Cilex-Apollon Laser Beams Alignment and Diagnostics Systems with Tango*

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ICALEPCS 2013

TUPPC043

Cilex-Apollon is a high intensity laser facility delivering at least 5 PW pulses on targets at one shot per minute, to study physics such as laser plasma electron or ion accelerator and laser plasma X-Ray sources. Under construction, Apollon is a four beam laser installation with two target areas. To control the laser beam characteristics and alignment, more than 75 CCD cameras and 100 motors are dispatched in the facility and controlled through a Tango bus. The image acquisition and display are made at 10 Hz. Different operations are made on line, at the same rate on acquired images like binarisation, centroid calculation, size and energy of laser beam. Other operations are made off line, on stored images. The beam alignment can be operated manually or automatically. The automatic mode is based on a close loop using a transfer matrix and can correct the laser beam centering and pointing 5 times per second. The article presents the architecture, functionality, performances and feedback from a first deployment on a demonstrator.

MOTION CONTROL

Automatic alignment

To deliver 5 PW, the Apollon laser is amplified 5 times by multi-pass amplifiers like drawn Figure 1. This amplification needs an accurate alignment and is very sensitive to temperature changes. To get the amplifier's best, each amplifier is made with an automatic alignment loop at entrance. An alignment loop is made of 2 motorized mirors (M1, M2) and 2 CCD cameras (C1, C2). The alignment system moves the beam centroid to the reference up to 5 times per second.

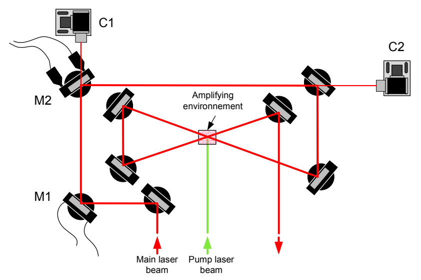

Figure 1 : Pulse laser amplifier

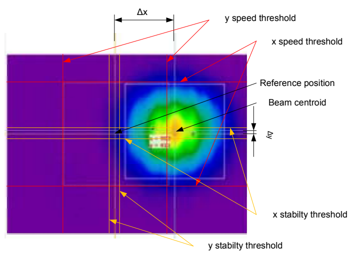

Figure 2 : Alignment loop parameters

Different parameters are used to improve the alignment :

- a **stability zone**, around the reference position, improves the alignment stability
- the 2 motor speeds to improve the position accuracy and the response time. Motor speed changes if the beam position is upper or lower the **speed threshold**.

Manual control

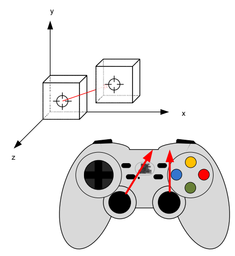

Figure 3 : motion control by gamepad

Motors can be manually controlled too. An easy way to move the motors is to use a gamepad. This advantages are :

- **simple to use** : just move sticks and push a button to a high speed motion or another one to a step by step motion.
- **useful** : it is possible to control simultaneously 4 motors. So we can move the laser targets in the 3 dimensions.
- **low cost** : the gamepads are standard
- **perenity** : the compatibility with many gamepad is guaranteed by python library *pygame.*

Another way to control a motor is to use the motor graphical user interface (GUI). This application permits to :

- move a motor, by clicking on the buttons
- chose the motors which are controlled by the gamepad
- change motor parameters
- control alignment loops

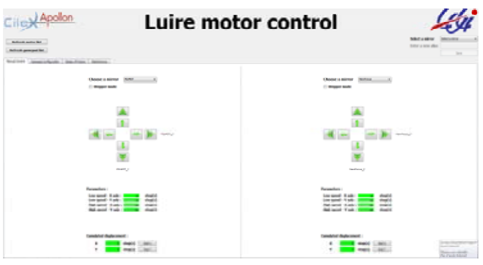

Figure 4 : motion control GUI

IMAGES ACQUISITION SYSTEM

Images acquisition and calculation

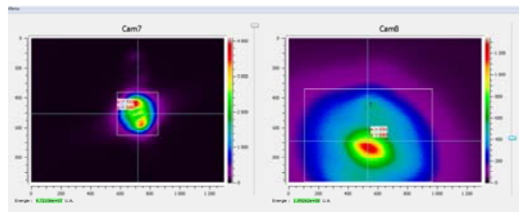

Figure 5 : Image acquisition GUI

The image acquisition is based on the Lima library, a C++ library compatible with many kinds of Giga Ethernet CCD cameras. The acquisition have to :

- work at 10Hz, the laser frequency,
- acquire images with different sizes (1600x1200, 1296x966, 640x480)
- the image resolution is 16 bits. (imposed by Lima)

The calculation software is used to extract the beam caracteristics. It uses the acquired images to extract:

- the beam centroid
- the beam barycenter
- the beam energy
- the beam size
- the binarized beam

And it activates an alarm if the beam centroid goes outside a circular alarm zone defined by the user.

