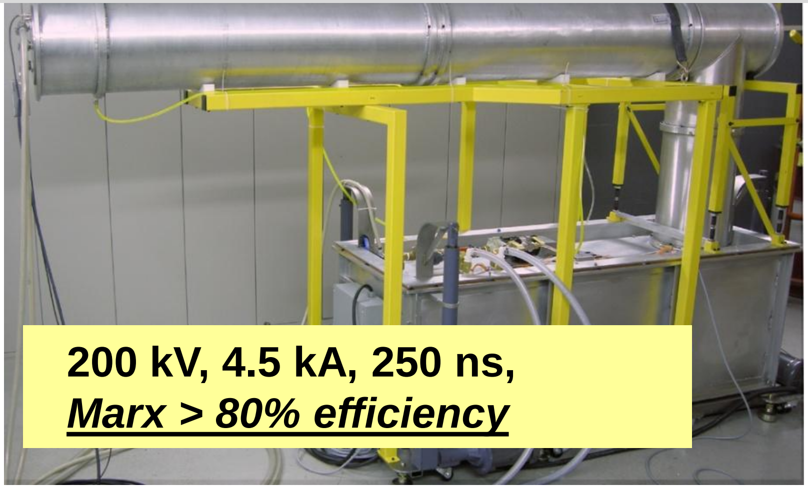
Continuous Runs: 10 hrs at 2.5 Hz (90,000 shots)



Research path to reactor grade durability (~10^9 shots) for Electra

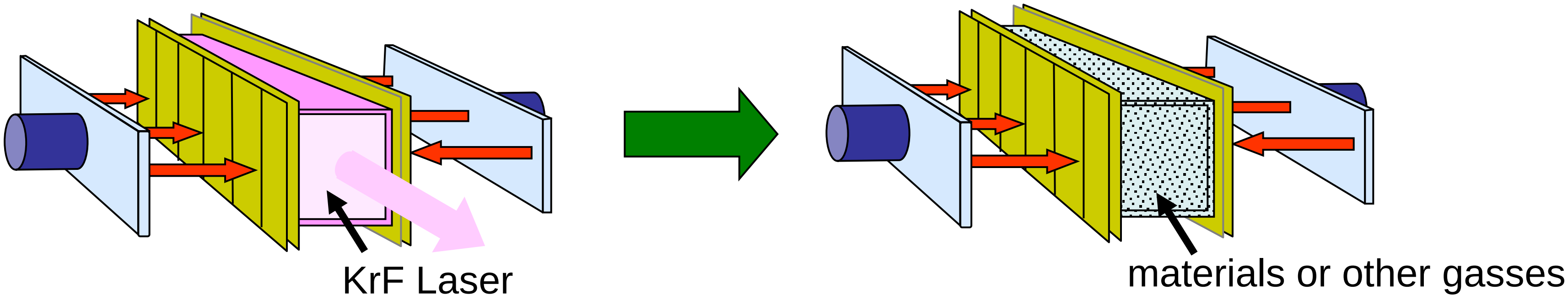
Utilize all solid state switching for Electra’s pulse power.

All Solid State Pulsed Power demonstrator
Continuous run: 11.5 M shots @ 10 Hz



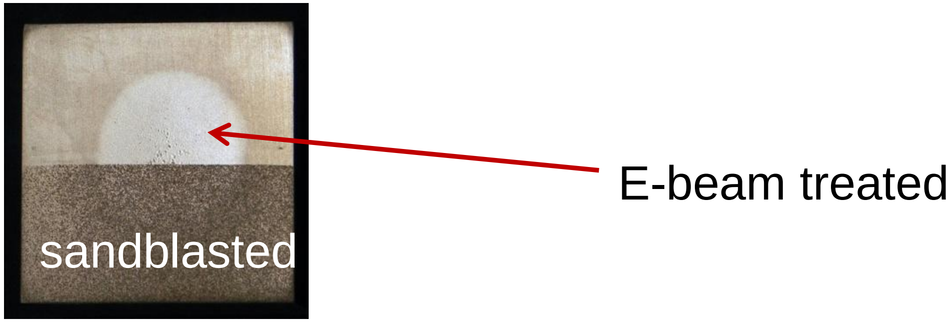
Mechanisms that limited lifetime of Electra’s plasma-cathode diode were identified and corrected on Electra (up to 100,000 shots.) All solid state pulse power would allow much longer run times & tests.

