UCRL- 100056
PREPRINT

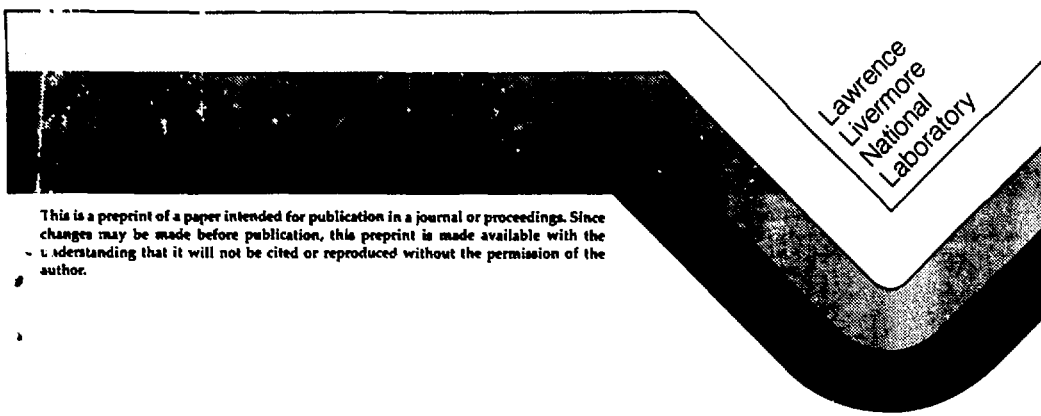
MIX EXPERIMENTS WITH THE NOVA LASER

V. C. Rupert, J. D. Kilkenny, P. G. Skokowski

Conference Proceedings of
Physics of Compressible Turbulence Mixing

October 24-27, 1988
Princeton, NJ

October 1988



MIX EXPERIMENTS WITH THE NOVA LASER

UCRL--100056

DE89 004775

V. C. Rupert, J. D. Kilkenny, P. G. Skokowski
Lawrence Livermore National Laboratory
P.O. Box 808, Livermore, CA 94550

The NOVA mix experiments are designed to study mix between two dissimilar materials subjected to strong (M ~50) shocks and variable accelerations in a direction normal to their common boundary. The main purpose of the experiments is to provide a data base with which predictive models can be compared and normalized. Together with shock tube experiments[1], which explore a different regime, the current NOVA tests investigate the shock induced source terms in our model[2] and the evolution of both Rayleigh–Taylor stable and unstable interfaces.

In these experiments, a laser pulse of 1/3 μm wavelength and 1 ns duration is used to generate a radiation source which is more uniform that the original laser beams. This source heats the front surface of a material of density ρ1, which ablates and expands back towards the source. Momentum conservation causes a shock to propagate through the material away from the source and through the interface of the ablator with a material of density ρ2. The evolution of the interface between the two materials is studied to determine the extent and composition of the mixed region. On some experiments a tamper has been used to hold the sample in place. This results in an additional interface through which mix can occur. To date the experiments have been geared towards diagnosing only the ablator interface, although simulations do provide a prediction of the mix through the tamper boundary as well.

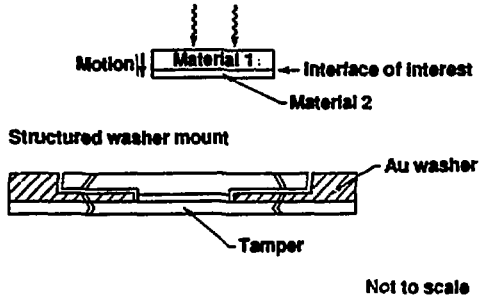


Fig. 1 Nominal Nova mix sample and mounting scheme.

The sample used in these experiments is shown in Figure 1. Selection of the materials is based on:

the requirement for high mix ($\rho_1 \neq \rho_2$) or low mix ($\rho_1 \sim \rho_2$);
their spectral signature, for diagnostic purposes; and
the ease of fabrication.

Current samples use a polypropylene sulfide ablator (PPS), with molybdenum (Mo) or Parylene C (PyC) for the second material, and Parylene N (PyN) for tamper. Although the most recent shots have not

included the tamper, the data presented herein were obtained with tamped samples as shown in Figure 1. Nominal dimensions of these samples are 50 to 60 μm thick PPS, 1.5 to 2 μm thick Mo or 15 μm thick PyC and 3 μm PyN. The nominal target diameter (at the interface) is of the order of 200 μm.

