Development of the laser diagnostics for Vulcan

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Introduction

The Vulcan facility is under constant request from the users and the laser operators to improve the laser diagnostic systems. The main requests are:

- Implement viewer tools for the users and operators of all the diagnostic data;
- Improve reliability of the diagnostics;
- Implement automatic data analysis to identify possible issues;
- Concentrate all the important information on one screen close to the control system;
- Implement loop stabilization system (like automatic alignment);
- Provide after shot data analysis;
- Record more metadata related to the shot.

In this report we report the work on the software and PCs involved to address these issues.

Diagnostic Architecture

Due to the extension of the Vulcan laser and the number of diagnostics the system need to be distributed over different PCs, all connected to the network. A scheme of the architecture is shown in Figure 1.
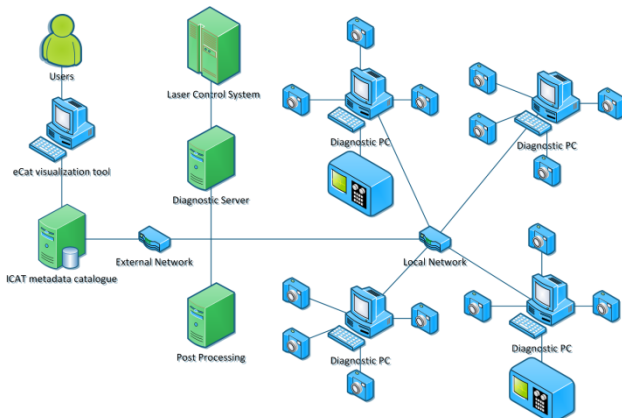

Figure 1: Diagnostic Architecture

The keys elements of the system are:

Diagnostic PC:

- Control Diagnostics (Cameras, Oscilloscopes, Spectrometers, etc.)
- Control Motors (Picomotors, Thorlabs)
- Save Data on Shot
- Perform Simple Analysis and Generate Report
- Report if parameters are out of acceptance window
- Perform simple loop (automatic alignment)

Diagnostic Server:

- Control Diagnostic PCs
- Communicate with Laser Control System
- Generate XML Descriptor File for Data Channels
- Collect & Report Messages from Diagnostic PCs

Post Processing PC:

- Perform more complex Analysis (Autocorrelator).
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Diagnostic PC and Post Processing PC

All the diagnostics are connected to a local PC, in charge of control it and save it when it is needed. The software developed to do this is called *CameraSoftware* and it has been developed mainly in VB.NET with some analysis wrote in C++ (Figure 2).
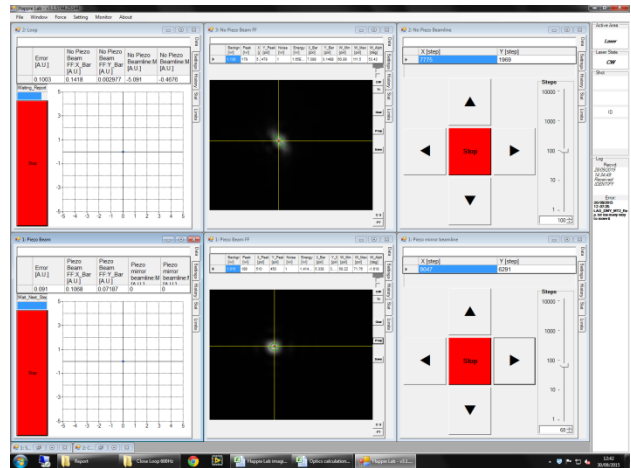

Figure 2: *CameraSoftware* **screen shot with two cameras, two motorized mirrors and two loops.**

The software allows different sub-windows to be opened, accordingly to the local requirement. The overall software is in charge to communicate with the Diagnostic Server as a client, manage the data files and act as a server to provide diagnostic data to other PCs (like for the automatic alignment).

On each sub-window it is possible to select the location of the diagnostic accordingly to the structure provided by the

diagnostic server, when the data need to be saved and all the infrastructure for the data analysis, including a reporting system and "parameter in range" check.

The data is saved first locally and then moved to the remote repository. If it is not possible, like for network issue, it will be moved when it will be possible. The data is saved remotely in two locations, one for internal use and the other for ingestion into the ICAT metadata catalogue (see below).

Already implemented sub-windows are:

- Camera: able to manage an USB UEye camera and include spot analysis, with centroid and spot size, and references;
- OceanOptic spectrometer, including analysis with bandwidth, centroid, min and max wavelengths;
- Filterwheel: to control motorized filterwheel for automatically or manually changing filter at different laser energies;
- Motors: to control motorized mirrors or slide with Picomotors or Thorlabs DC motors;
- Gentech: able to readout laser energy measurement from a SOLO box from Gentech;
- Oscilloscope: able to manage a Tektronix oscilloscope and download traces;
- Loop: able to perform proportional loops (see below).

The post processing PC is devoted to analysis saved data after the shot, when it will be available. The main purpose is to perform more complex analysis that cannot be performed easily on the diagnostic PC. The software is based on the *CameraSoftware* core with different sub-window.

Each sub-window has a list of the data that need to be analyzed. The analysis is performed has soon as the data is available and the results are saved accordingly to the related shot.

Current implemented sub-window is the autocorrelator analysis, including determination of the FWHM of the pulse.

Loop sub-window (Automatic alignment)

The loop sub-window implements a simple proportional loop. It is able to take user defined number on input N from any *CameraSoftware* sub-window across the system (like a Camera sub-window) and control a user defined number of output M. Again the possible output control must be a sub-window in a *CameraSoftware* anywhere in the system (like a Motors sub-window).

It uses the result from the local analysis as input and it is able to weight differently different inputs. The number of input N must be greater than the number of output M.

