Modeling of Z-Ablation

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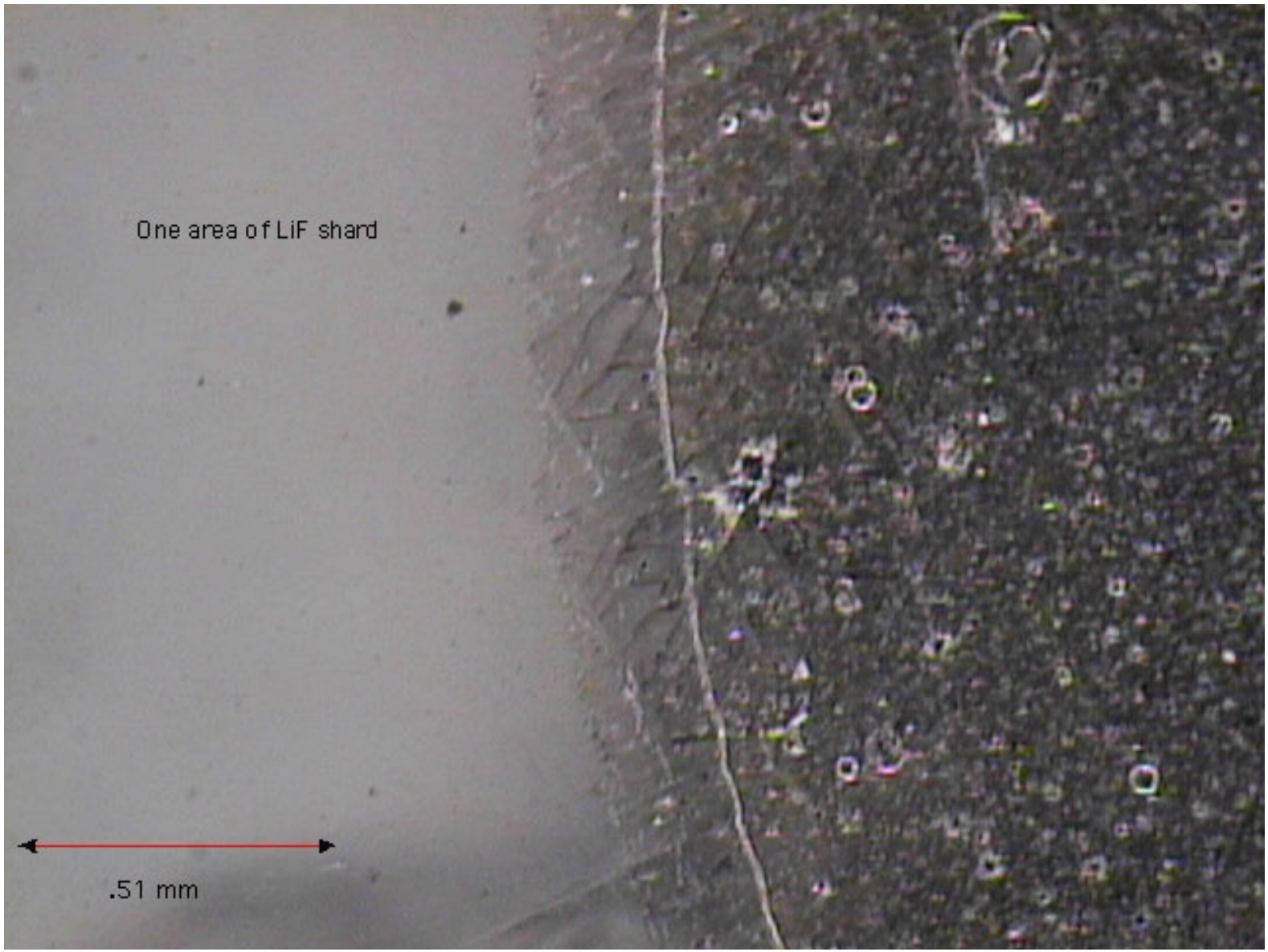
Z Experiments To Understand How IFE Target Chamber Materials Respond to Intense Short-Pulsed X-rays

