Progress in Inertial Fusion Energy Technology: October 2001 – February 2002

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Progress in IFE Technology: October 2001 - February 2002

Target Fabrication, Injection, and Tracking - GA

D.Goodin, R. Petzoldt, N. Alexander, A Nikroo, L. Brown, G. Besenbruch

- Completed final design review for the Target Injection and Tracking Experimental System for use with both direct and indirect drive targets.
- Together with Sandia National Laboratory and others, we are designing a target supply system for z-pinch power plants.
- Held US/Japan Workshop on Target Fabrication and Injection at General Atomics. Prepared CD with proceedings.
- Defined potential processes to fabricate hohlraum walls with mixture of Hg, Hf, Xe and Kr.
- Started preparations for IAEA Technical Meeting on Physics and Technology of Inertial Fusion Energy Targets and Chambers to be held at General Atomics 17-19 June 2002.
- Additional information about this meeting can be found at http://web.gat.com/conferences/iaea-tm/main.html

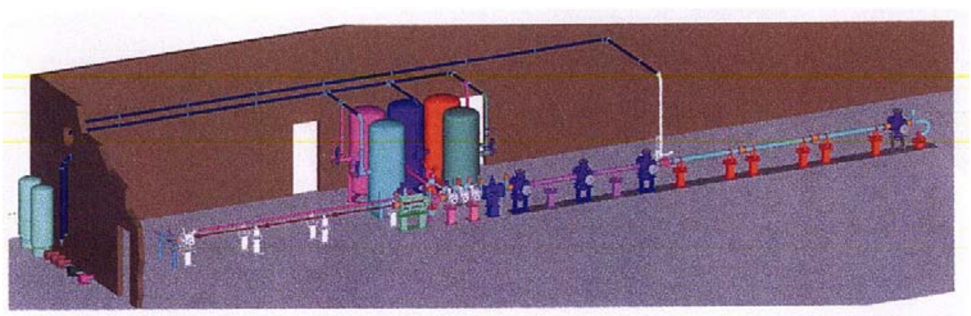


Figure 1. Illustration of IFE Experimental Target Injection and Tracking System to be Installed in GA's Building 22

Figure 2. US/Japan Workshop Attendees

Publications and Presentations

Presentations at the US/Japan workshop on Target Fabrication and Injection, San Diego, CA, December 3-4, 2001.

[1] D. T. Goodin, "IFE Target Fabrication and Injection at GA", **[2]** R. W. Petzoldt, "Target Injection for IFE",
[3] N. B. Alexander, "Target Supply Systems for Z-pinch IFE", **[4]** S. Willms, "Overview of IFE activities at LANL",
[5] B. Rickman, "Chemical Process Modeling for Target Fab Scaleup", **[6]** J. Hoffer, "Cryo Layering for IFE Applications",
[7] A. Greenwood and E. Stephens, "High-Z coatings for Targets", **[8]** W. Steckle, "Polymer foam Developments for IFE target Fabrication at LANL", **[9]** N. Alexander, "Advanced target concepts for survival during Injection",
[10] L. Brown, "Fluidized Beds for IFE Target Fabrication", **[11]** C. Halvorson, "Cryogenic Fuel Layering for IFE"

Progress in IFE Technology: October 2001 - February 2002 (Cont'd.)

Safety and Environment — Idaho National Engineering and Environmental Laboratory

L. C. Cadwallader, D. A. Petti, B. J. Merrill and R. L. Moore

- Work continues on initiating event identification for conceptual IFE power plant designs.

- The HYLIFE-II plant is currently under study.

- Results of the HYLIFE-II and the SOMBRERO tasks [1] will be documented in a report due in the next quarter [2].

- These preliminary lists of initiating events support safety assessment and create a basic framework of events to consider in future risk characterization of new plant designs.

