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Automatic Weather Station (AWS) Lidar

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Abstract - A ground based, autonomous, low power atmospheric lidar instrument is being developed at NASA Goddard Space Flight Center. We report on the design and anticipated performance of the proposed instrument and show data from two prototype lidar instruments previously deployed to Antarctica.

I. INTRODUCTION

In 1993, the Laser Remote Sensing Branch at Goddard Space Flight Center was invited to develop a compact, low power, diode laser based lidar as part of the University of Illinois atmospheric research program at the South Pole. The instrument was to be deployable to the Antarctic Geophysical Observatories (AGO), operate continuously during the polar night, and record the occurrence of polar stratospheric clouds (PSC). These clouds form at altitudes from 12 to 27 km and are implicated in the destruction of polar stratospheric ozone [1,2]. Two prototypes of the AWS lidar have been deployed to Antarctica. The AGO Lidar was deployed in January 1999 and a scanning Micro Pulse Lidar (MPL), part of the South Polar Atmospheric Radiation and Cloud Lidar Experiment, was deployed in December 2000. Both instruments employ the micropulse lidar technique in which high peak power laser pulses at low repetition frequencies (~10 Hz) are exchanged for low peak power pulses at several kHz repetition frequencies thereby conserving average laser power.[3]

The AWS Lidar will be a compact autonomous, rugged and highly portable lidar that will operate continuously in an insulated enclosure, charge its own batteries through a combination of a small rugged wind generator and solar panels, and transmit its data from remote locations to ground stations via satellite. A network of these instruments will be established by collocating them at remote Automatic Weather Station (AWS) sites in Antarctica under the auspices of the National Science Foundation (NSF). The NSF Office of Polar Programs provides support to place the weather stations in remote areas of Antarctica in support of meteorological research and operations. The AWS weather data will directly benefit the analysis of the lidar data while a network of ground based atmospheric lidar instruments will provide knowledge

regarding the temporal evolution and spatial extent of Type Ia PSCs. These particular polar stratospheric clouds, comprised of frozen nitric acid trihydrate (NAT) and water ice, help liberate the chlorine free radical, Cl-, in the polar stratosphere during the austral springtime. The atomic chlorine then catalytically dissociates the stratospheric ozone over Antarctica resulting in the the ozone hole. In addition, the lidar will monitor and record the general atmospheric conditions (transmission and backscatter) of the overlying atmosphere which will benefit the Geoscience Laser Altimeter System (GLAS) instrument to be flown on the ICESAT mission later this year.

II. DESIGN

The proposed AWS Lidar system, its block diagram shown in Figure 2, uses a highly efficient diode pumped microchip laser, a novel refractive telescope, photon counting detectors and custom low power lidar electronics.

The instrument has been divided into two parts to ease thermal design: an above surface non temperature controlled enclosure and a buried, temperature controlled electronics box. The above surface box contains the athermal telescope and laser beam expander. These are coupled by fiber optics to a buried box that contains all of the active electronics and electro-optics. The temperature one meter below the surface remains nearly constant at approximately -50°C and the surrounding snow is excellent insulation so the box interior temperature can be controlled with waste heat and a small additional heater.

A Microchip Laser Transmitter

The laser transmitter is a diode pumped solid state, microchip laser from Litton-Airtron, Synoptics that produces 7.5 uJ per pulse at 1064 nm and up to 12 kHz pulse repetition frequency (PRF). An integral frequency doubler converts approximately 32% of the output to 532 nm, or about 2.4 uJ per pulse in the green. The laser is passively Q-switched and a beam sampler picks off ~1% of the transmit light to trigger the photon counting lidar electronics and monitor the average transmit laser power.

B Receiver

A novel, athermal, refractive, fiber coupled telescope is being developed for the AWS Lidar. A refractive telescope design was chosen to avoid the problems inherent with reflective optics spoiling the polarization of the scattered laser light. The telescope uses 100 mm diameter achromats that are epoxied into fiberglass tubes and an FC fiber coupler is epoxied at the focal plane of each lens. The multiple telescope tubes and laser beam expander tube are aligned on a large aperture collimator and then epoxied together while their co-alignment is monitored. The thermal expansion coefficients of the materials are closely matched to reduce temperature sensitivity while still keeping the cost low by using standard, off-the-shelf parts. The telescope will be tested in a temperature chamber over an extended temperature range to ensure acceptable performance. Two of these telescope tubes, each with a narrow band-pass filter and a thin film polarizer, are epoxied together to form the polarization sensing receiver. This modular telescope design permits additional tubes to be added to increase collection aperture. If weight becomes a concern, composite tubes rather than fiberglass can be used instead.