- 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

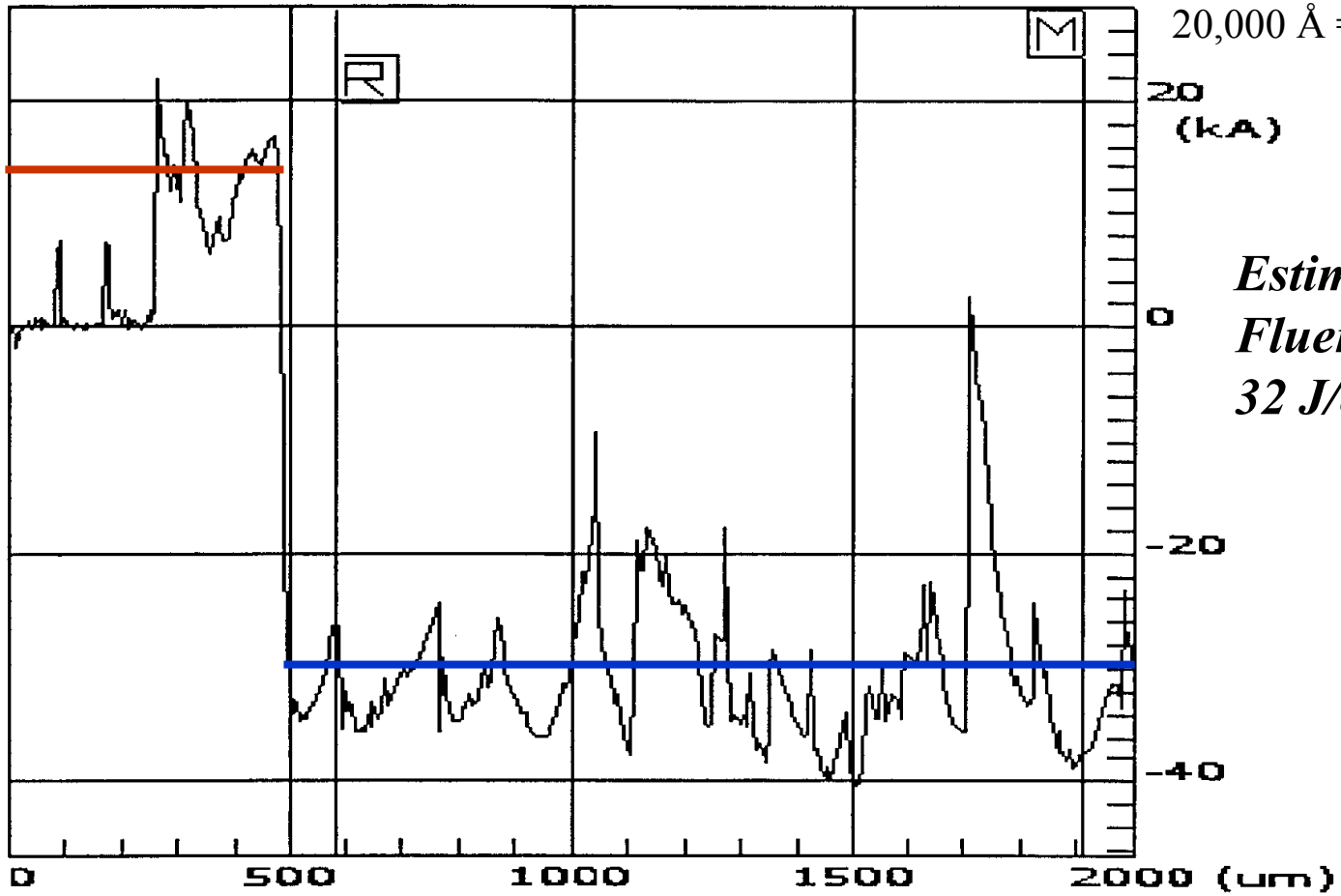


Measured Profile of LiF Shot With W Wire Array X-rays Shows 3 μm Net Ablation

Z Shot 783

1.5 μm of re-condensation or splash

3.0 μm of erosion



Estimated Fluence = 32 J/cm²

