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Pleiades Experiments on the NIF: Phase II-C

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Introduction

Pleiades was a radiation transport campaign fielded at the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory (LLNL) between 2011 and 2014 [1,2]. The primary goals of the campaign were to develop and characterise a reproducible ~350eV x-ray drive and to constrain a number of material data properties required to successfully model the propagation of radiation through two low density foam materials. A further goal involved the development and qualification of diagnostics for future radiation transport experiments at NIF. Pleiades was a collaborative campaign involving teams from both AWE and the Los Alamos National Laboratory (LANL).

The Pleiades platform consists of a vacuum gold half-hohlraum (halfraum) attached to a gold cylinder containing the foam material under observation. 80 beams from the lower hemisphere of NIF deliver ~360kJ of laser energy to the halfraum over 2.5ns, which in turn generates the x-ray drive. This drive propagates into and through the foam in the cylinder. A SiO_2 aerogel disc sits at the interface between the halfraum and cylinder in order to reduce the M-band x-ray emission from the halfraum which reaches the foam.

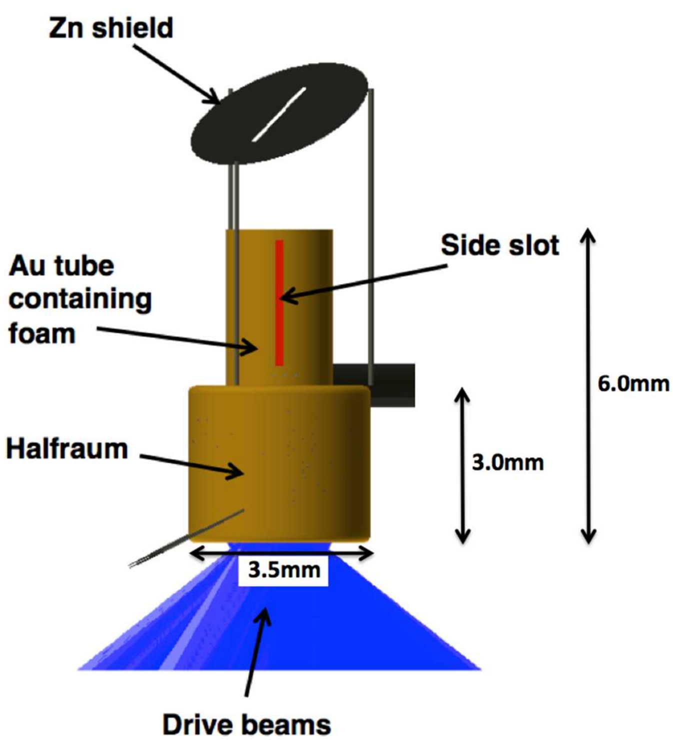

Figure 1: Diagram of a typical Pleiades Phase II target.

The radiation flow through the foam as a function of time is measured via x-ray emission from a side slot in the gold cylinder which is imaged using a suitable x-ray detector located in a Diagnostic Instrument Manipulator (DIM)-based diagnostic on the equator of the NIF target chamber. The flow is also quantified in terms of 'burn-through' time, i.e. the time at which the radiation begins to be emitted, above a threshold, from the foam at the opposite end of the cylinder to the halfraum. This burn-through can be measured using a Dante soft x-ray diagnostic or another DIM-based diagnostic located at the north pole of the target chamber. If measurements are to be taken using this polar DIM, a Zn shield which contains a narrow imaging slot is placed over the end of the gold tube, so that the signal reaching the diagnostic is reduced in order to prevent saturation of the recording medium.

The two foam materials studied were: SiO_2 aerogel and chlorinated High Purity Emulsion CH (HiPE / C_8H_7Cl), both in a density range of ~90-120 mg/cc.

Phase I of Pleiades consisted of a set of three halfraum-only shots performed to prove and characterise the x-ray drive generated by the halfraum. Phases II-A and II-B successfully developed a number of diagnostics, as well as constrained the necessary material data properties for HiPE.

