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Experiments for the validation of debris and shrapnel calculations

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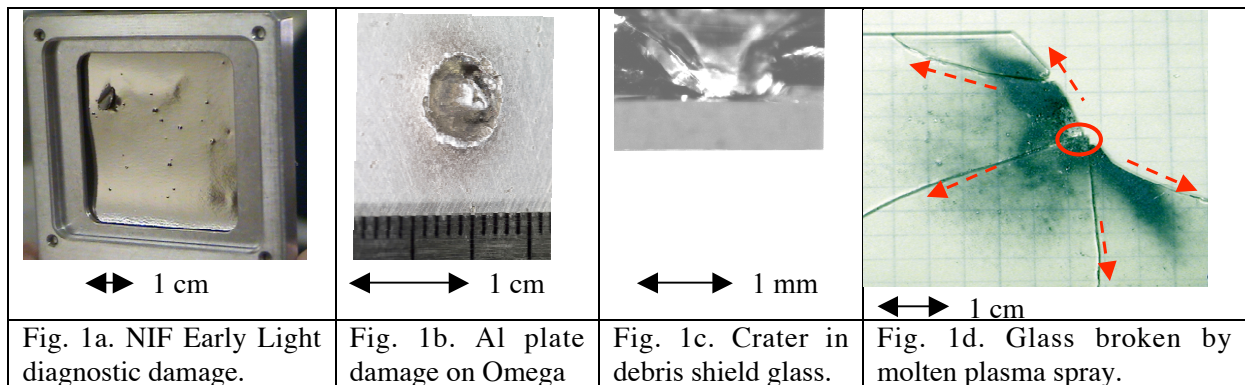
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Abstract. The debris and shrapnel generated by laser targets will play an increasingly major role in the operation of large laser facilities such as NIF, LMJ, and Orion. Past experience has shown that it is possible for such target debris/shrapnel to render diagnostics inoperable and also to penetrate or damage optical protection (debris) shields. We are developing the tools to evaluate target configurations, in order to better mitigate the generation and impact of debris/shrapnel, including development of dedicated modelling codes. In order to validate these predictive simulations, we briefly describe a series of experiments aimed at determining the amount of debris and/or shrapnel produced in controlled situations. We use glass plates and aerogel to capture generated debris/shrapnel. The experimental targets include hohlraums, halfraums, and thin foils in a variety of geometries. Post-shot analysis includes scanning electron microscopy and x-ray tomography. We show results from a few of these experiments and discuss related modelling efforts.

1. Introduction

Predicting and mitigating damage from debris and shrapnel is an important part of the design of experimental configurations for high-power laser facilities. The program to assess and reduce this damage is part of an on-going collaboration between researchers at LLNL, CEA, and AWE. An integral part of this collaboration is the design, implementation, analysis and modelling of dedicated experiments. In this paper, we summarize some of these on-going experimental campaigns to assess target debris and shrapnel. (Generally, we use the term debris to mean vapor or plasma, and shrapnel to mean fragmented pieces of target elements or molten droplets.) As motivation, Fig. 1 gives a sampling of some recent damage events on various facilities associated with shrapnel impacts. These events show the importance of understanding the state, size, and velocity of generated shrapnel. Debris and shrapnel generation, by laser and x-ray sources, is a new simulation area that requires a close collaboration between experimental and modelling efforts to develop a validated, predictive capability.



2. Helen Experiments

Debris and shrapnel experiments are on-going on the Helen laser in preparation for the Orion laser facility. Figure 2 shows one experiments where a gold halfraum was surrounded by glass collection plates. Blow-off from the halfraum was collected on the plates and analyzed to show the pattern of debris. LLNL simulations of the blow-off showed good agreement with analysis of the glass.

