The Auger Observatory roving LIDAR system

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Abstract

A fully portable LIDAR system has been designed for use with the Auger fluorescence detectors (FDs). The primary purpose of the roving LIDAR is to provide the FDs with artificial tracks that are generated by atmospheric scattering of a 355 nm laser beam. The laser is mounted on a steering mechanism, giving all sky coverage and an absolute accuracy of better than 0.1°. The energy in the beam can be adjusted between 5 mJ and 200 μJ. The absolute beam energy is monitored to an accuracy of better than 10%. At full energy the laser beam produces a track that has brightness greater than the fluorescence track of a 10^{20} eV cosmic ray. The laser tracks have a wide range of uses for developing our understanding of the behavior of the FDs. These include absolute FD calibration, track reconstruction accuracy, FD timing, multi-mirror event reconstruction, FD trigger efficiency and FD aperture determination. The roving LIDAR is also used for atmospheric monitoring. A receiving mirror and photomultiplier tube (PMT) are mounted on the steering mechanism to measure the backscatter signal from the laser track. In this paper we will describe the roving LIDAR system and present results from tests of this system.

1. Introduction

A fluorescence detector (FD) measures fluorescence and Cherenkov light from cosmic ray tracks generated as the secondary particles of an extensive air shower (EAS) traverse the atmosphere. From this measurement the position, arrival direction, energy and mass of the primary cosmic ray can be inferred. The complex interaction between the light signal, the atmosphere and the detector need to be understood if the properties of the primary cosmic ray are to be interpreted correctly. As part of this process it is useful to be able to generate artificial cosmic ray tracks for the FDs that have well understood properties. For this purpose, a prototype laser system was built for use with the Auger Engineering Array FDs [2]. Based on experience with this prototype, the Auger collaboration has built a mobile steerable LIDAR/laser system - the “roving LIDAR”. This sys-

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tem can fire well calibrated laser beams into the atmosphere that generate tracks through atmospheric scattering. The roving LIDAR is also equipped to make elastic backscatter measurements of the local atmospheric conditions.

2. The roving LIDAR

The roving LIDAR (see Fig. 1.) is based on a BigSky Ultra CFR frequency tripled YAG laser. This laser generates 7 ns long light pulses at a wavelength of 355 nm. The maximum pulse energy is around 6 mJ and the maximum firing rate is 20 Hz. The laser head is mounted on an optical table that is on a steering mechanism made from a modified commercial telescope mount (Meade LX200). The steering mechanism allows the laser beam to be pointed, under computer control, to any point in the sky. With careful alignment the absolute pointing accuracy in a given direction can be better than 0.1°. In addition to the laser head, the optical table also has elements to steer, monitor and improve the spectral quality of the beam.

The LIDAR backscatter receiver is attached to the bottom of the optical table. The laser beam is directed by laser steering mirrors along a 90 cm arm that stands on the optical table. A laser mirror at the end of the arm directs the beam so that it travels parallel to the optical axis of the LIDAR backscatter receiving optics. By introducing this parallax offset the distance at which the beam image enters the light detector of the LIDAR backscatter receiver is increased. This reduces saturation effects caused by near-field scattering from the laser beam.

A pickoff mirror in the laser beam path directs a fraction (∼10%) of the laser energy into a laser energy probe and also into an optical fiber. The optical fiber directs laser light to the PMT that measures the backscatter signal. The energy probe monitors the relative energy of the laser while the fiber system monitors combined changes in the laser energy and the gain of the PMT. The relative energy measured by the energy probe is periodically calibrated against the total energy of the laser beam to the sky. The sky energy is measured with an absolutely calibrated total energy laser probe (LaserProbe RjP-445). The absolute uncertainty of the total energy probe, traceable to National Institute of Standards and Technology (NIST) standards, is better than 10%.

The timing of the laser shots is controlled by a “GPSY” GPS laser controller. This unit allows the absolute emission time of the laser beams to be controlled to better than 100 ns. A record of the times of all laser shots is stored so that the laser data can be easily extracted from the FD data.

The LIDAR backscatter receiver consists of a 20 cm diameter mirror viewed by a Photonis XP3062 PMT with a BG-3 UV filter. An adjustable aperture on the front of the PMT is used to adjust the distance at which the laser beam image is seen by the PMT. The electronic signal from the PMT is recorded by a dual channel 12 bit transient digitizer (Pico Systems ADC-212/50). The signal is split