The ideal experiment would have the materials moving only in a direction normal to the original interface. Figure 2 shows the trajectories of various parts of the target for a NOVA shot at 7 kJ. Ablation of the front part of the PPS layer sends a shock through the sample. When the shock breaks out at the back of the tamper, the later expands into the surrounding vacuum. The concomitant rarefaction wave propagating back through the sample produces a small additional acceleration of the PPS/Mo interface in the same direction as the shock impulse. Figure 3a shows the density distribution through the sample 7ns after the start of the laser pulse, and Figure 3b shows its variation in time across the PPS/Mo interface. The latter shows a change in densities prior to shock arrival (at ~ 1 ns) due to a slight preheat of the materials

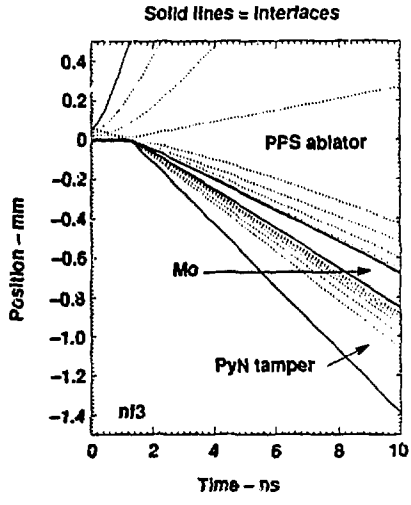


Fig. 2 Trajectories of various parts of a high mix sample.

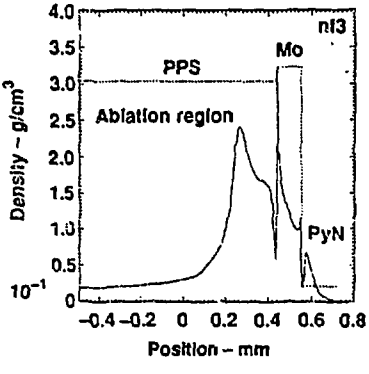


Fig. 3a Density distribution along the sample at 7ns - dashed lines show the locations of the different materials.

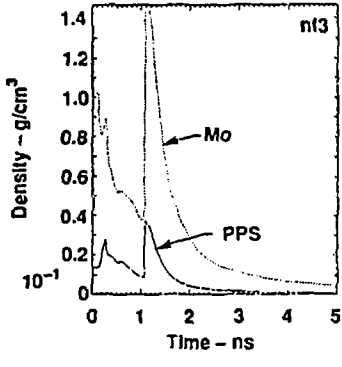


Fig. 3b Density variation across the PPS/Mo interface.

Mix calculations using the kε model[2,3] implemented in our hydrodynamic code imply that most of the mix occurs just after shock passage both at the Rayleigh Taylor unstable (PPS/Mo) and stable (Mo/PyN) interfaces. While the mass of mixed material changes insignificantly thereafter, the width of the mixed layer increases as the materials expand (Figure 2). At times of the order of 6ns, the width is sufficient to be observable with diagnostics of 10 to 20 μm resolution.

Point projection spectroscopy (Figure 4) is used to image the sample and unambiguously determine the extent of the different materials in the instrument's line of sight. The system is currently configured to probe the 2 to 3.2 keV range which encompasses the sulphur k edge (in PPS), the Molybdenum L_I to L_{III} edges, and the Chlorine K edge (in PyC). The tamper (PyN) is not highlighted in this energy range. Figure 4 shows an image which would be obtained for an unmixed sample.

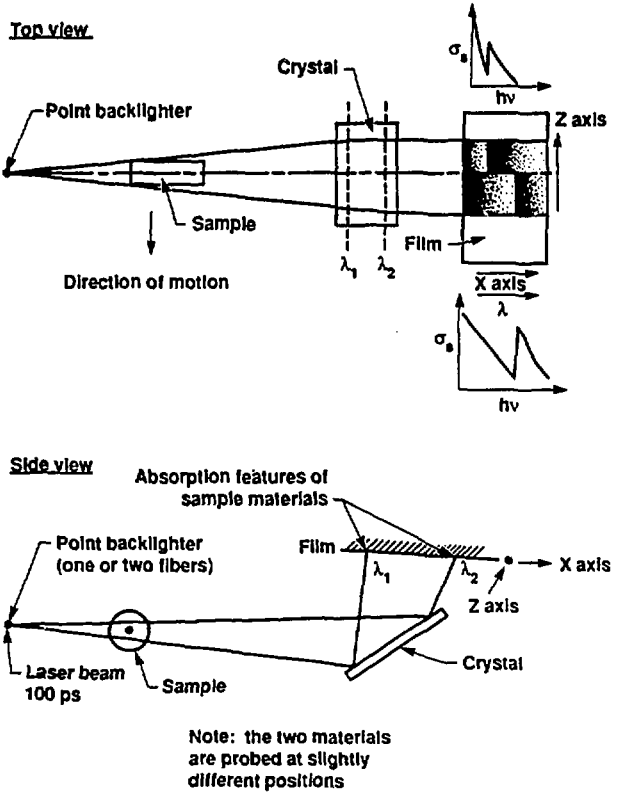


Fig. 4 Point projection spectroscopy principle.