The AWS Lidar must be able to operate continuously both day and night, and due to the dynamic nature of the near surface polar atmosphere, be able to profile the lower atmosphere (surface to 10 km) with one minute sampling. To ensure acceptable daytime performance, a temperature controlled etalon/interference filter is used to narrow the receiver bandpass to 100 pm. Graded index, multimode fiber optics couple the light collected by the telescope to the etalon/interference filter and then to the photon counting detectors. Single photon counting modules from EG&G Canada are used to detect the collected light. A custom, low power multi-channel scalar using field programmable gate arrays has been developed to record the lidar profiles. This advanced multichannel scaler card provides up to five parallel channels for simultaneous depolarization measurements and consumes less than 2.5 Watts of power.

III. PROTOTYPES

A AGO Lidar

AGO Lidar I was deployed to the Antarctic Geophysical Observatory P1 site on the polar plateau in January 1999[4]. The AGO platform provides instrument power, data storage, and a warm environment for up to 10 instruments. Total power available for science instruments is approximately 50 W. As such, the lidar instrument was designed to operate at a 33% duty cycle and to consume only 8 watts of power continuously. To achieve this, the lidar uses custom, low power electronics, high efficiency power supplies and

redundant semiconductor laser transmitters. With both lasers operating, the instrument transmits approximately 1 uJ per pulse at 4 kHz PRF. Figure 2 shows 2.5 hour night time data set acquired with the AGO Lidar prior to deployment in Antarctica. The data, shows multiple cloud layers occurring during the integration period and has been range corrected and smoothed. Two cross polarized detectors are used to sense depolarization of the scattered light and estimate cloud-ice particle content. The transmitted laser light is highly linearly polarized (>300:1 polarization ratio) and polarizing elements separate the parallel and perpendicular components and are detected separately.

B MPL

The South Polar Atmospheric Radiation and Cloud Lidar Experiment (SPARCLE) includes a scanning micropulse lidar instrument which was installed in the Atmospheric Research Observatory at the Amundsen-Scott South Pole station in December 1999. The external scanning system enables the lidar to make lidar measurements at any elevation angle from horizontal up to zenith. The data is used to estimate cloud optical depth and cloud extinction to backscatter ratio. A one hour, lidar profile is shown in Figure 3. The data from the summer field season 1999-2000 reveals near continuous cloud cover with dynamic, fast changing structure occurring from 3 to 8 km above the surface. The MPL instrument will continue to work throughout the austral winter, 2001.

IV. CONCLUSIONS

The AWS Lidar will be a rugged, self-contained, autonomous and portable instrument that will employ field tested hardware and techniques from both the AGO Lidar effort and the MPL program. It will be deployable by small fixed wing aircraft such as the Twin Otter and operate continuously through the polar day and night while transmitting data back to ground stations via satellite. The data will be analyzed for estimates of cloud optical thickness, extinction to backscatter ratio, and occurrence of Type Ia polar stratospheric clouds. The first AWS Lidar will be deployed in phases over the next three Antarctic summer servicing seasons with additional instruments deployed at the rate of 1-2 per year.

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- [4] J. A. R. Rall and James B. Abshire, "AGO Lidar / Antarctic Miniature Lidar," IGARSS, Seattle, WA, July 6-10, 1998

