Update on Alternate Chambers Activities and Neutron Damage Modeling

presented by: Jeff Latkowski
contributors: Wayne Meier, Ralph Moir, Charles Orth,
Susana Reyes, Dave Steich, Mike Tobin, Maria Jose Caturla

Laser IFE Meeting
May 31, 2001

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

Outline

- Alternate chamber concepts
- Driver-chamber interface work
- Neutron damage modeling

We are tasked with consideration of alternate chamber concepts

- We are to consider this as a multi-year (~ 5) program:
  - Current budget is $410K per year
  - Analytical and/or experimental activities are appropriate
- We view this as an opportunity to revisit some older concepts (with modern data and tools) as well as a chance to be very creative/develop new concepts
- We will develop a plan to initially pursue 2-3 concepts; some down-selection may occur at a later date
- We will leverage off of LLNL strengths:
  - target design
  - chamber design & response to target emissions
  - liquid concepts

Most of our team has been assembled

- Jeff Latkowski
- Wayne Meier
- Ralph Moir
- Charles Orth
- Susana Reyes
- Dave Steich
- Mike Tobin

- Don Blackfield may be joining us later in the year

An initial literature survey is complete

Title	Reviewers
A Laser Fusion Reactor Concept Utilizing Magnetic Fields for Cavity Wall Protection	Charles, Dave, Jeff, Wayne
Direct Energy Conversion of Inertial Confinement Fusion and Experiments with Laser-Produced Plasma in Magnetic Fields	Dave, Mike, Wayne
Chamber Technology Concepts for Inertial Fusion Energy—Three Recent Examples	Charles, Jeff, Susana
Conclusions and Directions for the OFE Inertial Fusion Reactor Studies	Dave, Jeff, Mike, Wayne
Synergism in Inertial Confinement Fusion: A Total Direct Energy Conversion Package	Jeff, Mike, Wayne
Development of Laser Fusion Power Plant KOYO—System Optimization and Development of Key Technologies	Dave, Jeff, Wayne
Instability Analysis of a Magnetically Protected Cavity in a D-3He Inertial Confinement Fusion Reactor	Dave, Jeff, Wayne
Design Windows and Chamber Issues	Jeff, Mike, Wayne
Turbostar: An ICF Reactor Using Both Direct and Thermal Power Conversion	Charles, Wayne
A High Gain Fusion Reactor Based on the Magnetically Insulated Inertial Confinement Fusion (MICF) Concept	Charles, Jeff, Mike, Ralph, Wayne
Calculation and Experimental Investigation of Fusion Reactor Divertor Plate and First Wall Protection by Capillary-Pore Systems with Lithium	Ralph, Wayne
Design of Laser Fusion Reactor Driven by Laser-Diode-Pumped Solid State Laser	Charles, Ralph, Wayne

* Thanks to Susana Reyes for conducting the search and assembling the papers; Thanks to Judy Knecht for distributing the papers amongst the team