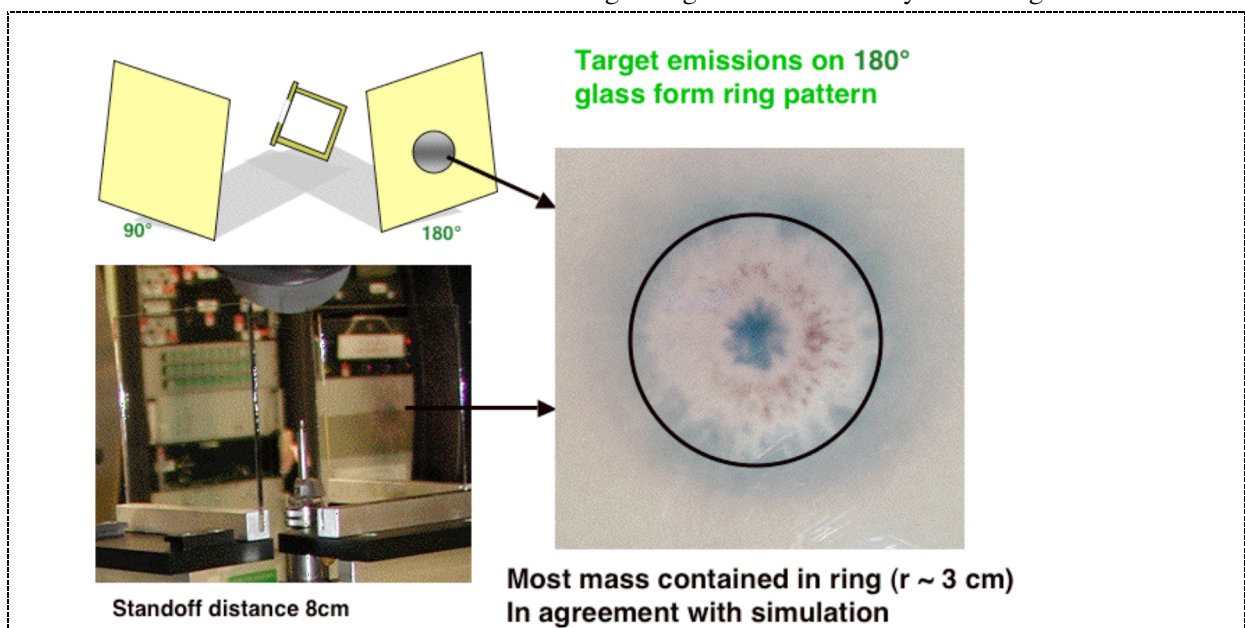


Figure 2. Glass plates surround a halfraum target in one of the Helen campaigns. Close up of the ring of gold formed at the 180° plate shows the pattern of gold that is matched to the simulation. X-ray transmission analysis is done to determine the density of gold deposited as a function of position.

3. Janus Experiments

The Janus laser is being used for a number of experiments in which thin plates representative of typical diagnostic shields are irradiated and material is spalled off the backside and collected in aerogel and on glass plates. Representative shield materials include Ta and V. Upcoming Janus experiments will also include single crystal V, so we can use crystal properties to guide the material models. Figure 3 (top left) shows one of the Janus aerogels. Below that, in the same figure, is the X-ray tomography of the sample. On the right we show collection on a glass plate at different levels of magnification. At the highest level, obtained using a scanning electron microscope, we see evidence of both solid and molten shrapnel fragments.

