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EXPERIMENTAL INVESTIGATION OF TRANSPORT IN LASER-TARGET IRRADIATION EXPERIMENTS

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The purpose of this work is to study by experiment the penetration depth of the heat front in a solid submitted to the strong irradiation of a laser, and also to analyse the effect of the laser wavelength on the thermal heat transport.

The target are irradiated by the output beam of a Neodymium glass laser which delivers 10 J in 100 ps at 1,06 μ wavelength, and when frequency doubled, 5 J in 80 ps at 0,53 μ . The light intensity onto the target are then $2 \cdot 10^{15}$ W/cm² at 1,06 μ and 10^{15} W/cm² at 0,53 μ . The targets employed are thin films of polystyrene whose thickness can range from 300 Å to a few microns. The diagnostics of thermal transport were the following : transmission of reflection of laser light by the target, X ray emission, thermal ion velocity in the front and the rear of the target. All measurements were made as a function of foil thickness. Depending upon the diagnostics, criteria were choosen for penetration depths characterization : 90 % foil and plasma opacity, saturation in plasma reflectivity or in X ray emission, change in the ion velocity of the thermal ions emitted on the rear side of the foil. Fig. a gives an example of foil transmission and reflection at $2 \cdot 10^{14}$ W/cm². Fig. b gives X ray emission as a function of foil thickness. Fig. c shows the effect of laser wavelength on foil transmission. In order to analyse experimental results, a numerical simu-

lation of the experiment was made with a 1D Lagrangian code, in planar geometry, and numerical determination of heat penetration was made. The table I summarizes these results and their comparison to the experiments. The column corresponds to the type of diagnostic and the row to different experimental conditions.

As a result it appears that the experimental value for heat penetration are smaller than given by the numerical simulation. This involves strong flux limitation and even with a flux limit factor of $f = 0.05$ the computed value (row a. in table I) are still larger than experimental determination. It does not seem reasonable at that time to assume that the flux limit is even more smaller. One have to think of the limit of the validity of the comparison between a one ID planar simulation with the experiment which include some 2D aspect on transport. Another possibility to obtain agreement between experiment and simulation will be to reduce also the flux. However this argument must be handled with care. It is not the laser flux which should be reduced but the heat thermal flux from critical region toward the target interior. Experimental results could be interpreted by introducing some anisotropy in heat transport. Assuming for example a strong lateral conduction. The second result of this experiment is to show the more efficient transport

when plasma heating is made with a short wavelength: thermal front penetrates deeper in the target, however the interpretation of this effect does implies only that the ablation velocity is larger in the case of the short wavelengths. It appears that when comparing experiments and numerical simulation, even for the short wavelength, we must include a flux limitation which is of the same order at 0,53 μ and 1,06 μ .

In conclusion, strong transport inhibition is evidenced laser target irradiation experiments. Short wavelength seems more favorable for heat penetration in solid but still subject to flux limitation problems.

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Fig. A

Reflection and transmission of the laser pulse versus foil thickness. The foil thickness corresponding to 10 % of transmission is defined as d_T ; here $d_T = 0,11 \mu\text{m}$.

Fig. b

Variation of the transmission versus foil thickness at 1,06 μm and at 0,53 μm ; $d_T(\omega_0) = 0,22 \mu\text{m}$ and $d_T(2\omega_0) = 0,43 \mu\text{m}$

Fig. c

X-ray emission for the 1-2 keV channel versus foil thickness at 1,06 μm and at 0,53 μm . The foil thickness corresponding to the saturation of the signal is defined as d_x : $d_x(\omega_0) = 0,15 \mu\text{m}$ and $d_x(2\omega_0) = 0,35 \mu\text{m}$.

	$d_T(\mu\text{m})$	$d_{i1}(\mu\text{m})$	$d_{i2}(\mu\text{m})$	$d_x(\mu\text{m})$
ω	0.11	0.12	0.20	0.11
$2 \cdot 4 \cdot 10^{14} \text{ W/cm}^2$				
a	(0.22)	(0.22)	(0.22)	
b	(0.32)	(0.67)	(0.43)	
ω	0.22	0.17	0.32	0.15
$2 \cdot 10^{15} \text{ W/cm}^2$				
a	(0.44)	(0.46)	(0.60)	
b	(0.70)	(2.0)	(1.5)	
2ω	0.43	0.30	0.50	0.35
10^{15} W/cm^2				
a	(0.9)	(0.75)	(1.5)	
b	(1.4)	(2.2)	(2.0)	

Table I

Summary of the experimental results for the characteristic foil thicknesses d_T , d_{i1} , d_{i2} , d_x . d_T and d_x have been defined in fig. a and in fig. c; d_{i1} and d_{i2} correspond respectively to the thicknesses for which the velocity of the fastest of the thermal ions and of the peak of the thermal ions in the rear side of the foil is smaller than the corresponding velocity in the front side of the foil.

The values between parenthesis are the corresponding results of the numerical simulations for two values of the flux limit factor: line a, $f = 0,05$; line b, $f = 1$.