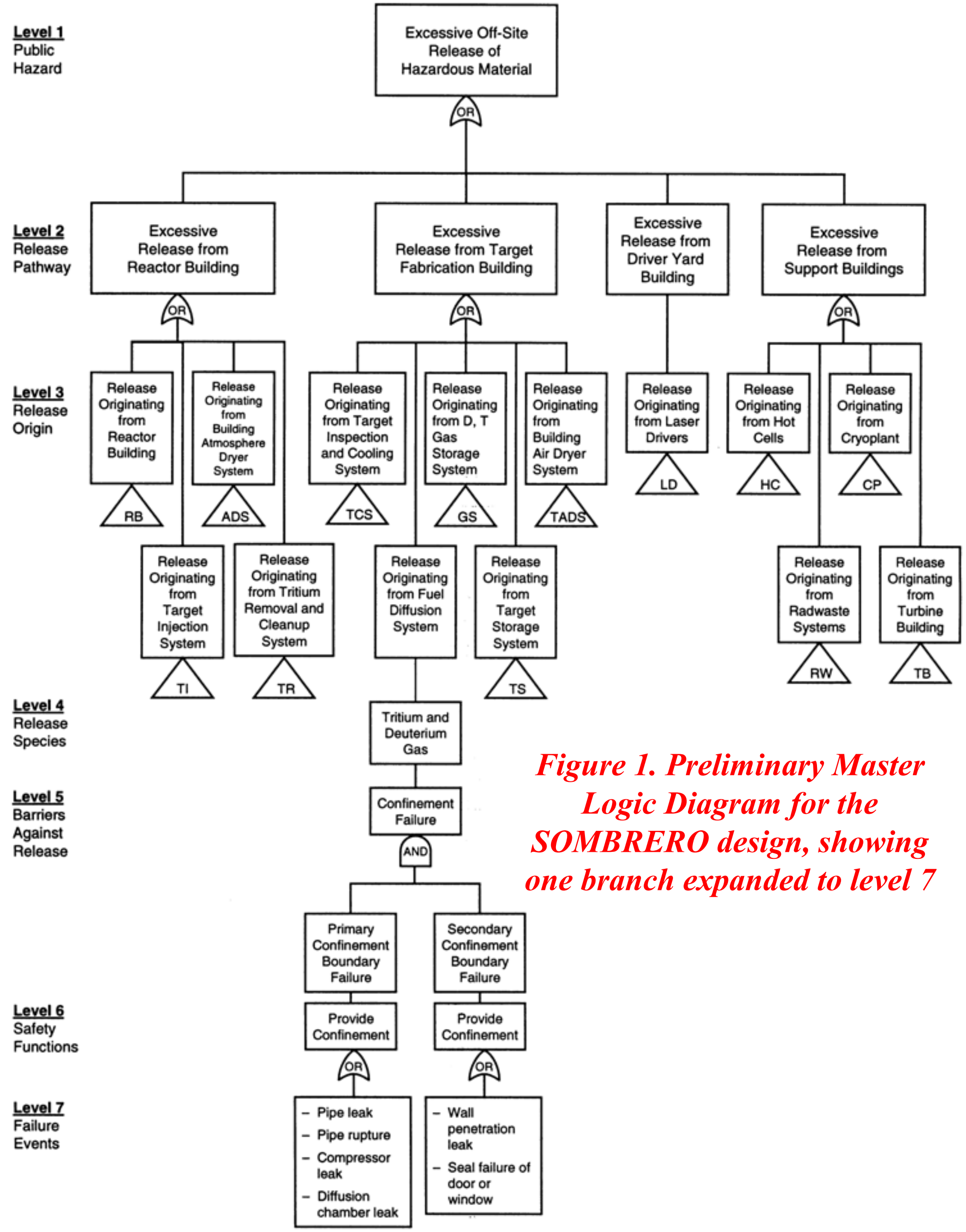


Figure 1. Preliminary Master Logic Diagram for the SOMBRERO design, showing one branch expanded to level 7

Publications and Presentations:

[1] L. C. Cadwallader and J. F. Latkowski, "Preliminary Identification of Accident Initiating Events for IFE Power Plants," INEEL/CON-2001-0567, presented at the 19th Symposium on Fusion Engineering, 21-25 January 2002, Atlantic City, NJ.

[2] L. C. Cadwallader and J. F. Latkowski, "Preliminary Identification of Accident Initiating Events for Inertial Fusion Energy Power Plant Designs," INEEL/EXT-01-1600, to be published.

