Prediction of double shock formation by exploding high gain ICF target in Xe gas filled chamber

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The spherical micro-explosion of a 132 MJ high gain indirect drive target radiating and expanding into a surrounding 6μg/cc Xe atmosphere is simulated in 1D using the BUCKY radiation hydrodynamics code with 121 group FAC Xe opacities and equations of state. An interesting double shock is formed by the Marshak wave and exploding target debris. Explanation of this shock formation is presented.

Initial Observation

- 1-D BUCKY simulations with FAC opacity and EoS data supplied by LLNL show a double shock form in a 6m chamber with a 132 MJ yield target.

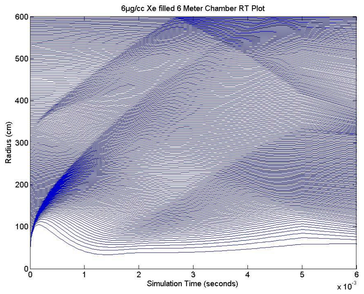

Figure 1: Radius vs Time plot for a 6 m chamber filled with 6 μg/cm^3 Xe. Note the formation of the second shock at ~340 cm.

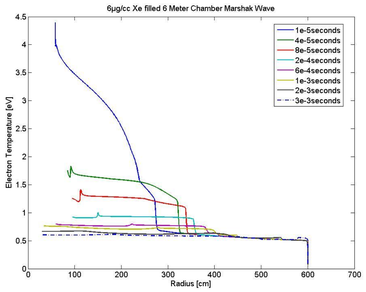

Figure 2: Marshak heat wave graph for 6 m chamber filled with 6 μg/cm^3 Xe. Note the large decrease in the front gradient at ~340 cm

- Additional simulations with a chamber fill of 1.83 μg/cm^3 of Ar show similar results.

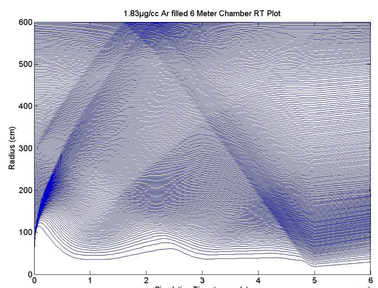

Figure 3: Radius vs Time plot for a 6 m chamber filled with 1.83 μg/cm^3 Ar. Note the formation of the second shock at ~280 cm.

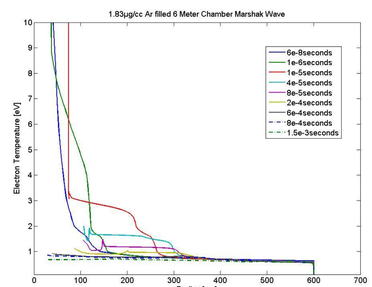

Figure 4: Marshak heat wave graph for 6 m chamber filled with 1.83 μg/cm^3 Ar. Note the large decrease in the front gradient at ~280 cm

132 MJ target 6 m Chamber

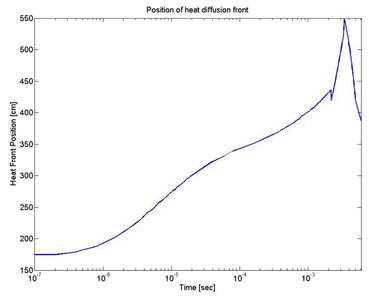

Figure 5: Plot of the position of the Marshak front. Note the dip at 2 ms, this is from the inner shock colliding with the Marshak front.

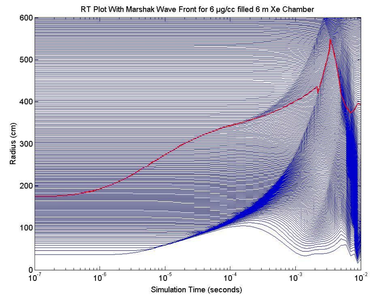

Figure 6: Plot of the Marshak front (red) from Figure 5 superimposed on the RT plot from Figure 1.

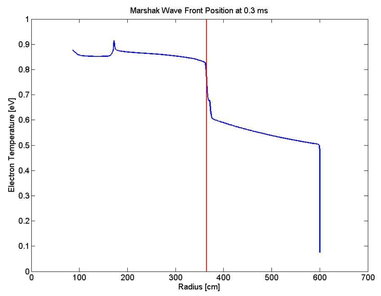

Figure 7: Plot of the Marshak wave at 0.3 ms. Note the appearance of the second shock as a compression heating wave ahead of the Marshak front, which is denoted by the red line.

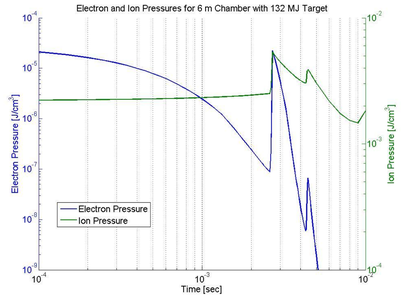

Figure 8: Plot of the ion and electron pressures. Note the two distinct spikes that correspond with both fronts reaching the wall.

- While a 132 MJ target is at reactor scale, a simulation at 13.2 MJ is useful to run as it is on a scale reproducible on NIF.

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13.2 MJ target 5 m Chamber

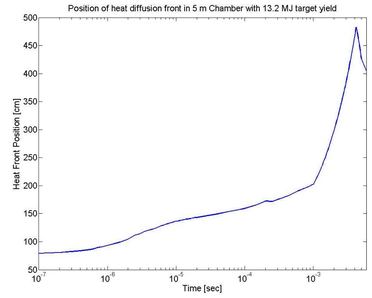

Figure 9: Plot of the position of the Marshak front. The large increase in slope corresponds with the inner shock colliding with the Marshak front.

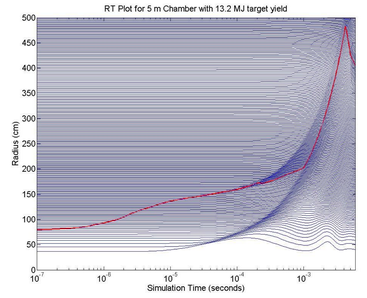

Figure 10: Plot of the Marshak front (red) superimposed on the RT plot for the 13.2 MJ simulation.

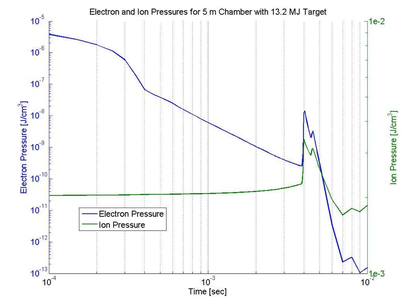

Figure 11: Plot of the ion and electron pressures. Note the two distinct spikes that correspond with both fronts reaching the wall.

Conclusions:

- The secondary shock is caused by the slowing down of the Marshak thermal wave below the ion sound velocity of ~7.43*10^4 cm/s.
  - Figure 7 shows the launching of the second shock and at that time the front velocity is 7.33*10^4 cm/s
- The launching of the second shock produces a compression heat wave that is incident on the first wall at ~2.7 ms.
- The phenomenon is seen in a target with a 13.2 MJ yield, which is possible to reproduce on NIF.