Plasma Diagnostics

Plasma scale length effects on an imaging geometry

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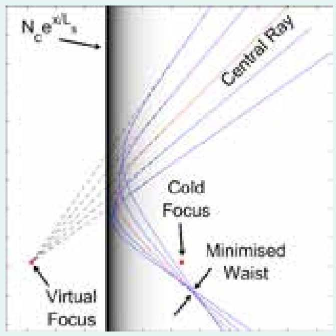
This report characterises the severity of optical aberrations for planar and focusing plasma mirrors. Ray trace simulations enable characterisation of the geometric optics through measurements of the reflected beam's minimised waist. Planar investigations illustrated the radial displacement of optical aberrations to be directly proportional to the plasma scale length, and through normalisation enable a single profile to portray the resultant angular distortion.

The severity of aberration within an elliptical and hyperbolic plasma mirror was explored for a broad range of geometries, and demagnifications from an incident F/3 beam. Elliptical plasma mirrors harness the formation of a caustic within the reflected optical beam. Optimisation of this geometry deduced an optimal minor-to-major axis ratio of 0.654.

Simulations provide a theoretical minimum waist which is achievable within geometric optics for which results were consistently below the diffraction limit.



Schematic of a focusing beam incidence into an exponentially decaying plasma profile from a planar plasma mirror

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Shielding effectiveness of a copper box against laser driven electromagnetic pulses

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Laser interactions have been known to generate Electro-Magnetic Pulses (EMP) during high energy laser driven interactions with matter. EMP generated in this way can induced rapid changes in current in sensitive electronics, leading to often irreparable damage.

As a result, over the past year, research into the shielding effects of copper boxes (as shown in Figure 1) was conducted to try to improve the protection of critical diagnostics and computers near to the laser interaction chamber.

The diagnostics used were Mobius loops, which output a voltage relating to the changing electric field strength. One was placed inside the box and one outside, after having found their signals to be similar without any shielding in place. With the shielding in place, the integrated energy of the signals showed a reduction of ~25x, demonstrating that the boxes are a very effective for protecting electronics, as shown in Figure 2.

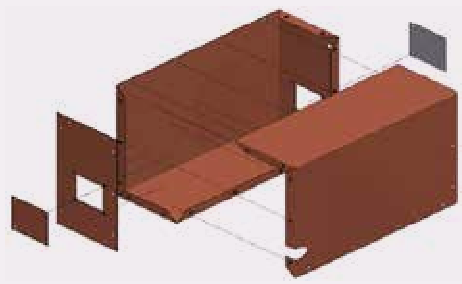

Figure 1: Schematic of box used, measuring ~50 x 40 x 20 cm, made of 1 mm thick copper.

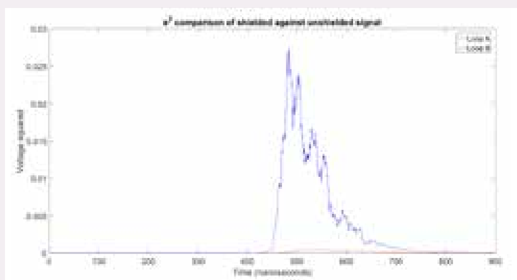

Figure 2: Graph comparing Mobius loop A's shielded signal to Mobius loop B's unshielded signal

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Remote control of delay generators and high voltage output devices from Stanford Research Systems

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Over the past year, two new pieces of software for the control of Stanford Research Systems devices have been developed, allowing the remote control of high voltage power supplies and delay generators.

The pieces of software were developed in C# for the Keithley USB to GPIB converter and most RS232 interfaces, allowing for a choice of connectors, while also providing the majority of functionality available manually.

The main interface of the high voltage control software can be seen in Figure 1. The software also includes a user management system for additional safety and data logging, to allow voltage stability testing of devices.

Figure 2 shows the main interface of the delay generator controller, which allows each channel to be set separately while also offering advanced output and triggering options in separate windows.

