Dependence of target-rear-surface transverse plasma expansion on laser polarisation

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Controlling the collective motion of plasma electrons in response to perturbations produced by intense laser light is key to the development of high power laser-driven particle and radiation sources. In the case of a laser-solid interaction, such as those employed for ion acceleration, the collective motion of the ponderomotively-driven electrons in ultrathin foils on the verge of undergoing relativistic induced transparency (RIT) leads to asymmetries in the 2D spatial profile of the beam of accelerated electrons [4, 5]. In a recent investigation by Gonzalez-Izquierdo *et al.* [6], it was demonstrated that such asymmetries are sensitive to the laser polarisation, and that these asymmetries are subsequently mapped into the resultant beam of accelerated protons [6, 7].

In this experiment, optical probing of the rear-surface of a target during a laser-foil interaction enabled changes to the target rear surface reflectivity to be characterized, which in turn enabled target heating and plasma formation to be diagnosed, including lateral expansion of the plasma [8].

The experiment was performed using the Astra-Gemini laser at the Rutherford Appleton Laboratory (RAL), which delivered pulses of 40 fs (FWHM) duration, at a central operation wavelength, λ_L, of ∼800 nm. To control the laser optical polarisation, thin mica waveplates were used to switch between linear ($\Delta\theta = 0$), elliptical ($\Delta\theta = \pi/4$) and circular ($\Delta\theta = \pi/2$) polarisation, where $\Delta\theta$ is the phase difference between the two orthogonal electric field components of the laser beam. A double plasma-mirror system was implemented to increase the temporal intensity contrast of the pulses to $\sim 10^9$ at 5 ps prior to the peak of the pulse, and the pulse was focused to the target employing an F/2 off-axis parabola (OAP), to produce a FWHM spot size of 3 μm at normal incidence to the target, with an encirled energy of ∼ 2 J [9]. Planar aluminium foils with thickness of 100 nm were employed throughout the study. The low-energy probe beam was focused by an F/40 OAP onto the target rear at an angle of 30^o, with central wavelength and duration equal to that of the main driver pulse. An f = 30 cm lens was used to collect light reflected from the rear-surface, which was then imaged onto a CCD (Andor Ixon). The probe was timed to arrive (3.0 ± 0.04) ps after the main pulse arrived at the target. A schematic illustrating this arrangement is shown in figure 1.

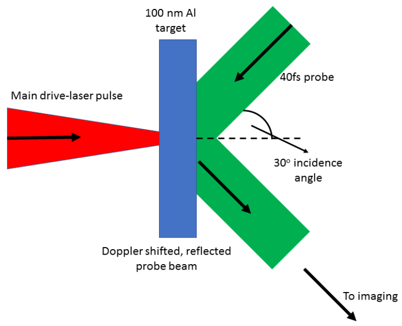

Figure 1: Schematic of the experimental set-up, illustrating the beam path of the target-rear-surface reflected probe beam.

A number of 100 nm thick Al targets were irradiated with either linearly, elliptically and circularly polarised light. It was observed that variation of the drive-laser polarisation resulted in noticeably different plasma and structure formation on the rear-surface, diagnosed by a change in reflectivity in the on-shot probe image when compared to a reference image of the un-shot target taken prior. An example of the differences in structure observed when the polarisation of the drive laser was varied is shown in figure 2.

The p-polarised case (shown in figure 2(a)) displays a number of radial spoke-like features projecting from a central region, which is approximately of the order of the size of the laser focal spot. In this case, the filamentary-types structures are seen to propagate ∼ 200 μm to the target edges, indicating a propagation velocity of approx-

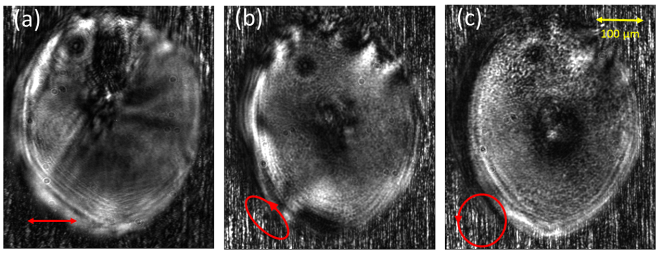

Figure 2: Raw probe images of the target rear-surface for targets irradiated by (a) linear, (b) elliptical, and (c) circular polarised laser pulses. Images taken 3 ps after main pulse.

imately $0.25c$. It should be noted that there is a predominant expansion in the horizontal direction, i.e. the axis of polarisation.

When the drive-laser polarisation is changed to circular, the filamentary structures seen in the linear case are observed to disappear. Instead, a circular plasma distribution is present. The expansion velocity is reduced when compared to linear polarisation, with a value of $\sim 0.1c$. Moreover, when the drive-laser polarisation was set to elliptical, i.e. $\Delta\theta = \pi/4$, features of both the linear and circular cases were seen to be present.

Conclusion

To conclude, we have presented a snapshot of preliminary results from an investigation of target rear-surface plasma dynamics. It is observed that the plasma expansion is sensitive to the initial laser polarisation. In addition, we observe that the lateral plasma velocity on the rear-surface of the target is greatly increased when the target when linearly polarised light was incident, with expansion predominantly accelerated along the axis of laser polarisation. Analysis and modelling of the collected data is ongoing.

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