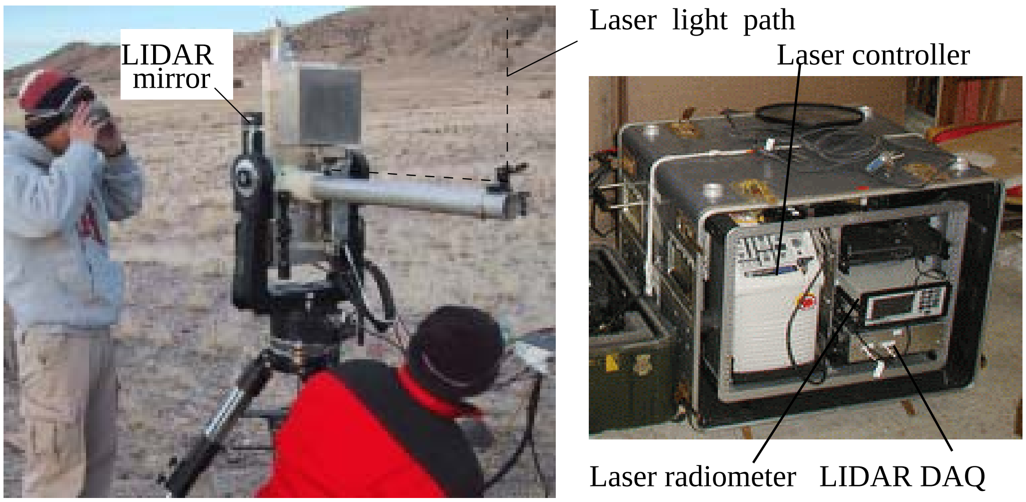

Fig. 1. The photograph on the left shows the steering mechanism deployed near the HiRes FD in Utah. The steering mechanism, laser and LIDAR DAQ are controlled from the electronics crate, shown in the right hand picture.

between the two channels, one of which is run at high gain and the other at low gain. For a typical LIDAR run the digitizer records 3200 samples at a 20 MHz sampling rate giving a total range of 24 km.

The laser controller, laser probe radiometer, GPSY unit and LIDAR digitizer are mounted in an electronics rack which is mounted inside a weatherproof fiberglass case. The fiberglass case protects the sensitive components of the roving LIDAR during transportation and deployment.

3. LIDAR control

The roving LIDAR in controlled by a Labview program running on a laptop computer. The program controls the LIDAR steering mechanism, laser controller, GPSY unit, laser energy radiometer and the LIDAR digitizer. When the LIDAR control program is started it reads from a setup file that specifies the firing rate of the laser and the offset of laser firing from the GPS second. The program then prompts the operator to specify a driving file which contains a list of commands to point and fire the LIDAR system. Once the driving file is specified the roving LIDAR will complete the sequence of measurements without the need for operator intervention. The control program generates a log file that records the pointing direction, GPS time and energy of each laser shot. The average LIDAR backscatter trace for each pointing direction is stored in this log file. This trace is also displayed on the computer screen , along with other diagnostic information.

In addition to the LIDAR control software other Labview programs have been developed that allow individual components of the roving LIDAR to be run for diagnostic purposes. A program has also been written to perform an automated calibration of the relative laser energy probe.

4. Tests in Utah and planned deployment in Argentina

The roving LIDAR has been tested at the HiRes FD observatory and in Southern Utah. These tests have shown that the roving LIDAR works and can run long firing sequences without operator intervention. Laser tracks from the system have been seen in the HiRes FDs at the specified laser firing GPS times. These tracks have been used for FD relative sensitivity studies and for atmospheric measurements. A series of LIDAR backscatter measurements have also been made. As a result of the tests, improvements to the software and hardware of the roving LIDAR are being made. It is expected that the completed system will be shipped to Argentina by mid-2003.

The roving LIDAR has a wide range of uses for monitoring the performance of the Auger FDs and surface detectors (SDs), including:

Atmospheric monitoring: The mobility of the roving LIDAR allows it to be deployed almost anywhere in the Auger array, including areas where the Auger fixed LIDAR systems do not give good coverage. Atmospheric monitoring measurements can be made with the on-board LIDAR, or by looking at the laser track images seen by the FD telescopes.

FD track reconstruction: The mobile laser system will generate artificial cosmic ray tracks for the FDs. These will be used to study track reconstruction accuracy, FD trigger efficiency and FD aperture. Detailed studies can also be undertaken on the FD optical characteristics and on the reconstruction of multi-mirror track events.

Hybrid timing studies: The FD/SD hybrid shower reconstruction accuracy depends strongly on the relative time accuracy between the FDs and the SD tanks. Hybrid timing studies have been undertaken with the prototype laser system [1]. A fraction of the laser light pulse is fed via optical fiber into a surface detector tank while the rest of the light makes a track in the atmosphere for the FDs. These timing tests will be continued with the roving LIDAR.

Absolute FD calibration: Well calibrated laser beams can be used to cross-check the absolute FD calibration. These measurements, already tested with the prototype laser system [2], will be continued with the roving LIDAR.

1. Fick, B. and Sommers, P. 2002, Auger GAP note GAP-2002-001
2. Roberts, M., Sommers, P. and Fick, B. 2003, Auger GAP note GAP-2003-010