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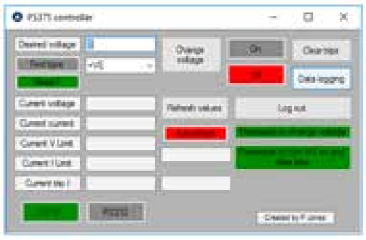

Figure 1: Graphical User Interface of the High Voltage Power Supply Controller

Figure 2: Graphical User Interface of the Delay Generator Controller

Absolute calibration of Fujifilm BAS-TR image plate response to high energy protons in the range 10-40 MeV

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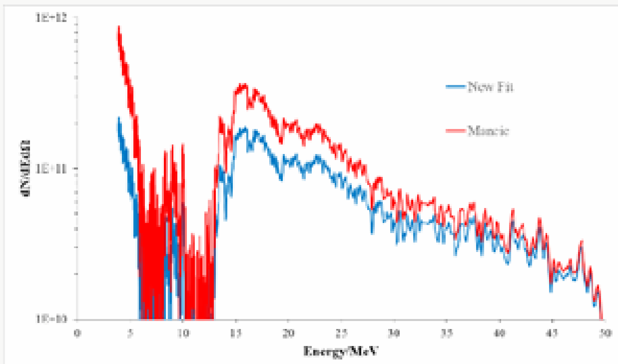
The response of Fujifilm BAS-TR image plates to high energy laser accelerated protons up to 40 MeV has been determined. These were calibrated using a Thomson parabola spectrometer and Colombia Resin #39 (CR-39) solid state detector to determine absolute proton number in specific energy ranges determined through the use of specific iron or copper filters in front of the CR-39. This calibration fills the gap in the literature which has existed for calibrations between 20 and 80 MeV, and is in agreement with previous works. Proton spectra were taken from the Thomson parabola spectrometer to compare the new calibration with a previous one. The two spectra were found to be in good agreement, confirming the validity of the technique.



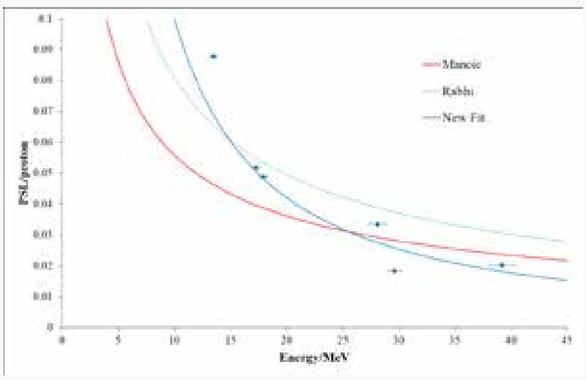


Figure 1 (left): PSL per proton calibration curve, compared to those extrapolated from previous works

Figure 2 (above): Comparison of proton spectra obtained with the two different calibration curves

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Monte Carlo simulations of x-ray generation to analyse scintillator spectrometer

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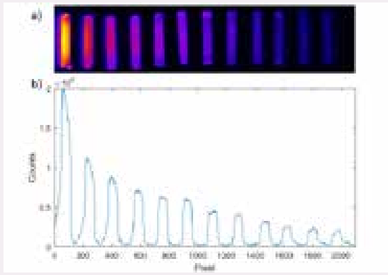
For a number of years, a scintillator based absorption x-ray spectrometer has been deployed in the CLF to measure the x-rays emitted from solid target experiments. The main advantage of this diagnostic compared to similar diagnostics is that it instantly digitises the data, and is able to operate at much higher repetition rates than current laser systems in the CLF. In order to take advantage of these capabilities, a number of simulations have been conducted and programmes have been developed to aid analysis of the experimental data taken using the diagnostic.

The operation and implementation of the scintillator based spectrometer is explained is detail in this paper. The method behind generating the response function is also discussed, along with the creation of the x-ray spectrum from different targets and input electron spectra using GEANT4. Using the response function and the spectra, we are able to show how both affect the outputs of the diagnostic in Figure 2.

Finally, we also show how to extract the temperature from the data using a least squares method that is fitted multiple times to take into account the uncertainty of the experimental data.



