Elliptical focal spots for the Shenguang II (SG-II) Laser Facility, China

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Introduction

The target areas of the Vulcan laser system have often required control of the size and homogeneity of focal spots. This has frequently meant the use of Random Phase Plates (RPP) [1] which have played a vital role in allowing the high-profile experimental physics programme to be pursued. The experience gained in the design, manufacture and use of these diffractive optics, for different wavelengths (351nm ~ 1.053µm) and for various optical arrangements has been widely appreciated and has allowed collaborations to be established with other high-power laser groups across the world.

This report outlines such a collaboration with the National Laboratory for Condensed Matter Physics, Institute of Physics, Beijing, China. This is one of the top five National Laboratories in China, and is operated by the Chinese Academy of Sciences and the Ministry of Science and Technology of China.

Experimental Requirement

The experiment in Beijing was on a large multi-beam (each 240mm in diameter), near infrared laser system and aimed to make simultaneous Thomson scattering measurements of the electron temperature and of the heat flux in plasmas. The plasma was formed by 3 beams being focused by a 750 mm lens, with a similarly arranged heating beam as well as a separate probe beam. The focal spot size was required to have a homogeneous intensity profile, be 500µm full-width half-maximum (FWHM) and be circular in shape when viewed from the target normal. Figure 1 shows the configuration of these beams where the 4 main beams are seen impinging on the target from an oblique angle of 60°.

Here at RAL, the standard RPP pattern used for producing a circular focal spot has concentric rings of width, W, with each ring broken up into separate elements each approximately W wide, with the phase of each element randomly chosen to be either 0 or π. The basic element size W is calculated from $F\lambda/d$, where F is the focal length of the lens, λ the working wavelength and d the spot size. For the Beijing laser operating at 1.053µm this implied an element size of 1.58mm but this is for a phase plate used with the optic axis normal to the target.

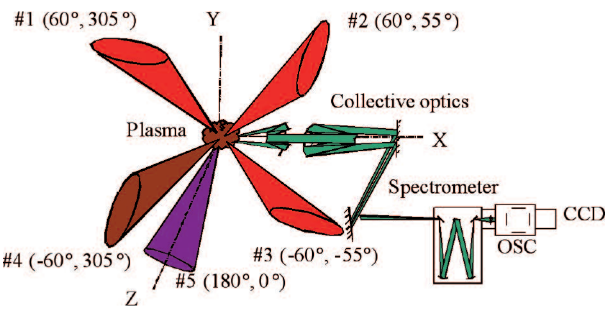

Figure 1. Schematic of the experimental setup.

With the fact that the beams are substantially angled (and cosine 60° being 0.5) this would have led to an elliptical on-target spot size of 500µm in one direction but 1000µm in the orthogonal direction.

In order to bring the spot back to circular necessitates a compensatory distortion in the RPP pattern. For a given F and λ, as the element size W in the RPP pattern increases, the focal spot size d, will decrease. Thus, by distorting the pattern by a factor of 2 in one axis, (resulting in effective element sizes 1.58mm up to 3.16mm), the focal spot size becomes 500µm by 250µm (FWHM) used on axis, but circular, 500µm in diameter when correctly orientated for the 60° angled target.

Figure 2 shows the center section of the distorted RPP pattern where instead of circular rings there are now elliptical annuli filled with the varying scale elements.

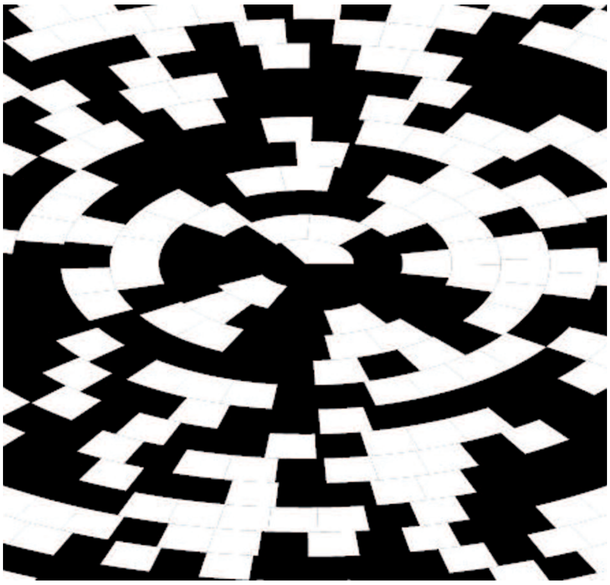

Figure 2. Central portion of the Random Phase Plate used to produce elliptical focal spots.

Results

The mask and the phase plates are made via a photo-lithographic process and although the mask was able to be produced satisfactorily there were difficulties with the phase plates themselves. The phase plate substrates supplied by the Chinese Institute of Physics were relatively thick and heavy and the spinning plant normally used was unable to produce the required depth of photo-resist. Fortunately, the CLF has close links with Colsi Coat Ltd, Oxford, and the plates were able to be processed there. Four identical RPP's were produced and supplied for the experiment, one for each of the main beams, where the plates were individually orientated to each produce the circular focal spot on target.

With the required focal conditions in place the experiment was enabled to be conducted. It was deemed to be a complete success and a paper is now in the process of being submitted to Physics Review Letters.

Acknowledgements
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References

1. Y. Kato, K. Mima, N. Miyanaga, S. Arinaga, Y. Kitagawa, M. Nakatsuka and C. Yamanaka, *Random phasing of high-power lasers for uniform target acceleration and plasma-instability suppression, Physical Review Letters,* **53**, 11, 1057-1060, (1984)