Optical Transition Radiation from conical guide elements on Vulcan Petawatt

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Introduction

High intensity (>10^{18}W/cm^2) laser-plasma interactions produce beams of fast electrons. These electrons have applications in studies for warm dense matter and the fast ignition fusion scheme[1][2]. However, the high divergence of the beams limits their utility[3][4]. It has been shown that it is possible to guide these electrons by exploiting the self generated magnetic fields produced at gradients of resistivity[5]. Theoretical studies have shown that conical guide elements are able to collimate fast electron beams[6]. Scitech and CLF target fabrication have created novel conical targets for use on Vulcan Petawatt in an attempt to experimentally demonstrate resistive guiding.

Front Surface Imaging

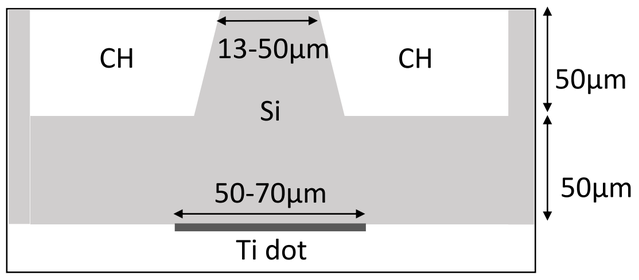

Figure 1 – Diagram of the cone targets. A silicon cone is surrounded by plastic cladding

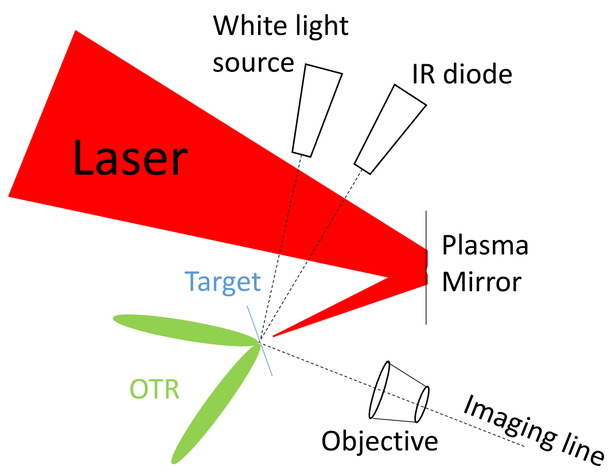

Figure 2 – Schematic diagram of Front Surface Imaging diagnostic

- The small size (13-50µm) of the conical guide elements require a highly precise alignment system
- Laser jitter means missing some targets is unavoidable
- A novel Front Surface Imaging (FSI) system was implemented to achieve this
- The target surface is illuminated by a white light source and IR diode
- Scattered light enters an objective at 8cm away and is redirected out of the chamber
- Images are formed on a CCD and IR camera

Alignment Procedure

Pre-shot alignment

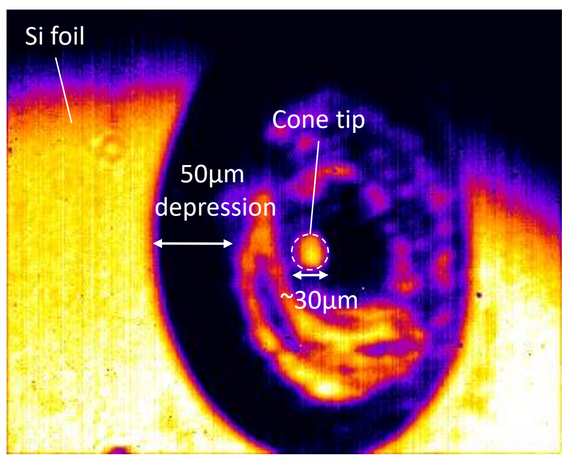

Figure 3 – Image on an unclad cone on IR camera. Illuminated cone tip can be seen in the centre of the surface depression

- The surface is illuminated by an IR diode
- The cone structure can be seen on IR camera
- Scatter from the alignment laser can be seen on the camera and aimed at the cone tip

Post-shot characterisation

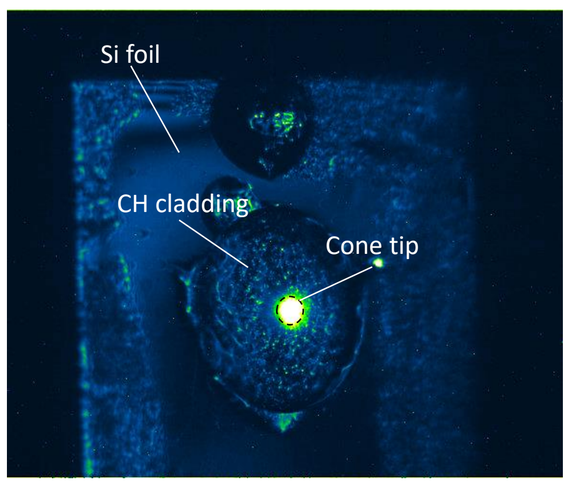

Figure 4 – Overlaid images: reference image of illuminated target and on-shot plasma self-emission.