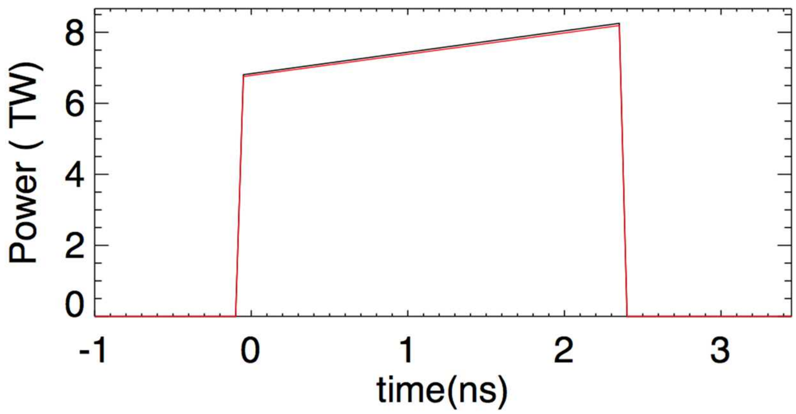

Figure 2: Laser pulse shape used in the drive for Pleiades. The power shown is that for a single quad out of the 20 used to form the 80 beam laser drive.

Phase II-C

The final phase of the Pleiades campaign consisted of seven shots fielded between June and September 2014. The goals of this series of shots were:

Determine photocathode selection for upcoming Menkar shots. The Menkar campaign is another radiation transport campaign which utilises many of the same diagnostics as Pleiades. In this case the diagnostic was a Transmission Grating Spectrometer (TGS) fielded in the polar DIM [3]. Three Menkar shots took place in September 2014 immediately following the conclusion of Pleiades II-C. The choice of either an Au or CsI photocathode for the TGS when used on Menkar, would be made based on the photometrics observed in a number of these Pleiades shots.

Determine empirical pointing offsets for the TGS in advance of Menkar. The TGS fielded in the polar DIM on the Menkar shots required a series of precursor shots in order to iteratively calibrate its alignment. The later Pleiades shots of this series formed part of that alignment sequence.

Further improve diagnostic timing. The timing of both the Dante and TGS burn-through data from previous Pleiades shots had an associated uncertainty. Beams from the upper hemisphere of NIF were introduced to provide timing fiducials for these diagnostics.

Constrain SiO_2 foam material data properties. The opacity and EoS properties of SiO_2 aerogel would be constrained via the fielding of this foam at various densities on a number of shots.

Study the possible impact of the Zn shield on Dante results. It was postulated that the Dante signal recorded on Pleiades shots may be enhanced when a Zn shield was present as part of the target. This was found not to be the case through the fielding of an A/B comparison pair fired as part of the series.

The seven shots of phase II-C took place in two groupings, three in June and the remaining four in late August / early September. For this series, the side slot usually found on a Pleiades target was absent; as equatorial measurements were not required and it was felt that this slot may also affect the symmetry of the radiation flow which is typically modelled using a 2D cylindrically symmetric computer code. A list of the shots fielded is given below.

Shot*	Foam	Density [mg/cc]	TGS
N140609-002	SiO_2	93.6	□
N140609-003	SiO_2	96.8	□
N140609-004	SiO_2	113.5	□
N140610-001	HiPE	102.7	□
N140831-003	SiO_2	94.5	□
N140906-004	HiPE	105.7	□
N140607-001	HiPE	104.4	□

*The date of each shot can be determined from the shot designation, for example N140609-002 was fired on 9th June 2014 and was the second shot that day.

June 2014 Shots

In June 2014, four Pleiades shots were fielded in a single 31 hour period. This represented a significant achievement for NIF as a facility and also for the AWE and LANL Pleiades team. Due to the time constraints for this set of shots, the TGS was only fielded on the first, as a DIM-based diagnostic requires a number of hours to configure and field on a shot.

Good quality SiO_2 spectral and burn-through data were recorded on this shot. Issues with the alignment procedure for the TGS were also identified and corrected.

