Gemini diagnostics

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Introduction

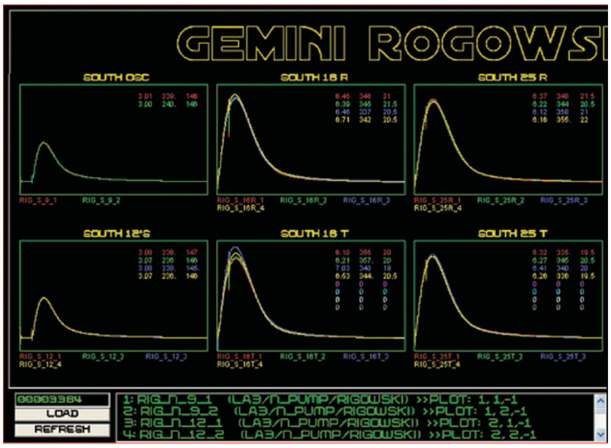
One of the key aims of the Gemini project was to fully characterize the laser pulses from day one to help diagnose the laser system and aid the experimenters in understanding the processes they are studying. This information should be available in the laser and target area control rooms following every shot, once every 20 seconds. The parameters, near field, far field, energy, spectrum and pulse length were defined as key data to record for the target area. Other data such as input beam parameters and Quantel traces were required to help operators monitor the laser performance. This work links in with the eCLF project to capture, ingest, store and retrieve the laser data [1].

This report documents the diagnostic packages written to cover these requirements on the Gemini System.

Quantel Rogowski data

Each of the Quantel lasers has 56 pairs of flash lamps that are fired on full power shots. To observe their performance a single Rogowski coil is attached to each pair of lamps to monitor the discharge current. The induced pulse is a few ms long and approximately 15 Volts peak height. Any change in pulse shape is indicative of a lamp failure or capacitor bank problem. To fully monitor these coils on both laser systems requires 112 channels of simultaneous ADC running at ~500 kSamples/Sec. There were several potential routes including the CAMAC system used on Vulcan, or purchasing 14 individual 8 channel PCI cards. The most cost effective solution was found to be using two standalone 64 channel 16 bit ADC's running at 500 kS/s from D-TACQ Solutions Ltd. These units run an embedded LINUX system and can be controlled directly over the network by a web services interface. Software was written in VB.net to send the appropriate web services commands to set-up and arm the ADCs; it also monitors them for a trigger and re-arms them for the next shot. The ADCs were programmed to FTP the data back to the control PC after each shot. A second program was written to load and analyse the Rogowski traces after each shot (figure 1). It measures peak height, FWHM and switch on time from each trace and can stop the control system if a problem is detected.

After the first few shots it was evident that the capacitors fired later induced spikes onto the earlier ones which could affect the measurements, (figure 1). To remove the noise a polynomial fit was performed in the regions of interest and measurements were then made from the fitted data. Finally the raw data and measurements were saved to the Gemini data server.



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1: RIG_n_9_1   (LA3/n_PUMP/RIGOWSKI) >>PLOT: 1,1,-1
2: RIG_n_9_2   (LA3/n_PUMP/RIGOWSKI) >>PLOT: 1,2,-1
3: RIG_n_12_1  (LA3/n_PUMP/RIGOWSKI) >>PLOT: 2,1,-1
4: RIG_n_12_2  (LA3/n_PUMP/RIGOWSKI) >>PLOT: 2,2,-1
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Figure 1. Partial screen shot of Rogowski traces, noise spikes are evident on the right hand traces.

Spectrum

Pulse spectrum is an important parameter as it affects the ultimate pulse length and can easily be distorted by gain pulling in the amplifiers and cut offs in the optical chain. To check for these problems five spectrometers were purchased to measure the spectrum from LA3, after each of the final amplifiers and after each of the compressors. Fibre optic cables were run from the sampling points back to the spectrometers. Software was written in LabVIEW2 to capture the spectra and calculate the shortest possible pulse length it would support. This was then saved to the data server.