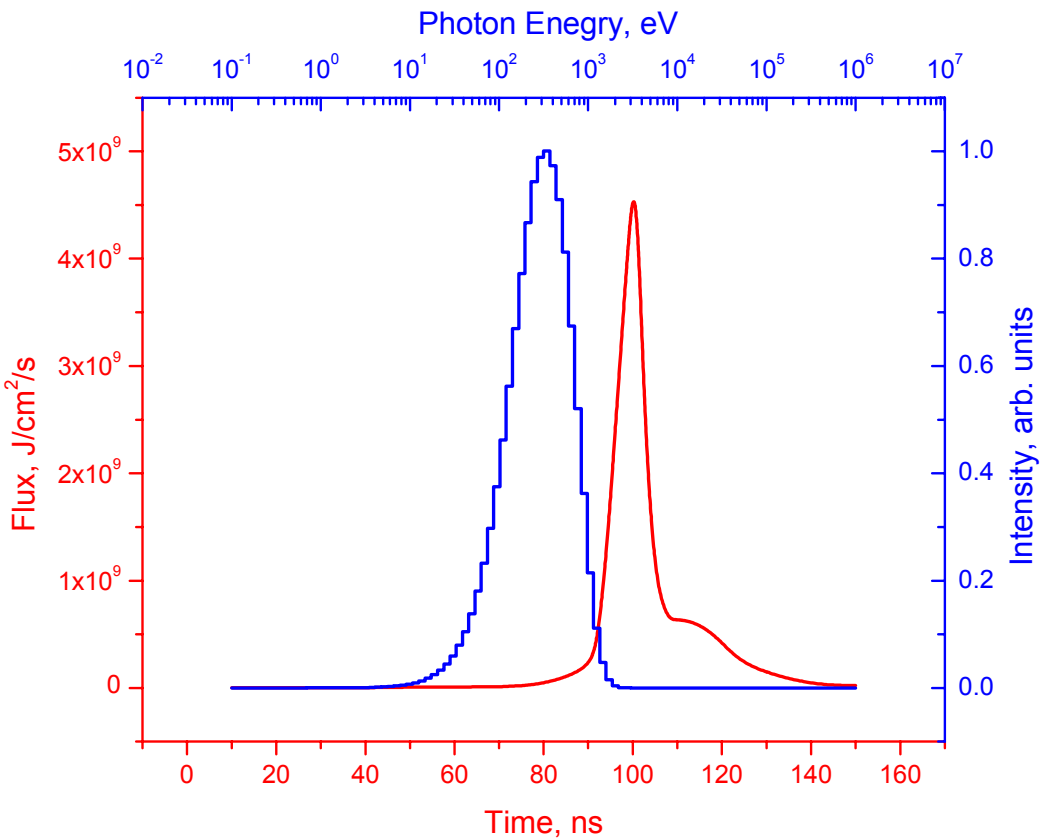
Gross Vaporization = 3.0 or 4.5 μm?

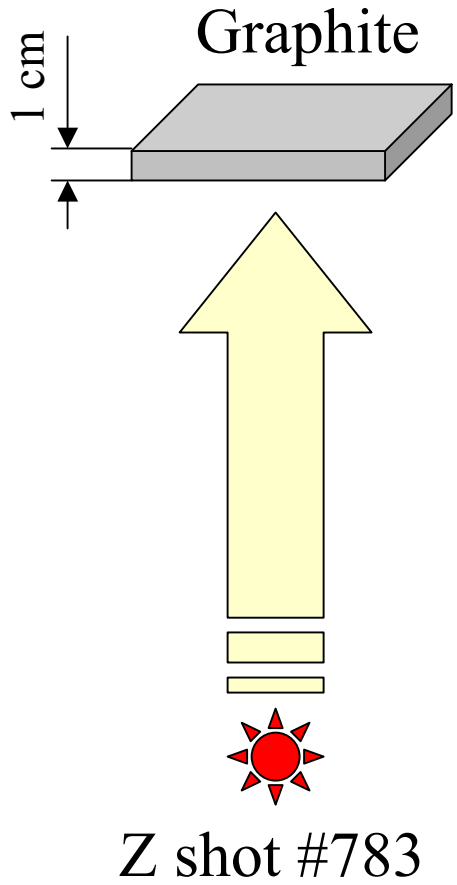
BUCKY is a Flexible 1-D Lagrangian Radiation-Hydrodynamics Code: Used to model first wall heating, vaporization and re-condensation

- 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.