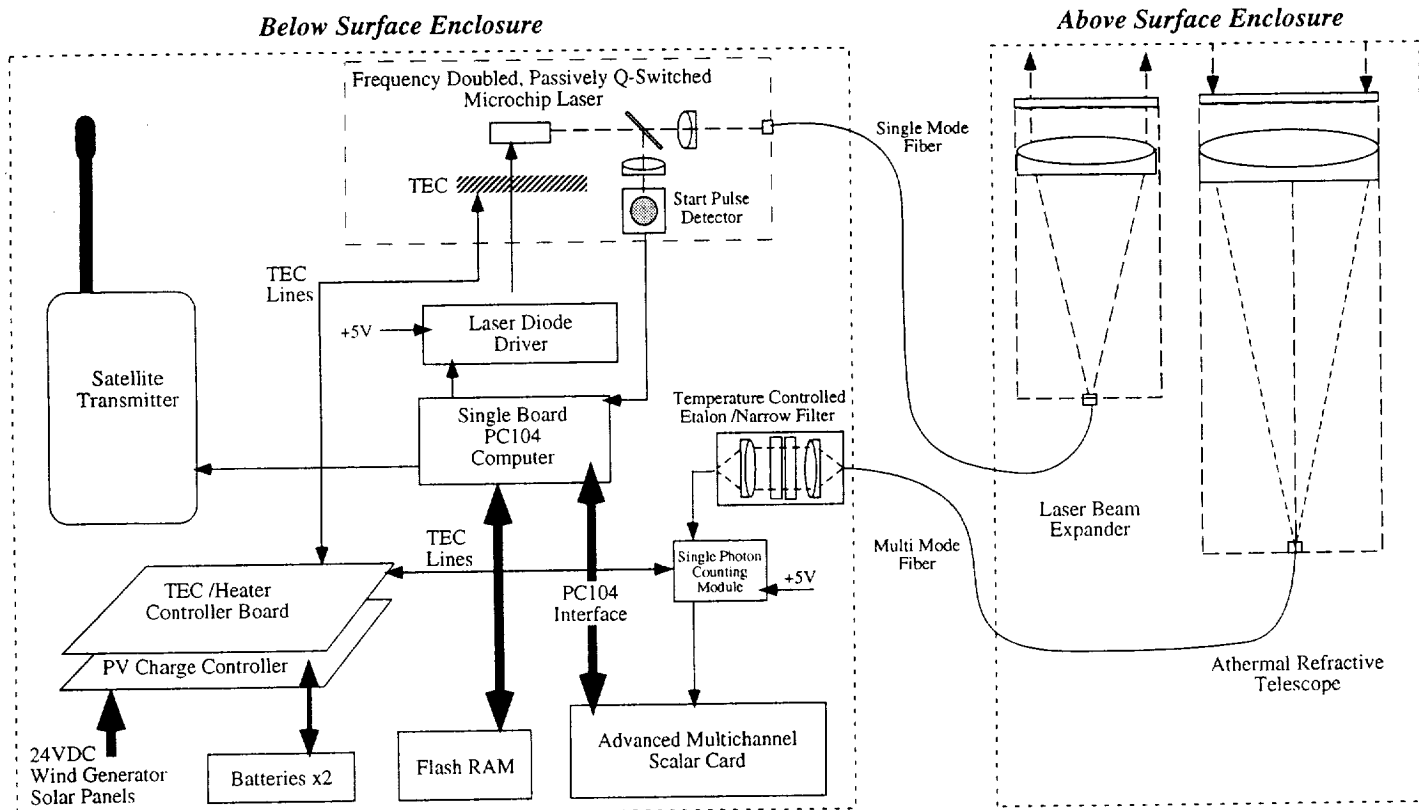


Fig. 1. AWS Lidar block diagram showing contents of above surface and buried enclosures.

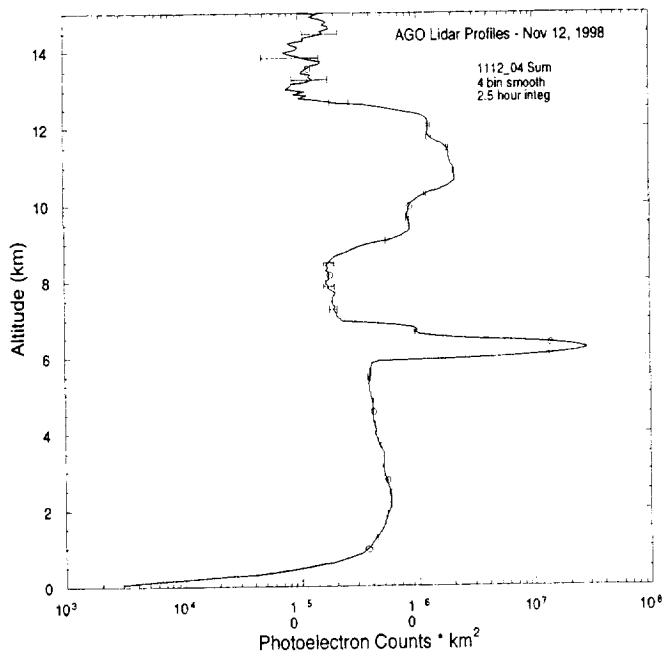


Fig. 2. AGO Lidar atmospheric profile, 2.5 hour integration with 4 bin smoothing.

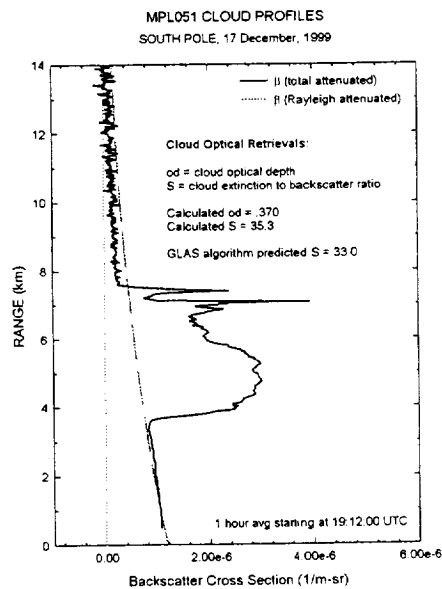


Fig. 3. Micropulse Lidar profile, 1 hour integration.