Measurements of Laser Imprinting on the OMEGA Laser System

Laboratory for Laser Energetics, U. of Rochester

Y. Srebro and D. Shvarts
Physics Dept, Nuclear Research Center, Negev, Beer-Sheva, Israel

We present radiographic measurements of laser imprinting on targets with pre-imposed, single-mode modulations. These “control modes” allow us to assign an equivalent mass perturbation to the initial imprint levels. Using this technique we compare the imprinting produced by different pulse shapes and measure the effect of uniformity improvements. Sharply rising pulses produce less imprint than slowly rising pulses—a result of the rate at which the coronal plasma is produced. The effect of smoothing by spectral dispersion (SSD) on these pulses can be similarly explained. Two-dimensional simulations of imprint are in good agreement with the experimental observations. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority.
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Simulation of method

<table>
<thead>
<tr>
<th>Amplitude O. D. (µm)</th>
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<tbody>
<tr>
<td>10^1</td>
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<tr>
<td>10^-1</td>
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<tr>
<td>10^-3</td>
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Time (ns)

0.0 0.5 1.0 1.5

Rippled target
Laser imprint
Equivalent surface perturbation

T. R. Boehly et al.
University of Rochester
Laboratory for Laser Energetics

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Collaborators

O. Gotchev  S. Skupsky
V. N. Goncharov  V. A. Smalyuk
J. P. Knauer  R. P. J. Town
D. D. Meyerhofer

Laboratory for Laser Energetics
University of Rochester

Y. Srebro and D. Shvarts

Nuclear Research Center, Negev, Beer-Sheva, Israel
Ben-Gurion University, Beer-Sheva, Israel
The effect of beam smoothing and pulse shape on laser imprinting is measured using mass equivalence

- Use preimposed modulations to calibrate imprinting at $\lambda = 30 \, \mu m$ and $60 \, \mu m$.
- The method detects changes in imprint due to beam smoothing.
- Slowly rising pulses produce greater imprint than steeply rising pulses.
- SSD has greater effect on the slowly rising pulses.
- The dependence on pulse shape results from the rate that the conduction zone is formed.
- These results have verified code performance and SSD smoothing rates.
Pre-imposed target modulations are used to determine the equivalent surface perturbation of laser imprinting.
Imprint Measurements

X-ray radiography is used to measure imprinted perturbations produced by two pulse shapes

$\Delta t = 100 \text{ ps}$

$8 \mu \text{m}$

6 drive beams

$I = 2 \times 10^{14} \text{ W/cm}^2$

Foot ramp

3 ns, flat
Fourier analysis is used to compare the imprinted to preimposed modulations at a single wavelength.

The equivalent surface perturbation for imprinting clearly shows the effect of beam smoothing.
At $\lambda = 60 \, \mu m$, the level of imprinting and the effect of SSD depend on pulse shape.
Rapid-rise pulses (**square**) produce smoothing plasmas faster than slow-rise pulses (**ramp**)
The “diffusion length” for thermal smoothing extends into the energy-deposition region

\[ <d_c> = \frac{1}{k} \ln \left[ \frac{\int e^{-k(x-x_a)} E(x) \, dx}{\int E(x) \, dx} \right] \]

Ablation surface
Critical surfaces
\( t = 0.3 \text{ ns} \)

Energy deposition (10^{14} \text{ J/cm}^3\cdot\text{s})

Distance from ablation surface (\mu m)

The imprinting mass equivalence is measured at two spatial wavelengths.
The imprint efficiency without SSD is measured at two wavelengths and compared to *ORCHID* simulations.

- The calculated imprint efficiencies are similar to those measured.
Observed imprint reduction by SSD (2 to 2.5) is consistent with decoupling times and smoothing rate.
Summary/Conclusions

The effect of beam smoothing and pulse shape on laser imprinting is measured using mass equivalence

• Use preimposed modulations to calibrate imprinting at $\lambda = 30 \, \mu m$ and $60 \, \mu m$.

• The method detects changes in imprint due to beam smoothing.

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