

Atmospheric Monitoring at HiRes - Hardware Systems 2

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Abstract. Each night the High Resolution Fly's Eye observatory collects data, calibration systems monitor the atmosphere. The active systems include two steerable lasers, and an array of devices called flashers. This poster describes these systems.

1 Introduction

Air Fluorescence cosmic ray experiments use the atmosphere as a calorimeter. The properties of this calorimeter, especially its optical clarity, vary with time and with position. Because the particle flux is relatively low, both the time and the distance between events is quite large. Over a 5 year operational period, HiRes may expect to see a handfull of super GZK candidates. The distance between these showers and the detectors are expected to average about 25km. Unfortunately no test beam exists for air fluorescence experiments. This and the challenge to monitoring a variable atmosphere lie at the crux of the air fluorescence experiments attempting to unravel the question of a possible GZK cutoff or lack thereof.

2 Atmospheric Monitoring Hardware at HiRes

The only practical alternative to a real test beam of high energy particles is to direct a pulsed light beam into the sky and record the light scattered by the atmosphere using the same detector that measures light from air showers. This technique provides both a probe of the aerosol distribution in the atmosphere and a test of the detector response to a source of know properties.

HiRes uses active and passive systems to monitor atmospheric clarity. The passive systems include an array of IR detectors that measure the sky temperature. The presence of clouds can be determined in this fashion since they are

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warmer than the clear sky. These systems are described in another poster in this conference (Pace et al. 2001). The active systems include an array of xenon flashbulb devices dubbed "flashers" and two steerable laser systems. The layout of these systems is shown in Fig 1. An array of 10 vertical flashers are located between the two sites. These are operated remotely under radio control. An 11th flasher is located at the site of the original Fly's Eye II detector and produces an inclined track (20 degrees) that passes between the two detectors. A steerable laser system is located at each site. The lasers can be fired in any direction above the horizon. While scattered light from each laser is observed at each detector, only the data from the laser at the other site is read out.

3 Flashers

Flashers are robust stable inexpensive light sources that can be located in harsh environments. (They are described in considerable detail elsewhere. (Wiencke et al., 1999a)) Flashers are self contained and require no external connections. 10 of the 11 flashers used by HiRes are operated remotely via radio control. A block diagram of the system is shown in figure 2. Flashers produce a pulsed broadband beam of light that is approximately 1 us duration. The energy of a flasher in the 300-400nm range of interest is approximately 100 micro Joules.

Originally used as a diagnostic tool for the Fly's Eye detector, the optics of a flasher are similar to a reflecting telescope but with the light traveling in the opposite direction. A Xenon flashbulb is located with the midpoint of its two discharge electrodes at the focal point of a 20cm f2.0 spherical mirror. The reflected light travels upwards through a Pyrex window at the end of cylindrical steel housing. A heater element mounted below the Pyrex window can be turned on to melt frost or snow and evaporate dew.

Flashers have a RMS shot to shot stability of 5 %. Typical stability over a year of operation is less than 10%. The trigger circuit that determines the firing voltage was designed