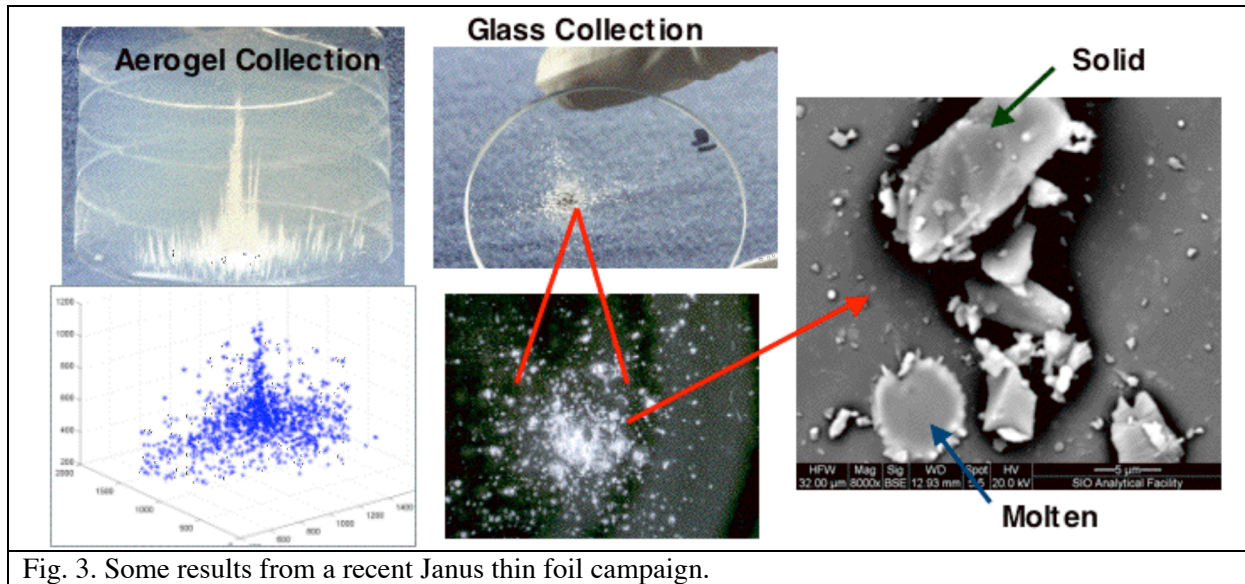


Fig. 3. Some results from a recent Janus thin foil campaign.

4. LIL Experiments

A novel mini-chamber, shown in Fig. 4, has been designed to study laser and x-ray induced fragmentation. This chamber is tailored for the LIL laser, but could be modified to be fielded on other facilities. We maximize the amount of data obtained from a shot by allowing several thin samples of different materials to be irradiated by x-rays generated by a laser pulse hitting a gold foil. The spall from up to 28 different samples will be collected individually using aerogel collectors. The mini-chamber will also be used to capture fragments from a single halfraum with Al cooling rings to obtain good spatial resolution and assess geometrical effects.

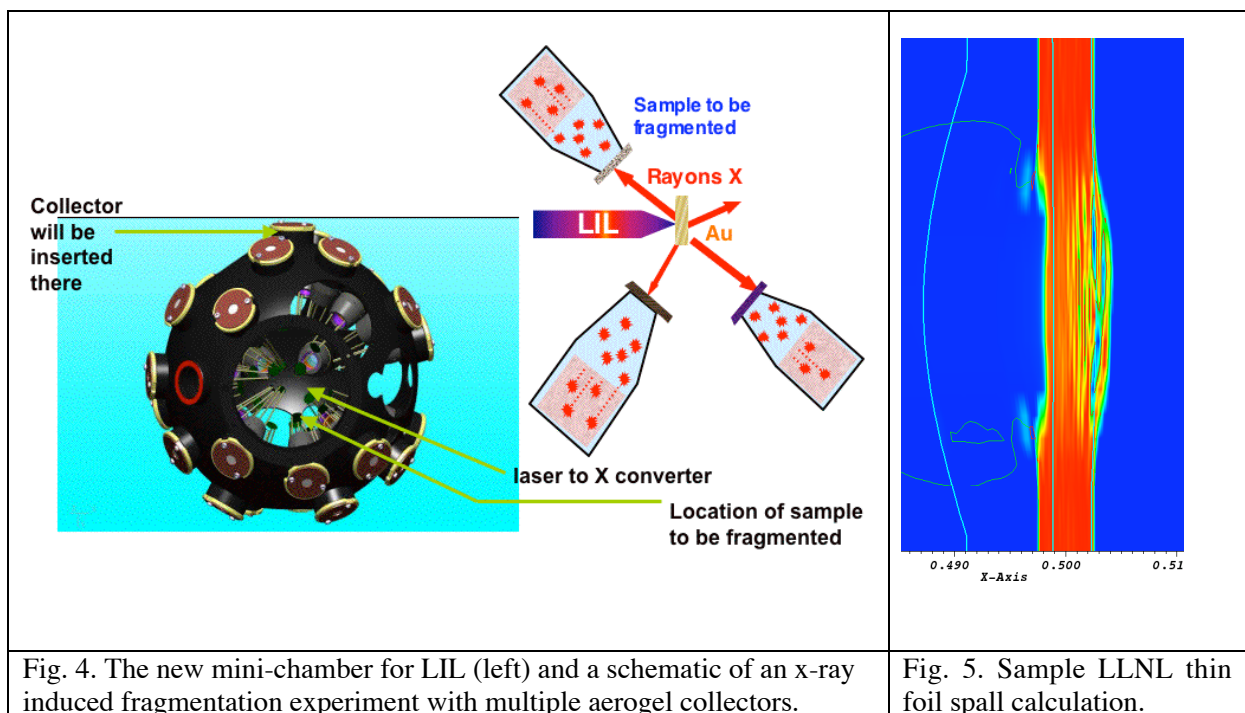


Fig. 4. The new mini-chamber for LIL (left) and a schematic of an x-ray induced fragmentation experiment with multiple aerogel collectors.

