Generation of high-pressures in aluminum by femtosecond low-energy laser irradiation

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The study of High Energy Density (HED) states of matter is an emerging field in physics. Such states are usually created in the laboratory by producing very high pressures by means of shock waves driven by laser pulses with nanosecond pulse duration and high-energy (>100 J/pulse). Nevertheless short-pulse lasers (femtosecond duration) can also create very strong transient pressures.

Here we present experimental results obtained with the laser facility of LOA in France. Aluminum targets have been irradiated with fs-laser pulses at the typical intensity of $I \approx 10^{21}$ W/cm^2. Hot electrons are produced in the interaction and deposit their energy in the bulk of the material creating a sharp temperature gradient, which produces expansion of the inner layers of the targets and finally generates an intense shock (initially $P \approx 200$ Mbar, even if such pressure is of course not maintained in time).

As a diagnostics, we used a streak camera recording the target rear-side self-emission in the visible range. Targets of different thickness have been used allowing observing a transition of target rear side emission to a sharp signal characteristic of shock breakout. Also, using different interferential filters we could measure the color temperature of target rear side, which resulted in good agreement with predictions from numerical simulations.

Hydro simulations show that the shock dynamics is strongly affected by the target expansion induced by the strong preheating caused by hot electrons. As the shock travels in the expanding density profiles the pressure decreases due to the impedance mismatch effect but at the same time the shock tends to accelerate due to the reduced density. The interplay between these two effects results in shock travelling at approximately constant velocity in the preheated target.

Our results show that, using fs-laser (3J/pulse in 30 fs), it is possible to produce shocks at very high pressures and perfrom significant physical measurement on matter in extreme conditions. This may open new possibilities for research on physics of high-energy densities (HED).