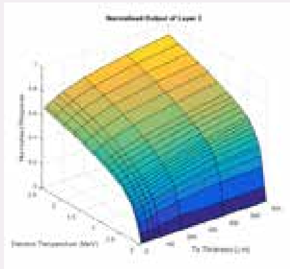


Figure 1 (top): a) Example data from the scintillator based x- ray spectrometer. The x-rays are entering from the left and being absorbed as they pass through the array. The photons that are emitted are recorded on a camera. b) shows a lineout of the image. The signal clearly falls as a function of layer.

Figure 2 (bottom): A collection of normalised outputs for layer two as a function of electron temperature and Ta thickness

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Time-dependent Nyquist limited Fourier transform analysis of electromagnetic pulse data

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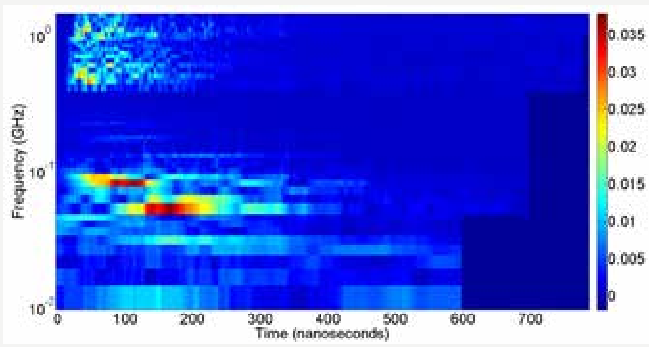
During a high power laser-target interaction, electromagnetic pulses (EMP) are generated with frequencies on the order of magnitude of 10^3 GHz. Current oscilloscope capabilities are on the order of 10 GHz; far below the pulses being measured. Therefore oscilloscope diagnostics on these experiments are working at their bandwidth limits, and sampling lengths begin to limit the valid frequency output from existing binned (time-dependent) Fourier transform techniques. We describe a technique created around Nyquist's theorem on digital sampling rates of analogue signals, varying bin sizes of different frequency blocks to allow for time-dependent valid and broad spectra analysis from EMP measurements.



Time-dependent Nyquist limited Fourier transform analysis of the experimental EMP data. This shows clearly how the different EMP frequencies vary over time after the laser interaction. On the right of the figure, and more prominently in the lower frequencies, there is a region that was not analysed due to bin length constraints and is highlighted in dark blue.

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Ray tracing investigation of plasma gratings

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Based on the success of plasma mirrors as optics in high intensity laser systems, the possibility of forming a diffraction grating from a plasma in a similar manner was investigated. A ray tracing simulation was written in MATLAB for this purpose, and was used to find the path of light rays interacting with a plasma mirror and various models of plasma grating. The simulations show that if a sawtooth plasma structure could be produced, this could be effective as a >80% efficient plasma grating. However, the ray paths are very sensitive to inhomogeneities in the plasma, meaning that structures that could feasibly be produced by the interference of beams, such as a sinusoid and a Fourier series triangular waveform, will not act as effective, efficient plasma gratings.

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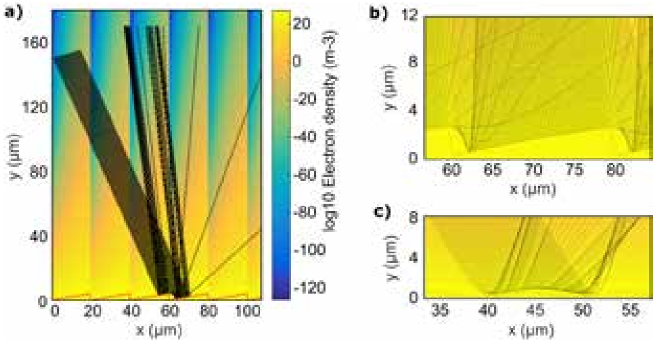

[a] Ray trace of a sawtooth plasma grating structure, demonstrating that the majority of the incident rays are reflected from the grating at a consistent angle, which is different to the incident angle. The red line shows the critical surface of the plasma.

[b] A close-up of the sawtooth structure shown in [a].

[c] A similar close-up, this time of a Fourier sum triangular structure. It can be seen that, in contrast to [b], the rays are reflected over a wide range of angles, despite the apparently straight sides of the critical surface.