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Dynamics of Relativistic Transparency and Optical Shuttering in Expanding Overdense plasma

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Overdense plasmas are usually opaque to incident laser light. But when the light is of sufficient intensity to drive electrons in the plasma to near light speeds, the plasma becomes transparent. In the physical picture, as the electrons reach near light speeds their mass increases due to relativistic effect. The increase in electron mass in turn slows their motion such that they can no-longer shield the plasma from the incident laser, making the plasma subsequently transparent to the incident laser. This process – known as relativistic transparency (RT) – takes just a tenth of a picosecond. Yet all studies of RT to date have been restricted to measurements collected over time-scales much longer than this, limiting our understanding of the dynamics of this process. Here we present optical signatures of relativistic transparency by measuring the time-resolved electric fields and temporal phases (with temporal resolution $\sim$50 fs) of the light, initially reflected from, and subsequently transmitted through, an expanding overdense plasma due to temporal evolution of RT. These measurements are done using a single-shot Frequency-Resolved-Optical-Gating (FROG) technique. The measured electric fields show the temporal chopping nature of RT in expanding overdense plasma from nanofoils. In addition the temporal phases of the corresponding electric fields record the plasma critical surface movement via Doppler-shift in reflection and plasma refractive index in transmission. Our result provides insight into the dynamics of the transparent-overdense-regime (TOR) of relativistic plasmas, which should be useful in the development of laser-driven particle accelerators, x-ray sources, and techniques for controlling the shape and contrast of intense laser pulses.