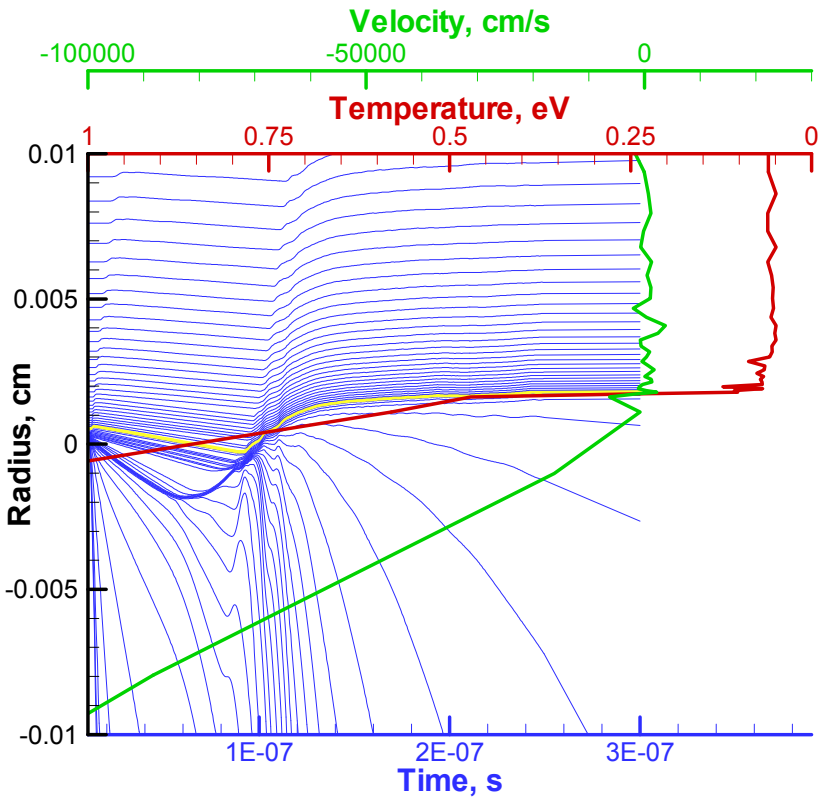




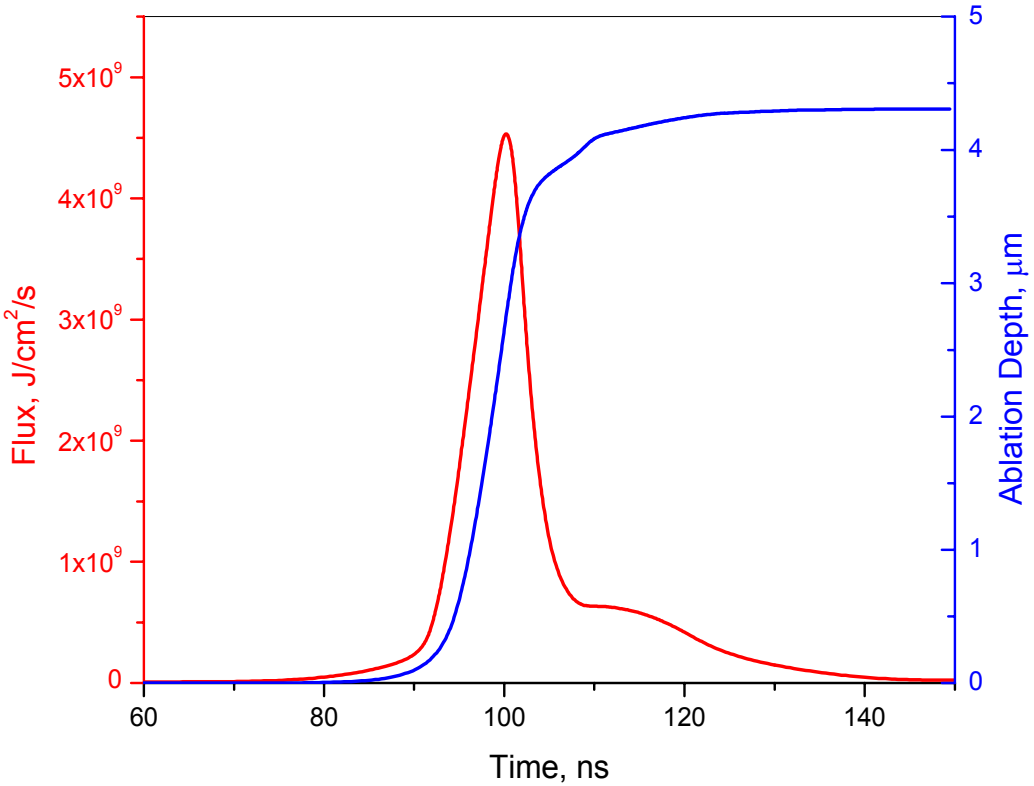
Different Approaches to Calculate Erosion Depth Yield Consistent Results

