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Optical Probing of Ultrafast Laser-Induced Transitions from Solid to Overdense Plasma

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Capturing the target behavior during a high-intensity laser-solid interaction is crucial to understanding the interplay of fundamental processes such as ionization, collisions, and plasma kinetics. Furthermore, the pre-plasma evolution caused by the laser's rising edge is key for enhancing the properties of the accelerated particles and secondary X-ray sources. We present experimentally and numerically the onset and development of a plasma induced by the interaction of laser pulses with nm-thin DLC foils. A chirped probe pulse propagates longitudinally through the foil and records the ultrafast transmission dynamics during a single-pulse illumination. Numerical results shed light on the dynamics of the generation and evolution of a plasma. To achieve a good agreement between simulation and experiment, we developed a novel Two-Step Model. First, a solid-state interaction model is used to describe the interaction up to the target-melting. Second, a PIC-code is used for the kinetic description of the plasma. This investigation provides a direct insight into the interplay of various ionization processes. In addition, a detailed description of the spatio-temporal evolution of the plasma properties is obtained. Finally, this work is a first step towards providing the description of unprecedented detailed pre-plasma conditions for relativistic laser-solid interaction in PIC-codes and experiments.

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