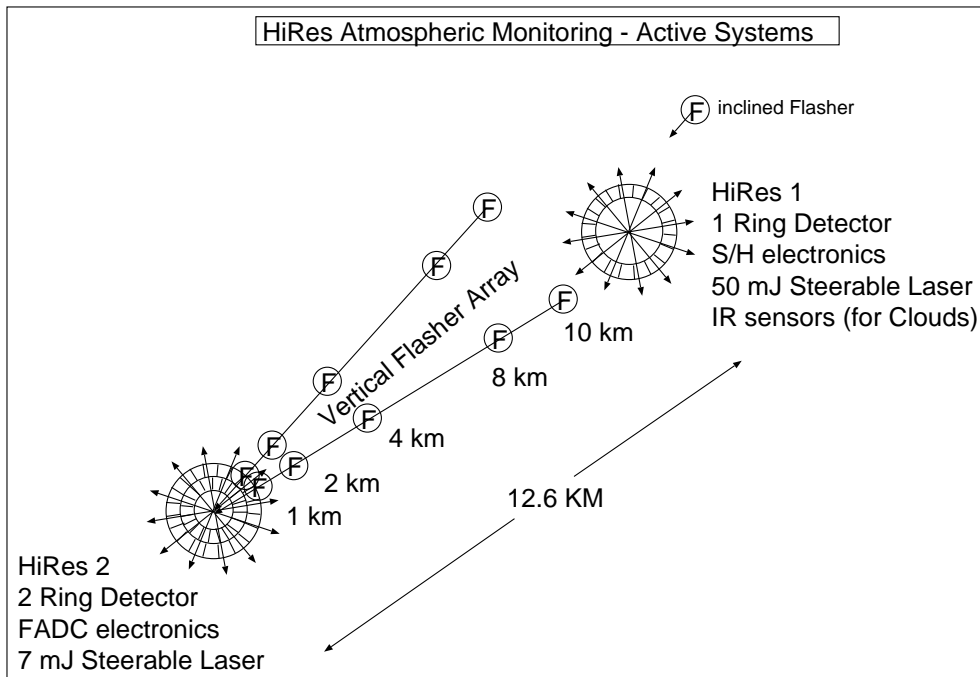


Fig. 1. Fig. 1 Layout of the atmospheric monitoring systems at the High Resolution Fly's eye Observatory

with passive components to be especially stable. A DC-DC converter supplies high voltage from a battery charged by a solar panel. As this HV charges capacitor connected across the Xenon bulb electrodes a lower voltage from a divider develops across three Sidacs type diodes. The breakdown voltage of these diodes is essentially insensitive to temperature variations. At the breakdown voltage it causes a trigger pulse to be delivered to a third electrode between the two primary electrodes in the bulb. This initiates the plasma discharge and consequently the flash.

A one way VHF (461 MHz) radio link from a base station located at HiRes2 controls the flashers. The link uses touch-tones. Each tone is the superposition of two audio frequencies and provides 16 possible digits. A pair of tones forms a command. To minimize the number of components in the field, the control system was designed with an identical simple control circuit at each flasher. All flashers operate on the same frequency and receive and decode all tones broadcast from the central transmitter. Jumpers on the control boards map the tone pair command to various functions on the flashers. The most important commands are flash once, window heater on, and window heater off.

4 Lasers

The steerable laser systems (Wiencke et al., 1999b) use a frequency tripled YAG laser to produce a pulsed beams of 355nm light that can be steered in any direction above the horizon. This wavelength is closely matched to one of the lines (357nm) of nitrogen fluorescence in air. The time duration of each laser pulse is approximately 7 ns. The lasers