Progress in IFE Technology: October 2001 - February 2002 (Cont'd.)

Laser Damage to Optics—University of California, Los Angeles (UCLA)

N.M. Ghoniem, Z. Wang and Q. Hu (http://puma.seas.ucla.edu/web_pages/)

- Development of a National Plan for Chamber Technology as a follow-up on the IFE materials plan, completed earlier this year.
- Developed a structural model for global mirror deformation, as a result of thermal and mechanical loads, and incorporating the variations in material swelling and dimensional changes in the neutron and charged particle irradiation fields, as shown in the Fig. 1.
- Completed assessment of the experimental database on Laser-Induced Damage from open literature sources, and compared the results of UCSD experiments of damage to aluminum to the available database. See Figure 2.
- Completed revision to the article submitted to Phys Rev on laser damage, and the article was re-submitted and subsequently accepted for publication. Laser Induced Damage Threshold in covalent materials (e.g. Si and SiC) has been theoretically determined.
- Provided guidance on the manufacturing of SiC laser optics to MER through the SBIR process. Samples are to be shipped to UCSD for further testing and verification of our models of LIDT.

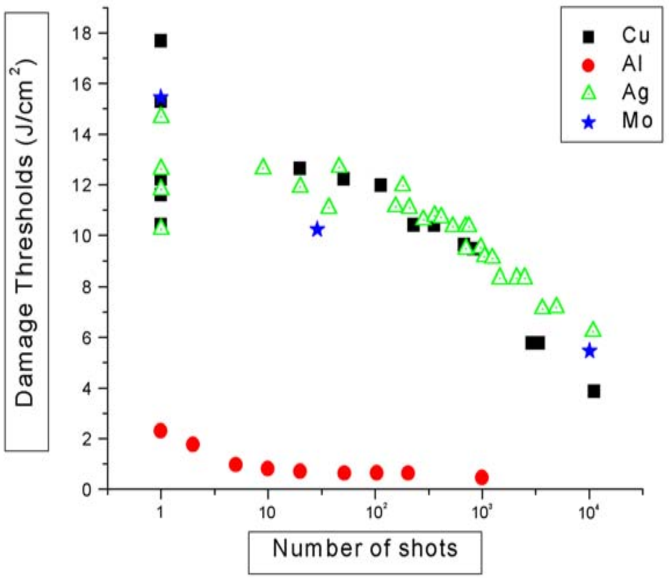


Figure 2. Laser-Induced Damage Threshold (LIDT) is a strong function of material & # of shots

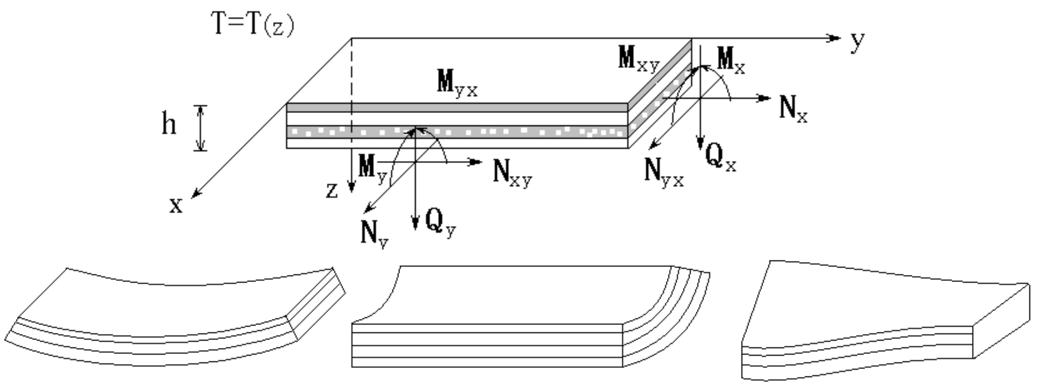


Figure 1. Model for global mirror deformation

Publications and Presentations:

[1] D. Walgraef and N.M. Ghoniem, "The Effects of Crystal Anisotropy and Adherence Forces on Laser Induced Deformation Patterns in Thin Films," accepted, *Phys. Rev.*B.

