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Experiments for the Validation of Debris and Shrapnel Calculations

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Experiments for the validation of debris and shrapnel calculations

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Abstract. The debris and shrapnel generated by laser targets are important factors in the operation of a large laser facility such as NIF, LMJ, and Orion. Past experience has shown that it is possible for such target debris to render diagnostics inoperable and also to penetrate or damage optical protection (debris) shields. We are developing the tools to allow evaluation of target configurations in order to better mitigate the generation and impact of debris, 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 and aeorgel 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 the results of some of these experiments and discuss modelling efforts.

1. Introduction

Predicting and mitigating damage from debris and shrapnel is an important part of the design of experimental configurations for high-powered 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 the 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.

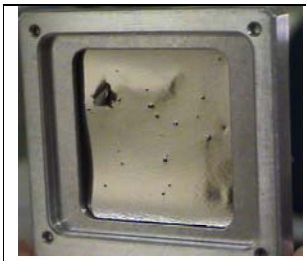		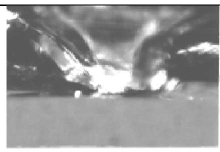	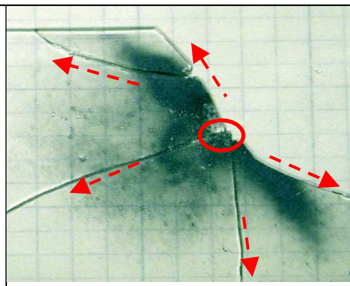
Fig. 1a. NIF Early Light diagnostic damage.	Fig. 1b. Al plate damage on Omega	Fig. 1c. Crater in debris shield glass.	Fig. 1d. Glass broken by molten plasma spray.

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 of these experiments where a gold halflraum 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 imulations of the blow-off showed good agreement with analysis of the glass.

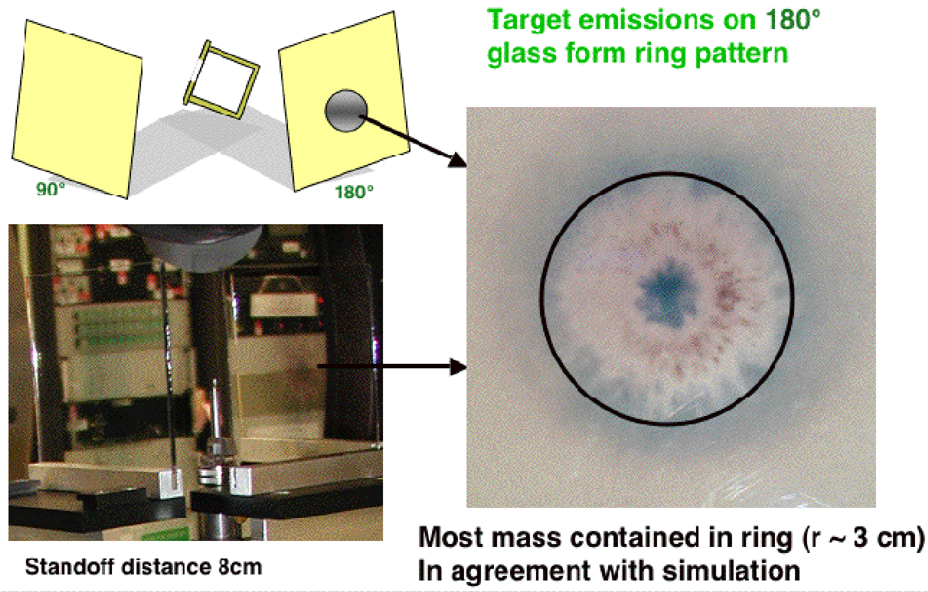

Figure 2. Glass plates surround a halfraum target in one of the Helen campaigns. Close up of the ring of gold formed at the 180^{o} plate shows the pattern of gold that is matched to the simulation. X-ray transmission analysis is done to determine the density of gold deposited as a function of position.

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 of the backside of the thin plate and collected in both aerogel and on glass. 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 shows one of the Janus aerogels and below that in the same figure is the X-ray tomography of the sample. On the right we show collection on glass, which is analyzed by the scanning electon microscope to determine qualities of the material blow-off.

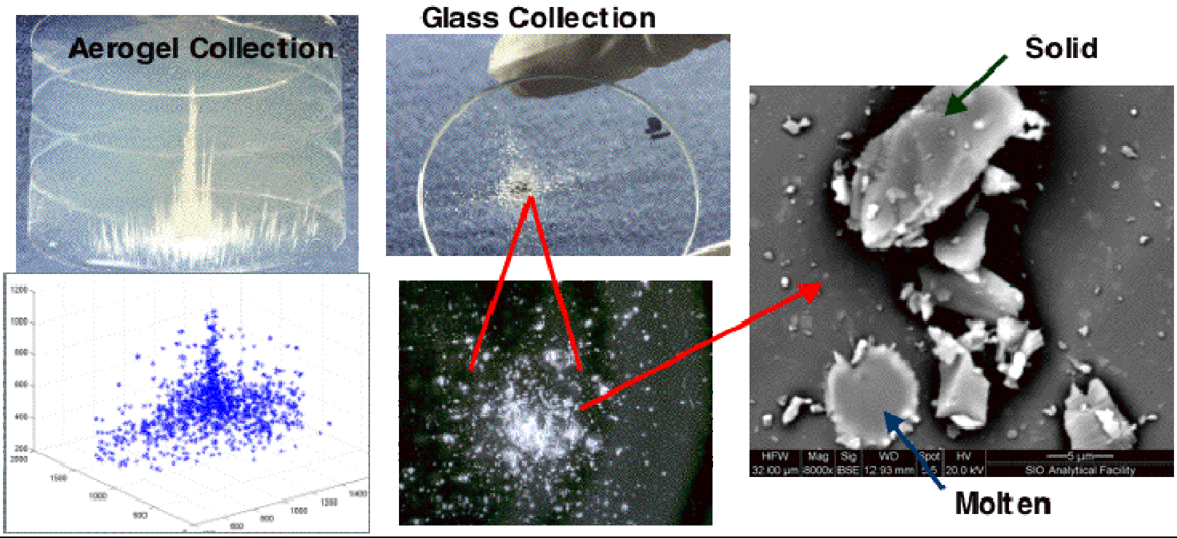

Fig. 3. Some results from a recent Janus thin foil campaign.

