Tailoring the expansion-to-propulsion ratio of laser-induced tin targets for EUV nanolithography

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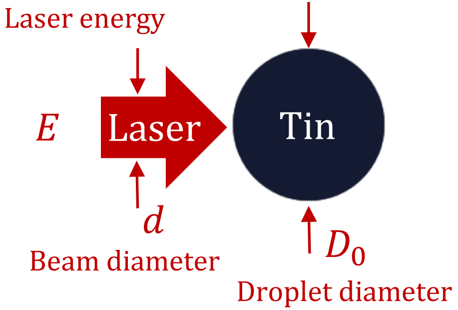
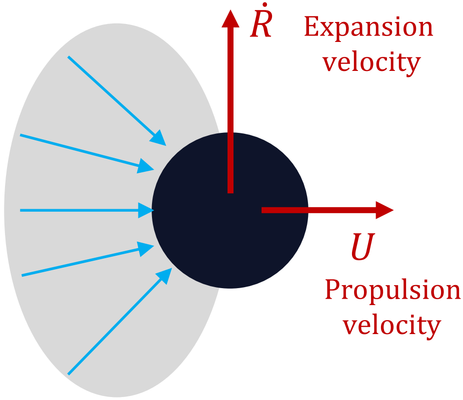
Laser-tin interaction



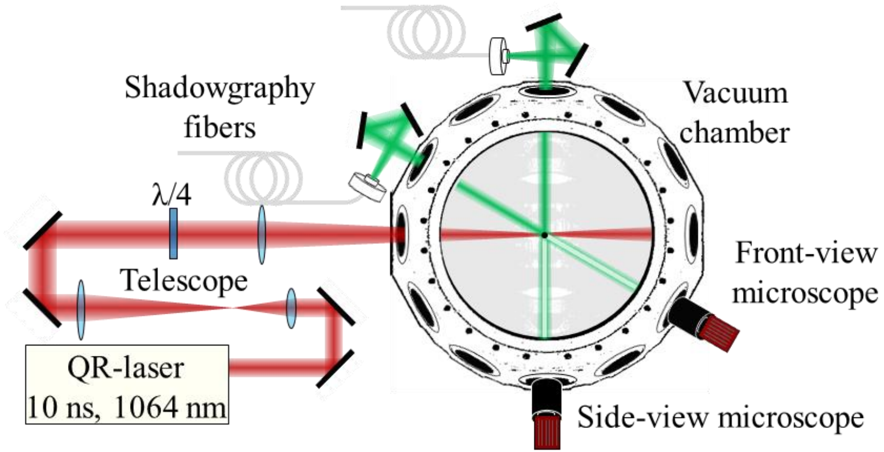
How do experimental parameters influence the kinetic energy partition?

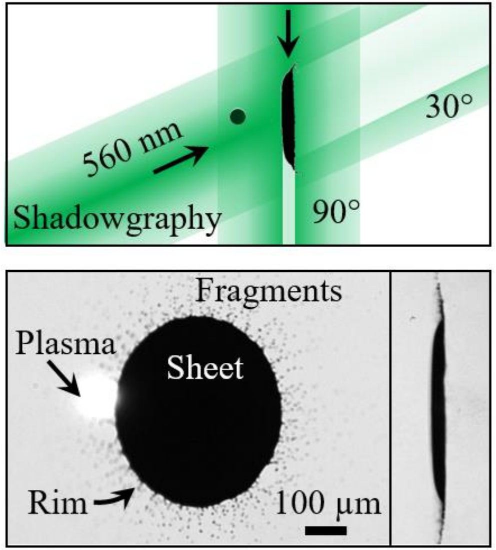
Link light-matter interaction to plasma expansion and to early hydrodynamic response.

Early hydrodynamics



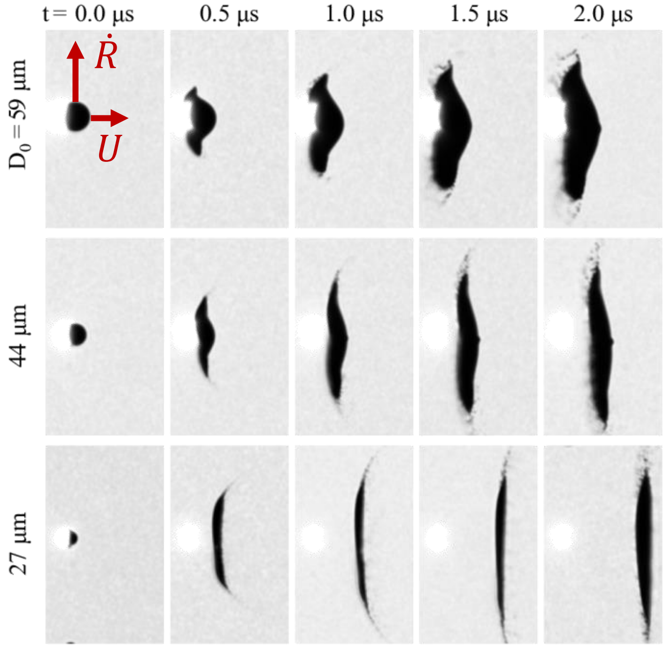
Experimental method and parameters explored





- We explore a large parameter space: tin droplet diameter D_0, laser beam diameter d and energy E.