Applications are being developed for Electra's high-power repetitive E-beam technology



1) E-beam shown to harden surfaces:

Less erosion on E-beam treated portion of nickel plate



2) Pulsed E-beam showed catalyst free removal of NOx from fossil fuel power plants

3) Pulsed E-beam fuel reformation:

Demonstrated conversion of natural gas to precursor for liquid fuels

Potential to convert biomass to liquid fuels

Fusion should be developed as a phased program, with well defined gates to advance to the next phase

Phase I:

Basic IFE Science and Technology

Phase II:

Develop full size components

Phase III:

Fusion Test Facility

- Demonstrate integrated physics / technologies for a power plant.
- Tritium breeding, fusion power handling.
- Develop/ validate fusion materials and structures.
- **READY FOR PILOT POWER PLANT**

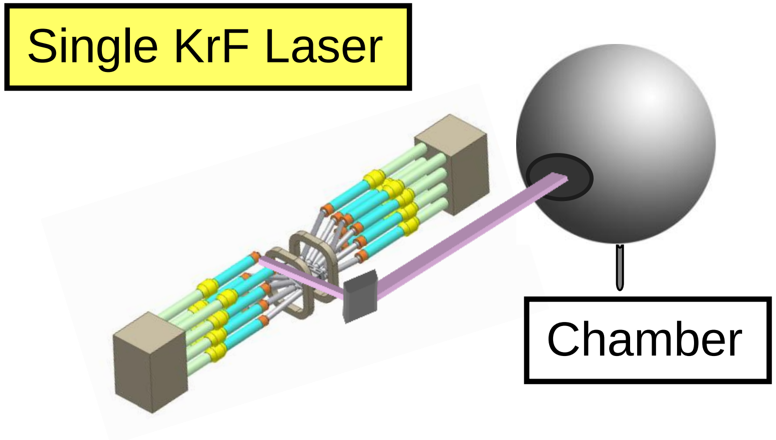
Increasing size
Increasing performance
Decreasing scientific risk
Increasing Industry Partnership

Example: development plan for IFE with KrF

<u>Phase I</u> – Complete full performance subscale KrF system

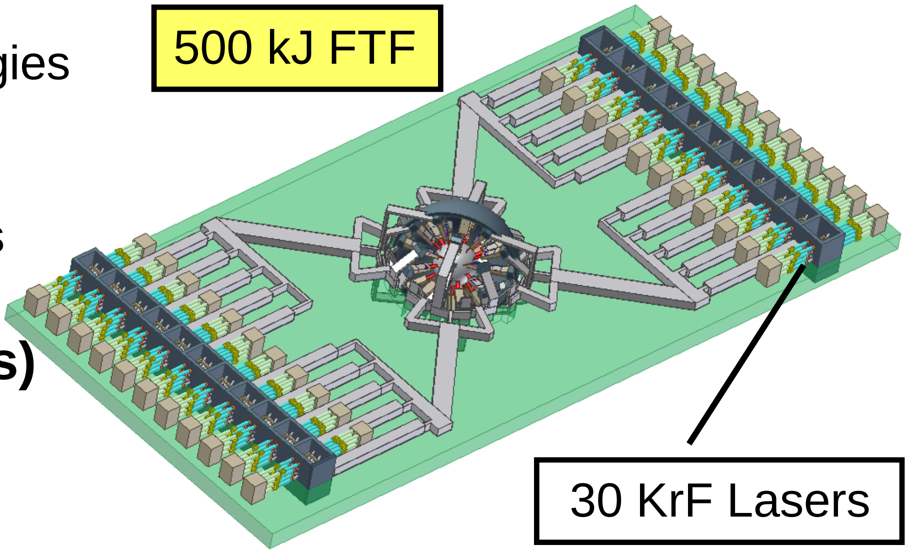
<u>Phase II</u> Develop full size components

- Single 5 Hz 18 kJ KrF laser beamline
- Target fabrication /injection /tracking
- Chamber, optics technologies
- Refine target physics



<u>Phase III</u> Fusion Test Facility (FTF) ~250 MW Fusion (thermal) power

- Thirty 18 kJ KrF laser beamlines
- Show integrated physics / technologies
- Gain (about) 100
- Tritium breeding, power handling
- Develop fusion materials /structures



<u>Phase IV</u> Prototype Power plant(s)

- Electricity to the grid