[2] L. Snead, N.M. Ghoniem and J. Sethian, "Integrated Plan For Materials R&D in Laser Inertial Fusion Energy (IFE)," NRL Report.

Progress in IFE Technology: October 2001 - February 2002 (Cont'd.)

Integration, Systems Studies, Safety & Environment and Driver-Chamber Interface — Lawrence Livermore National Laboratory

W. R. Meier, J. F. Latkowski, R. W. Moir, and S. Reyes

- HIF Systems Modeling:
  - IBEAM code modified to include new models for calculating the beam sport size on target.
  - Driver cost results were combined with HYLIFE-II power plant models to help select a new design point for more detailed studies (see Fig. 1).

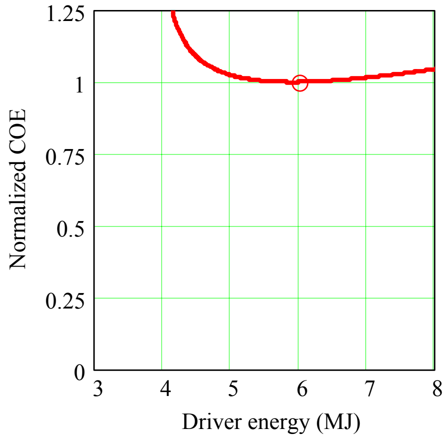


Figure 1. We find a minimum cost of electricity for a 6 MJ, 112-beam driver.

- Safety and Environment:
  - Included "clearance index" (CI) calculation in activation code "ACAB" for waste management considerations and calculated CIs for HYLIFE-II and SOMBRERO.
  - Application of CIs to HYLIFE-II showed that the confinement building activation would qualify for clearance (CI < 1) after ~ 1 yr cooling. See Fig. 2. (Paper submitted to ISFNT-6).
  - Completed liquid screening for potential blanket materials in HYLIFE-II using tritium lean targets. (Paper submitted to ISFNT-6).
  - Compared radiological vs. toxicological issues of two potential target materials: Pb, Hg.
  - Preliminary calculations for x-ray ablation experiments show that PLEX facility can provide relevant energy densities for wetted-wall materials (e.g., Li, flibe, Pb, etc.).
  - Doctorate Extraordinary Award from the UNED University in Madrid, Spain, for S. Reyes thesis dissertation on safety assessment for IFE.

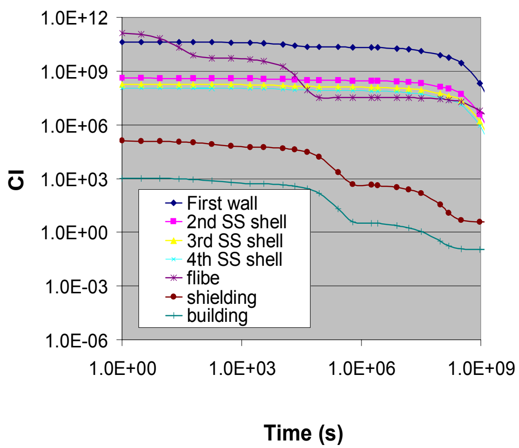


Figure 2. The HYLIFE-II confinement building (5000 m^3) reaches clearance level after ~ 1 yr of cooling

Publications and Presentations:

Submitted to 6th International Symposium on Fusion Nuclear Materials, San Diego, 7-12 April 2002:

[1] Meier, W. R., et al., "Progress Toward Heavy Ion IFE"

[2] Reyes, S.; Sanz, J.; Latkowski, J. F., "Use Of Clearance Indexes To Assess Waste Disposal Issues for the HYLIFE-II Inertial Fusion Energy Power Plant Design"

[3] Reyes, S., et al., "Liquid Wall Options For Tritium-Lean Fast Ignition Inertial Fusion Energy Power Plants"

Others:

[4] Meier, W. R., "An integrated research plan for the IFE element of the Virtual Laboratory for Technology," *Fusion Engineering and Design*, Jan, 2002, V60(N1):37-43