Experimental results: morphology, propulsion velocity and radial expansion rate

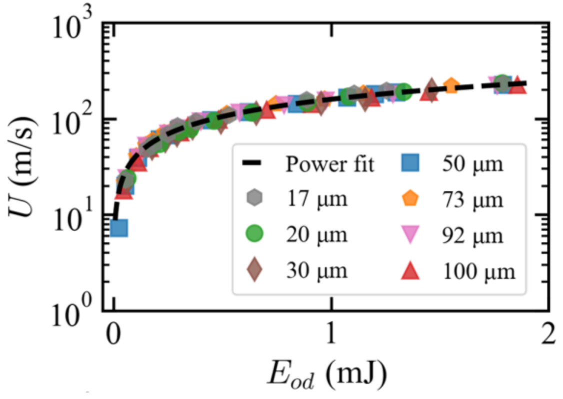


$U = K_U E_{od}^{\alpha}$

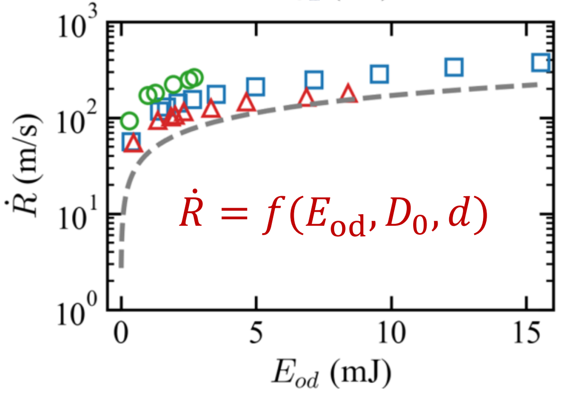
$U = f(E_{od}, D_0)$

$\dot{R}_0 > U$

Propulsion velocity



Radial expansion rate



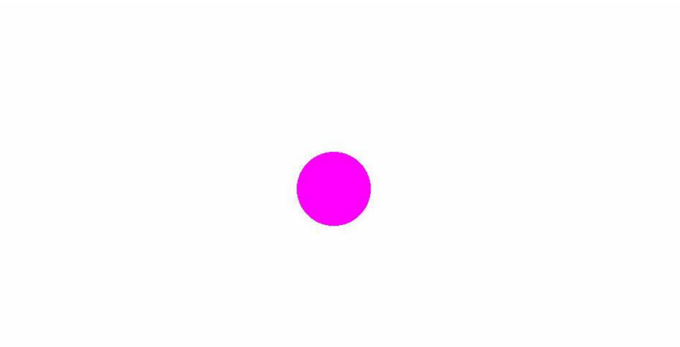
- Smaller d/D_0 ratios lead to targets with larger curvature.
- U-E_{od} data collapse on a single curve for a given D_0
- U data can be predicted by a function of E_{od} and D_0.
- Tighter beams lead to larger $\dot{R}_0$.

Kurilovich et al., Phys. Rev. Appl. 6 (1) (2016)
Liu et al., J. Appl. Phys. 129 (5), 053302 (2021)
Liu et al., Phys. Rev. Appl. 13 (2), 024035 (2020)
Kurilovich et al., Phys. of Plasmas 25, 012709 (2018)

RALEF 2D results: comparison of simulations with experiments (using U and $\dot{R}$)

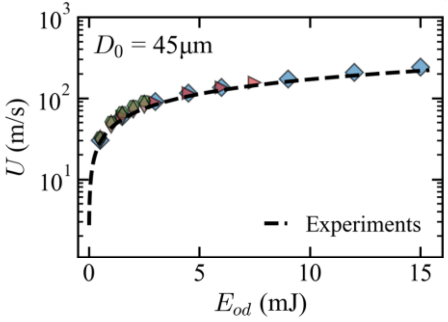
Input parameters: τ_p = 10 ns, λ = 1064 nm, d, D_0 and E.

