Implications of Fast Ignition for Inertial Fusion Energy Power Plants*

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* Work performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

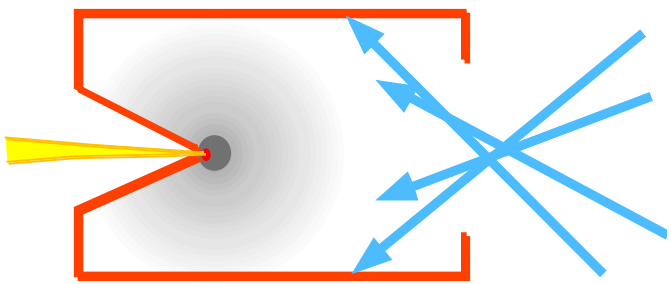
Fast ignition offers a step-change in the pursuit of inertial fusion energy (IFE)

- Reduction in total driver energies, driver cost, and cost of electricity (COE)
- Reduction in radiation damage rates
- Possibility to use advanced targets:
  - reduce or eliminate need for breeding blankets
  - exceptional safety & environmental characteristics
- Relaxation of target fabrication requirements

Fast ignition is expected to open the parameter space for ***innovation*** in chamber design (materials and configuration) and power conversion system design.

Fast ignition could be used with a variety of target designs

- Equimolar D-T targets:
  - By moving from central, hot-spot ignition to fast ignition, the total driver energy falls from 3-5 MJ to less than 1 MJ
  - Even with added cost of ignition beam(s), might provide *30-40% reduction in capital cost*
  - Expect similar reduction in COE



Fast ignition target concept showing driver (blue) and ignitor (yellow) beams. In this concept, plasma blowoff is excluded from the ignitor laser path and the driver lasers are concentrated at one end of the chamber.

Fast ignition...target designs, (Cont'd.)

- High-yield D-T targets:
  - In lieu of reducing the driver energy, one could choose to hold it constant and reach higher fusion yields
  - Yields per target might increase from ~ 400 MJ to more than 1000 MJ
  - Repetition rates could be reduced from ~ 5 Hz to only 1-2 Hz
  - Wider range of available target yields increases chamber design *flexibility*
  - For example, at low repetition rates, chamber clearing might be able to rely upon gravity clearing rather than forced flow schemes with a large pumping power

Fast ignition...target designs, (Cont'd.)

- Tritium-lean targets:
  - Tritium-lean targets would operate at high areal densities ($\rho r \sim 10$-20 g/cm^2) and have overall tritium percentages as low as 0.5%
  - Main fuel would be deuterium; sparkplug region, which the ignitor beam(s) would strike, would contain 20-50% tritium
  - Due to high ρr and low tritium inventories, *targets may be self-sufficient from tritium breeding perspective*
  - Freed from need to keep blanket tritium breeding ratio above unity, one could select materials by other design criteria:
    - Vapor pressure (affects beam propagation)
    - Chemical compatibility
    - Power conversion (higher temperature operation and/or direct conversion)
    - Pumping power (important for liquid wall chambers)
    - Coolant material abundance and cost
    - Safety and environment

Fast ignition targets may be simpler and more robust

- Since a central spark is not needed and shock waves need not propagate through the wall to the center, there is no problem with central mixing caused by a rough interior ice surface or with an asymmetric target

- Might be able to “hard-freeze” targets down to 4 K, simplifying storage and injection

- Alternate fuels with reduced cryogenic requirements might be possible; For example, $B_2D_3T_3$ melts above liquid nitrogen temperatures.

Many issues must be explored

- Fast ignition physics is being studied by groups domestically and internationally
- Fast ignition target designs are being developed as part of the IFE Science program funded by OFES during FY2000
- We propose to leverage this effort by focusing on the *power plant design issues* and implications of fast ignition
- Proposed areas of research are target design, target fabrication and injection, blanket engineering, and power plant design and economics

Target design

- An integrated set of calculations for a fast ignition target design will be performed with LASNEX radiation hydrodynamics code.

- Additional work on tritium-lean, fast ignition targets is needed to verify the required target symmetry, driver energies, fusion yields, and internal tritium production.

- Claims that fast ignition will ease target fabrication requirements and enable single-sided compression need to be verified through a set of calculations that develop gain curves for fast ignition targets with reduced surface quality.

Target fabrication

- In addition to target design activities that will determine acceptable surface roughnesses, techniques for fabrication of fast ignition targets need to be explored.

- We will identify key differences in fast ignition targets–including tritium-lean varieties–and identify and quantify advantages and disadvantages relative to traditional central hot-spot targets.

- Techniques for mass production of fast ignition targets within specifications and at an acceptable cost need to be studied.

Blanket engineering

- A set of alternate blanket materials will be explored. These materials will be selected for characteristics such as vapor pressure, chemical compatibility, power conversion, pumping power, and safety.

