Modeling of Z-Ablation

I. E. Golovkin, R. R. Peterson, D. A. Haynes
University of Wisconsin-Madison

G. Rochau
Sandia National Laboratories

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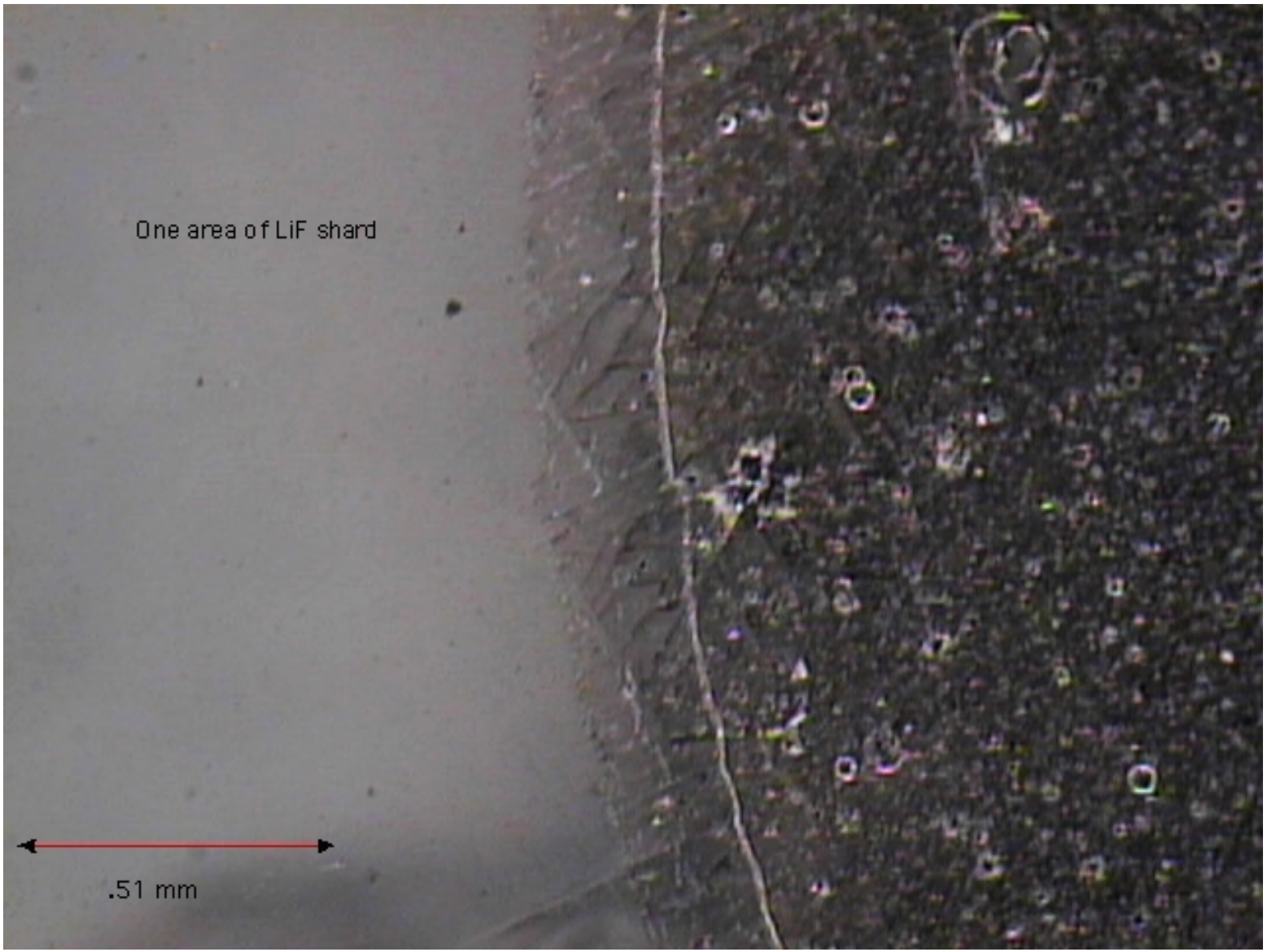
Z Experiments To Understand How IFE Target Chamber Materials Respond to Intense Short-Pulsed X-rays