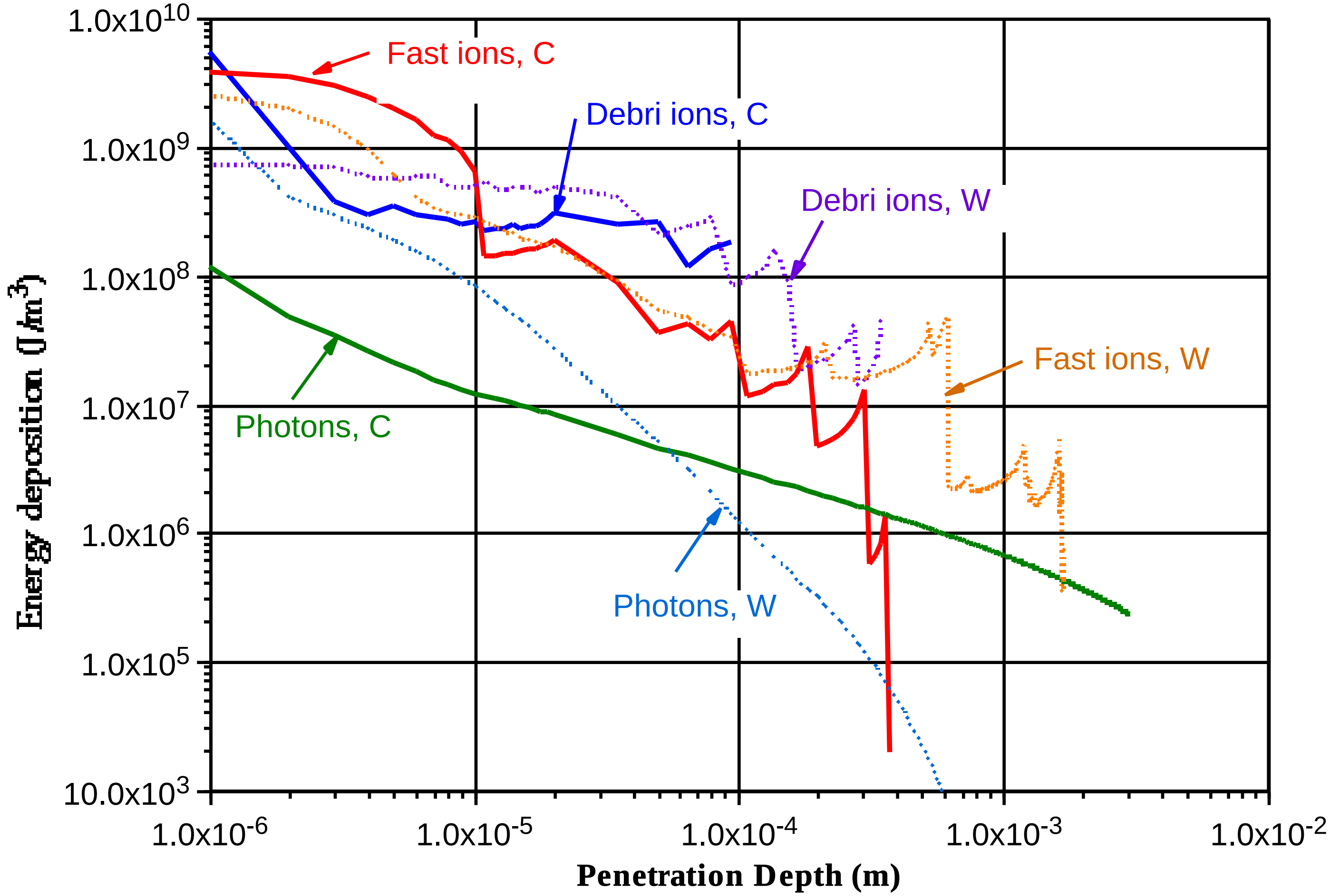
Our approach for the next few months

- For each concept, we will begin by assuming that it will actually work:
  - We will perform basic analyses for each concept
  - We will determine the benefits/advantages of each concept
- We will perform a thorough literature search:
  - Identify key issues/holes for each concept
  - Ensure that the physics is sound
  - Assess the technical risk inherent to each concept
- Our decisions (regarding which concepts to pursue) will be made by a trade-off between the potential benefits and the technical risk