[5] Sanz, J.; Cabellos, O.; Yuste, P.; Reyes, S.; Latkowski, J. F., "Pulsed activation of structural materials in IFE chambers," *Fusion Engineering and Design*, Jan, 2002, V60(N1):45-53

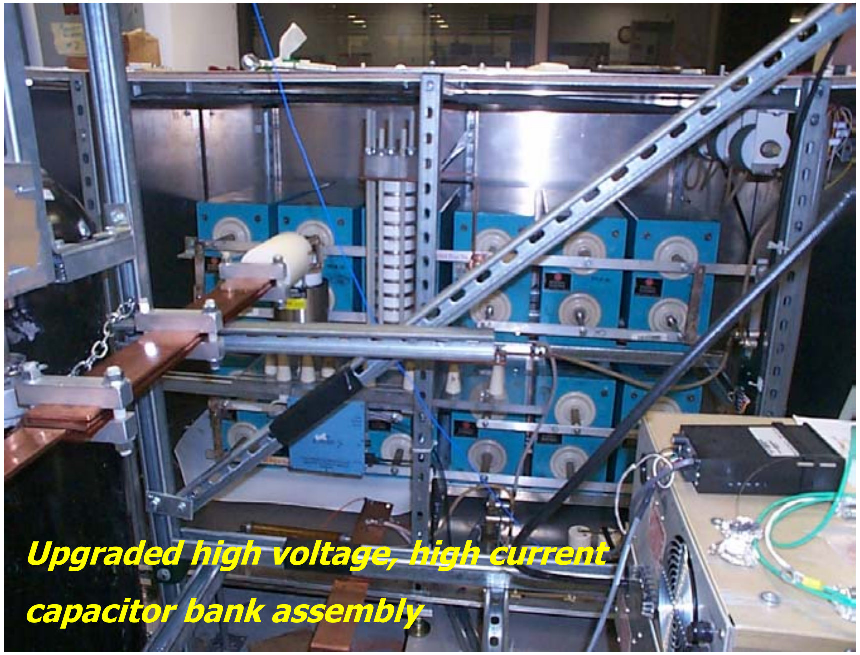
[6] Latkowski, J. F., et al., "Plan for PLEX X-Ray Ablation Experiments and Analysis," LLNL, UCRL-ID-146648 (2002)

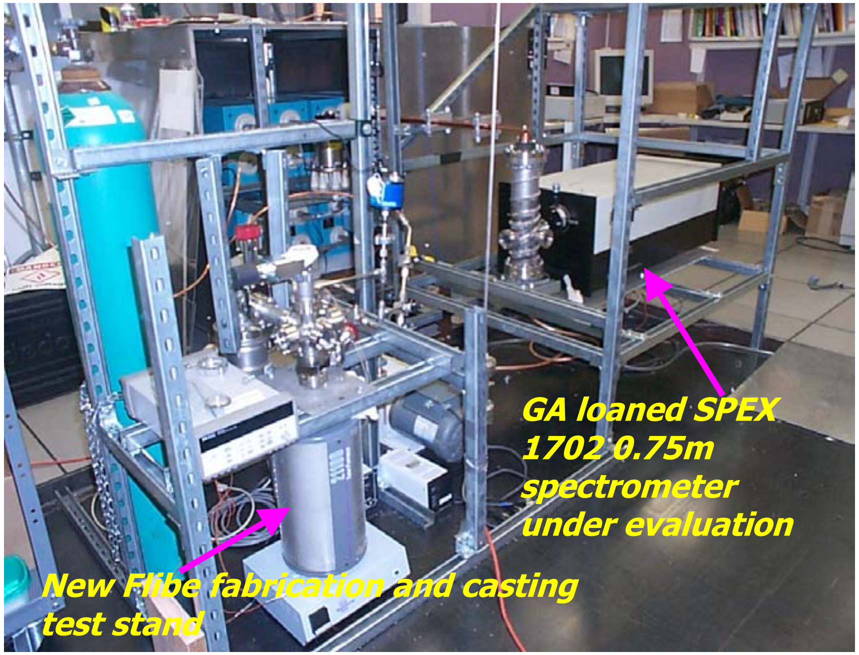
Progress in IFE Technology: October 2001 - February 2002 (Cont'd.)