If the sample did indeed move only in a direction normal to the original interfaces, any overlap of the material spectral features (lines or edges) would indicate mix, and the mixed region width could be determined. In practice, as soon as the sample moves out of it's mounting washer, lateral expansion occurs and two dimensional effects need to be accounted for.

Figure 5 shows a 2 dimensional calculation of a low mix target with no mix model invoked. A 1-D calculation of the same configuration shows that 10-20 μm of mix could be expected at 7ns between the PPS (ρ ~ 1.36) and the PyC (ρ ~ 1.29), or the PyC and PyN (ρ = 1.26). Figure 5 clearly shows the lateral expansion of the target (original diameter 200 μm), the jetting tendency of the ablator around the rest of the target, and the lag of the target edges due to the restraining effect of the large diameter tamper. Note that the part of the tamper shielded by the gold washer remains cold and dense so that the tamper just appears to stretch around the expanding PPS and PyC. This figure also shows that the bulk of the material interfaces remains fairly planar and normal to the initial target axis. The same general behavior is observed for high mix targets, although the jetting of the ablator around the Mo is more pronounced. These computations indicate that the apparent mix (overlap of spectroscopic features), due to the non planarity of the (unmixed) interfaces, should be within instrumental error for the current experiments, since, in the outer regions, the densities drop rapidly, and the overlap widths in the direction of observation are small. One dimensional calculations incorporating mix models should adequately describe the observed mix width. Two dimensional calculations such as those shown in Figure 5 are fraught with difficulties, even in the absence of mix, and are expensive in both computer memory usage and time. They cannot be used for parameter studies inherent in experimental design or repeated for each realization of the experiments. They have been used mainly to study the mounting schemes which, experimentally, appeared the best (minimum target curvature), and provide guidelines to the correlation of experiments and one dimensional calculations with mix.

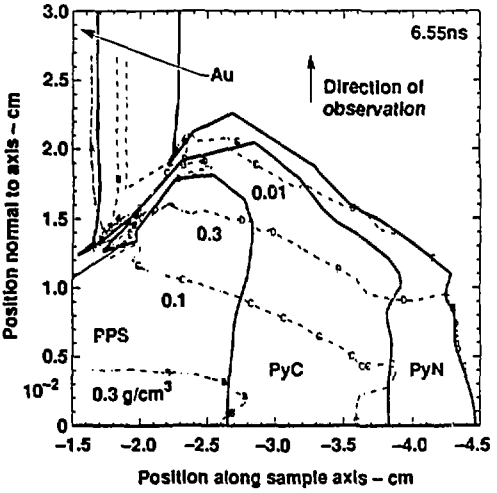


Fig. 5 Two dimensional calculation of a low mix type target.

Experiments have been conducted for two classes of targets. The "low mix targets" use materials with closely matched densities. Since the mix process depends on the Atwood number, little mix should occur for these samples. Figures 6a and b show the experimental data, and a simulated radiograph from a 1-D calculation for a low mix shot at 8 kJ. Both simulated and experimental data clearly show a sulphur edge shifting to higher energy in the heated PPS on the ablative side (bottom of picture), and the 1s-3p line of sulphur like chlorine, followed by the chlorine edge. The overlap of the sulphur and chlorine features translate to 14 μm in the simulated data. The experimental overlap of 40 μm is consistent with this value when motion blurring (200 ps snapshot) and instrumental resolution are taken into account.

Since the simulated radiograph was obtained from a 1-D calculation, it does not display the shadow of the mount. In fact it is possible to "see", inside the washer, the hot ablating PPS. Note that the opacity data used to obtain Figure 6b represents an average ion at the density and temperature of the material at the given position, so all the fine details of the experimental spectrum are not recorded.

The oval shapes seen in Figure 6 (and 7) are due to the reduced chord length at the edge of the target (Figure 4 side view).

