Measurements of Radiative Shock Properties using X-ray Thomson Scattering

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Radiative shocks are shock waves whose structure has been altered by radiation transport from the shock-heated matter. Such shocks are present in numerous astrophysical systems, including supernova remnants, supernovae, and accretion disks. Recent experiments have used the Omega laser to study radiative shock systems that are optically thin upstream and optically thick downstream. A thin slab of low-Z material is driven into a 1.1 atm. cylinder of high-Z gas at speeds > 100 km/s, producing strong radiative effects. Energy lost to radiation escaping upstream causes the shock to collapse spatially, producing a thin dense shell. X-ray Thomson scattering is employed, in the Compton scattering regime, to measure the electron temperature in the shocked matter. The experiment used emission from a Mn x-ray source at 6.15 and 6.18 keV, oriented to produce scattering at angles near 100 degrees. The x-ray spectrum was detected using a crystal spectrometer and a gated, multi-strip, microchannel-plate detector.

Creating radiative shocks

- Omega Laser used to create high energy density system
- 10 drive beams
- ~400 J per beam
- λ = 35μm, UV radiation
- Irradiance ~5 x 10^4 W/cm²
- Pressure ~46 Mbars

- Laser focused onto piston (Be drive disk)
- Ablated Be plasma launches piston, driving a planar shock into the high Z gas
- Strong radiative effects produced by fast moving shock

X-ray Thomson Scattering

- Scattering of probe beam (I_p) from free electron
- Experiment in non-collective Thomson scattering regime since λ_e < λ_D
  where λ_D is the Debye Length
- Use penetrating x-rays to probe dense "collapsed" region and post shock region
- Structure factor calculated and fit to collected spectrum (data)
- Electron Temperature calculated from width of Compton shifted peak

Results

- Scattered light is collected in gated Thomson spectrometer
- Light dispersed by HOPG crystal
- Imaged onto 4 strip MCP

- Mn backlighter delayed 19ns from drive beams
- Scattered off of dense collapsed region
- Electron temperature = 55 eV, Z free = 44
- Temperature consistent with Simulations
- High Z free possibly due to photo-ionization

Target Design

- Effects of radiation on the dynamics of the system depend on how the radiated photons are attenuated
- System is designed to be optically thin upstream and optically thick downstream

Summary and Conclusions

- We have produced a radiatively collapsed shock in the laboratory
- X-ray Thomson scattering data has been collected
- Some temperature measurements made
- More data analysis required