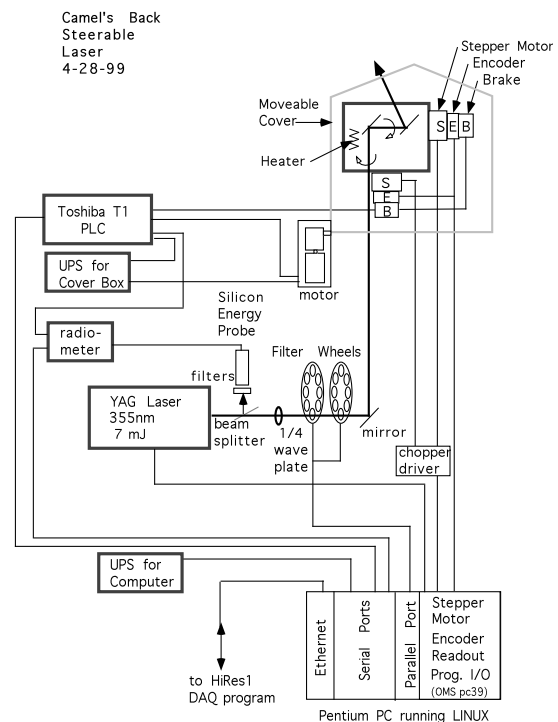


Fig. 3. Fig. 3 Block Diagram of a HiRes Steerable Laser system

HiRes Radio Controlled Flasher System

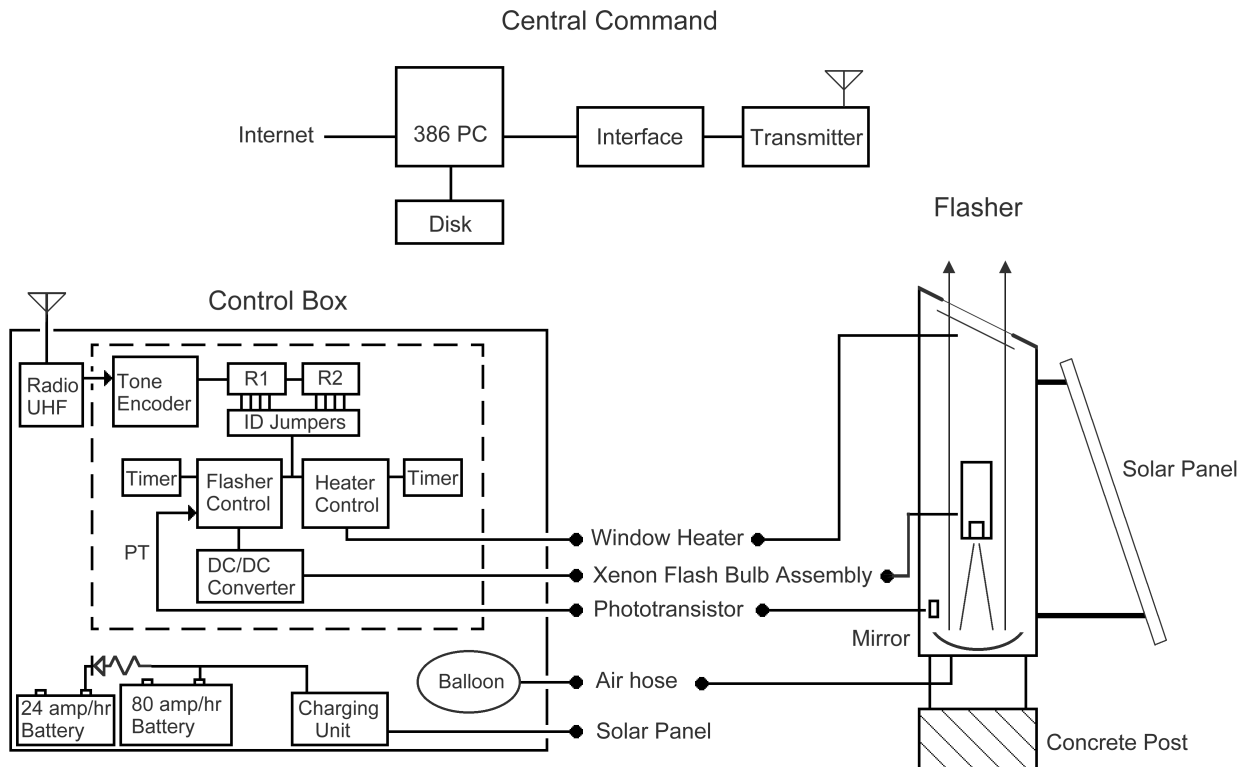


Fig. 2. Fig. 2 Overview of a radio controlled Xenon “Flasher”

used have been designed for field applications. The laser located at the HiRes2 detector has a maximum energy per pulse of 7mJ. The laser at HiRes1 has a maximum energy of 50mJ. The shot to shot variation is about 3 percent RMS. The direction, energy, polarization, and time of each pulse is measured and recorded locally. Different energies and polarizations can be selected. The systems are operated remotely. Operators running the HiRes1 detector also operate both steerable laser systems.

Figure 3 shows a block diagram a steerable laser system. After the light leaves the laser head, approximately 1% is sampled by a beam splitter and measured by a photodiode read-out by a radiometer. The energy sent to the sky is determined by multiplying this measurement by a calibration constant. The calibration constant is the ratio of monitor measurements and measurements from an energy absorbing pyroelectric probe placed temporarily where the beam exits the entire system.

After the beam splitter, the beam passes through a quarter wave plate oriented to transform the linear polarized light exiting the laser into circular polarized light to be sent to the sky. This is important because molecular scattering is polarization dependent and the orientation of the linearly polarized light would rotate as the beam direction was changed.

This complication is eliminated by using a polarization that is symmetric about the beam axis.

The beam then passes through a computer controlled filter wheel (2 filter wheels in the case of the system at HiRes2) These allow the operator to vary the intensity of the beam. This is necessary to avoid saturating the HiRes detector at the other site when the beam passes near by. Such shots have turned out to be quite useful for measuring the aerosol phase function over a wide range of scattering angles and to measure the horizontal aerosol scattering length.

