

# Automation of a Lidar for high-speed internet operation

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## ABSTRACT

A backscattering Lidar system has gone through an automation process for operation through a high-speed internet gateway in a fiber-optic network interconnecting research groups for experimental demonstrations of specific technologies or novel Internet applications. This network is essentially a large, geographically distributed laboratory facility, available worldwide to the research community, for field trials of optical components and equipment, for fundamental and applied research in optical transmission and networking technologies, and for the development of advanced Internet applications. The description of the steps taken to automate this system will be given in detail. The laser source, a meteorological mini-station, a sliding rooftop door, and a transient recorder for acquisition were adapted for LABVIEW controlling and to be put into a web station for control through the internet and enhancing its operational capabilities. This upgrade in the system was lowcost and can provide multiple applications such as long-term operation during field campaigns and/or as an educational tool to the lidar technique and atmospheric studies.

**Keywords:** LIDAR, Automation, High Speed Internet

## 1. INTRODUCTION

The Laser Environmental Application Laboratory (LEAL) is located at the Centre for Laser and Applications of Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN-SP) and has been monitoring the air quality since 2001 with an elastic backscattering aerosol, first of its kind in Brazil.<sup>1</sup> Aiming to have a climatological aspect to its research studies the LEAL has a need to run for long periods of time and therefore the experiment might be very time consuming and obliges the attendance by trained personnel in the laboratory site. Besides, recently a fast internet network has been created in the State of So Paulo (Brazil) which connects many academic institutions, research centers and weblabs a weblab is by definition a laboratory which can be controlled via internet<sup>2</sup>. The network was named *KYATERA* \*<sup>2</sup> Given this opportunity LEAL was upgraded to a hybrid system which can be manually and remotely controlled. In this paper we show the steps taken to have most of the LIDAR LEAL system automated and therefore capable of being controlled and monitored through the web. The main software used was Labview for controlling the devices, pre-processing the data and webpublishing. While the system control is not an entirely new concept<sup>3,4</sup> the fact to be put in a fast collaborative network largely enhances its potential for applications specially as a learning tool. The Weblab will hold an experiment connected to a computer through diffent standard interfaces (DAQ, serial, USB and Ethernet) and with the host computer connected to the Internet. The client can be any computer connected to the Internet running a simple browser. Once connected, the client will see the same front panel as the local host and also have the same program functionality. Then, the user interface for the application shows up in the Web browser and is fully accessible by the remote user. The acquisition is still occurring on the host computer, but the remote user has total control and identical application functionality. Other users can also point their Web browser to the same URL to monitor the application in progress. To reduce confusion, only one client can control the application at a time, but the client can pass control easily among the various clients at run-time. At any time during this

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\*KyaTera comes from Kya (net in Tupi-Guarani, one of the languages of the aboriginal people in Brazil) and Tera (from Terabits per seconds =  $10^{12}$  bits per second).

process, the operator of the host machine can assume control of the application back from the client currently in control. Enabling the Remote Panels feature of LabVIEW is a very simple process that walks the user through the creation of a Web page that automatically embeds the appropriate LabVIEW application into the new Web Page. With the previous ideas in mind we started developing an application in which the user will have access to all modules described and control/monitor them through the Web. An example is given below where one can follow the data being acquired. We should give a description of the LEAL weblab system architecture and the details of the main instruments which have been adapted to be controlled via internet as well.

## 2. SYSTEM DESCRIPTION

The system developed at CLA is an aerosol backscattering lidar system, operational since 2001 and is being used for monitoring and categorizing the pollution in the So Paulo Metropolitan Area. From the point of view of setting up a weblab the lidar system consists of three main modules:

