Microjets are faster than a speeding bullet

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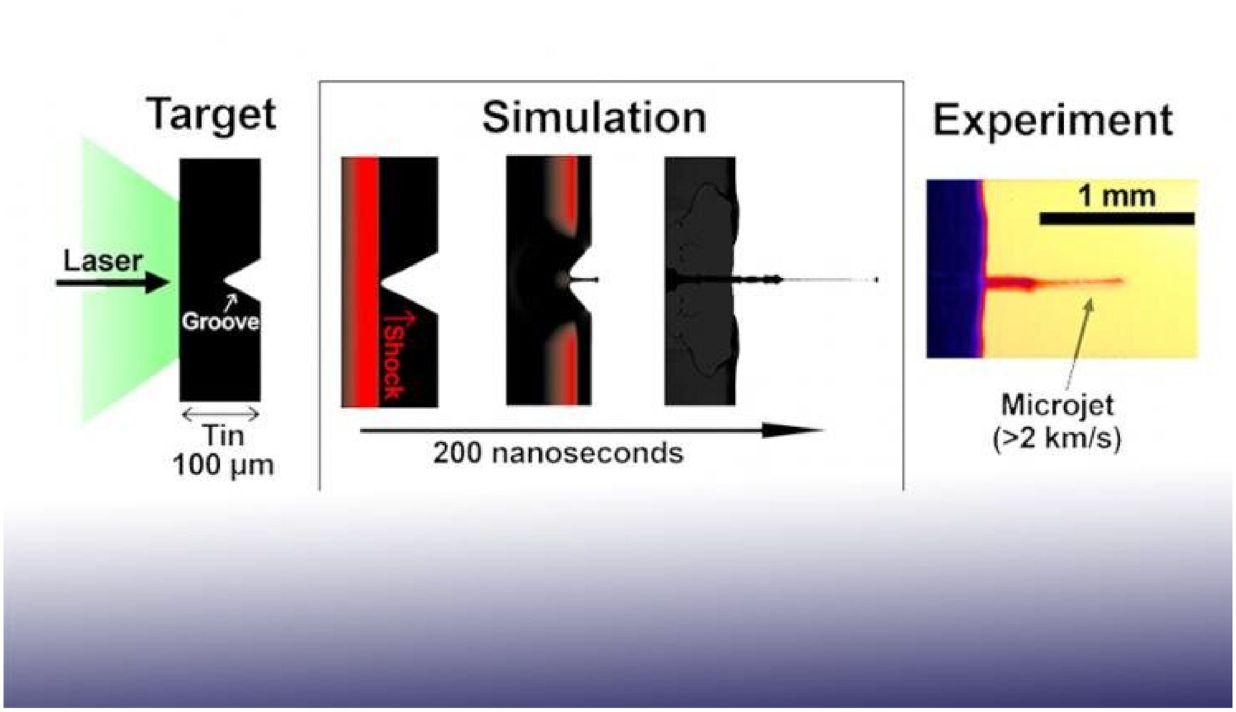

In experiments performed by the MERIT project, lasers shock microscopic tin samples and create microjets that travel at several kilometers per second. Simulations are critical to understand the dynamics of jet formation. Credit: Lawrence Livermore National Laboratory

When a shock wave travels through material and reaches a free surface, chunks of material can break away and fly off at high speeds. If there are any defects on the surface, the shock forms microjets that travel faster than a speeding bullet.

Understanding how these microjets form and how they interact with material help to improve spacecraft shielding and understanding a planetary impact.

Lawrence Livermore National Laboratory (LLNL) scientists produced hydrodynamic simulations of laser-driven microjetting from micron-scale grooves on a tin surface. From these simulations, they were able to see microjet formation across a range of shock strengths, from drives that leave the target solid after release to drives that induce shock melting in the target.

When a metal sample is subjected to dynamic pressure from an impact, an explosion or irradiation by a high-power laser, a shock wave can develop near the loaded side and propagate into the sample. When the shock interacts with the sample's free surface, it accelerates the surface and may cause localized material failure. As the shock wave interacts with surface defects (such as pits, bumps, voids, grooves or scratches), material can be ejected as clouds of small particles, or thin, directed jets at velocities significantly faster than the free surface.

Simulations are critical in studying microjets as they travel 1-10 kilometers per second (km/s), whereas a bullet travels about 0.3 km/s.

"The tin was designed with micron-scale grooves in the surface so we can generate microjets, studying how they propagate and interact," said LLNL physicist Kyle Mackay, lead author of a paper appearing in and chosen as an editor's pick in the *Journal of Applied Physics*.

The research is part of the Metal Eject Recollection Interaction and Transport (MERIT) project at LLNL.

The team found that jet formation can be classified into three regimes: a low-energy regime where material strength affects jet formation; a moderate-energy regime dominated by the changing phase of tin material; and a high-energy regime where results are insensitive to the material model and jet formation is described by idealized steady-jet theory. Mackay said transitioning between these regimes can increase the mass of the jet by 10 times.

"It's no surprise that the harder you smack something, the more things come off of it," said LLNL physicist Alison Saunders, a co-author of the paper and lead on the MERIT project. "But there is a lot of subtlety involved in understanding the materials physics that leads to such a relationship, and for a material like tin, which undergoes many phase transitions under shock loading, the relationship is far from linear."

More information: K. K. Mackay et al. Hydrodynamic computations of high-power laser drives generating metal ejecta jets from surface grooves, *Journal of Applied Physics* (2020). DOI: 10.1063/5.0028147

Provided by Lawrence Livermore National Laboratory

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