It is also possible to turn down the laser energy by reducing the voltage on the flashlamp that pumps the laser. However, it is better to avoid this when possible because of the nonlinear behavior of the optics that produce the frequency tripled 355nm light from the 1064nm primary beam. Reducing the beam energy tends to increase the fraction of 1064nm and 532nm contamination in the 355nm beam. For the 50mJ laser at HiRes1 it is necessary to adjust the flashlamp voltage to avoid potential long term damage to the energy absorbing attenuation filters. In this system, two dichroic mirrors are located in the beam immediately after the laser head to reduce beam contamination.

It is also possible to control the polarization of each laser with a second quarter wave plate. At the system at HiRes2,

two quarter wave plates are arranged in a second filter wheel to produce vertical or horizontal polarization when the beam is pointed towards the HiRes1 detector. At the HiRes1 system, the two quarter wave plates are mounted in computer controlled rotation stages to allow any polarization to be selected.

After the beam passes through the filters and quarter wave plate it is directed vertically by a dichroic mirror up the center of a large vertical pipe. The steering fixture is mounted on top of the vertical pipe. The pipe and the supports holding the optical table are embedded in the concrete foundation of the shelter. To ensure beam pointing is not affected by vibration caused by wind loading or by people walking in the shelter, these supports do not make contact with any other part of the structure except the concrete base.

The steering assembly is mounted at the top of the vertical pipe. The steering head contains two dichroic mirrors mounted so that the angle of reflection is always 45 degrees. The mirror controls the azimuth direction, and the second the elevation. The laser direction is read by two rotary encoders. When not in use, the laser steering head is protected by a computer controlled cover.

Both laser systems are controlled by PC's running Linux. A motion control board controls the steering head. This board requires only simple ASCII commands in units of degrees and features an on-board processor that provides feedback between the encoders and stepper motors to archive and maintain accurate beam direction. The filter wheels are controlled via a parallel port. Communication with all other system components including the laser is made via serial ports.

The firing times of the lasers are synchronized to the GPS second using a specially designed GPSY module. (Smith et al. 2001). The GPSY provides two trigger pulses. The first triggers the flashlamp and the second triggers the laser cavity Q-Switch. The HiRes1 steerable laser is fired at 4 hz with a 111 millisecond offset from the GPS second. A 222 millisecond offset is used by the HiRes2 laser. The offset is measured to a precision of 25ns. This allows the laser tracks to be cleanly separated from the data sample. It also provides a check on the overall timing of each system including the hardware and the off-line analysis.

5 Operation

The steerable lasers and the flashers operate almost continuously each night of detector operation. To simplify programming and operation, the on-line control programs require only a few commands at the start of the night to begin operation, and a single command at the end of the night to shut the systems down. The actual firing patterns are specified in ASCII configuration files that can be easily modified without requiring any program changes.

Each flasher in the vertical flasher array is fired 10 times

every 10 minutes. The flashers one and two km from the HiRes2 detector are sensitive to aerosol scattering. When aerosols are present they cause the tracks from these flashers to brighten and widen. The flashers at 4km are relatively insensitive to aerosols because the increased scattering out of the beam is compensated by attenuation back to the detector. The flashers at 8 and 10km produce dimmer tracks when aerosols are present because attenuation dominates.

Each laser fires a pattern of 1000-1300 shots per hour. Vertical shots are used to extract vertical aerosol total optical depth. Aerosol phase function and horizontal scattering length are extracted from near horizontal shots fired across each detector. A pattern of shots fired at 5-15 degrees in elevation are used to extract vertical optical depth over the detector aperture. These tracks can also be used to study atmospheric horizontal uniformity and changes in the detector aperture.

6 Shoot the Shower

In addition to regularly scheduled shots, a scheme of shower directed firing dubbed "Shoot the Shower" will be implemented. The idea is to probe the atmosphere between the shower and the detectors a few minutes after the shower appeared. When a high energy shower candidate is observed, the parameters that define the detector shower plane will be passed to the local laser. That laser will interrupt its normal scan to fire a pattern of shots in the same plane. These shots will appear as tracks to the other detector. If the plane contains clouds or other aerosol structure, they will appear as discontinuities. It may also be possible to extract aerosol parameters from these shots. For high energy showers seen in stereo, both detector/shower planes will be scanned.

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