Magnetic deflection/protection

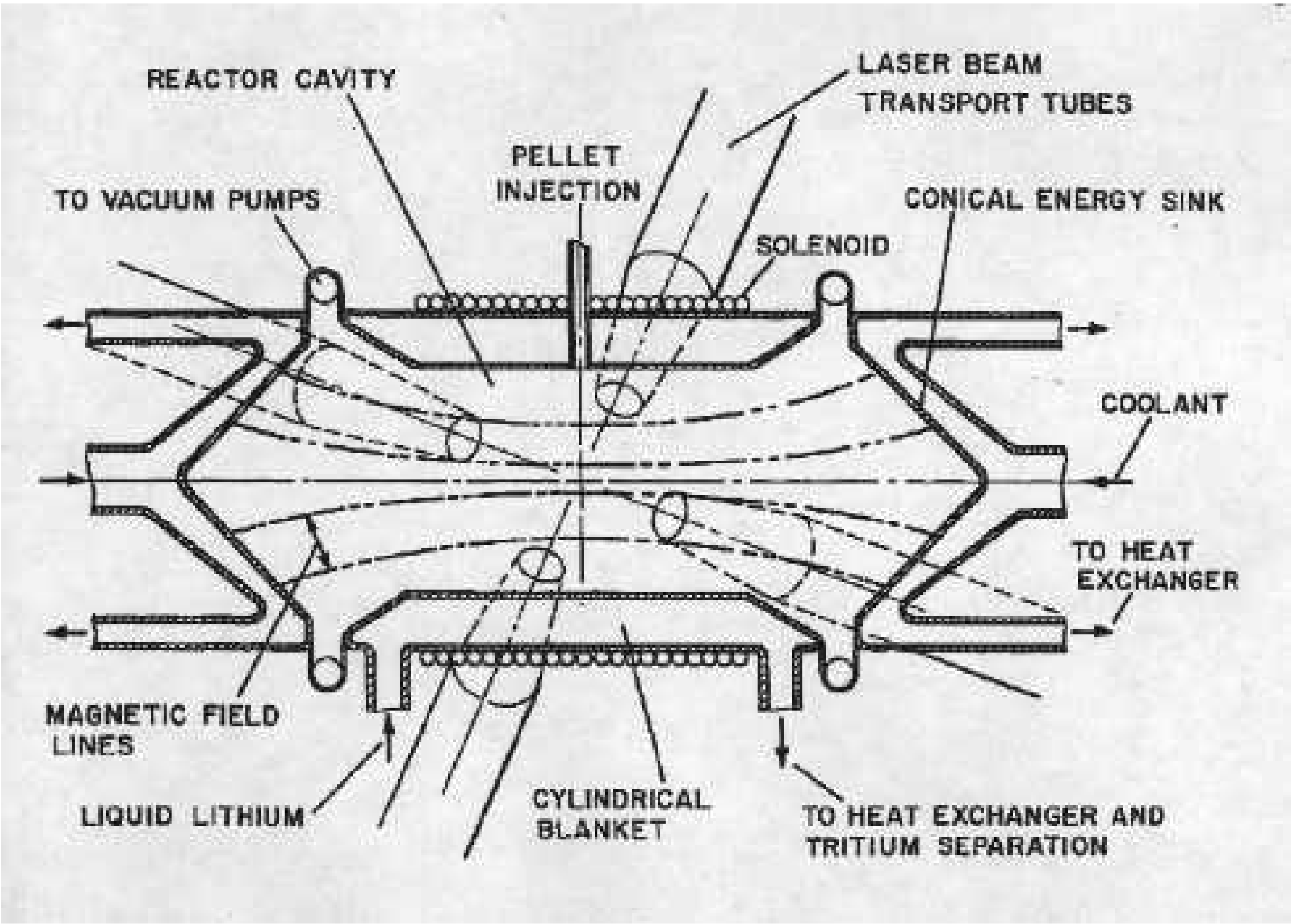
- Pros:
  - May reduce/eliminate ion loading on first wall
  - May increase plant efficiency/reduce COE with direct conversion
- Cons:
  - Still need to deal with x-rays (less energy but higher power)
  - Need to protect magnets
  - Magnets may be large and power hungry
  - Field instabilities an issue?
  - Must deal with many penetrations/non-ideal geometry
  - Difficult to deal with ~ 100 ns pulses?
- Other comments:
  - Tweak target design to increase ions/decrease x-rays?
  - Only one design (LANL, 1974) with self-consistent parameters has been completed to date

Photon and ion attenuation in carbon and tungsten



Source: R. Raffray, March ARIES Meeting

Sample of a magnetically protected first wall



I.O. Bohachevski et al., *Nuclear Technology/Fusion*, **1**, 390 (1981)

Liquid walls will be investigated

- Pros:
  - Renewable surface to deal with ions and x-rays
  - Considerable work has been performed on liquid walls
- Cons:
  - Liquid condensation/re-establishment of protective film for next shot
  - Flow control is a big issue
  - Fabrication of porous structures
  - Flow around beamports and on inverted surfaces
  - Response of thin film to x-rays and debris
  - Flow of vapor up beamlines
- Other comments:
  - Could consider “advanced” molecular liquid (if wetted-wall design) that would breakdown into gases that could be pumped to ease chamber clearing
  - Move to an indirect-drive, distributed-radiator target?