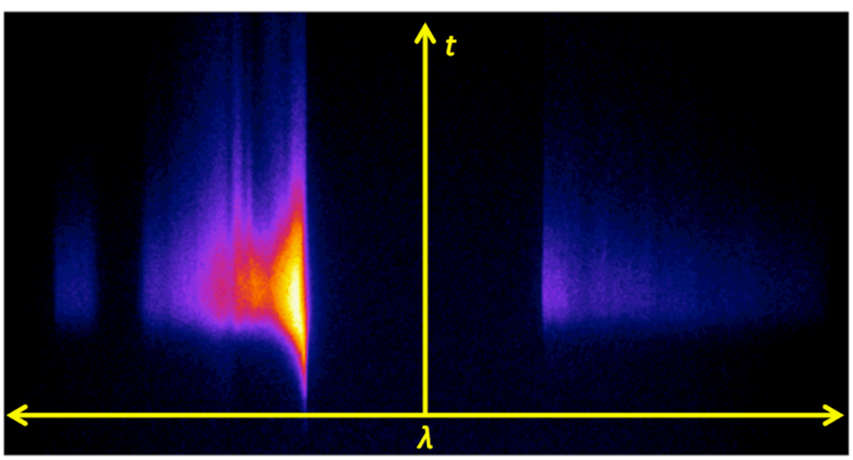

Figure 3: SiO_2 spectral data recorded via the TGS on N140609-002 using a CsI photocathode. The central dark region is due to the presence of a ‘zero-order’ block which prevents the brightest part of the diffracted spectrum from saturating the detector. Burn-through was measured at ~3.5ns with the streak camera window covering 10ns.

A single beam from the upper hemisphere of NIF was introduced to provide a known timing fiducial which the Dante diagnostic could be timed to. This beam was delayed until t_0 + 8ns and was pointed at the base of the cylinder where it meets the halfraum. The timing signal produced in the Dante results is shown below.

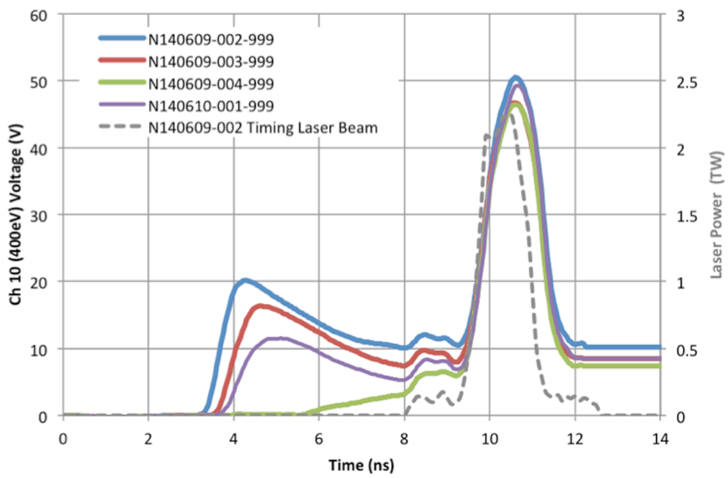

Figure 4: Timing fiducial observed in the signal recorded by a single Dante channel.

August / September 2014 shots

For the second set of Pleiades II-C shots, the timing fiducial was repointed in order to provide better timing data for the TGS rather than Dante. The new aim point for the beam was the top of the Zn TGS shield.

In order to aim the TGS diagnostic to the accuracy necessary for the upcoming Menkar shots, an iterative alignment procedure was employed. One of two TGS builds was fielded on each of the three Pleiades shots and also on a number of other shots fielded around the same period. After each shot an image plate present in the TGS assembly was analysed to determine where the diagnostic was pointed. This image plate recorded a time integrated image of the experiment and its position relative to the TGS's axis. Empirical offsets to the pointing of the TGS were developed and applied to subsequent shots in order to gradually improve the aiming and bring it to within the required tolerance for Menkar.

Unfortunately, the timing fiducial used for the TGS increased the uncertainty of the image plate analysis and so was dropped after its first use on N140831-003. The alignment images recorded for the three Pleiades shots are shown below.