4. CEA Experiments

A new Target Debris Collection Holder (TDCH) has been designed for the LIL laser. This device will maximize the efficiency of shots by allowing several thin foils of different materials to be irradiated by x-rays generated by a pulse of x-rays hitting a gold sample in a singe shot. The spall from each of the different thin foil materials will be collected in up to 24 different aerogels. The TDCH will also be used to capture fragments from targets with Al cooling rings to obtain spatial resolution as well.

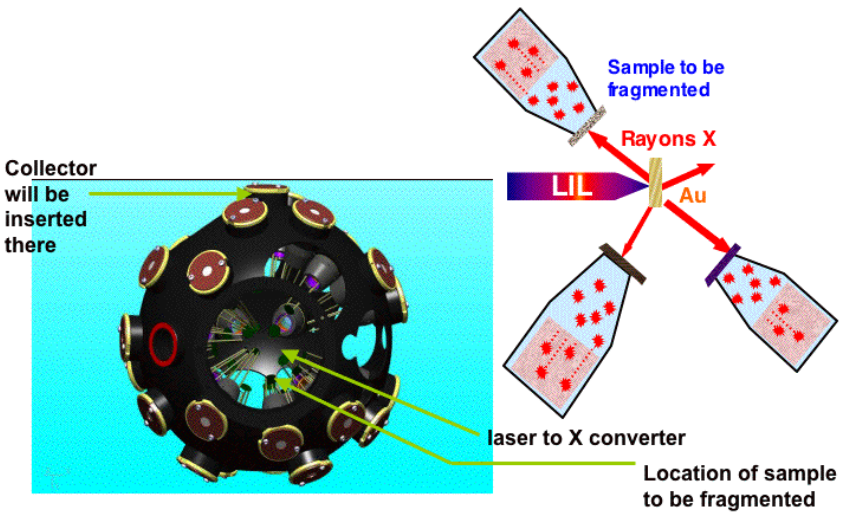

Fig. 4. The new TDCH for LIL and a diagram of the collection pattern.

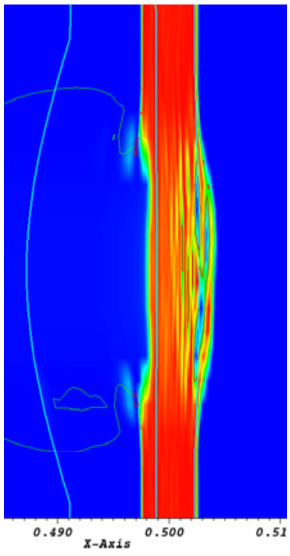

Fig. 5. Sample LLNL thin foil spall calculation.

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 proceedings[1,2]. At CEA, the modelling effort includes codes such as Hesion, Ester and Chivas. Figure 6 shows typical results from these simulations. Note that the codes are able to model fragment formation, thus allowing us to track both the size and vector velocity of the generated shrapnel. Close collaboration between the modelling efforts allows us to do additional benchmarking, since this area of simulation is so new.

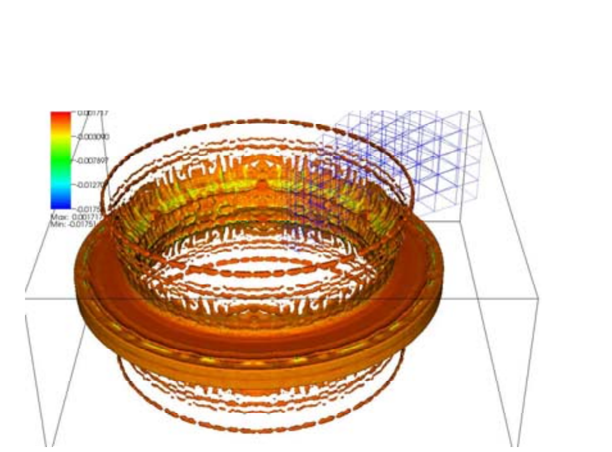	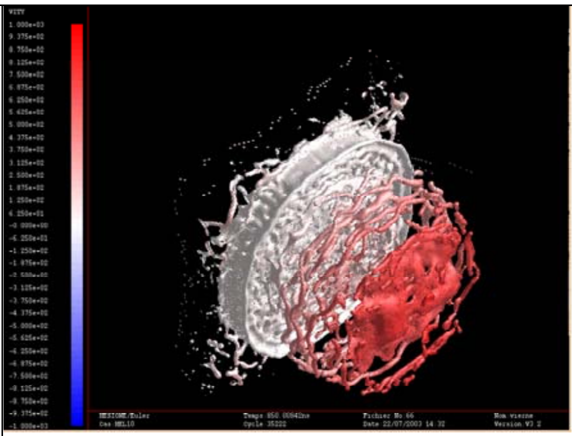
Fig. 6a LLNL simulation of Al cooling ring.	Fig. 6b CEA simulation of spall from Al foil.

6. Conclusion

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

7. References

[1] Masters, et al., this conference.
[2] Fisher, et al., this conference.

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