Fast ignition offers many potential advantages

- The potential advantages of fast ignition overlap all areas of IFE: heavy ions, KrF, DPSSL, direct-, and indirect-drive
- Given:
  - –Tremendous international interest in fast ignition
  - –Recent Japanese results
  - –Interest in US in building high-powered lasers
- We feel that it is to our benefit to get ahead of the curve on fast ignition → we will perform analyses for how one might implement fast ignition in a laser-IFE power plant
- We will attempt to answer the question: "**Even in the event that it does work, is there a systems-level analysis that holds together?**"

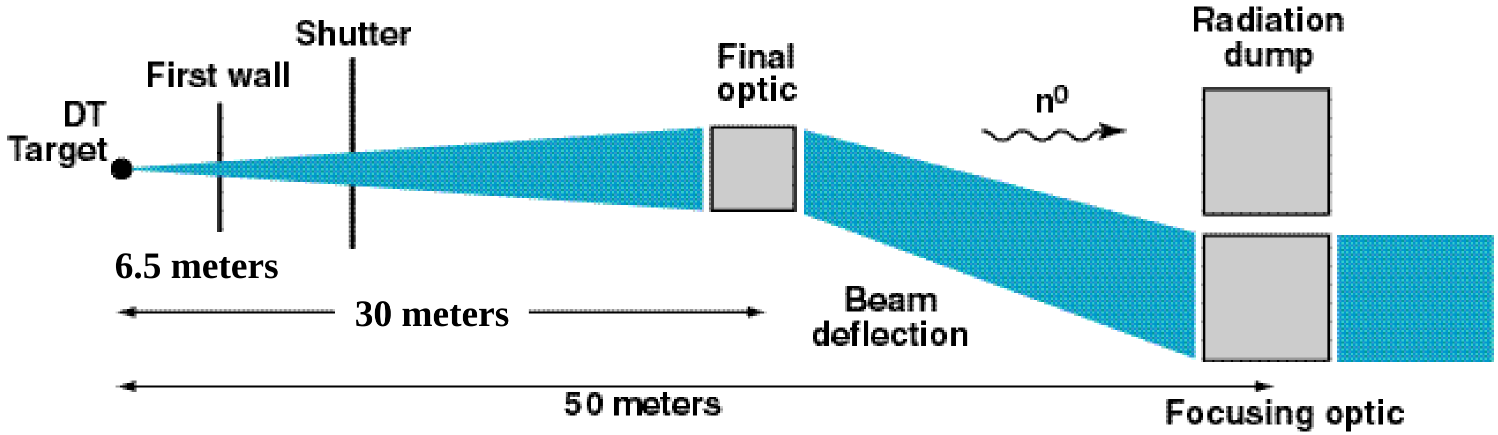
Plan for rest of calendar year

- Devote ~ 2 person-months to each of 2-4 concepts
- Conduct thorough literature searches and simple calculations
- Write report with a ***detailed work plan*** for each concept:
  - Analyses that are needed
  - Codes that need to be imported, modified, created
  - Data that are required (e.g., detailed target output)
  - Experiments that are needed to demonstrate feasibility

Summary of DPSSL-Sombrero results for the final optic

- Model differed from the baseline Sombrero design:
  - Transmissive final optic at 30 m
  - Total open solid-angle fraction of the beams was 5%

- Final optic doses:
  - 8.7 krad/s n + 1.4 krad/s γ (2.8×10^{11} rad/FPY n + 4.4×10^{10} rad/FPY γ)
  - Doses are ~ 20% lower than those obtained with a mono-energetic (14.1 MeV) source. Here, we account for scattering within the target ($\rho r = 3$ g/cm^2).
  - Given these values, Steve Payne (LANSCE) irradiation of fused silica samples to 10^{11} rad is equivalent to ~ 4.6 full-power-months for an IFE final optic



Final optic summary, (Cont'd.)