BUCKY calculations for LiF

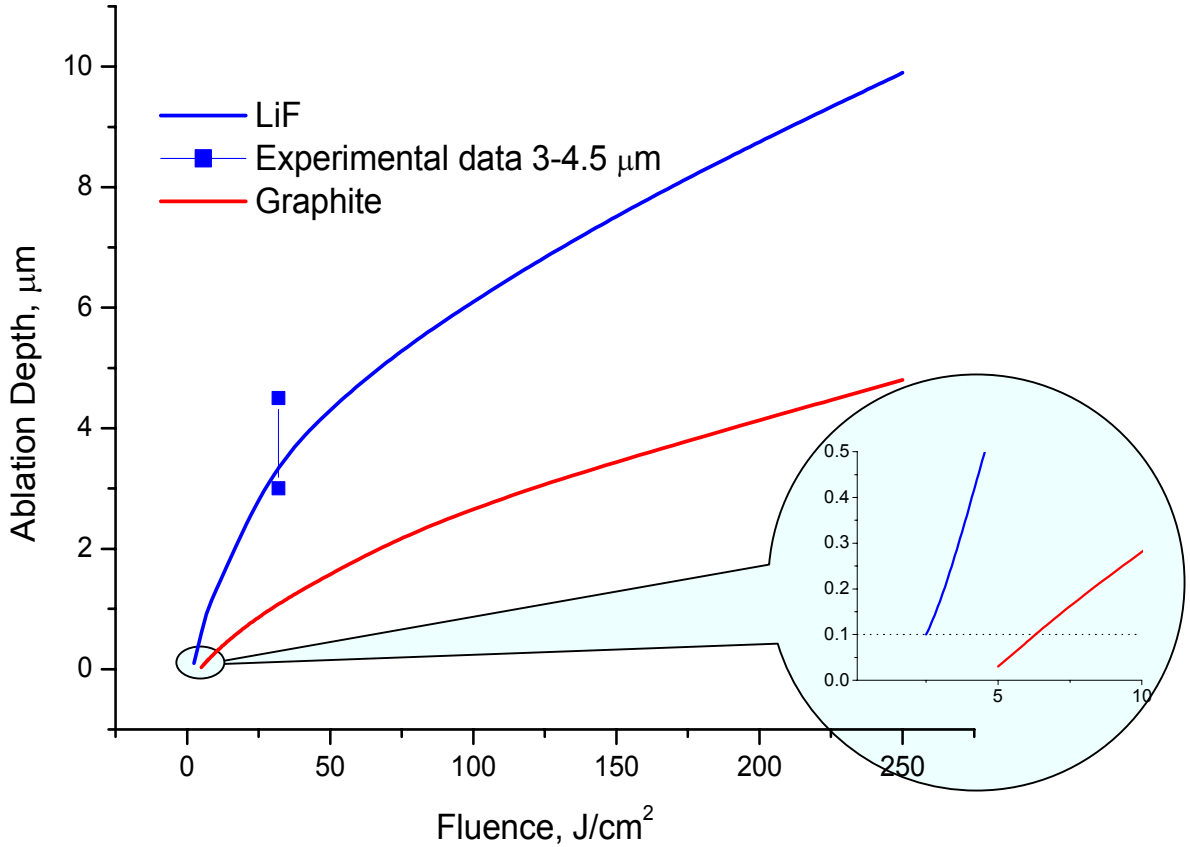
Material treated as plasma



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	1.83x10^4	2.50x10^4
Specific Heat, J/g/eV	9.62x10^3	3.50x10^4
Thermal Conductivity, J/cm/s/eV	1.64x10^3	1.55x10^4
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.