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Atmospheric monitoring at HiRes - Hardware systems 1

M. D. Roberts, for the HiRes Collaboration

University of New Mexico, Albuquerque, NM 87131

Abstract. Atmospheric monitoring is critical for air fluorescence detectors, which use the atmosphere as their detector medium. At HiRes, most atmospheric monitoring is done with steerable laser systems located at the two detector sites. In addition to these lasers, we have other systems designed to cross-check the atmospheric calibration and to provide an estimate of the energy resolution due to atmospherics. This paper will describe two of these systems: a horizontal extinction length monitor and a roving steerable laser system.

1 Introduction

The air fluorescence technique uses the earth's atmosphere as a medium to convert the energy of primary cosmic rays into a detectable nitrogen fluorescence signal. This technique provides large acceptance for high energy cosmic rays and a unique ability to measure shower development. The large distances at which events can be seen (up to 40km) requires a thorough understanding of the attenuation and scattering of light in the wavelength acceptance region of the fluorescence detectors (300-400nm). The Rayleigh scattering of light in the molecular atmosphere is well understood and is very stable, with only small variations that can be characterized by surface temperature and pressure measurements. The effect of aerosols in the atmosphere is, however, much more difficult to characterize. The density, size and scattering properties of the aerosols are highly variable on short time-scales.

Atmospheric monitoring at HiRes is done primarily through two steerable laser systems, one located at each of the two fluorescence detectors (HiRes-1 and HiRes-2). Descriptions of the two detectors, which are separated by 12.5 km, are given in Abu-Zayyad et al. (1997) and Bergman et al. (2001). The arrangement of lasers and fluorescence detectors form a pair of bi-static LIDARs, where light scattered from a laser beam from one site is viewed by the fluorescence detector at the other site. The steerable laser systems are described in detail in Wiencke et al. (1999A), and the atmospheric analysis based on these systems is discussed in Roberts et al. (2001) and Wiencke et al. (2001).

The atmospheric characterization based on the laser beam scattering information is limited by a number of factors: the understanding of the laser energy and the detector calibration, knowledge of the scattering behavior of the aerosols and assumptions about the uniformity of the aerosols across the aperture. The hardware systems described in this paper were designed to provide an independent cross-check of the atmospheric calibration provided by the steerable lasers.

2 Horizontal extinction length monitor

The horizontal extinction length monitor (HELM) has been designed to measure the combined Rayleigh and Mie extinction length at ground level. It is able to measure the extinction length at a number of wavelengths in and near to the wavelength acceptance of the fluorescence detectors. The atmospheric path over which this measurement takes place is designed to coincide as closely as possible with the path of laser based scattering measurements of horizontal extinction. The HELM measurements will allow us to understand the systematic uncertainties in determining the horizontal extinction length from the bi-static LIDAR measurement. We can then apply the lessons learned from this comparison to the atmospheric calibration of the HiRes fluorescence aperture derived from other LIDAR measurements.

The HELM consists of two components, a multi-wavelength DC light source and a photometer (see figure 1). The light source and detector are separated by the atmospheric path that is to be characterized. The intensity and stability of the light source limits the range of light source/detector separation to distances of 10-35 km. The light source is based around a 35W OSRAM SYLVANIA High Intensity Discharge (HID) lamp. This lamp provides a bright continuous spectrum of light over the range of wavelengths to be measured by the HELM system. The electronic control ballast of the

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Correspondence to: M. Roberts (roberts@cosmic.utah.edu)

