Progress in Research on IFE Chambers and Targets

June – September 2003

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Progress in IFE Technology: June-September 2003
Integration, Systems Studies, Safety & Environment and Driver-Chamber Interface — Lawrence Livermore National Laboratory

• Completed IFSA paper on fast ignition. Found that for a HIF plant, driver can be reduced from 7 MJ to 2.75 MJ and from 120 beams to 48 beams. The COE is reduced by about 25% (see Figure 1).

• Compiled a thermo-mechanical stress analysis of proposed high-temperature C/C-SiC compact heat exchangers for use in molten salt protected IFE power plants (see Figures 2 and 3).

• Completed multimaterial version of ABLATOR code for modeling of x-ray ablation on IFE first wall and optics, paper presented at IFSA conference.

• Performed safety analysis of beryllium use in IFE, compared radioactivity versus chemical toxicity hazards. Results show that beryllium chemical exposures would be more hazardous that radioactive doses in case of accidental release of activated flibe.

Publications and Presentations
The infrastructure has been built to integrate the graphical user interface (in Java) with the underlying native atomic codes written in Fortran. Java Native Interface and process creation technology are applied for communication between the Java user interfaces and the Fortran codes.

The NCSA Hierarchical Data Format (HDF5) has been successfully used as the data format standard for storing the various atomic data, including the wave functions, transition energies, oscillator strength and so on.

A preliminary web site (http://lapop.ep.wisc.edu:8990/Webatom-root/index.jsp) aimed to provide useful tools for atomic data and spectrum analysis online has been set up. Further work is required for practical use.

Tasks accomplished for developing the YAC code:

1) Capable to calculate the relativistic wave functions for any elements in the periodic table and to plot in graphs.
2) Capable to compute the energy level structures under two different atomic models, the detailed term accounting (DTA) model and the relativistic single-configuration single-transition unresolved transition (RSSUTA) model.
3) Capable to compute the oscillator strengths between the energy levels under the RSSUTA model.

Future work:

1) Photo-ionization calculations under the self-consistent field approximation.
2) Free-free bremsstrahlung calculations.
3) Incorporate these three major components (bound-bound, photo-ionization, bremsstrahlung) to calculate the spectrum and opacity.

Figure 1. Screenshot of the YAC code to display the energy structures and line transitions.

Publications and Presentations:
Thick-Liquid Protection—University of California at Berkeley

P. F. Peterson, J. Freeman, P. Bardet, C. Debonnel, G. Fukuda, H. Zhao, D. Olander

• UC Berkeley has extended its earlier work on HIF beam-tube vortexes to larger-scale vortexes by a combination of wall blowing and suction. Initial experiments with a 22-cm diameter device demonstrated that the liquid pool that initially accumulates at the bottom of the vortex chamber can be cleared by a phased startup of injection nozzles, forming a stable vortex layer with a thickness between 1.0 and 3.0 cm (thickness up to 25% of the chamber radius) depending on the number of injection nozzles running. In initial experiments, stable operation with Froude numbers \((V^2/Rg)\) as low as 4.0 have been obtained. Due to the kinetic energy injected by the blowing jets, turbulence intensity in these vortex flows is expected to be substantially larger than in the fully-developed turbulent film flows that have been studied previously for MFE chamber protection. Upcoming work will use particle image velocimetry to measure turbulence intensity in beam-tube vortex flow, and further work will be performed to refine the control of large vortex flows using combined blowing and suction.

Publications and Presentations

Experimental effort:

We completed the investigation of transient condensation of lithium fluoride vapors in conditions relevant to IFE systems chamber. We achieved clean, high-vacuum conditions before vapor injection. The brittle nature of the ablated LiF crystal does not allow to use it as discharge confining material in the vapor source. High temperature ceramics also proved to be incompatible with the viscous and thermal shock developed in the high current arc thus we had to rely on poly-carbonate material. Despite the presence of traces of non-condensable gases generated by the ablation of the poly-carbonate, the results show that LiF vapors are cleared from the chamber volume in less then 20 ms, as can be seen in Figure 1.

Modeling:

In order to apply the Tsunami code with condensation at the boundaries to the conditions encountered in the experiments, we modified the condensation subroutine to account for the presence of a mixture of gases, one component of which does not condense. Preliminary results of the decrease of the total mass present in the numerical domain due to condensation in the first millisecond are showed in Figure 2.
Thick-Liquid Protection — Georgia Institute of Technology
S.G. Durbin, M. Yoda, S.I. Abdel-Khalik