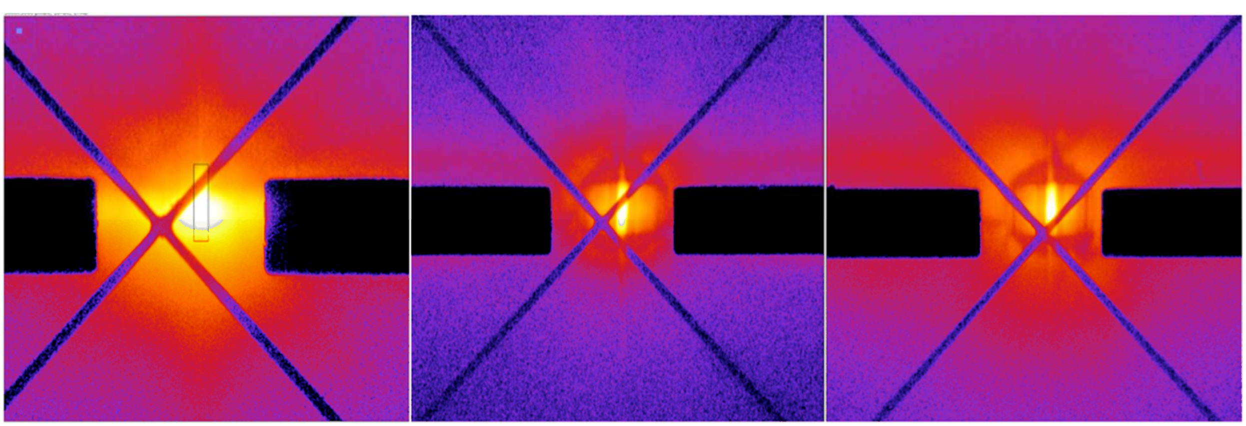

Figure 5: Polar time integrated images of the N140831-003, N140906-004 and N140607-001 experiments respectively which were used to iteratively improve the aiming of the TGS diagnostic for following shots. The dark regions are gaps in the image plate.

A CsI photocathode had been used in the TGS for the majority of Pleiades shots, as well as the first shot of the Menkar campaign. The signals recorded when using CsI tended to be at or near saturation for the TGS streak camera. In addition CsI data showed a signal variation which appeared to be independent of the actual strength of the x-ray source observed. An Au photocathode was introduced for these three shots which was expected to give a lower and more consistent signal.

The shot N140831-003 recorded a lower than expected signal via the TGS, but as the first shot of the three had the diagnostic slightly mispointed. It was expected that once the pointing was corrected, the signal would increase to the expected level. The analysis of the image plate from the following N140906-004 and N140607-001 shots showed that the pointing had been significantly improved. However, the TGS signal recorded on these two shots was significantly reduced, suggesting a lower sensitivity for the Au photocathode used at the photon energies recorded by the TGS. Based on these results it was decided to switch back to CsI for the remaining AWE shots in 2014.

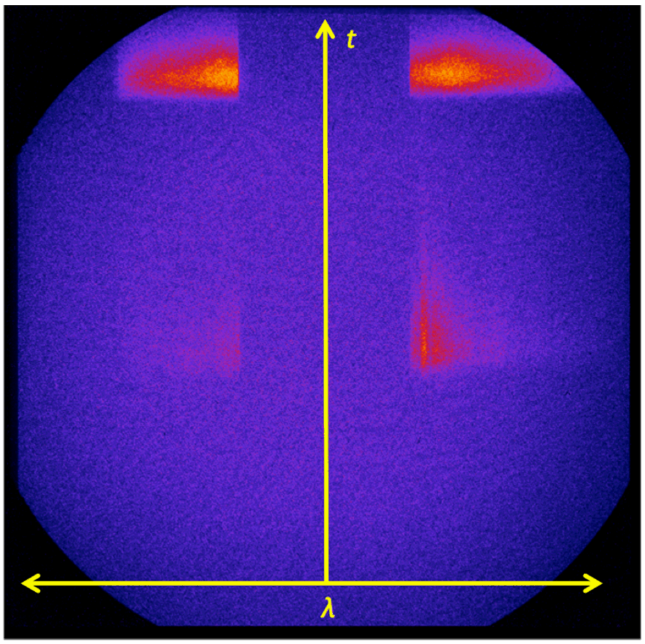

Figure 6: TGS spectral data recorded for the N140831-003 shot using an Au photocathode. The signal at the top of the image corresponds to the timing fiducial introduced to improve diagnostic timing. Burn-through was measured at ~4.5ns with the streak camera window covering 10ns.

Summary

Seven shots were fired in 2014 as part of the final phase of the AWE and LANL Pleiades radiation transport campaign. These shots further constrained necessary material data properties for two foam materials under investigation as well as developed diagnostics and timing capabilities required for future radiation transport experiments, e.g. the Menkar campaign.

Acknowledgments

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[3] A. S. Moore et al. Review of Scientific Instruments 83, no 10 (October 2012).