Non-classic efficient cavity pressure acceleration method applied to obtain very fast and dense macroparticles

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Abstract

In the investigations a scheme called cavity pressure acceleration (CPA) was applied, which allows propelling plasma objects in arbitrary direction in relation to the laser beam incident on a target and more efficient use of laser pulse energy absorbed and definitely increasing pressure causing acceleration of the foils. CPA eliminates the basic contradiction of the classic ablative acceleration process, in which this way of getting high microprojectile velocity simultaneously leads to mass loosing and density decreasing. Results obtained on PALS (Prague Asterix Laser System) show that the application of the CPA method allows for speed of the driven plasma objects to obtain values (average velocity ~ $6x10^7$ cm/s) comparable with top global results. Several other important results were also obtained e.g.: successful attempt to drive very thick foils (up to 500 μm Al) to the speed of ~ $1.0x10^7$ cm/s, the result is not having its counterpart in the literature and indication of a simple and effective method to significantly increase the density of driven objects without significant reduction of speed through the use of targets with "covered channel", which leads to a much higher energy density transmitted by the driven object, and the very high pressure generated by it, which is very important advantage in terms of possible use in impact fast ignition experiments.

Introduction

We present some results obtained during the experiment performed on PALS. We used iodine laser and cavity pressure acceleration (CPA) method [1]. Two different ways of macroparticle acceleration were investigated to obtain superfast macroparticles: FORWARD and BACKWARD acceleration. Additionally, application of the “covered channel” targets gives an evident increase of density of accelerated plasma flowing from the channel, which is a key problem from the point of view of possible applications in impact fast ignition area. The paper is aimed at impact fast ignition direction and tries to find more efficient methods of production of superfast and dense macroparticles.

Targets and results

Two kinds of cavity targets which were applied in the experiment are presented in Fig. 1.

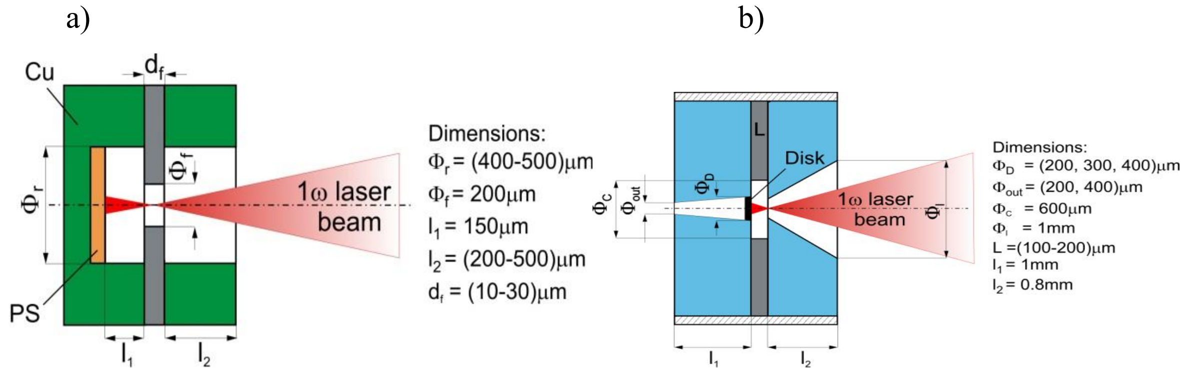

Fig. 1. Targets applied in CPA experiment: “backward” (a) and „forward” (b) acceleration.

The typical result obtained for BACKWARD acceleration experiment is shown in Fig. 2, where a sequence of two shadowgrams showing the movement of 20 μm PS foil at two selected times is presented. The average speed can be found to be ~ 6 x 10^7 cm/s.

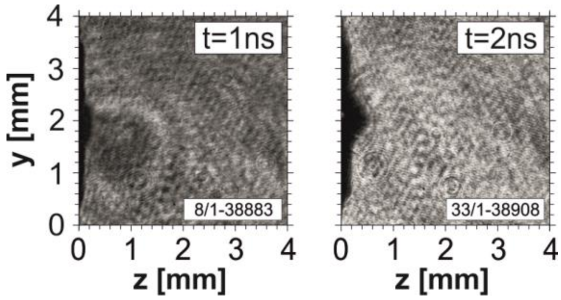

Fig. 2. Shadowgrams of 20-μm PS foil accelerated by 1-ω iodine laser pulse of energy E_l = 500 J.

Having in mind that the foil started with zero velocity, it means that maximum velocities v_{max} of accelerated Al and PS foil fragments can approach ~ 1.0 x 10^8 cm/s, i.e. the top result obtained in NRL Washington [2] and, moreover, they were obtained for thicker (higher mass density) foils (10 μm Al and 20 μm PS foils vs. 10.5 μm CH foil). Targets for forward acceleration were made in two variants – with cylindrical and conical channels. The disks of thicknesses of 10 to 100 μm made of Al or PS were taken. The velocities of the accelerated disks were 2 – 3 times lower than in the case of backward acceleration.