- Light Source which consists of a 20 Hz pulsed solid state laser running at the second and third harmonics (532 nm and 355 nm) with energies up to 100/40 mJ (532/355 nm). The laser system is Q-switched single Nd:YAG crystal which operates with a repetition rate of 20 Hz and short pulse of approximately 4 ns in the visible (532 nm). The average emitted power can be selected up to values as high as 3.3 W. The emitted laser pulses have a divergence of less than 0.5 mrad. The whole system, power supply plus laser head is very compact and can be both manually and remotely operated through a RS232 interface. This RS232 can be interfaced with the Labview software and operated by applying the commands (ASCII mode) available from the manufacturer.
- a 30 cm diameter Newtonian Telescope with a focal length of 1.3 m. The telescope field of view (FOV) is variable (0.5-5 mrad) by using a small diaphragm. The lidar is currently used with a fixed FOV of the order of 1 mrad, which according to geometrical calculations permits a full overlap between the telescope FOV and the laser beam at heights higher than 300 m above the lidar system.
- The backscattered laser radiation is then sent to a photomultiplier tube (PMT) coupled to a narrow band (1 nm FWHM) interference filter, to assure the reduction of the solar background during daytime operation and to improve the signal-to-noise ratio (SNR) at altitudes greater than 3 km. The PMT output signal is recorded by a dual Analog - Photoncounting system. Data are averaged between 2 to 5 minutes and then summed up over a period of about one hour, with a typical spatial resolution of 15 m, which corresponds to a 100 ns temporal resolution. A low-noise photomultiplier tube with a 1-nm interference filter for background rejection (day) and noise-to-signal level enhancement
- The acquisition system (AS) is a fast processing device combination of a powerful A/D converter (12 Bit at 40 MHz) with a 250 MHz fast photon counting system in order to increase the dynamic range of the acquired signal substantially compared to conventional systems. It is also computer controlled and interfaced by a TCP/IP Ethernet interface. The controller accepts commands with ASCII syntax similar to the GPIB. Integrated to the AS there is a trigger input used to synchronize to an external laser flash lamp or Q-switch trigger or run internally triggered. The system is connected to a PC computer and controlled with Labview with all the programs already developed at the manufacturer (Licel GmbH).

## 3. WEBLAB DESIGN

The LEAL weblab design is schematically described on figure 1 which involves three main subsystems: the Web Interface, the Lidar Control System and Webserver and Data Analysis System Software. The combined use of this three systems will allow users to obtain control of the remote lidar equipment. The Lidar subsystem contains the Labview software programs developed under the Windows XP platform which are described as vi's (Virtual Interfaces). With this system at operation the user should be able to:

- Connect to a homepage of a web-based laboratory, namely the weblab itself

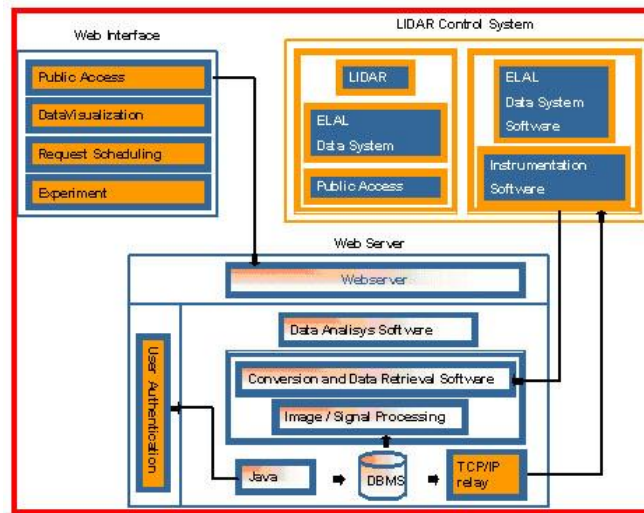


Figure 1. WebLab Architecture Diagram. This 3-part diagram shows the functionality of the ELAL system. The first part comprehends the Hardware Control where most of the instruments should be controlled. Another part is the webservice data management where all access to a database should be taken care of. The last part concerns the authentication and security aspect where a middleware should be used.

- Identify the user and get authorization in the web server side in order to grant a valid session ID in the laboratory environment
- Select the experiments available in the weblab
- Show the corresponding webpages
- Conduct the remote experiment and get a real-time image in the browser, here special care should be taken of since in a standard internet provider some latency should be expected, in the case of a high speed internet this latency time should be minimum
- Terminate the session by releasing the server connection

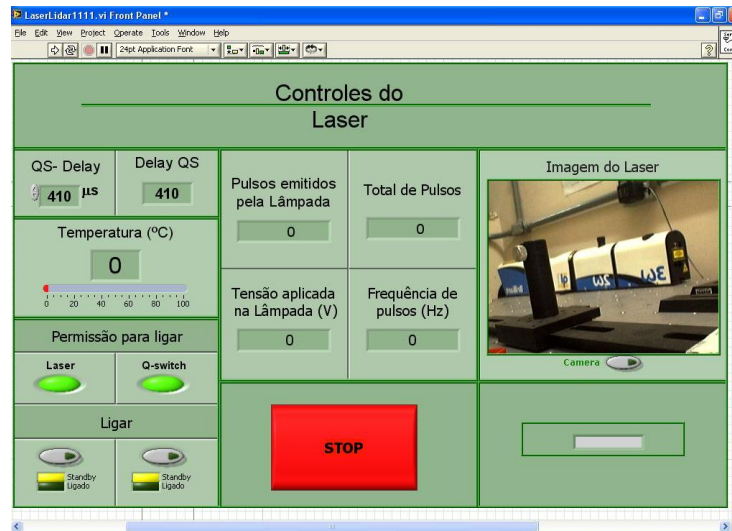


Figure 2. The laser VI front panel shows the parameters to be controlled in order to have the laser running. It contains the main information of the laser configuration which the user should be aware of and also an embedded VI which gives an image of the laser running. One has to bear in mind that to have both VI's at the same time may impair the whole system performance. Some claims that a newer version of Labview has taken care of such a feature though.