- Quantified impact of boundary-layer cutting and flow straightener modifications at $Re = 130,000$
  - “Hydrodynamic source term” (droplet formation due to turbulent breakup)
  - Surface ripple
  - BL cutting of well-conditioned flow appears to eliminate hydrodynamic source term
- Boundary layer cutting, see Figure 1:
  - “Cut” away 0.25 mm BL fluid on one side of liquid sheet at various $x$-locations
  - Removed liquid ($\sim 0.18$ kg/s) diverted to side
- Mass Flux ($x/\delta = 25$), see Figure 2:
  - Hydrodynamic source term sensitive to initial conditions
  - Good flow conditioning more important than BL cutting
  - Preventing blockage of fine screens major issue
- Surface Ripple ($x/\delta = 25$), see Figure 3:
  - Std. deviation $\sigma_z$ averaged over central 75% of flow
  - BL cutting reduces surface ripple by 17% for standard flow conditioning
  - Fine screen has larger impact on flow

Figure 4. Cross-section from averaging 130 PLIF images over 4.3 s
- Sharp protrusions near edges of cut jet
- Cut jet has smaller $y$-extent

Publications and Presentations
**Progress in IFE Technology: June-September 2003 (Cont’d.)**

**Target Fabrication, Injection, and Tracking – GA/LANL**  
*D. Goodin, A. Nobile, R. Petzoldt, B. Vermillion and G. Besenbruch*

- Developed a new method to expand the range of possible hohlraum materials in Flibe to include materials that are solid at Flibe operating temperatures. Very fine seed particles (~0.5 micron) provide a large surface area for plating to occur thereby minimizing plating in small fluid openings (e.g. screens and tritium vacuum disengagers) in a liquid wall power plant. The particles would be filtered in a slip stream after growing to about 1.5 micron.

- Completed the design and ordered a unique rifled barrel for hohlraum injection system.

- Evaluated several sabot materials for acceptable operation at up to 400 m/s in our 8 m gun barrel, achieved sabot separation and deflection at over 300 m/s, and shot targets the full 17 m length of the system beyond the barrel.

- Calculated radial displacement of membrane supported capsule in rotating hohlraum (see sketch below) during injection. If the capsule is attached to the membrane, additional displacement due to rotation induced stretching of the membrane is negligible.

**Publications and Presentations**

**ARIES:**


**IFSA:**


First-ever Growth of Fiber Arrays for High-Z Hohlraum Materials: Developed a new method of fabricating low-density hohlraum materials using diffractive optics to generate multiple reaction zones (See Fig. 1), so that many fibers can be grown at once. In this way, a 7x7 array of 49 carbon fibers were grown from ethylene. This demonstrates that it is possible to create lattice-like structures in rapid succession as will be needed for low-density hohlraum materials.

Calibrated & used a new apparatus for measuring the temperature at the tip of a fiber, allowing the fiber growth rate to be correlated to the reaction temperature, giving reaction kinetics and thermodynamics. For the first time, the mass-transport-limited growth curve was measured for an LCVD reaction, allowing the process to be better controlled (see Fig. 2).

New materials were grown from the vapor phase and the fiber growth rates were measured: Tungsten Carbide Fibers were grown from a mixture of tungsten hexafluoride and ethylene.

A new method for measuring the temperature distribution across the fiber tip and the fiber diameter was implemented. This uses a chopped infrared image of the fiber tip(s) during growth to give real-time data for controlled growth.

Invented and implemented a new method of measuring fiber growth rates in real-time, using laser light interference between the focusing objective and fiber tip. In essence this is a FP-interferometer, allowing measurement of the fiber tip position to within a fraction of a wavelength of light. This is perhaps the most important contribution thus far, as a knowledge of the fiber tip location allows us to track the growth for uniform growth.

**Publications and Presentations**


We have continued our analysis of the dynamics associated with an expanding laser-produced plasma in a steady state external magnetic field. In the early phase of the plume expansion, the directed beta \( \beta_d = 4\pi nMV^2/B^2 \) is on the order of a few thousand. This indicates that the hot, highly conductive ionized plume has effectively displaced the magnetic field from its volume through the generation of large diamagnetic currents. (See Figure 1.)

Spectroscopic measurements of the plasma expanding across a transverse magnetic field were used to determine temporal as well as spatial profiles of electron temperature and electron density. In our experiment we observed a 30% increase in electron temperature near stagnation indicating higher collisionality resulting from confinement of the energetic plume. (See Figure 2.)

Laser-based diagnostic techniques have been surveyed for in situ time resolved measurement of particle size, velocity, and number density of aerosol particles in IFE relevant ablation plumes. Complete diagnosis of aerosol behavior requires a combination of two or more measurement techniques. Methods such as cavity ring down laser spectroscopy, dark field imaging, and laser induced incandescence have been assessed.

Work was completed and documented on the propagation of short-pulse lasers in gases beyond the breakdown threshold. Optical emission spectroscopy was used to measure the spatial and temporal evolution of electron density and temperature in air and argon plumes. One article was accepted for publication in Journal of Applied Physics, and another was submitted to Applied Spectroscopy.

**Publications and Presentations**