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Optical probing of plasma dynamics in intense laser interaction with nanostructured solids

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Nanostructured solid targets have gained significant attention in high-intensity laser-plasma interaction due to their potential to improve laser absorption, enhance particle acceleration, and enable access to extreme-energy-density states [1].

However, experimentally probing the interaction dynamics and critical plasma properties remains challenging, as their evolution occurs on nanometer spatial and femtosecond temporal scales. Such measurements are particularly important for capturing the interaction of the leading picosecond pedestal and the steep rising edge of the amplified laser pulse, as they can pre-ionize and expand the target before the main peak of the laser[2]. The resulting pre-expansion can significantly alter the initial shape of the nanostructured target, adversely affecting laser absorption and particle acceleration. Accurately capturing these dynamics is essential for benchmarking plasma simulations and guiding the design of contrast-optimized targets.

Here, we present an optical pump-probe setup capable of resolving pre-plasma dynamics during the interaction of a 150 TW ultrashort pulse laser with nanostructured targets, with nanometric spatial and sub-picosecond temporal resolution. By combining scattering and Doppler spectrometry-based measurements [3], we characterize pre-plasma expansion, velocity, and particle acceleration under different laser contrast conditions. These measurements provide insights for understanding how modified nanostructure profiles of the target affect laser-plasma coupling and ion acceleration.

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