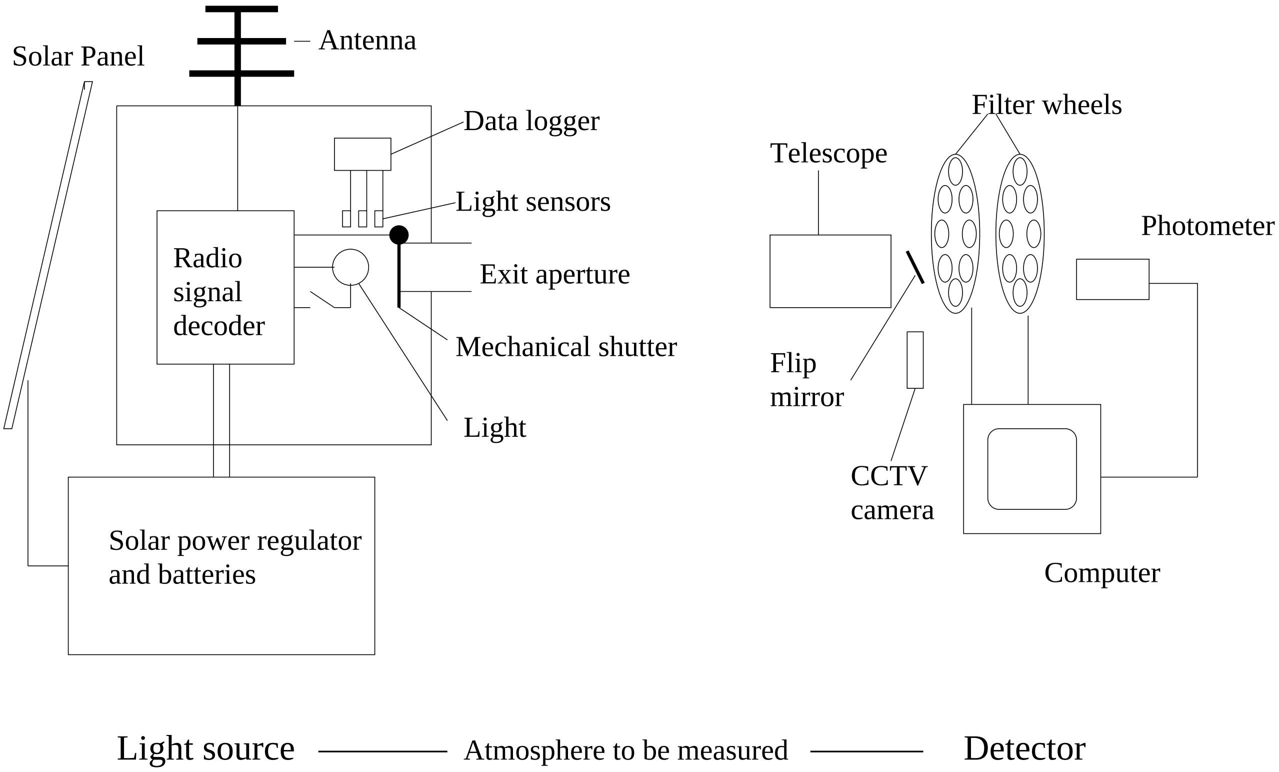

Fig. 1. Schematic diagram of the HELM system. The light source is shown on the left and the detector is shown on the right. Source and detector separation are expected to be between 10km and 35km. A flip mirror at the back of the telescope allows the image to be diverted from the photometer to a camera or an eyepiece, so that image focus and alignment can be verified.

HID allows the light to stabilize after only a few minutes.

The light source is designed to be remotely deployable and has the option to be powered by either main power or by a solar panel/battery combination. The power to the light is switchable by remote radio control. A shutter, also under radio control, can block the light signal so that background measurements can be taken without power cycling the light. The radio control electronics were developed at HiRes for an array of remote Xenon flashers (Wiencke et al. , 1999B). The computer that controls the operation of these flashers will eventually be used to control the operation of the remote light source. The light output of the bulb will be monitored locally at each of the measured wavelengths by silicon diodes with appropriate narrow-band filters. The output of the diodes will be recorded by a local data logger, which will also monitor temperature and power supply voltages.

The light detector (see figure 1) is based around a commercial astronomical photometer (Optec SSP7) coupled to a Meade ETX astronomical telescope. The light sensor is a Hamamatsu R4040 bi-alkali photo-multiplier tube.