### 3.1 Laser Control VI

This VI controls the laser via the RS232 port and receives as input ASCII commands provided by the laser manufacturer (Quantel/BigSky Laser). The users has control to turn the laser on/off and selecting its output power figure 2. Embedded to this VI is another VI which has a webcam (connected to the USB port) to monitor visually when the laser is running or not. One has to bear in mind though that a switch has to be added to this two VI's as the simultaneous and continuously running of both could seriously impair the application speed and consume the memory access by all other processes running in parallel in the entire computer.

### 3.2 Transient Digitizer VI

This package of VI's were provided by the hardware manufacturer are to control the Transient Recorder/digitizer which is connected by a standard ethernet interface and use the TCP/IP protocol in which the controller can have a static IP address or a dynamically assigned address (DHCP). The package has built-in access to control the photomultiplier voltage and a trigger module which can synchronize the TD to an external laser flash or Q-switch trigger.

### 3.3 Mini-meteo Station and Ceiling Door Control VI

The LEAL system operates in a room which has a sliding open door on the ceiling which should be shut in case of precipitation, this was until then done manually. For that purpose a moisture sensor was adapted to measure the air relative humidity (RH), temperature and dew point. This sensor has an electronics box which sets a RH threshold (previously selected by the user) with which it will when in the imminence of precipitation act on the sliding door motor to close it and through a microswitch to shut down the laser as well. The Meteo station is interfaced by the serial port of the PC and controlled via a Labview VI figure 3.

The entire set of VI's should be connected via TCP/IP protocol and get the front panels using the built-in Web Server in Labview. This allows all the Vi's to be controlled individually in the internet from a remote computer or even among the different terminals in a laboratory environment.

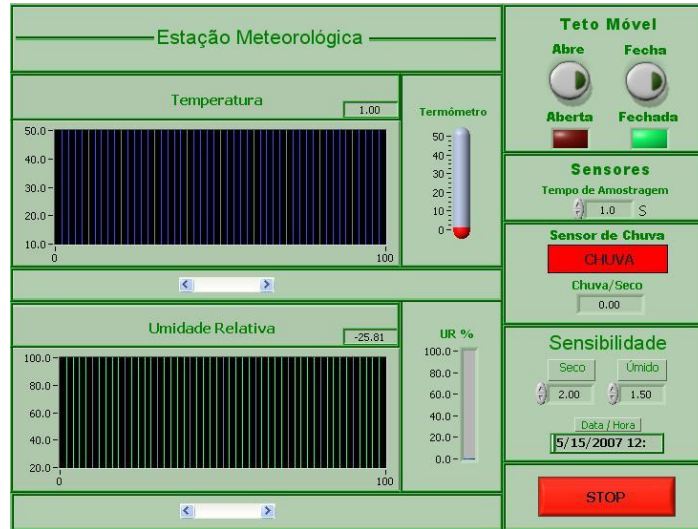


Figure 3. The minimeteo VI monitors the temperature, relative humidity and dew point sensors and has a pre-set which enables a RH threshold which will control a ceiling sliding door in the event precipitation occurs. In the future an extra webcam should be embedded as well to have visual information on the cloud coverage.

### 3.4 Data Visualization and Web Publishing

In order to follow the status of the measurement and verify data alignment a VI was developed in which the raw data generated in the TR is converted from binary to ASCII and then the signal as follows:

$$S_{corr} = (S_{raw} - BG) \times (bin_i \times resol)^2, \quad (1)$$

Where  $S_{raw}$  is the ASCII converted data (analog or photoncounting), BG is the Background Radiation,  $bin_i$  is the bin number and  $resol$  is the resolution, typically 15 or 30 meters. The visualization front panel contains information on the time/date of measurement, the altitude of the different aerosol layers/clouds in the atmosphere, and the signal intensity which is somehow proportional to the amount of scattering hence the aerosol load in the atmosphere, as seen in figure 4.

The Labview programming is done in Graphical User Interface environment and has many drivers libraries such as RS-232 C, GPIB Ethernet, USB, VXI and DAQ.<sup>5,6</sup> We give an example in figure 5 which shows the program structure for data visualization VI.