- We will complete a survey of liquids and down-select to approximately six that appear attractive. We will recommend analysis and experiments that will enable further down-selection.

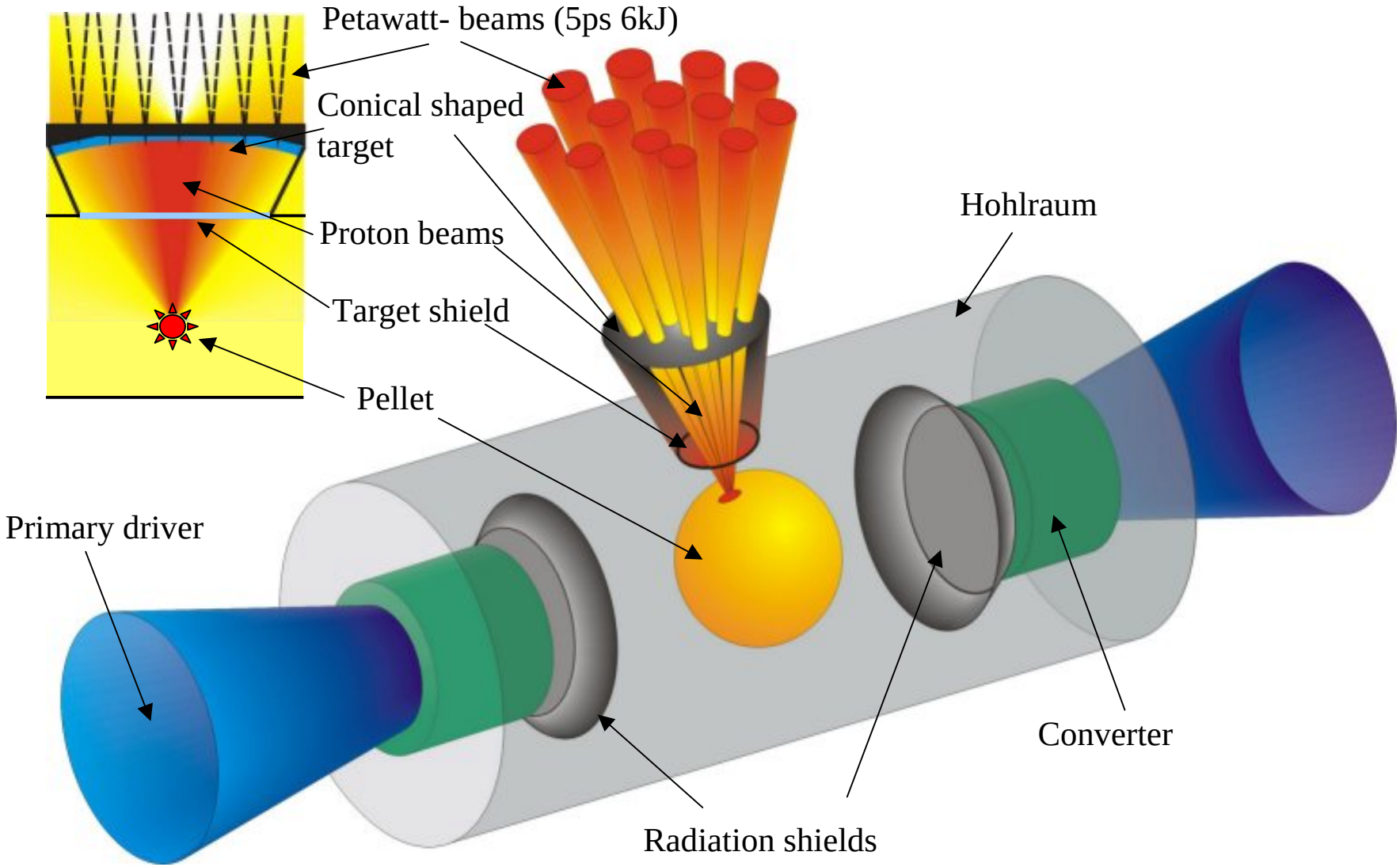
- Supplemental tritium breeding (TBR < 1 blankets with breeding in the target and/or target casing) and its effects upon safety and economics will be considered.

Power plant evaluations

- Results from target design, target fabrication, and blanket design tasks will be integrated into preliminary fast-ignited, power plant designs for one or more of the three target concepts.

- For each design, we will assess the technical risks, quantify the advantages and disadvantages, and make preliminary estimates of the COE.

- This study will set the stage for much more detailed power plant studies, which typically cost more than $1M.


Petawatt- beams (5ps 6kJ)
Conical shaped target
Proton beams
Target shield
Pellet
Hohlraum
Primary driver
Converter
Radiation shields