Vapor Dynamics and Condensation and Free Surface Flow Studies—University of California, Los Angeles (UCLA)

P. Calderoni, A. Konkachabaev, M. Abdou, N.B. Morley, T. Sketchele, A.Y. Ying

- Completed implementation of GA's recommendations on safety and the functionality aspects of pulsed high energy capacitor bank facility.
- Began to address the use of real-time diagnostics for condensation study.
- Constructed a Flibe fabrication and casting facility. Began Flibe casting in quartz tubes.
- Organization of numerical data regarding inlet flow profile and turbulence effects on jet ripple into a paper for the ISFNT-6. conference entitled "Effect of initial turbulence intensity and velocity profile on liquid jets for IFE beamline protection".





Example Features:

- *A redesigned signal conditioning circuit board using an Ignitron switch and 12 high current diode stack for optimal pulse shaping without voltage reversal*
- *A solid copper tri-axial transmission line for safe operation of high current discharges*

3 types of pressure diagnostics planned for Vapor Condensation Study:

- *A SPEX spectrometer for initial conditions characterization*
- *A high frequency (1460 Hz), high temperature (535 ^{o}C) piezoresistive pressure transducer traces pressure evolution in viscous regimes*
- *Capacitance manometers kick in as the gas density drops to molecular regimes*

Progress in IFE Technology: October 2001 - February 2002 (Cont'd.)

Thick-Liquid Protection — Georgia Institute of Technology

S.G. Durbin, J.R. Reperant, M. Yoda, S.I. Abdel-Khalik

- Quantify surface ripple using liquid probability distributions (LPD):
  - Probability of finding liquid at any spatial location.

- Measured LPDs for various slab jet nozzle geometries (Fig. 1) for Reynolds numbers *Re* ≤ 130,000 (Fig. 2):
  - Nozzle contraction type (matched circular-arc vs. 5th-order polynomial).
  - Rounded corners at nozzle exit.

- Measured LPDs for jets with 5% area blockage in flow conditioner section upstream of nozzle (Fig. 3).

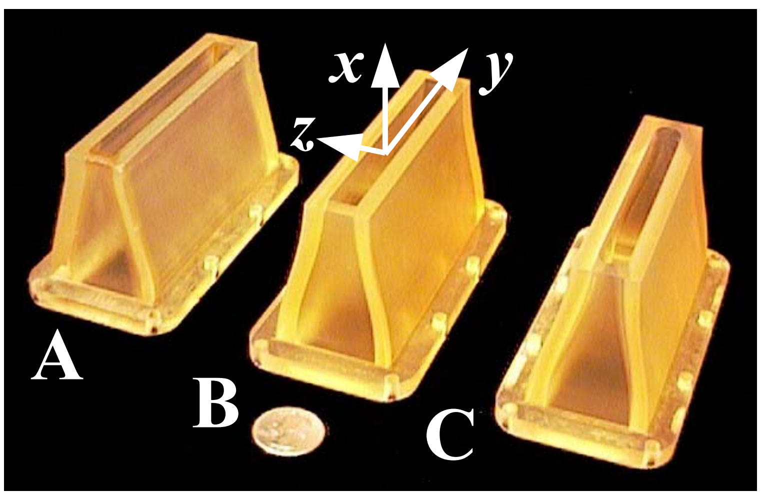


Figure 1. Nozzle geometry:
A: 2D circular-arc contraction (contracts only in z-dimension)
B: 2D 5th order polynomial contraction
C: B with rounded corners at exit