Results for the low mix shot contrast sharply with those for a high mix shot shown on Figures 7a and 7b. Here an overlap of the order of 150 μm is obtained experimentally and matched by one of the mix models. Several heated (Ne like) sulphur lines are clearly visible, in particular the 1s-2p line at 2.3 kev. Closer to the mixed region the cooler (Si or P like) 1s-3p sulphur line at 2.449 keV

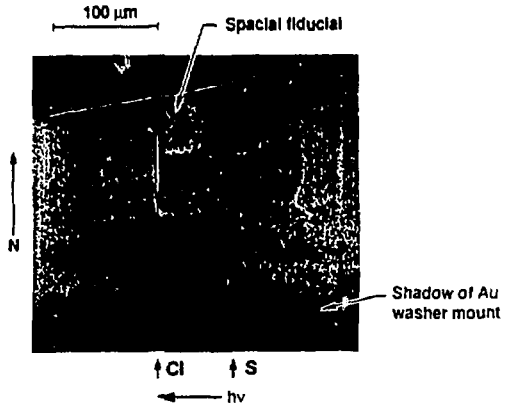


Fig. 6b Simulated radiograph - low mix shot

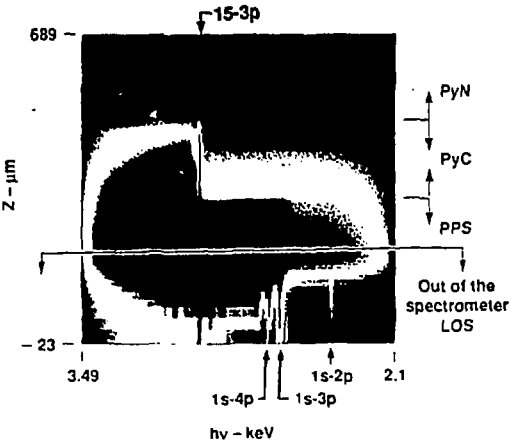


Fig. 6a Experimental radiograph - low mix shot

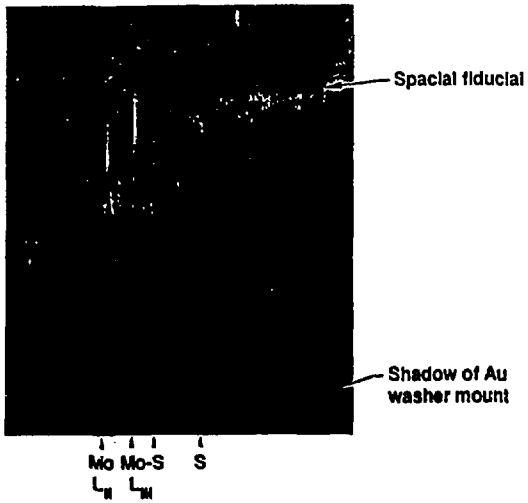


Fig. 7a Experimental radiograph - high mix shot

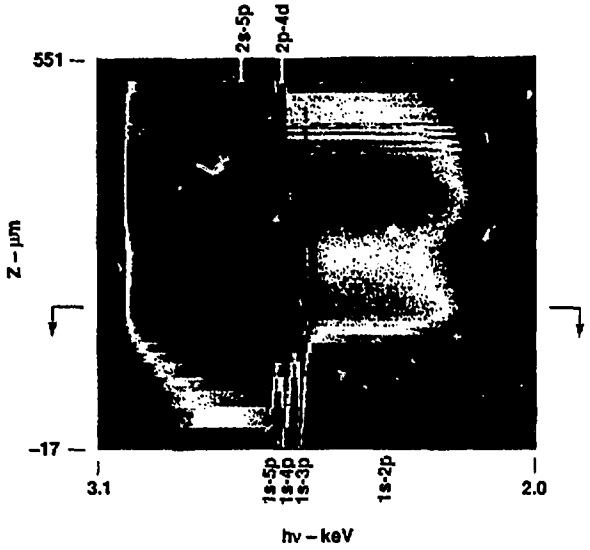


Fig. 7b Simulated radiograph - high mix shot

dominates the spectrum, while the dominant line for the Molybdenum is the 2p-4d Zr like line at 2.55 keV. The experiment had been designed specifically to maintain the sulphur sufficiently cold within the mixed region to avoid overlap of the 1s-4p S line and the 2p-4d Mo line: such an overlap, which invalidated the diagnostic method, had been observed in experiments with a thin ablator for early time snapshots.

