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Two-Dimensional-Space-Resolved, Picosecond-Time-Resolved, Velocity Mapping of Hot-Dense Intense Laser Produced Plasmas

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A detailed understanding of the critical surface motion of high intensity laser produced plasma is very crucial parameter for understanding the interaction [1,2]. We employ the pump-probe technique to report the first ever two-dimensional (2-D) ultrafast dynamics measurement of the critical surface of a solid plasma produced by a relativistically intense (5×10^{18} W/cm^2, 25 *fs*, 800 nm) laser on an aluminium coated BK7 glass target. Our earlier studies exhibit time resolved but spatially integrated [one dimensional (1-D)] dynamics of the plasma [3-6]. As motion of the plasma is strongly 2-D in nature, we developed a new technique which is capable of measuring time-resolved as well as space-resolved plasma dynamics. Our technique relies upon multichannel detection of light reflected from distinct points of the plasma in a single laser shot.

The experiment was carried out using TIFR 150 TW laser system with peak intensity of 5×10^{18} W/cm^2. The part of main beam is extracted using the thin beam-splitter and converted to second harmonic (400 nm). The spot size of probe on the target was 100 µm. The peak intensity of the probe was 5×10^{11} W/cm^2. The up-converted harmonic probe allows us interrogate the dynamics in plasma which is over-dense with respect to pump laser. Doppler shifts in the probe spectra are calculated by subtracting the central wavelength of the reference spectrum from that of the reflected probe spectra at different time delays. This technique provides high temporal resolution of the order of probe pulse-width, to capture ultrafast dynamics of plasma at very early time scales. Whereas an array of high-resolution multichannel spectrometer coupled to several optical fibers (8 to 16 in number) provides the spatial resolution. Spatial resolution offered by our technique depends on the total number of points across the probe beam wherever Doppler shifts are measured. We observed time dependent red and blue shifts and measure their magnitudes to infer plasma expansion velocity and acceleration and thereby the complete plasma profile. We notice a strong red-shift from different positions at the initial time of motion (< 3 *ps*) of critical surface towards the target; whereas at the later times (>3 *ps*) plasma starts expanding towards the vacuum inferred by a subsequent blue shift. Our measurements provides a space and time resolved velocity map of a critical surface of hot dense laser plasma.

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