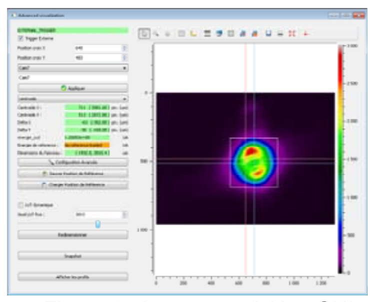

Figure 6 : Image acquisition GUI advanced view

Image server

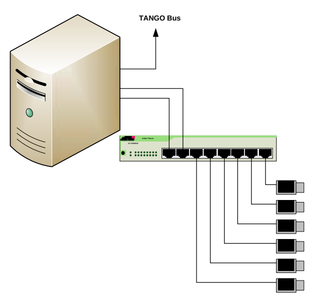

Figure 7 : Image server hardware architecture

The images acquisition system is made of several image servers (Figure 7). An image server is a PC which acquires images by 6 CCD cameras and runs the image acquisition and calculation drivers (to avoid network overload).
To connect as many cameras to a PC, we have to divide up them on 2 subnetworks (the bonding is not supported by the camera driver). It is possible to run 8 cameras per server but the server's central processor unit (CPU) is used at more than 90%. We have done a compromise between the cost and the reliablity of an image server, so we chose to run 6 images per server.

Some figures:

- 1 CPU, 4 cores, 8 GB RAM
- 3 network interfaces
- 2 Gigabit Ethernet link
- 6 CCD cameras per server

- 10 frames per second per cameras
- 16 bits images
- 70% used CPU capacity
- 70% of the video Ethernet link capacity used

SOFTWARE ARCHITECTURE

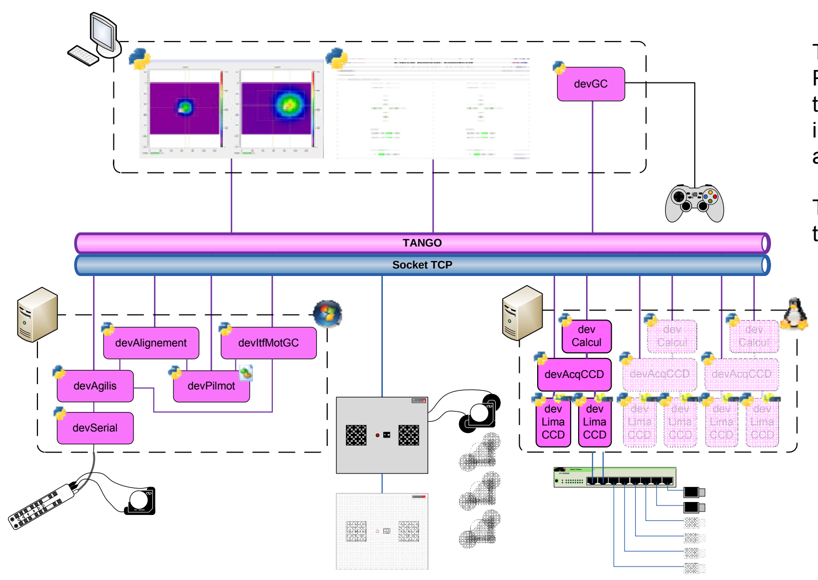

Figure 8 : alignment loop software architecture

The Figure 8 is the software architecture of an alignment system. One PC runs the motor drivers, alignment drivers and the driver which done the link between the gamepad and the motor drivers. One PC for the image acquision (an image server) and another PC runs the 2 GUIs and the gamepad driver.

The Apollon command control is developed in Python and it is based on the TANGO framework. TANGO permits to :

- have a **distributed command control system**
- run **different operating systems** (Windows or Linux) on the different installation's PCs
- **ignore the devices** (a motor is a motor regardless its model...)
  - today it possible to use 3 different motor controllers without change the architecture
  - we can use Giga Ethernet CCD cameras or FireWire CCD cameras just by changing the camera driver (devLimaCCD or dev1394)
- benefit of the **many TANGO tools** (like Astor, see Figure 9)
  - with Astor we can stop, start and supervise every drivers
  - with Jive we can test and supervise every drivers
  - with ATK we can test drivers with a GUI automaticaly generated

Figure 9 : astor device manager

*Work supported by CNRS, MESR, CG91, CRiDF, ANR