It is interesting to note that on the experimental radiograph the region of minimum backlighter transmission lies entirely within the mixed layer, and the ablator, as evidenced by the S 1s-3p line, extends beyond it. Computationally such a behavior is difficult to simulate as, in general, the high opacity of the Mo overwhelms the density distribution, which shows a peak in the PPS region, and leads to the minimum transmission region extending outward of the mix region throughout the Mo. Only one set of parameters in the mix model, out of many, resulted in a material distribution as shown in Figure 7b, which resembles the experimental data.

Under some broad assumptions about opacities, the areal mass of the different materials versus axial position can be extracted from the experimental data as shown in Figure 8.

These data can then be compared with calculated density distributions. Note that the mix calculations are one dimensional, and, to compare with the experimental data, some constant "effective sample diameter" at snapshot time is implicitly assumed. The two dimensional calculations show that such an assumption is not strictly correct; moreover, the narrow range around the nominal unmixed interface where 2-D calculations show material overlap within the instrument line of sight (no mix) is not simulated by the 1-D calculations. Hence at this time, only qualitative comparisons of the density distribution can be made between experiment and calculations. The total material overlap is not dependent on the various assumptions underlying either the experimental data reduction or the 1-D calculations, and quantitative comparisons are possible. Comparison of Figure 7 and 9a show

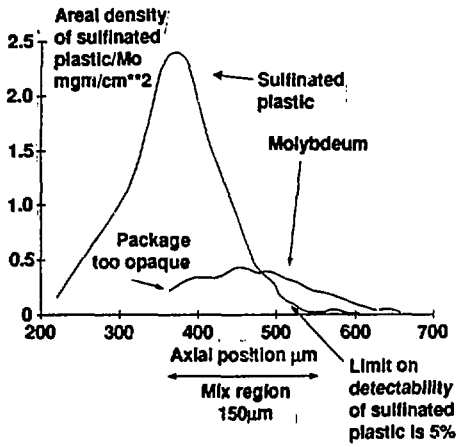


Fig. 8 High mix package - estimate of experimental mass distribution.

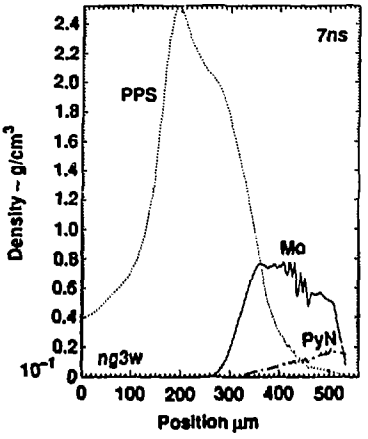


Fig. 9a Simulated density distribution - high mix package

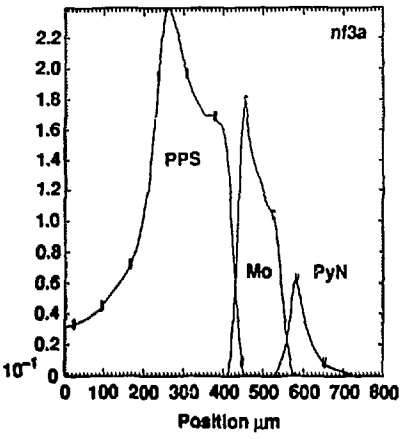


Fig. 9b Simulated density distribution - high mix package

that some appropriate choice of model parameters gives the correct mix width and also reproduces fairly well the axial mass distribution. Figure 9b shows poor results obtained from a different set of model parameters.

Calculations, such as those shown on Figure 9, show that the experiments are indeed providing data useful for normalizing our mix models. Many of the model parameters used to analyze NOVA data are identical to those used for the shock tube results.[1,2] More data from both sets of experiments are needed to uniquely define all the model parameters.

Development of the experimental techniques at NOVA have reached fruition, and we are ready to start a comprehensive experimental series where a single target configuration will be tested at various times with double backlighters.

ACKNOWLEDGEMENTS

The NOVA mix experiments are a cooperative effort between AWE and LLNL. Dr. P. Fieldhouse and his colleagues have been conducting a number of similar experiments with the Helen laser and providing timely information to aid in conducting and interpreting the NOVA experiments. We wish to acknowledge in particular the contributions of T. Goldsack and J. Hansom.

We are indebted to P. Crowley, E. Garelis and A. Winslow for the codes used in our calculations and to P. Keller and R. Williams for our graphics capabilities.

This program would not have been possible without the support of the U.S. DOE or the efforts of the NOVA operations team.

Work performed under the Auspices of the U.S. DOE by LLNL under Contract W-7405-Eng-48.

REFERENCES

1. B. Sturtevant
2. P. Crowley
3. C. Leith