- Final optic fluxes:
  - 9.7×10^{12} n/cm^2-s + 1.5×10^{12} γ/cm^2-s
  - 9.1×10^{12} n/cm^2-s fast neutron flux ($E_n > 0.1$ MeV)
  - These are a few percent higher than observed with a 14.1 MeV source; The target emits 1.058 neutrons per source neutron due to (n,2n) reactions

- Final optic gas production:
  - H = 27.5 appm/FPY
  - He = 69.1 appm/FPY

- Final optic impurity production:
  - C = 54.1 appm/FPY
  - N = 1.6 appm/FPY
  - Mg = 14.9 appm/FPY
  - Al = 3.9 appm/FPY

Modeling damage in chamber materials

Fusion irradiation simulated by a multiscale model

Neutron spectrum at the first wall

Defects for each recoil from molecular dynamics simulations

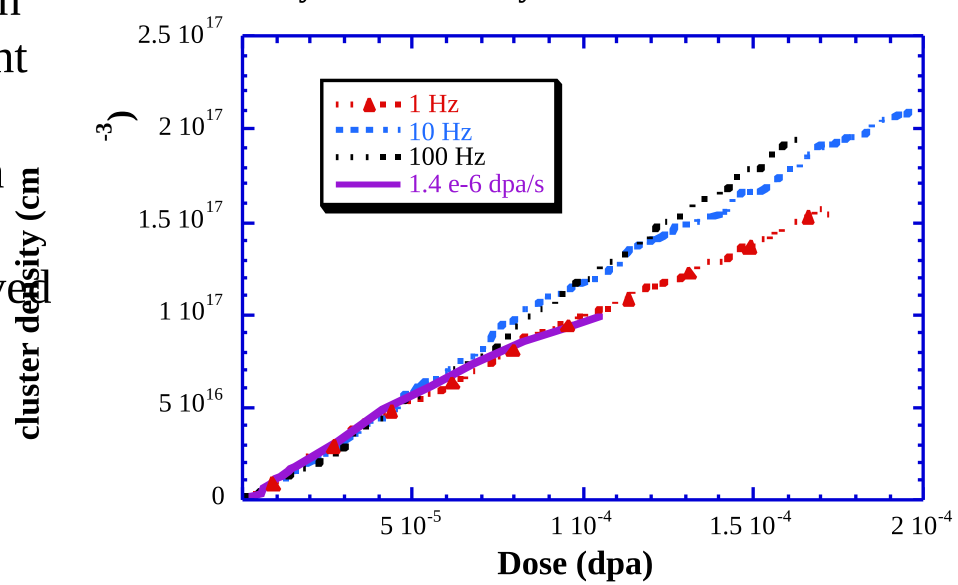
Defect accumulation and migration using kinetic Monte Carlo

Effect of pulse irradiation in Fe has been modeled using this approach for different pulse frequencies and compared to continuum irradiation

No significant difference has been observed between continuum irradiation and 1Hz pulses at very low doses

Simulations must be followed to higher doses

Vacancy cluster density in iron irradiated at 300K



Modeling damage in chamber materials: work in progress

- The Brenner hydrocarbon potential is being implemented into our parallel molecular dynamics code to model graphite.

- Database of defects produced in graphite by recoils ~ 10s of keVs

- Migration energies of defects in graphite

Summary

- Alternate chamber concepts work is underway:
  - Preliminary literature survey completed
  - Will consider magnetic deflection, liquid walls, and fast ignition
  - Will produce detailed work plan for each concept by end of CY

- 3-D neutronics analysis for DPSSL-driven version of Sombrero was completed:
  - Final optic dose: 2.8×10^{11} rad/FPY n
  - Samples have been irradiated to 10^{11} rad (see later talk for details)

- Neutron damage modeling for chambers has begun:
  - Hydrocarbon potentials are being implemented
  - Defect database is under construction