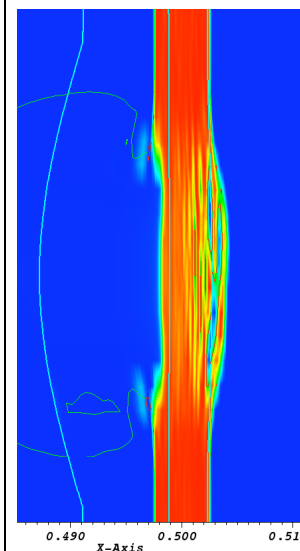


Fig. 5. Sample LLNL thin foil spall calculation.

5. Modeling Efforts

Active modelling campaigns include several detailed methods to describe both the laser plasma interaction and the material modelling. The LLNL effort includes a new modelling code, NIF ALE-AMR that is described elsewhere in these journal proceedings.[1,2] At CEA, the modelling effort includes codes such as Hesione, Esther and Chivas. Figure 6 shows typical results from these simulations. The codes have the physics to model fragment formation, thus allowing us to track state, size, and velocity of the generated shrapnel. Knowledge of these three properties of the shrapnel are needed to determine the impact on optics and diagnostics. Close collaboration between the modelling efforts at LLNL and CEA allows us to do additional benchmarking, which is important in this new area of simulation.

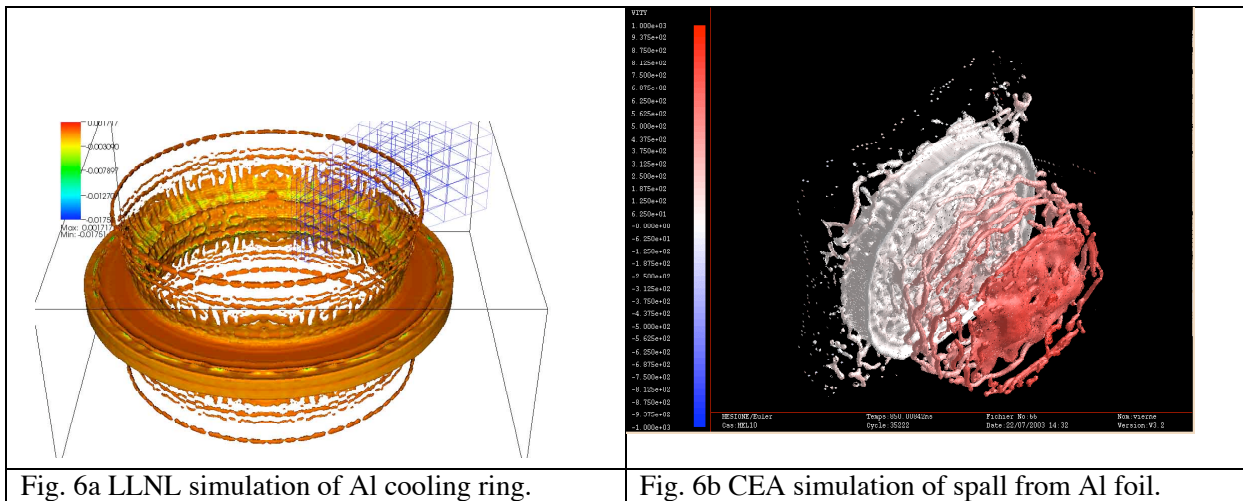


Fig. 6a LLNL simulation of Al cooling ring.

Fig. 6b CEA simulation of spall from Al foil.

6. Conclusion

Active experimental and modelling campaigns are on-going to further develop and validate methods to predict and mitigate the effects of debris and shrapnel on major laser facilities. The experiments involve intentional generation of debris and shrapnel through both laser and x-ray radiation sources. The generated material is collected and analyzed using a variety of methods. New modelling efforts are in place to explain these experiments, thus developing a validated, predictive capability of debris and shrapnel generation needed for target designs.

7. References

- [1] Masters, et al., these journal proceedings.
- [2] Fisher, et al., these journal proceedings.

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