Output: velocity field, mass distribution, temperature, pressure, kinetic energy…and U and $\dot{R}$

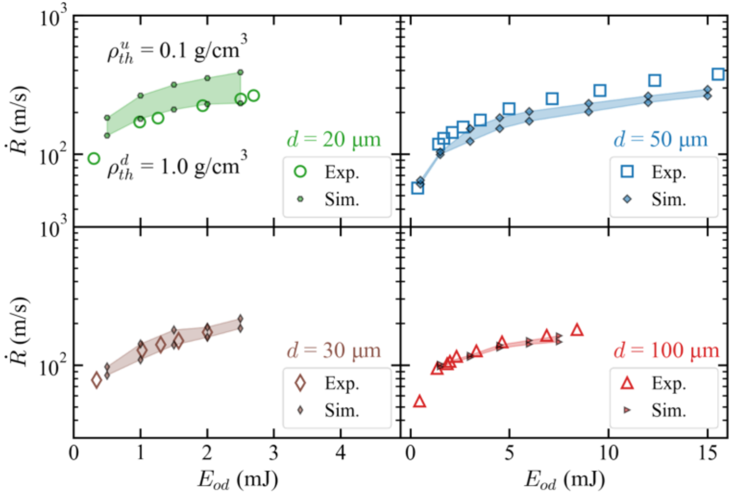


Experiments and simulations in reasonable agreement!!

Propulsion velocity



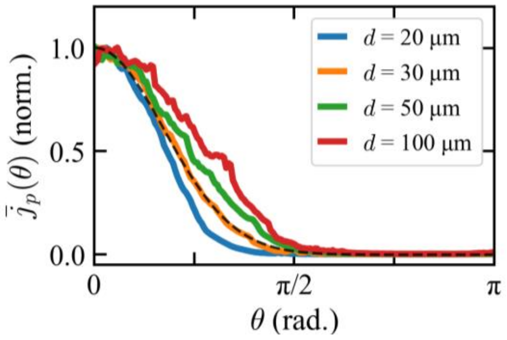
Radial expansion rate

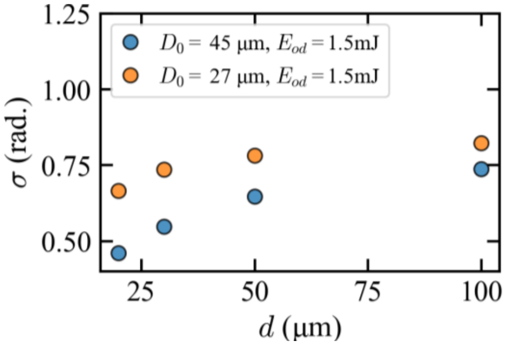


Kurilovich et al., Phys. of Plasmas 25, 012709 (2018)

Pressure impulse influence on the kinetic energy partitioning

Pressure impulse profiles

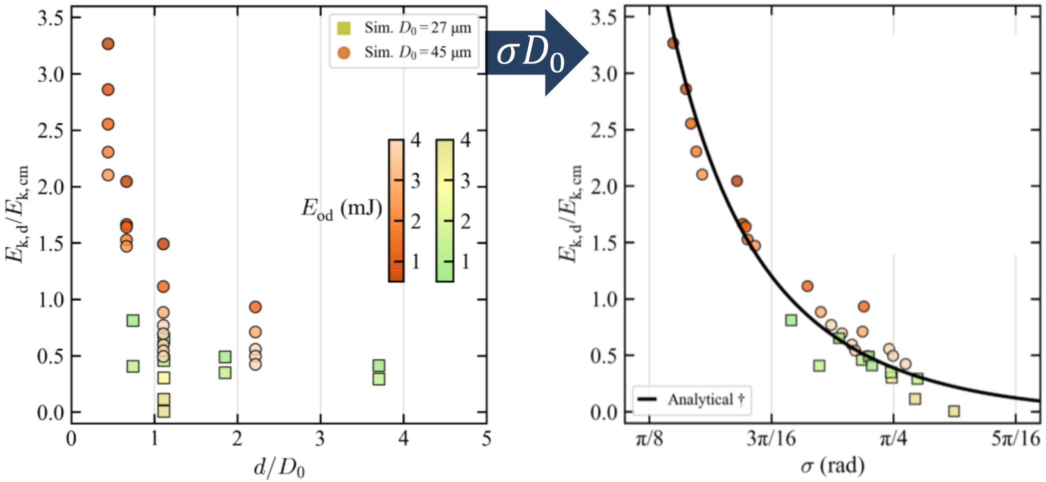




Pressure impulse width σ

- Gaussian is a good approximation
- Strong dependence with beam size
- Minor dependence with energy

Kinetic energy partitioning



- The width σ can be used as the sole parameter to extract the kinetic energy partitioning.

$$E_{k.d}/E_{k,cm} = f(d, E, D_0) = f(\sigma)$$

- The simulated energy partition is in excellent correspondence with analytical fluid-dynamics model

Klein et al., Phys. Rev. Appl. 3, 4 (2015)

† Gelderblom et al., J. Fluid Mechanics 794, 676 (2016)

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