The SSP7 has two filter wheels, allowing a selection of narrow waveband and neutral density filters. The five monitoring wavelengths are 365nm, 405nm, 436nm, 546nm and 577nm. The entire system is controlled by a laptop computer that will perform an automatic sequence of measurements whenever the fluorescence detectors are being operated. The photometer and electronics will be located in a mirror building at the HiRes-2 detector that is facing toward HiRes-1. For initial testing the light source will be deployed at HiRes-1 (12.5km distant). After this the light will be moved to a distance of around 35km, but still on the line connecting HiRes-2 and HiRes-1.

3 Roving steerable laser system

The steerable laser systems located at HiRes-1 and HiRes-2 are the primary source of information for atmospheric monitoring. Only lasers which are located at the fluorescence detectors can fire a laser beam along the exact path from a cosmic ray track to the detector. Having the lasers located at the detectors also allows for easy maintenance and monitoring of these systems. There are, however, a number of disadvantages in having the lasers and fluorescence detectors co-located. The principle one is that each of the laser beams can be seen by only one detector so the lasers do not provide information about the stereo performance of the fluorescence detectors. The lasers also act as a local source of light pollution for the nearby detector, producing very intense tracks in the mirrors that directly view the track as well as a diffuse multiple scattered signal that is seen by all of the mirrors. In addition, the laser beams that are fired towards the edge of the aperture where the greatest atmospheric absorption occurs can only be viewed at a limited range of backward scattering angles. This occurs because the two fluorescence

