Supersonic radiation driven heat waves in foam target heated by X-rays

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A combined hohlraum-target concept have been investigated in order to gain a high degree of plasma homogeneity in experiment on the energy loss of heavy ions in ionized matter and approach plasma with a coupling parameter Γ~0.5-1. In this scheme, low density mm-thick foam layers were heated by means of X-rays generated in the gold hohlraum. The application of low density CHO-foam layers for plasma production has demonstrated a very high hydrodynamic stability of the created plasma and its uniformity [1]. A wide verity of diagnostic methods has been applied for measurements on the thermal wave propagation, plasma opacities and plasma self-radiation.

In Hydrodynamic 1-D calculations, 2 mg/cc cellulose triacetate $C_{12}H_{16}O_8$ of 2 mm thickness was heated from the right side by an X-ray flux with the Planckian spectral distribution at temperature of 30 eV and 10 ns duration (experimental conditions), see Fig.1. For radiation transport in the diffusion approximation $C_{12}H_{16}O_8$ - opacities calculated in [,2] have been used.

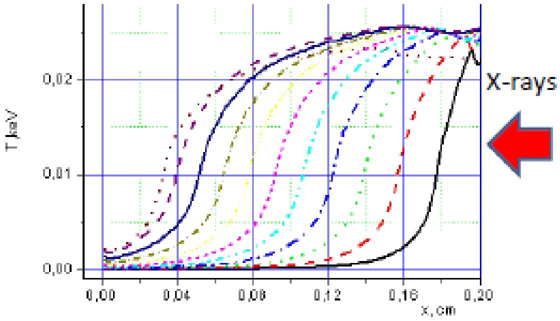

Figure 1: Propagation of the heating front through a 2 mm thick CHO-foam in time window from 1 to 10 ns..

Depending on the hohlraum spectra and foam density two different scenarios of a foam target heating by X-rays can be realized. If the mean photon pass in plasma is shorter than a plasma size, optically thick case, target heating occurs step by step (Fig.1) via propagation of the radiation driven supersonic thermal waves. If created plasma is optically thin (low target density or more energetic spectra of photons due to higher hohlraum temperature) volumetric heating takes place.

Propagation of the radiation driven supersonic thermal waves has been obsurved experimentally using a pin-hole camera coupled to the 4-frame gated MCP (microchannel plate) [3] and imaging the CHO-foam at different times of the heating process. An exposition time for every frame, in experiment 3-5 ns, and time delay between two subsequent frames can be variied. Frig. 2 shows the geometry of the combined target (picture left), the MCP-cheep with four imaging areas (right) and a measured time history of the heat-front propagating from the cylindrical hohlraum into the foam (center).

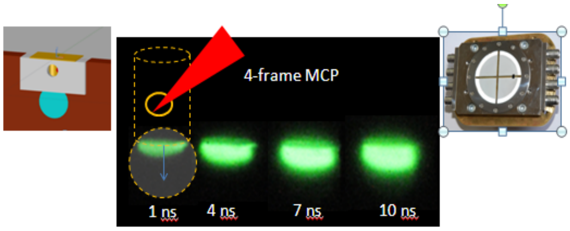

Figure 2: 2-D image of the foam region heated to plasma by hohlraum x-rays in the regime of supersonic radiation-driven heat waves, measured at different times.

The supersonic heat wave velocity $$V \sim \frac{T^{m+4}}{\rho \sim const} \qquad (1)$$

is a strong function of the plasma temperature T (in our case m~3) and doesn't depend on plasma density for hydrodynamic stable plasmas (ρ=const). After analyses of the radiation front position at different times one comes up with the averaged over the exposition time heat wave velocities and corresponding plasma temperatures.

$$V(1ns) = 1.2x10^{7}\ cm/s \rightarrow T \sim 25\,eV$$

$$V(4ns) = 8.3x10^{6}\ cm/s \rightarrow T \sim 23\,eV$$

$$V(7ns) = 4.0x10^{6}\ cm/s \rightarrow T \sim 20\,eV$$

$$V(10\,ns) = 1.4x10^{6}\ cm/s \rightarrow T \sim 15\,eV$$

In coming experiments this method will be applied for measurements of the plasma temperature in the time window of ion-plasma interaction.

References

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