Laser-Plasma Interaction Experiments at Shock-Ignition relevant Intensities

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1st shock breakout from Mo
2nd shock catching up

9th MEETING FUSION SCIENCE CENTER FOR EXTREME STATES OF MATTER
Lawrence Livermore National Laboratory
Livermore CA
AUGUST 4-6, 2010
Summary

High intensity laser-plasma interaction experiments provide valuable backscattering, fast electron, and shock wave timing data

Single high intensity beams interacting with imploding capsule:
- Up to 35% of the shock-beam laser energy is lost due to backscatter
- Up to 16% of the energy of the high intensity beams was converted into hot electrons of ~45 keV temperature

6 overlapping beams interacting a preformed plasma from planar target:
- The measured hot electron temperature is a factor ~3 higher (~150 keV) and conversion efficiencies are lower (~6%)
- The measured optical signatures of the 1st and 2nd shock waves roughly agree with 1D simulations
- A curved and delayed shock front at breakout indicates that 2D effects are important
Collaborators

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Shock ignition relies on a shaped laser pulse with a trailing high-intensity spike.

The ignitor shock wave significantly increases its strength as it propagates through the converging shell.
Laser-plasma interaction during the spike pulse and hot-electron generation are important issues for shock ignition

Shock-ignition target with 350-kJ total energy

- $I_{Laser}$
- $\rho R$ range of 100 keV $e^-$

Int. (10$^{15}$ W/cm$^2$)

Time (ns)

10.0 10.5 11.0

0 1 2 3 4 5

$\rho R$ (mg/cm$^2$)

0 20 40 60 80 100

Hot $e^-$ with Maxwellian $T_{hot} = 150$ keV, $E_{hot} = 17\%$ of spike energy, treated using a multigroup diffusion model

Gain

0 10 20 30 40 50 60

Shock-launching time (ns)

1-D 350 kJ

Marginally igniting (no hot $e^-$)

Boosted margin (with hot $e^-$)

*LILAC simulations by C. D. Zhou and R. Betti
60 OMEGA beams were split into 40 low-intensity drive beams and 20 tightly focused, delayed beams

- Density scale length ~200 μm
- The delay and intensity of the tightly focused beams were varied
- Laser backscattering and hot-electron generation were studied
Up to 35% of the shock-beam laser energy is lost due to backscatter

- No measurable signal of the 3/2 harmonic
- SRS dominates back reflection at highest intensity
- SBS reflection is relatively stable at ~10%
Up to 16% of the shock-beam energy is converted into hot electrons of 45-keV temperature.
A laser-plasma interaction experiment was performed in planar geometry with overlapping beams

- Pre-plasma: $\sim 2 \times 10^{14}$ W/cm$^2$
- Shock: $\sim 1 - 6 \times 10^{15}$ W/cm$^2$
- Density scale length: $\sim 500$ $\mu$m
The measured optical signatures of the 1st and 2nd shock waves roughly agree with 1D simulations with the code CHIC

Density

1st shock breakout from Mo into quartz (~1.5 ns)

2nd shock catching up (~2.2 ns)

Temperature

Shock breakout at rear side (~4.8 ns). Observed later in the experiment
1D hydrodynamic simulations predict an initial plasma pressure of ~200 Mbar for ~$1 \times 10^{15}$ W/cm$^2$.
VISAR measured a decaying, curved shock front in quartz for $1 \times 10^{15}$ W/cm$^2$

- 2D DRACO and CHIC simulations will study the shock front curvature and slowing down due to 2D effects

Predicted shock velocity from 1D simulation $\sim 47$ $\mu$m/ns
Up to 6% of the high intensity laser energy is converted into hot electrons

- The measured hot electron temperature is a factor ~3 higher compared to spherical target experiment
- 1D LILAC simulations will be performed to study the effect of the fast electron component on the shock formation and shock propagation
High intensity laser-plasma interaction experiments provide valuable backscattering, fast electron, and shock wave timing data

Summary/Conclusions

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