Experimental setup of the Vulcan HAPPIE Laboratory 2 for spatially and temporally coherent multibeam recombination

Contact *Adam25_50@msn.com*

Adam Rogers
Central Laser Facility
RAL

Cristina Hernandez-Gomez
Central Laser Facility
RAL

Marco Galimberti
Central Laser Facility
RAL

Ian Musgrave
Central Laser Facility
RAL

Bryn Parry
Central Laser Facility
RAL

Jonathan Phillips
Central Laser Facility
RAL

Introduction

High power lasers are exceptionally useful in modern scientific and commercial environments, providing a diverse range of uses and aiding continued advancement in many fields. With this advancement also comes the continued pressure to increase the output power of these lasers. However the highest achievable power of these modern laser systems are often limited more by the involved optical components than the technology behind the laser production. Factors such as amplified spontaneous emission, thermal effects, depolarisation loss and damage thresholds all limit the power that can be amplified and delivered within a laser system. One method that helps minimise and even eliminate some of these problems is to combine multiple lower power beams into one single high power beam. To enable wavefront and pulse shape control it is therefore required that technology able to combine these beams both spatially and temporally can be developed and applied to such systems. This project is a progression of the previous HAPPIE Lab experiment carried out by the CLF. The aim of the new HAPPIE Lab 2 is to both increase the scale of the experiment and to introduce new diagnostics into the setup.

Layout

The layout of the experiment was altered from the previous setup for multiple reasons. Firstly, a spatial filter was included after the apodiser to give the beam a well defined edge. Secondly, a delay stage in one arm of the beam was installed. This gives further control of the relative phase between the two arms. Additional diagnostics were also added. A microscope far field camera enables higher fidelity when recombining the beam. A near field camera was also included to view the image plane of the beam on the mirrors. **Figure 1a** shows the basic layout.

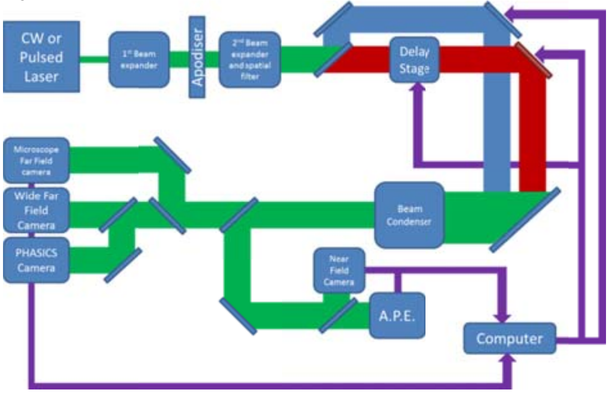

Figure 1a a schematic diagram of the new layout.

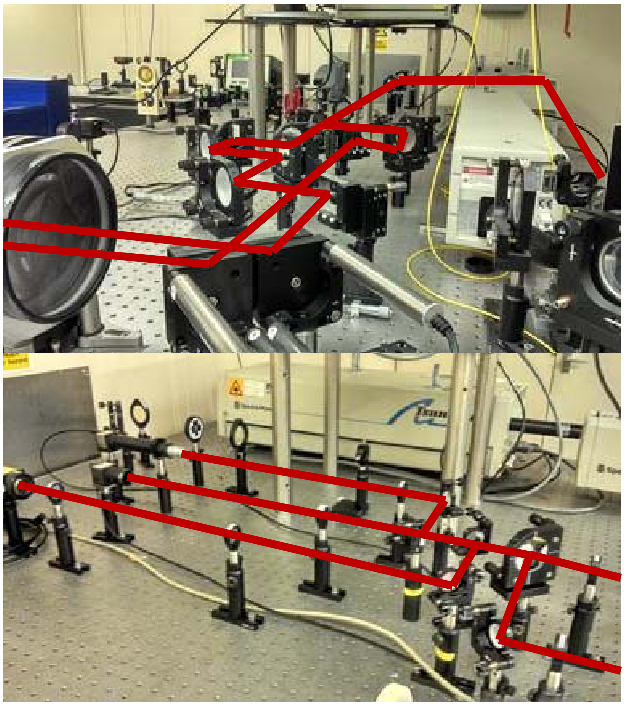

Figure 1b Top: Initial beam path of the CW onto the actuated mirrors. Bottom: Beam path into the diagnostics.

The delay stage and actuated mirrors are controlled by a set of Newport actuators. On the delay stage, the path length of one of the arms can be altered. On the mirrors; tip, tilt and piston are controlled individually for each mirror. These are then connected to control drivers which can be controlled though a computer. Currently these actuators are operated manually. Doing so enables the user to overlap the beams on the far field cameras and interference patterns can be seen as shown in **Figure 2.**

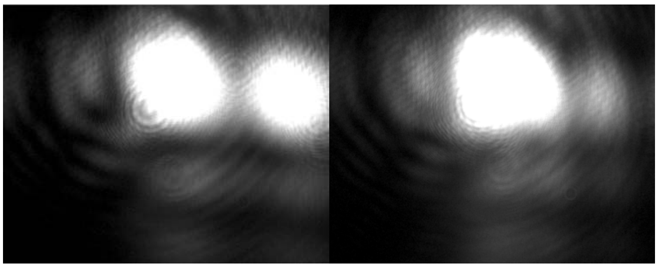

Figure 2 On the left, the two separate beams on the magnified far field. On the right, the beams brought together.