- Optical channel filtered to 2ω
- Target surface is illuminated with white light source
- Reference image is taken before shot
- On-shot image is taken of the plasma self-emission
- Images can be overlaid to confirm target hit

Optical Transition Radiation

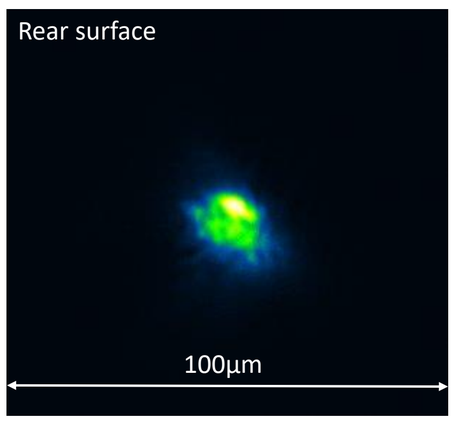

Figure 5 – OTR emission from the rear surface of a target

- Optical transition radiation (OTR) is given off when an electron beam passes through the interface between two media of different dielectric constants[7]
- In relativistic laser-plasma interactions, the JxB mechanism injects electrons into the plasma at twice the laser frequency
- A coherent effect causes optical radiation to be given off at the second harmonic wavelength

Results

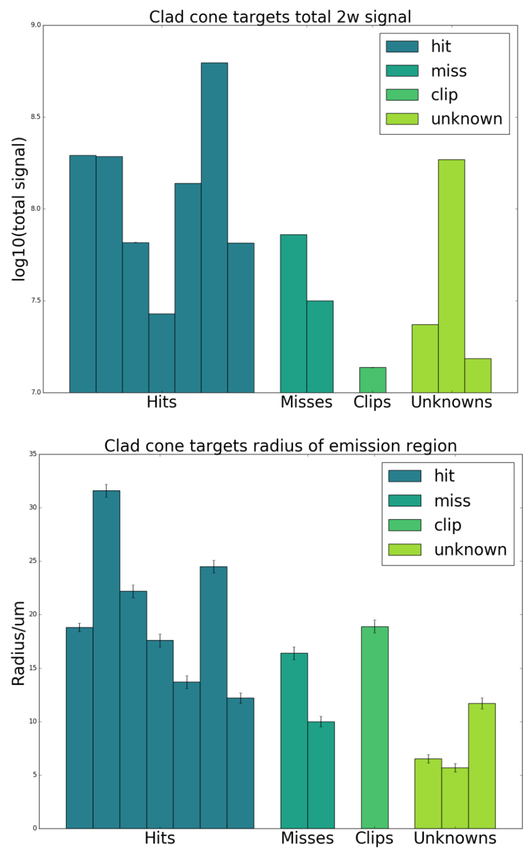

Figure 6 – Results of the measured emission region sizes and total OTR signal

- The average radii and total signal of the coherent emission were measured
- Each shot has been characterised as: Hit, Miss, Clip or Unknown using the FSI system
- The results show high variability even within the different shot categories
- Variability could be due to changes in laser or target parameters
- Even so over half the hits show more signal than the misses
- A more significant effect on beam divergence should be seen in the lower energy component of the e-beam

Conclusion

- FSI is a new technique for carefully aligning High Power Laser systems to small targets
- FSI was used in combination with OTR in order to investigate resistive guiding of electrons on Vulcan Petawatt
- No clear trend in hit/missed shots due to large variation in data
- Need to determine laser and target parameters responsible for variable data
- OTR data will be combined with other diagnostics to confirm the presence of any guiding effects

Acknowledgements

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References

[1] D. J. Hoarty et. al., HEDP **6** 105-108 (2010)
[2] R. Kodama et. al., Nature, **412**, 798 (2001)
[3] K. L. Lancaster et. al., Phys. Rev. Letts., **98**, 125002 (2007)
[4] J. Green et. al., Phys. Rev. Letts, **100**, 015003, (2008)
[5] S. Kar et. al., Phys. Rev. Letts., **102** 055001 (2009)
[6] A. P. L. Robinson et. al., PPCF, **57**, 6 (2015)
[7] C. Bellei et. al., PPCF, **54**, 3 (2012)