- This Project is a Partnership Between Several Institutions (SNL, U Wisc., U. Cal-Berkeley, ESL, NRL).
- Perform x-ray ablation experiments on Z at IFE chamber relevant fluences and spectra.
- Advance the technology (debris mitigation and diagnostics) of this type of experiment.
- Study several IFE relevant materials.
- Validate IFE chamber dynamics computer codes (BUCKY and TSUMANI).

Close-up Image of LiF Sample After Shot 783

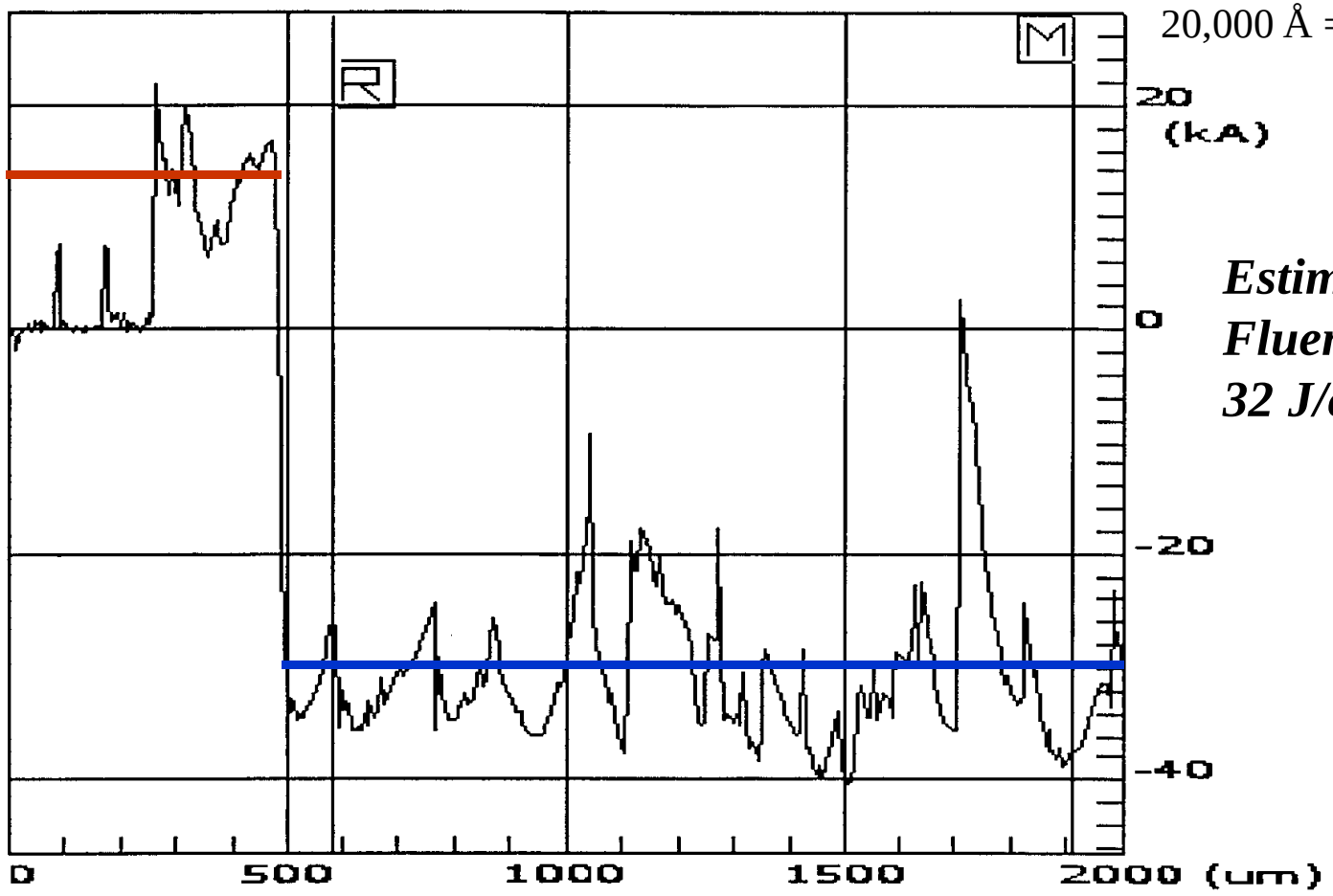


Measured Profile of LiF Shot With W Wire Array X-rays Shows 3 μm Net Ablation

Z Shot 783

1.5 μm of re-condensation or splash

3.0 μm of erosion



Estimated Fluence = 32 J/cm²

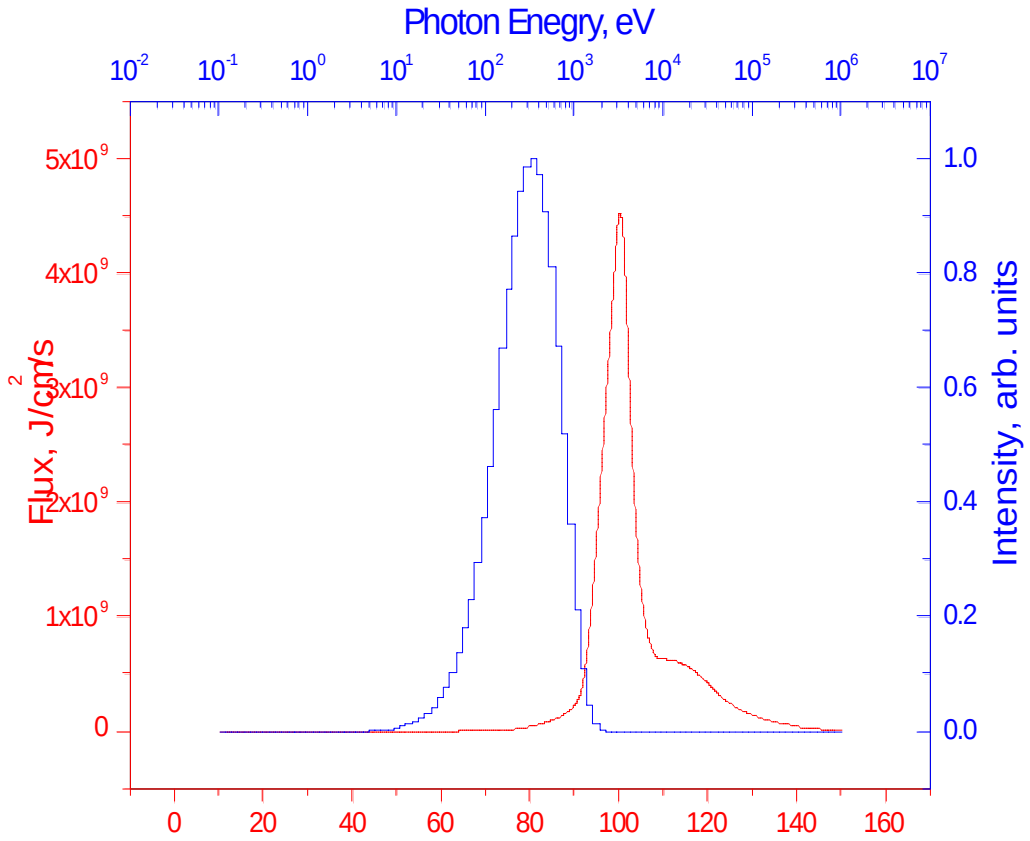
Gross Vaporization = 3.0 or 4.5 μm?