The loop speed, steps and max steps are user configurable. Control parameters are also user configurable to stop the loop when needed (i.e. image too weak).

The loop uses a matrix to calculate the output step from the input. The matrix could be setup manually or could be estimated automatically. In the automatic mode, the outputs are moved by a user defined step and the matrix is calculated using a multidimensional linear fit.

A preliminary test performed using a small laser, a motorized mirror with Picomotor and a piezo driven mirror has been performed. The beam position was measured in the far field using a UEye camera.

The piezo mirror was used to oscillate the pointing while the pico-motorized mirror was in charge to correct it. The results are shown in Figure 3.
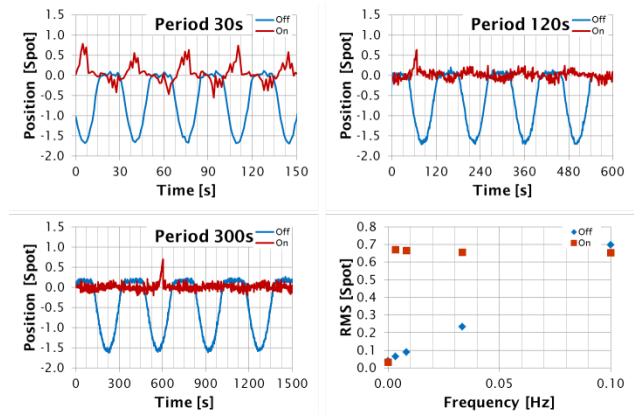
Figure 3: Automatic alignment test result

The loop it is able to remove the oscillation with period larger than 120s. Faster oscillations are not attenuated, as it is shown for the 30s period. In the traces there are occasional glitches. These are due by window making the PC busy and delaying the loop. However this will be not an issue by the fact that a PC based automatic alignment will be used to correct slow pointing drift and not fast movement.
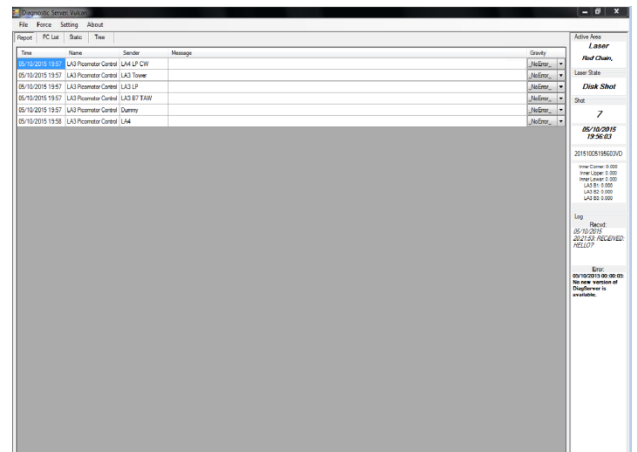
Diagnostic Server

The Diagnostic Server is in charge to coordinate all the diagnostics and Post Processing PCs. Is has a user defined structure of the laser specified as areas (like LA1, front end, TAW, etc.) and beams (like Beam 1, SAM, OPCPA, etc.).

This information is sent to the Diagnostic PCs and it is used to identify the location of the diagnostic and the filenames. It is also important to build the XML data channel descriptor file required for the process of ingestion into ICAT, already in use in Gemini.

This server is connected via a serial port to the laser control system. During a shot, it receives from him the data of the shot, like active area, predicted energies, shot number, etc., create a unique shot ID and distribute the information to the Diagnostics PCs and Post Processing PCs.

It is also in charge to collect all the messages from the Diagnostics PCs and Post Processing PCs. A screen shot of the software is shown in Figure 4.

Figure 4: Diagnostic server screen shot

Data visualization

The main goal in Vulcan is to be able to catalogue the diagnostic data using an ICAT system (http://www.icatproject.org) like the one already in use for Gemini. To achieve this, the data is saved in a special folder with a unique filename. From the folder, an ingestion tool processes each file, extracting metadata and cataloging it in ICAT. This data is then made accessible to operators and users via eCat, a web browser application which enables the data stored in ICAT to be displayed, searched and downloaded. The information on which data to catalogue is provided by an XML data channel descriptor file. This file is generated on request by the Diagnostic Server automatically. A preliminary test of the ICAT/eCat system using a small laser system has been performed with good results (Figure 5) and it will be tested on Vulcan shortly.
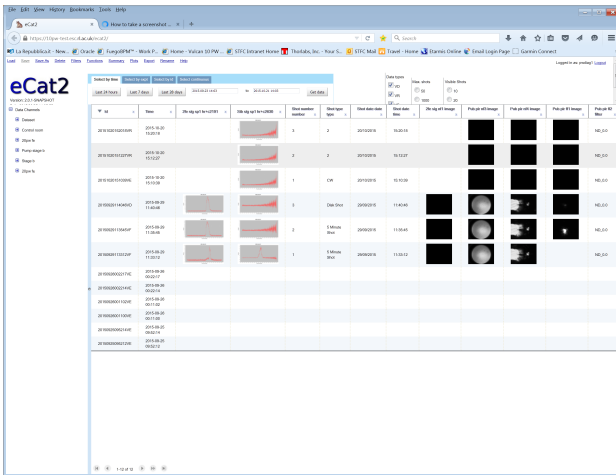

Figure 5: Screenshot of *eCat web page*

Conclusions

The diagnostic system of Vulcan is under updating to address different issues and improves efficiency. The system described in this report is currently under testing on a small system similar to Vulcan and it will be released shortly to the main laser. This it will allow to have automatic alignment, automatic data analysis and error reporting and data visualization. The aim is to provide to the users the data visualization of the laser data next year.