Implementation of an Optical Probe with Anamorphic Imaging in Gemini TA3

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1 Introduction

Optical probing diagnostics are key for laser plasma experiments to determine fundamental plasma properties and to characterise the interaction. In laser wakefield acceleration experiments with petawatt class lasers, the plasma channel can be greater than a centimeter in length, yet ∼100 μm in radius. This extreme aspect ratio means that imaging transversely with sufficient field of view (in the drive laser direction) and spatial resolution (in the plasma radial direction) is challenging with spherical imaging optics. With higher power laser facilities such as EPAC coming online, this aspect ratio will only increase. Here, a 3:1 anamorphic imaging system has been demonstrated on Gemini.

2 Imaging System Design

The imaging system had a magnification of 1 in the vertical direction (plasma radial direction) which was achieved with spherical lenses. A pair of f = 750 mm, 3" diameter lenses relayed the image out of the chamber, across a walkway and onto a diagnostic table. A pair of f = 200 mm, 2" lenses then imaged towards the cameras. A beamsplitter was placed between the f = 200 mm lenses for an interferometric measurement, using a Phasics SID4 HR wavefront sensor [1], and for shadowgraphy on a Allied Vision Manta-G235b camera [2]. Assuming ideal alignment, the wavefront measurement was detector limited in spatial resolution to 24 μm in this direction and the shadowgraph was diffraction limited to approximately 10 μm. The field of view was limited to the camera chip sizes.

In the horizontal direction, a magnification of 1/3 was required to view the whole diameter of the 25 mm back-lighter beam on both cameras. To achieve this, a pair of cylindrical lenses with f = -100 mm and f = 300 mm were placed between the f = 200 mm lenses. Figure 1 shows the envelope of the back-lighter and the image rays through the system in this direction. In an ideal system, spatial resolution was detector limited on both cameras, with 72 μm on the wavefront measurement and 17.6 μm on the shadowgraphy. The field of view was 25 mm, limited by the backlighter beam size.

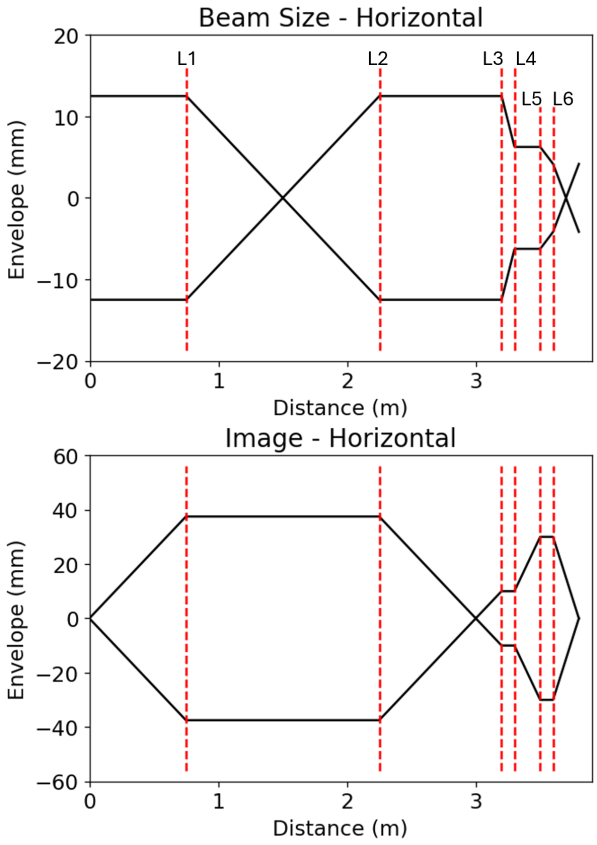

Figure 1: Back-lighter beam envelope (top) and image ray envelope (bottom) in the horizontal (drive laser) axis through the imaging system. L1 is an f = 750 mm spherical lens, L2 is an f = 750 mm spherical lens, L3 is an f = 200 mm spherical lens, L4 is an f = -100 mm cylindrical lens, L5 is an f = 300 mm cylindrical lens and L6 is an f = 200 mm spherical lens.

3 Results

Figure 2 shows an example raw image from the wavefront sensor when this imaging system was applied experimentally in a laser wakefield acceleration setup in Gemini TA3 which used a 15 mm diameter conical jet. The gas backing pressure used here was 70 bar. The full extent of the plasma profile can be seen with sufficient resolution in the plasma radial direction. Figure 3 shows

the measured density once background subtraction and an Abel transform were applied to the raw phase image. Figure 4 shows the density in the drive laser direction, averaged over the central region radially of figure 3.

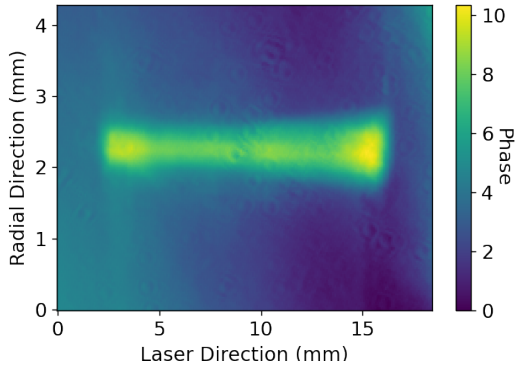

Figure 2: Raw phase image from wavefront sensor.

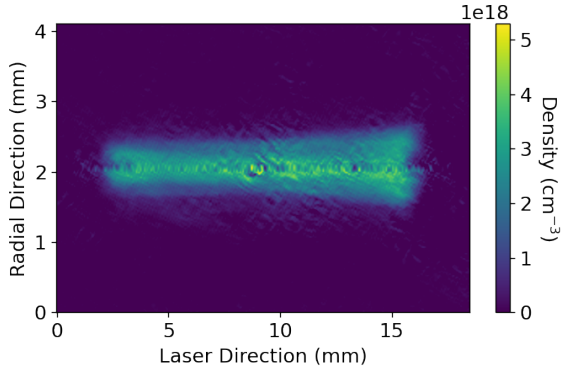

Figure 3: Measured density assuming cylindrical symmetry of the plasma channel.

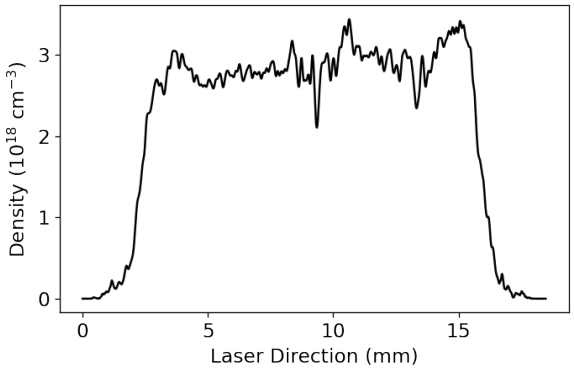

Figure 4: On-axis density seen by the drive laser.

4 Conclusion

An anamorphic imaging setup has been developed and implemented in Gemini TA3 for optical probing of a laser wakefield accelerator. Optics for this setup are all stock items so this arrangement can conveniently be implemented in future Gemini experiments. Knowledge gained from this setup will be transferred to the EPAC probe design.

References

[1] *Phasics*. https://www.phasics.com/en/product/sid4-hr-wavefront-sensor/.

[2] *Allied Vision*. https://www.alliedvision.com/en/camera-selector/detail/manta/g-235/.