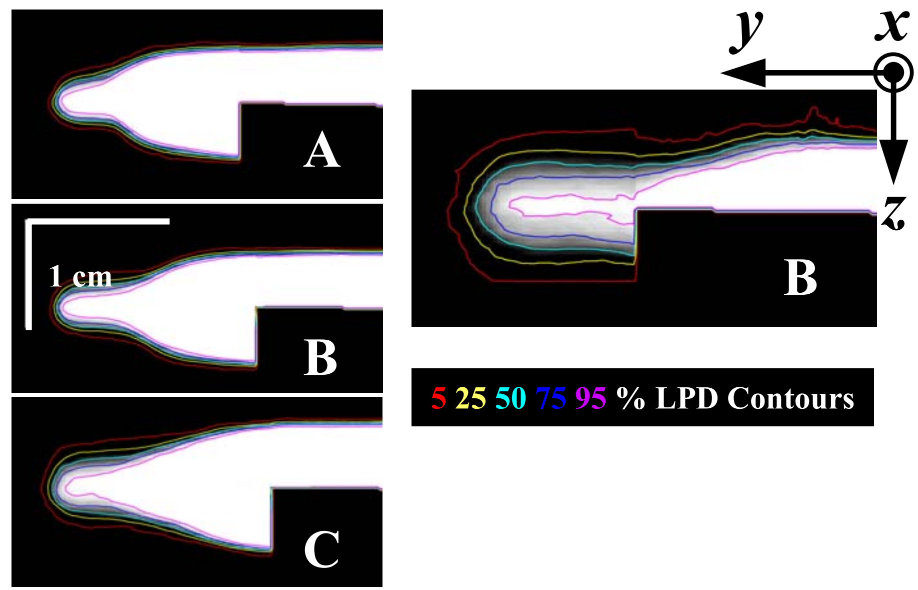


Figure 2. LPD similar in central region for all 3 nozzles

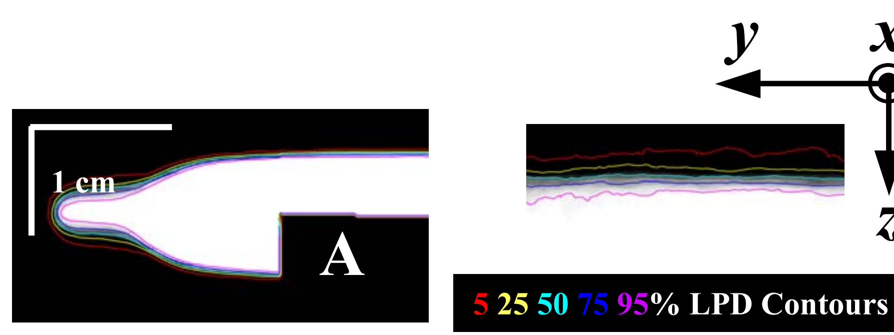


Figure 3. Blockage drastically increases surface ripple (both images at same scale)

Progress in IFE Technology: October 2001 - February 2002 (Cont'd.)

Laser Interactions and Final Optics Studies — University of California, San Diego

M. S. Tillack, M. Zaghloul, T. K. Mau, F. Najmabadi, J. Pulsifer, A. Gaeris, S. S. Harilal, B. Harilal, L. Chousal
(see: http://joy.ucsd.edu/RESEARCH/ife.shtml)

- Damage threshold measurements were compared with thermal stress analysis. The results are consistent within 50% assuming $2s_y$ (w/o strain rate effects) as the stress limit. Effects of spatial nonuniformity in the beam were analyzed and determined to play a small role.

- The effect of a liquid metal film on mirror reflectivity was modeled. For this effort, Pb optical data were obtained from J. A. Woolam. Pb is most deleterious among metals studied, while Na and Li are benign. 1 nm contamination is the limit for the 1% obscuration requirement.

- A study of gross mirror deformation impacts on beam spot size and illumination profile on target has been started.

- Aerosols were generated using a piezo-electric nebulizer. This method was shown to be acceptable for producing contaminants on optical surfaces in the range of 2-10 mm.

- Breakdown measurements were performed using a gated iCCD camera. Breakdown threshold in clean air agrees well with theoretical predictions.

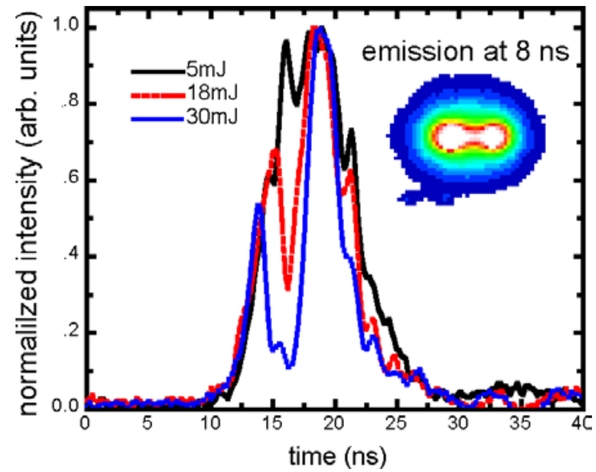


Figure 1. Normalized temporal profile of transmitted beam at different energies, showing initial energy absorption and subsequent bleaching.