In our experiments we paid particular attention to acceleration of very thick foils (heavy macroparticles). The shadowgrams in Fig. 3a show motion of the 500 μm thick Al foil (laser energy of 120 J). The calculated velocity of this foil is ~1.0x10^7 cm/s. It is not known in the literature the similar case of accelerating such thick foils reaching so high velocity. Contrary, at the experiment with the "classic" ablative acceleration method applied, the laser pulse of much higher energy E_l = 300 J was not able to move 300 μm thick Al target (Fig. 3b).

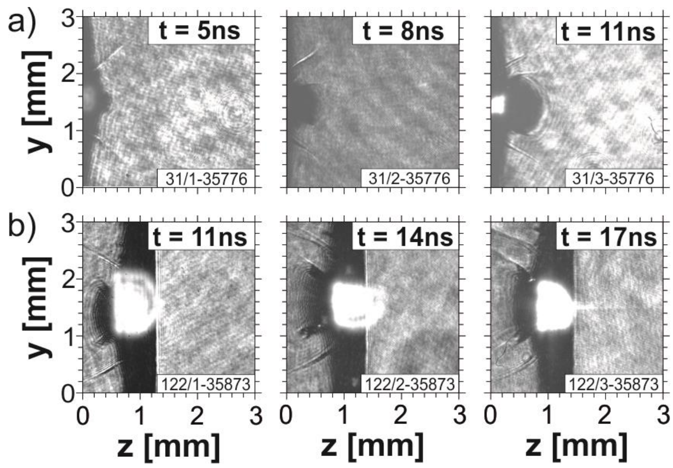

Fig. 3. Sequence of shadowgrams of 500 μm Al foil accelerated by the iodine laser pulse of 120 J (a) and set of shadowgrams for the classic ablative acceleration experiment, illustrating an attempt to accelerate Al target; laser pulse (E_l = 300 J) irradiates 300 μm thick Al target.

"Covered" targets

Fig.4 illustrates the acceleration of 10μm Al disk ("forward" scheme). It refers to two shots made for similar experimental parameters (the same disk thickness and energy E_l = 500 J and very similar target construction). The only difference was that the second sequence of shadowgrams illustrates the case when the exit of the channel was covered with thin (1.0 μm) Al foil. Comparison of these two shots shows that acceleration process with the covered channel target is more efficient. The cold plasma leaving the open channel quickly loses its density expanding into hemisphere.

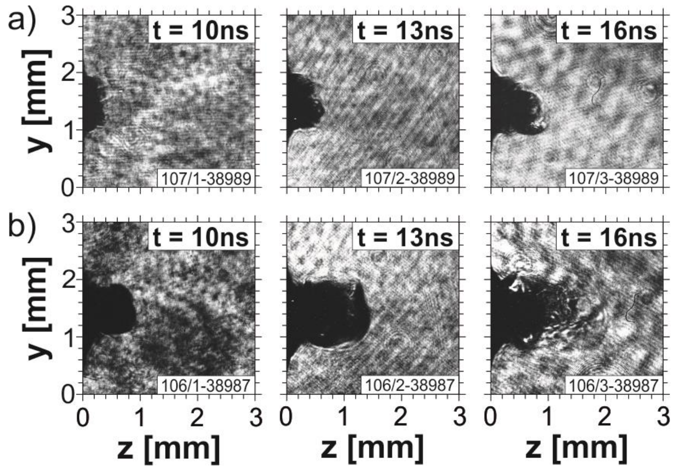

Fig. 4. Two sets of shadowgrams of 10-μm Al disk accelerated by 1-ω iodine laser pulse of energy E_l = 500 J. Shadowgrams in part a) refer to the "open channel" target and b) "covered channel" target.

In the case of the covered channel that expansion is much slower, energy of expanding plasma is transferred to the covering foil and it means the higher density and higher energy density of macroparticle. Additionally, an ultrahigh-pressure shock wave can be generated in the impacted foil covering the target.

Conclusions

CPA leads (especially for backward acceleration) to significantly higher velocities and mass densities of flyer foils than those obtained in traditional way (ablative acceleration scheme) in similar experimental conditions. The best results obtained are on the level of the world top velocities (NRL Washington[2], ILE Osaka[3]). A very high hydrodynamic efficiency obtained in CPA experiments may be a chance to meet the requirements of the laser system energy and construct an impactor for laser fusion experiments (more convenient is the forward version). Application of the "covered channel" target gives an evident increase of the density of accelerated plasma out bursting from the channel, which is a key problem from the point of view of possible applications in impact fast ignition area.

Refrences

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