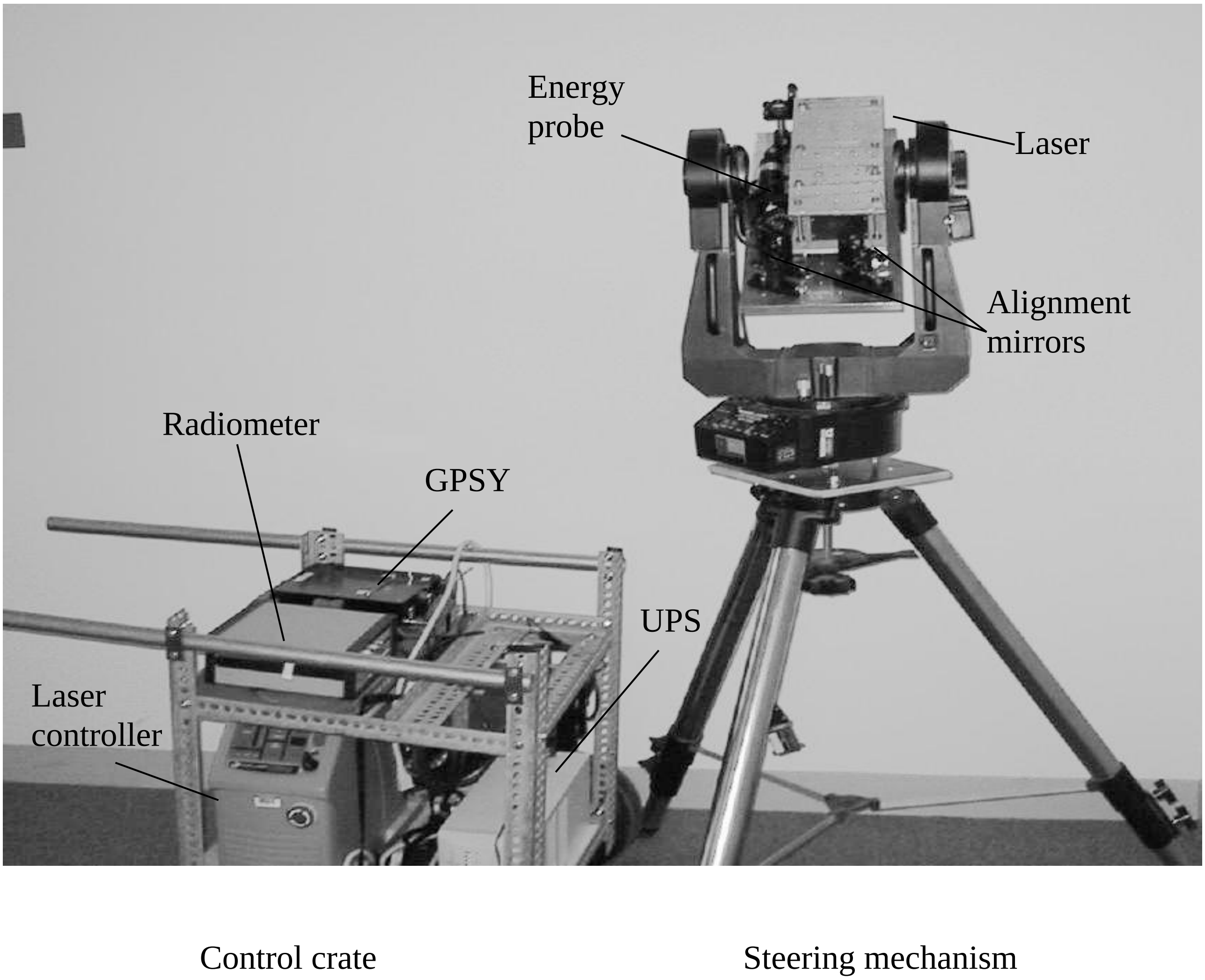

Fig. 2. Roving laser system.

detectors are close to each other compared to the distance to the edge of the aperture

To overcome these limitations we have made a portable steerable laser system. This system can be deployed anywhere in the aperture where motor vehicle access is possible. The roving steerable laser system is based on a 5mJ 355nm frequency tripled YAG laser (Big Sky Laser Technologies, Ultra CFR-THG-WS). The beam is aligned with two di-electric steering mirrors that also clean from the beam any non-355nm light left from the frequency tripling process. The polarization of the 355nm light from the laser is randomized, and approximately 10% of it is diverted to an energy probe to monitor laser energy variations. The output of this probe is calibrated routinely against a direct measurement of the output laser energy made with a total energy probe.

The steering platform of the laser is a modified Meade LX8 telescope, where the telescope optics have been removed and replaced with an optical platform. The power and laser control hardware are located in a separate portable electronics crate. This crate contains the laser control unit, GPS timing GPSY unit and a laser probe monitor. The GPSY unit is a GPS based timing system allows us to fire the laser at variable rates with a fixed offset with respect to the GPS second. Having the lasers fired at known times allows the laser tracks either to be vetoed at the fluorescence detectors or to be tagged so they can be easily detected in the data. A detailed description of the GPSY units can be found in Smith et al. (2001).

Power for the system comes from a generator, and is smoothed by an uninterruptible power supply, which also provides backup power when the generator is refueled.

The absolute pointing accuracy of the laser beam is 0.1° and the laser beam energy is variable from $\sim 500\mu$J to ~ 5mJ with absolute energy monitoring accurate to 10%. The system underwent preliminary testing at the end of year 2000 and will be used during the summer/autumn 2001 observing season at HiRes. Further development, including more automation of the system will continue.

3.1 Track simulation with the roving system

Laser tracks from the roving steerable laser system are the best simulation of cosmic ray events available. The tracks can be used to optimize stereo reconstruction software and can also be used to estimate the core location and arrival direction accuracy of the the fluorescence detectors. The laser tracks can be used to study the fine details of the detector response function, for example, the effect of gaps between photo-multiplier tubes in the cameras.

3.2 Atmospherics and energy resolution studies with the roving system

The roving laser will play an important part in the characterization of the atmosphere within the HiRes aperture. We plan to record laser tracks at varying distances from the HiRes-1 and HiRes-2 detectors. Using the atmospheric characterization derived from the steerable lasers at HiRes-1 and HiRes-2 the amount of light that should be seen from the remote laser tracks can be predicted. The difference between the predicted and measured intensity of the tracks can be attributed to atmospheric correction errors. This difference will be used for an estimation of the energy resolution of the fluorescence detectors.

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