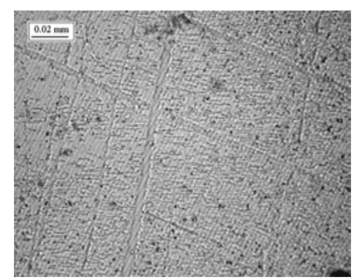


Figure 2. Example of Al surface damage after 10^4 shots

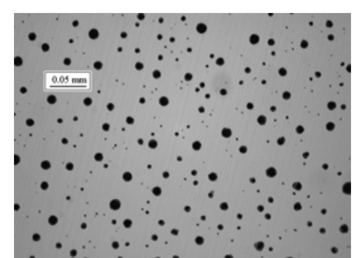


Figure 3. Nebulized aerosol on an Al mirror

Publications and Presentations:

19th Symposium on Fusion Engineering, Atlantic City, 22-25 January 2002:

[1] M. R. Zaghloul, M. S. Tillack and T. K. Mau, "Laser-Induced Damage of Metal Mirrors Under Long-Term Exposure at Shallow Angle of Incidence"

[2] T. K. Mau, *et al.* "Modeling of Mirror Surface Damage Effects on Beam Performance in a Laser-Driven IFE Power Plant"

Presentations at 3rd High Average Power Laser Program Workshop, 13-14 November 2002:

[3] M. S. Tillack, "Dust & LIDT Threat Modeling and Planned Experiments"

[4] F. Najmabadi, "Chamber Development Plan and Chamber Simulation Experiments"

UCSD Reports:

[5] S. S. Harilal and Bindhu Harilal, " Diagnostics of Laser Induced Spark in Air using fast ICCD Photography," UCSD-AET-0201, January 2002.

[6] Bindhu Harilal and S. S. Harilal, "Experimental Studies of the Energy Absorption and Emission from Laser Induced Spark in Air," UCSD-AET-0202, January 2002.

Progress in IFE Technology: October 2001 - February 2002 (Cont'd.)

Thick-Liquid Protection —University of California at Berkeley

P. F. Peterson, S. Pemberton, C. Debonnel, G. Fukuda, D. Olander

- HIF Point Design Support. The HIF VNL initiated a series of meetings and design activities in November, 2001 to identify promising parameter regions for a new HIF accelerator, final transport, target and chamber point design. UCB has been supporting this activity by identifying options for chamber geometries. These include the identification of several "annular array" geometries, where beams are removed from the corners and center of the square lattice to create a conical, annular beam array. Current efforts are focused on 11 x 11 and 9 x 9 array systems.

- Cylindrical and vortex flow testing and theory. UCB completed fabrication of a test stand for its cylindrical jet and vortex flow nozzles. Work in now underway making measurements of nozzle performance to support the HIF point design effort.

Figure 1. Side view of vortex nozzle in test stand operating at 30° inclination, with fan on left and extraction nozzle on right

Figure 2. Vortex injection nozzle

- Disruption experiments. UCB continued its work in the Vacuum Hydraulics Experiment (VHEX) facility studying the effects of target impulse loads in disrupting liquid structures. UCLA has loaned a 500 frame-per-second video system that is currently being installed. The major accomplishments for the period have included modifying the flow conditioning system to provide uniform jet velocities in the jet array, and performance of a large number of shots.

- Disruption modeling. UCB has begun to study energy dissipation mechanisms in voided blankets. Shock propagation into a voided liquid blanket, due to a surface impulse, initially delivers substantial kinetic energy and momentum to a thin layer. This work is quantifying how the kinetic energy is dissipated by conversion to turbulent kinetic energy, as the momentum is redistributed through the blanket.