Wavefront measurement methodology

Measurement of the wavefront within the HAPPIE Lab experiment uses multiwave lateral sheering interferometry, technology based on a modified Hartmann test. The Hartmann Mask, a 2D diffraction grating, splits the incident beam into four identical waves (**Figure 3c**) which are propagated along slightly difference directions. The beams interfere with each other as they propagate into the camera and after a few millimeters the beams are slightly separated. In an ideal case, an undistorted wavefront would create a unique set of fringes on the CCD camera, which can be calculated and used as a reference. When a distorted wavefront propagates through the system the, interference deformations are directly proportional the phase gradients. Measuring these deformations using spectral analysis with Fourier transforms of the image formed on the CCD allows phase gradient extraction in two orthogonal directions. The phase map is then obtained through integration of these gradients. This phase map can then be broken down into a set of Zernike or Legendre polynomials. Using these, an error signal generated by comparison to the results of an undistorted wavefront can then be applied to an adaptive mirror. This method does not provide piston measurement however. It is important within this experiment to measure the piston difference between the two beams. This enables the delay stage to adjust the path length of one beam to match that of the other and constantly adjusting this spatially locks them. By overlapping the edges of the two subbeams (**Figure 3a**) from the actuated mirrors, an interference pattern between them is formed. This pattern is further complicated when going through the Hartmann mask of the SID4. By analyzing this unique interference pattern, a phase difference can be measured. The area used to measure the phase difference can be adjusted using the SID4 software. This enables the measurement of both the individual phase map of each beam as well as the phase difference for piston measurement on the same camera.

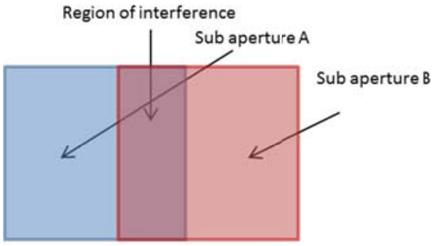

Figure 3a Diagram of the sub apertures in the near field

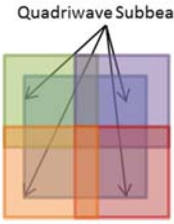

Figure 3c Diagram of the beam being split into four subbeams by SID4 Hartmann mask.

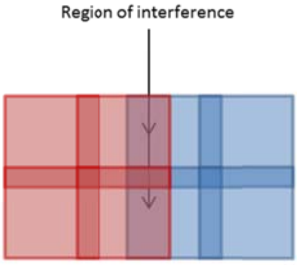

Figure 3b Diagram of the sub apertures corresponding quadriwave subbeams on the SID4 camera

Planned developments

Software developed for the previous setup can no longer be used for the current layout. The previous laptop has been replaced by a new computer assigned to handle all the software requirements of the system. Currently the system has the capacity to capture images and monitor the CW laser with the near field and far field cameras. It is then possible to control the actuated mirrors to combine the two beams.

The PHASICS camera used in the previous system will also be implemented into this system when possible. Using this equipment, a similar process will be used to create a feedback loop to automatically adjust the actuated mirrors to spatially lock the CW laser.

Finally once the Ti:Sapphire Tsunami is ready to be introduced into the system, the A.P.E autocorrelator will be able to monitor the combined pulse and provide the ability to temporally lock the laser using a similar feedback loop method.

Conclusions

The HAPPIE Lab setup has been successfully updated and the basic functions of the system are operational. Analysis of wavefronts with the system will soon be possible and from there automation can be developed. From here the beams can be spatially locked and focus can move onto temporal locking. Eventually two more beams can be introduced into the system and advancement from the previous setup will be achieved.

References

1. S. Mousset, C. Rouyer, G. Marre, N. Blanchot, S. Montant, B. Wattellier, “Piston measurement by quadriwave lateral shearing interferometry”, Optics Letters / Vol.31, No.17 / september 1, 2006 ; DOI: 10.1364/OL.31.002634

2. P.J.Phillips,C. Hernandez-Gomez, J.Collier, “Experimental setup in the Vulcan HaPPIE laboratory for Multi-beam combination to achieve Diffraction limit pulses”, STFC,CLF Annual report, 2009-2010

3. P.J.Phillips,C. Hernandez-Gomez, I.Musgrave, J.Collier, “Two beam spatial phasing with a CW laser”, 2011 Frontiers in Optics Conference Reference num. 1126358,16-20 October, 2011

4. P.J.Phillips,C. Hernandez-Gomez, I.Musgrave, J.Collier, W.Shaikh, “Two beam spatial and temporal coherent phasing with femtosecond”, CLF, Annual report 2012