Observation of Self-Similarity in the Magnetic Fields Generated by the Nonlinear Rayleigh–Taylor Instability

Proton radiography
radiochromic film pack

Proton radiograph

4 kJ, 2.5 ns
$4 \times 10^{14} \text{ W/cm}^2$

$15-\mu\text{m CH}$
or $7.5-\mu\text{m Be}$

20-\mu\text{m Cu}

0.3 kJ, 1 ps
$\sim 1.5 \times 10^{19} \text{ W/cm}^2$

$t = t_0 + 2.6 \text{ ns}$

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The scale-invariant regime of nonlinear Rayleigh–Taylor (RT) instability has been probed with proton radiography.

Summary

- The RT-generated magnetic-field distribution and its evolution was investigated using laser-driven CH and Be targets.
- The structural evolution was found to be scale invariant.
- The data are consistent with a bubble competition and merger model;* the merger rate for Be has been determined.

Collaborators

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MG-level magnetic fields generated by the nonlinear RT instability were observed in laser-driven foils*

- 15-μm-thick planar CH targets were irradiated at \( I \approx 4 \times 10^{14} \text{ W/cm}^2 \) on OMEGA EP
- Magnetic-field generation was diagnosed using side-on laser-driven proton radiography
- 2-D magnetohydrodynamic (MHD) DRACO** simulations predicted a broken foil with 2-MG magnetic fields caused by RT instability

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Magnetic-field generation has been studied in face-on geometry using the acceleration of planar targets.
Face-on probing reveals magnetic-field generation by the RT instability

![Proton radiograph]

$t = t_0 + 2.6 \text{ ns}$
The magnetic-field spatial distribution was characterized using the watershed algorithm.
For CH, the number of bubbles decreases and the bubble diameter increases with time.
The same trend is observed for Be targets.

Target: 7.5-μm Be

- Average size: 97 μm
- Average size: 116 μm
- Average size: 145 μm
- Average size: 167 μm

Number of bubbles

Bubble diameter (μm)
The normalized magnetic-field spatial distribution evolves self-similarly, independent of target material.
The evolution of the magnetic-field spatial distribution is consistent with a bubble competition and merger model.*

\[ N(t) \propto (\omega \sqrt{2D(t)} + 2C)^{-4} \]

\[ \langle \lambda \rangle(t) \propto \omega^2 D(t) \]

Target: 7.5 \( \mu m \) Be

\[ \omega_{\text{Be}} = 0.8 \pm 0.1 \]

*O. Sadot et al., Phys. Rev. Lett. 95, 265001 (2005);
D. Oron et al., Phys. Plasmas 8, 2883 (2001);
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The distribution of magnetic-field ringlets in CH targets shifts to longer wavelengths.