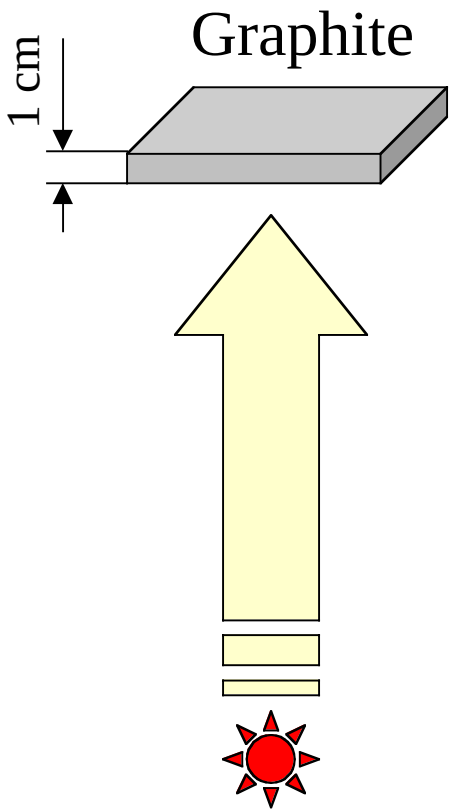
BUCKY is a Flexible 1-D Lagrangian Radiation-Hydrodynamics Code: Used to model first wall heating, vaporization and re-condensation

- 1-D Lagrangian MHD (spherical, cylindrical or slab).
- Thermal conduction with diffusion.
- Applied electrical current with magnetic field and pressure calculation.
- Radiation transport with multi-group flux-limited diffusion, method of short characteristics, and variable Eddington.
- Non-LTE CRE line transport.
- Opacities and equations of state from EOSOPA, IONMIX or SESAME.
- Thermonuclear burn (DT,DD,DHe3) with in-flight reactions.
- Fusion product transport; time-dependent charged particle tracking, neutron energy deposition.
- Applied energy sources: time and energy dependent ions, electrons, x-rays and lasers.
- Moderate energy density physics: melting, vaporization, and thermal conduction in solids and liquids.
- Benchmarking: x-ray burn-through and shock experiments on Nova and Omega, x-ray vaporization, RHEPP melting and vaporization, PBFA-II Kα emission, …
- Platforms: UNIX, PC, MAC

Sample BUCKY Simulation of Z X-Ray Ablation Experiments

- VISRAD (Prism Computational Sciences) calculation of source geometry for Z shot 783.
- Assumed Sample is in far-field where $I \propto 1/r^2$.
- Slab BUCKY (Univ. of Wisconsin) simulation.



