About non-uniformity smoothing using foam substrate

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Introduction

It is well known that laser-driven inertial confinement fusion requires a very high degree of uniformity of laser irradiation on a target in order to assure both a high degree of compression and the achievement of ignition via the formation of a central spark due to the convergence of spherical shock waves. Smoothing techniques (such as phased zone plates [1-3], random phase plates [4], kinoform phase plates [5], smoothing by spectral dispersion [6], induced spatial incoherence [7]) has dramatically improved our control on laser-implosions and laser-plasma interactions. However, there still remains an issue of non-uniformity at very early times, called "laser imprint" problem [8-12] and may affect compression uniformity at later times and in particular on the development of Rayleigh-Taylor instability [13].

In this context, the application of low-density foams can be used both as a mean of shock pressure amplification due to impedance mishmash effect [14] and as means of producing uniform energy deposition [15] This scheme, proposed originally as “foam buffered targets” [16], is now becoming again very important due to the problems encountered in achieving ignition at the National Ignition facility, problems which have been recognized to be mainly due to the onset of hydrodynamics instabilities triggered by non-uniformities of irradiation.

In order to analyze the possibility of smoothing large-scale non-uniformities, gas-jet-induced smoothing of laser beams was also studied in an experiment performed at PALS [17], and discussed in [18]. In such experiment the large-scale non-uniform irradiation was set by splitting the laser beam in two equal parts with a prism and producing a double focal spot on target. In this paper, we use the same approach for producing the non-uniformity, but we focus instead on the smoothing processes produced by the presence of a the low-density foam layer on the side of the target irradiated by the laser.

Experiment

The laser pulse at 0.44μm (the third harmonic of the emission wavelength) was Gaussian in time with a full width at half maximum (FWHM) of 400 ps and a single shot energy up to 400 J. As said in the introduction, we used the same experimental set-up and diagnostics system described in Ref. [18]. By splitting the laser beam in two equal parts with a prism we could obtain two focal spots with a diameter about 30μm separated by about 100μm, thus producing very large irradiation non-uniformity, a priori very difficult to smooth out. As diagnostics, we used time-resolved self-emission for the detection of shock breakout at the target rear face. A photographic objective has been employed to image the target rear face onto a streak camera (Hamamatsu C7700 with S-1 photocathode). A red RG60 filter before the streak camera cut out any 3ω light. The spatial resolution of CCD was 2.6 μm and the temporal resolution 3.12 ps. An x-ray pinhole camera was used to record images of plasma self-emission during the interaction.

The targets used in the experiment were either simple Al foils (10 μm thick) or double-layer targets made of foam (50 μm thick) and Al (10 μm thick). Different foam characteristics were used 5 mg/cm^3 density; 2) 50 mg/cm^3 density; and 3) foam with density 50 mg/cm^3 containing Au microclusters. Such Au microclusters were added to the foam in order to study the possible effects of radiative transfer on induced smoothing.

One of the main results is the difference in time-resolved rear-side self-emission images obtained with the streak camera for aluminum and aluminum-foam targets. If in the first case (Al target) the two shocks generated by the two laser spots emerge separately on target rear side. In the second case (Al+foam target) the shock breakout are quite larger and the two emission region merge with each other, so that the central part becomes even brighter than the regions corresponding to the two spot centers.

Analysis and simulations

The dependences of shock arrival time from the foam thickness and pulse energy is well described by a simplest hydrodynamic model of shock reverberation from foam-Al border taking Hugoniot shock polars for aluminium and foam from corresponding

Equations-of-States [19], and considering an ablation pressure as $P \approx 8.6\left(I/10^{14}\right)^{3/4}\lambda^{-2/4}\left(A/2Z\right)^{1/3}$ [20] (where I is the laser intensity on target in W/cm^2, λ is the laser wavelength in μm, and A, Z are the mass number and the atomic number respectively).

To provide a preliminary analysis we have realized 2D simulations with the hydrocode MULTI [21], which we recently used in analyzing and interpreting several experimental results related to laser-produced plasmas [22] and extreme states of matter [23]. In order to simulate the experiment with a 2D code, we assumed a large non-uniformity in axial-symmetric approximation, i.e. we have used a ring spatial profile for the laser spot. Although this is not a completely realistic model for the considered experiment, nevertheless it gives the possibility for at least a preliminary qualitative analysis, and a base for further modeling.

The results and analysis are presented in the poster and will be published soon.

Conclusion

We have experimentally observed and numerically analyzed the shock behavior for complex foam-Al targets. The area between the two spots in that case can be subject to larger pressures than the spots themselves.

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