Laser acceleration of small projectiles for hypervelocity impact experiments

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A new experimental concept is being developed to measure the enhanced momentum transfer during hypervelocity impacts of small solid projectiles on solid targets.

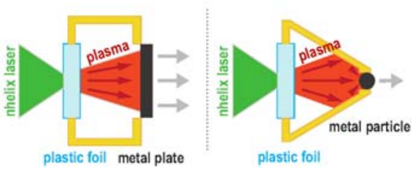

Figure 1: Proposed hohlraum target concepts for accelerating metal plates (left) and later small particles (right) to hypervelocities with the nhelix laser.

The magnitude of the *enhanced momentum transfer* caused by the ejection of material when a crater is formed on the target during hypervelocity ($v_{rel} \approx 10 - 15$ km/s) impacts is not well known for the materials and scales we are interested in, but it is believed to be at least tenfold [1, 2] compared to elastic collisions. We aim to measure the momentum transfer of dust-size metal particles colliding on larger metal targets with velocities in the aforementioned region. The collection of this data is critical e.g. to determine the feasibility of ideas proposed by G. Ganguli et. al.[3] for the active removal of space debris in the lower earth orbit. The experimental challenges of this project are both the acceleration of such small projectiles to hypervelocities and the accurate measurement of their velocities.

We will use a laser pulse from the nhelix laser system (~ 30 J energy over ~ 7 ns @ 532 nm) to drive a plasma expansion from a plastic foil mounted at the front of a hohlraum target. The rapidly expanding plasma will be used to accelerate a secondary projectile target to hypervelocities without melting it. At first we aim at accelerating small metal plates as depicted on the left side in Fig. 1 and to measure their velocity and momentum transfer onto a ballistic pendulum. Ultimately, the goal will be to accelerate spherical dust-size metal particles to hypervelocities and to gather extensive data on the momentum transfer for different materials and parameters. The targets will be fabricated in our own target laboratory at the Technical University of Darmstadt.

To accurately measure the velocity of the projectiles, we have set up a VISAR (*Velocity Interferometer System for any Reflector*) at the Z6 experimental area. The VISAR can measure velocities in the hypervelocity regime time-resolved on a sub-nanosecond scale with 1% accuracy. The VISAR requires a laser with high temporal coherence for its measurements. For this purpose we have comissioned a custom Nd:YLF laser by Continuum and modified it to better suit our needs. Dichroic mirrors were installed into the cavity to subdue the dominating 1047 nm lasing line in favour of the more exotic 1320 nm line and a 1320 nm diode laser which acts as an injection seed for the main resonator was incorporated into the system to provide the required temporal coherence.

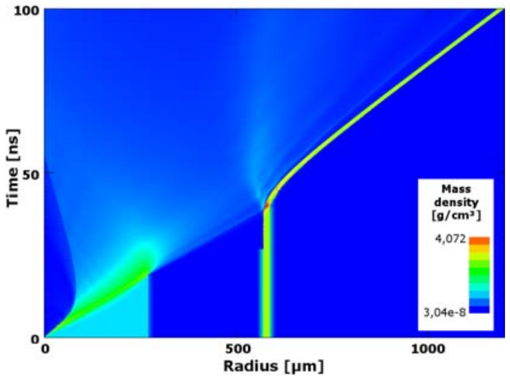

Figure 2: A simulation showing the temporal evolution (y-axis) of the mass density of a target consisting of a 270 μm plastic foil and a 16,5 μm aluminum metal plate, positioned 300 μm behind the plastic. The laser hits the plastic foil from the left edge at $t = 0$.

Simulations with the HELIOS 1D hydrodynamic code have been carried out (see Fig. 2) and are ongoing to help choose the initial values for important experimental parameters such as laser energy, plastic foil thickness and the distance between plastic foil and metal plate. Preliminary results indicate that plastic foils of thickness 50 - 100 μm combined with a distance of 300 - 600μm between plastic foil and metal plate is the optimal setup to reach velocities in the 10 - 20 km/s range without melting the metal plate.

References

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