### 3.5 Weblab as a teaching tool

The system besides the operational aspect can with its web controlling feature become a teaching tool for students in the engineering, atmospheric sciences and physics field as it will allow students to learn aspects in atmospheric dynamics and understand the atmospheric light scattering in the applications shown.<sup>7</sup> From figure 5 one can have a study on many aspects of the atmosphere such as:

- Planetary boundary Layer evolution
- Mixing layer, entrainment zone structure
- Cloud Height, cloud height base
- Cirrus altitude and cold-front onset
- Aerosol and plume transportation

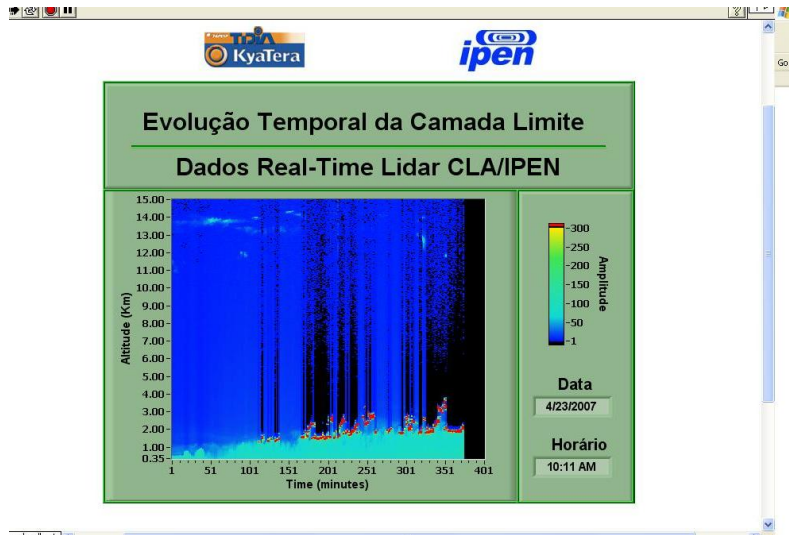


Figure 4. Real-data VI generated page in which the user/controller can have access to a pre-processed real data in which the light scattered signal intensity can be visualized for assessing the Planetary Boundary Layer dynamics, Cloud coverage and height and for alignment checking purposes

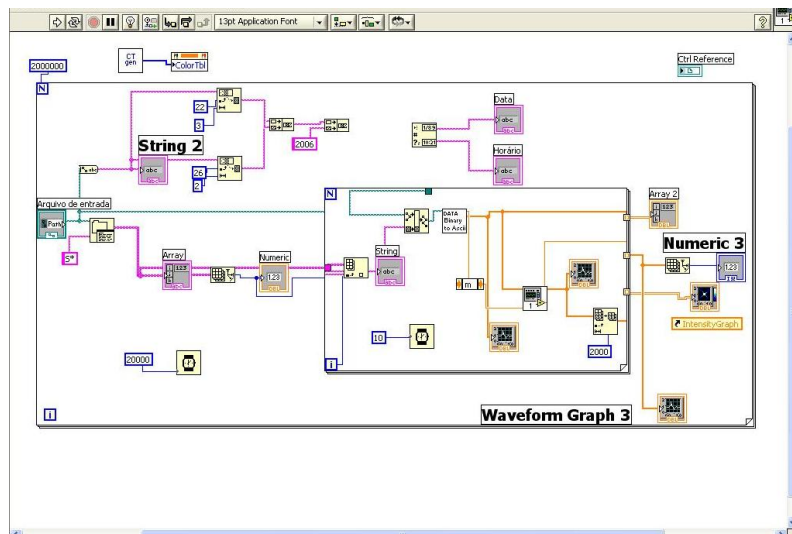


Figure 5. VI program panel in Labview for the data visualization module in the weblab. This VI iteratively access the lidar generated data and converts them into ASCII for pre-processing as equation 1 and them their display in a so-called "curtain" plot.

There will be a need for a management system which should take care of the user access to all VI's and yet has to guarantee the security of the system one candidate for this task was MOODLE which uses PHP scripts for user or lab demonstration registration and authentication, activities configuration and user management. The VI's are client accessed in a local server in a Labview generated HTML page. For the VI remote execution a runtime engine should be installed in the client computer.

#### 4. CONCLUSION

We presented here the steps taken to implement a web based lidar laboratory in a high speed internet environment. There were shown also how the different instruments present at the laboratory were interface to a PC via the Labview software. The good aspect of this implementation is that it will

1. Extend the time of acquisition since unattended operation should be possible
2. Allow distance learning for part time and remote students
3. Prepare students before having access to the actual laboratory since working with the class of lasers involved (CLASS IV) might be risky
4. Share expensive laboratory equipment with other universities and departments

In the future we intend to implement a web-based course for undergraduate meteorology and atmospheric sciences students. Also we will make a hybrid system which should evaluate its tasks on the type of gateway being in use, conventional internet or Internet 2 based on the latency time the applications are being taken. Besides we should be planning a joint campaign with other university campi belonging to the KYATERA network.

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