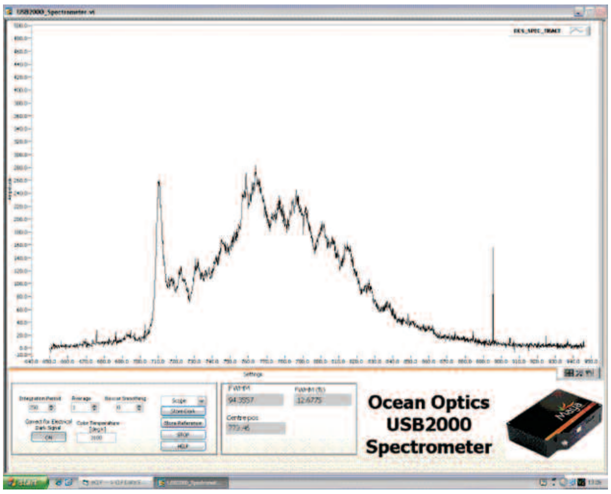
To monitor the oscillator spectrum an Ocean Optics USB 2000 spectrometer was purchased. Software was written to display the live spectrum and automatically save a sample every 5 minutes (figure 2).

Oscilloscopes

Oscilloscopes are routinely used for many electrical signals, e.g. radiation monitors, pyroelectric energy detectors, photodiodes. Within the Gemini system they are used to read data from the radiation detectors, Quantel and main pulse timing diodes and prepulse diodes. Software was written in LabVIEW to interface to several makes and models of scope, more details are given in a separate report [2].

Pulse length

To measure the compressed pulse length in each beam, two Grenouilles were purchased from Swamp Optics complete with Mesaphotonics Video Frog software. To avoid non-linear effects the compressed sample beam is taken



Integration Period: 250
Average: 1
Boxcar Smoothing: 0
Correct for Electrical Dark Signal: ON
Color Temperature [degK]: 3100
FWHM: 94.3557
FWHM (%): 12.6775
Centre pos: 773.46

Figure 2. Oscillator spectrometer trace – trace is saved every 5 minutes.

through a hole in the final turning mirror in the compressor. It ias then attenuated by two uncoated reflections before exiting the vacuum chamber through a 2.5 mm thick window. Further attenuation is possible via a ThorLabs motorised filter wheel placed directly in front of the Grenouille.

Additional software was purchased to communicate and read data from the Video Frog program. This was integrated in to a LabVIEW program to read and save the Grenouille data on every shot. Some problems with the triggering and data communications were experienced and are being resolved in conjunction with the software supplier.

Image acquisition

Near field and far field images at various points are acquired by digital FireWire CCD cameras (AVT Marlin F033B). They provide a resolution of 656 × 494 pixels and a dynamic range of 10 bit. To cope with the wide range of pulse energies, some cameras are fitted with a motorised filter wheel (Thorlabs). The cameras are capable of so-called deferred image transfer, meaning that they can hold an image in their internal memory until a read request is received from the host PC. This way it is ensured that no data is lost due to bandwidth limitations on the FireWire bus, while it is still possible to connect up to 8 cameras to a single PC.

The software running on the two host PCs which control 11 cameras is written in LabView. Image data are both displayed in real time and sent over Ethernet to the central data archive server. One of the 8 real-time image displays is shown in figure 3. The user can control the camera parameters from theses PCs. For instance, it is possible to switch from external to internal triggering for checking the alignment of the laser system with an injected cw diode laser beam. In order to minimise the volume of generated data, only a region of interest (ROI) is usually read out from the camera sensor. The size and position of this ROI can also be changed during runtime. Since information about the current configuration of the laser system (cw or pulsed beam, expected pulse energy) is available over Ethernet, the aim is to fully automate the setting of the camera parameters.