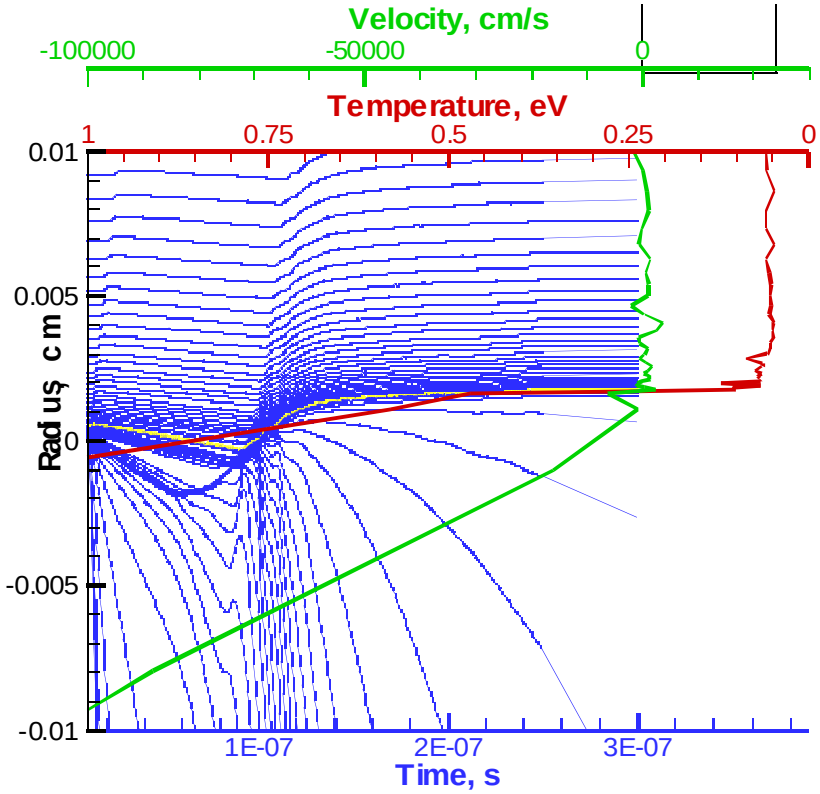


Z shot #783

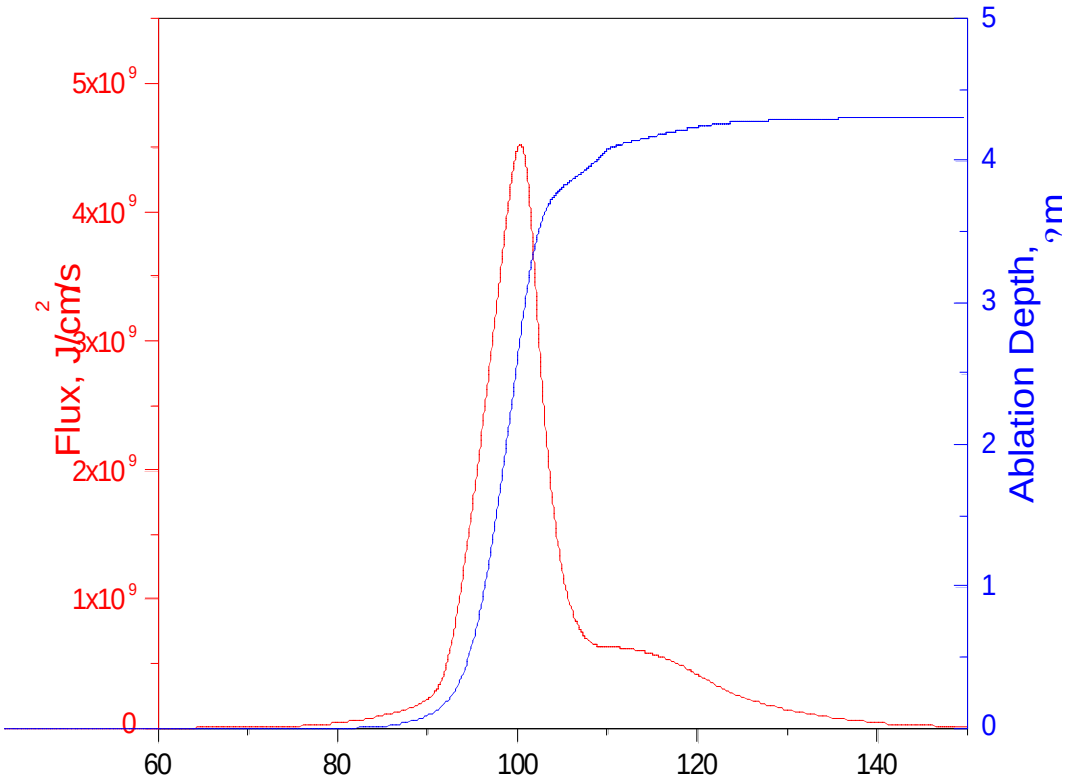
Different Approaches to Calculate Erosion Depth Yield Consistent Results

BUCKY calculations for LiF

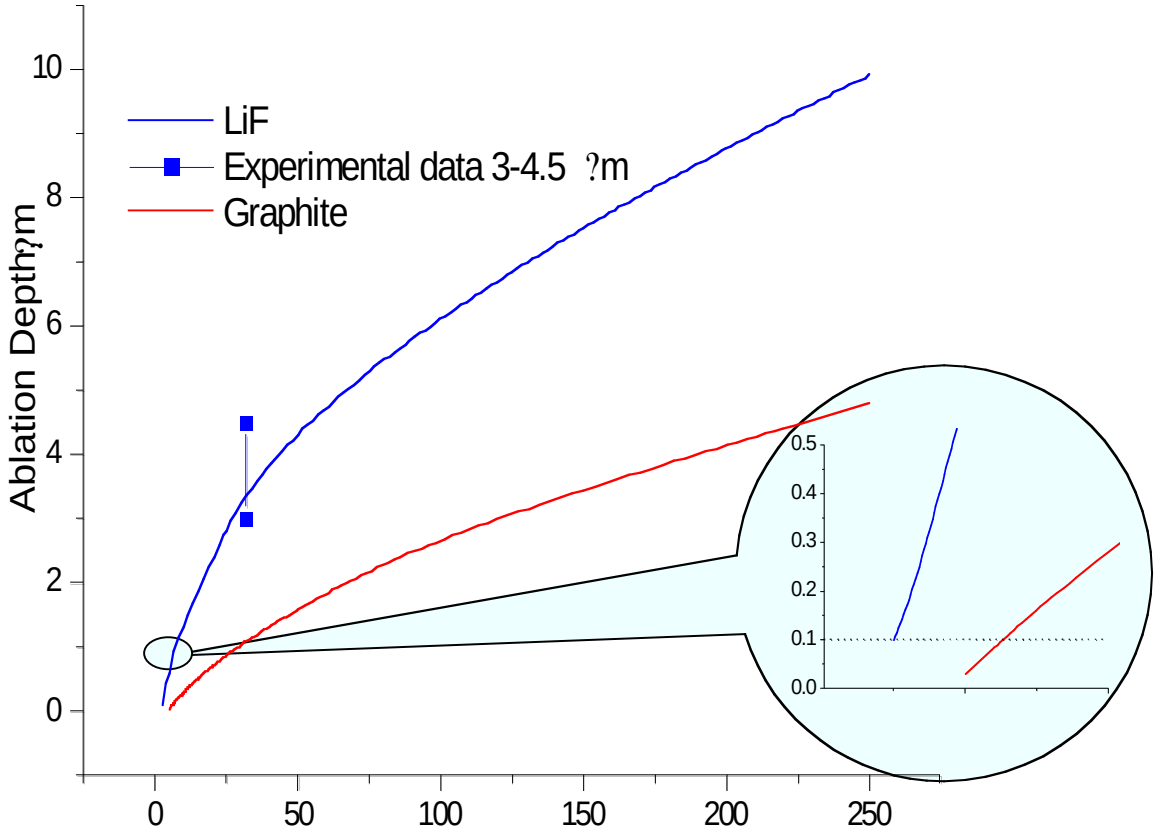
Material treated as plasma



Material treated as condensed region



Erosion Threshold (Ablation Depth < 0.1 μm) for LiF is 2 J/cm^2, and for Graphite - 6 J/cm^2



Limitations

- We calculate "Ideal vaporization", erosion of real materials is likely to be higher
- Uncertainties in material thermal properties
- We assume smooth surfaces and pure materials
- Realistic x-ray spectra are needed

	LiF	C
Specific Heat of Vaporization, J/g	1.83×10^4	2.50×10^4
Specific Heat, J/g/eV	9.62×10^3	3.50×10^4
Thermal Conductivity, J/cm/s/eV	1.64×10^3	1.55×10^4
Vaporization Temperature, eV	0.169	0.338

Conclusions and Future Work

- We performed BUCKY simulations to study materials respond to intense short-pulsed x-rays.
- Minimum fluence that causes detectible erosion for LiF is 2 J/cm^2, and for Graphite - 6 J/cm^2.
- More experiments and calculations for high-quality graphite.
- We plan to study other materials (e.g. W, Si Al), and perform sensitivity analysis with respect to material thermal properties and x-ray spectra.