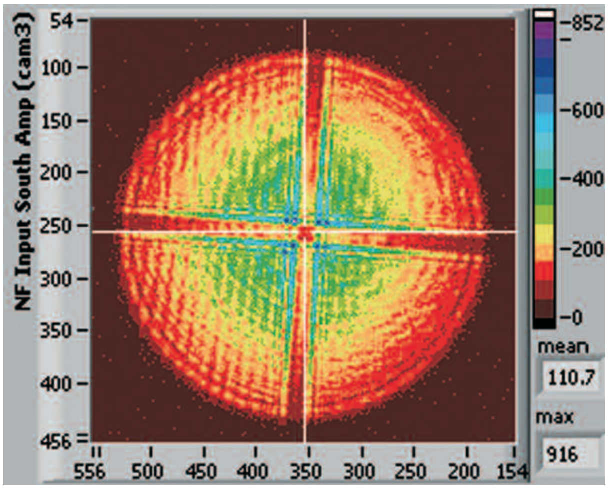


Figure 3. Near field image of cw alignment beam with shadow of crosswire.

Some real-time image processing is also carried out in the acquisition software. Both centroid position and integrated intensity are calculated for each acquired frame. The latter is converted to pulse energy, using calibration values that can be entered by the user.

Energies

To measure the pulse energy three approaches have been taken. Firstly an estimation of the energy is made by integrating the beam near field images from the image acquisition system. This is then calibrated using a conventional pyroelectric detector. This technique is used to measure the Quantel pump energies and has proved accurate and reliable. Secondly, leakage through an HR turning mirror is focused directly onto a Gentec QE12 pyroelectric energy meter, used with a Solo2 readout unit. Again this must be calibrated against the actual energy in the main beam. The red (800nm) energy before and after the compressor is measured in this way. Thirdly a fibre optic system was built using integrating spheres to capture the leakage light throughout the optical chain and transport it via fibre optic cable to form a dot on a high sensitivity camera. This dot is integrated to give the pulse energy (figure 4).

The first two techniques have limited dynamic range and it is necessary to change the range of the readout or the attenuation on the camera to ensure the result is correct at both high and low energies.

Non-shot data

In addition to the on shot diagnostics there are several other important data sources that are monitored, e.g. chamber pressures, front end performance, room temperature etc. Typically data is logged from these sources every few seconds to build up a picture of the overall performance, rather than trying to measure them on an actual laser shot. The pressures are read via RS232 link to the Pfeiffer MaxiGauge controller. The front end data is taken directly from the existing Astra frontend diagnostic PC.

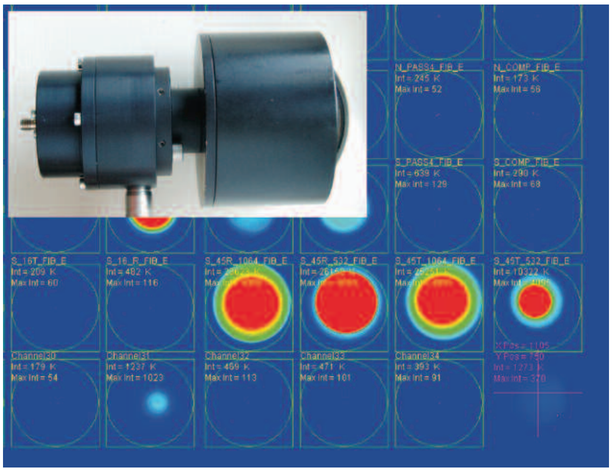


Figure 4. Multi channel energy diagnostic. Each dot is created by light collected from a different integrating sphere. Inset: Photo of 75 mm diameter integrating sphere.

Data display

The majority of this diagnostic data is displayed on a bank of monitors in the laser control room. This was done using VNC to copy the screens of each individual diagnostic PC, it also has the advantage of allowing the PCs to be controlled remotely. To avoid operators having to remember a vast number of IP addresses a DNS server was setup to give each PC a more memorable name.

Conclusions

Over the last year a multitude of diagnostics have been installed in the Gemini laser bay. They run automatically and enable the operators to monitor many of the key laser parameters after every shot to assess and tune the laser performance.

References

1. eCLF Project Progress. CLF Annual Report 2008, p229.
2. eScience-CLF Data Acquisition System. CLF Annual Report 2008, p236.