Development of Portable and Mobile Aerosol Lidars

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Abstract: In this paper, a 3D scanning 1.5μm eye-safe portable aerosol lidar system is introduced. It was developed devoted to measure aerosols in the troposphere in terms of aerosol extinction and backscatter coefficient, as well as the optical depth. An eye-safety analysis for the system led to the atmospheric transmission window at 1.5554 microns to be chosen for the OPO wavelength. With two persons, the system can be transported inside minivan, unloaded and set up for fieldwork within 15 minutes. Scanning measurements of cloud layers and 3D aerosol distribution have been made.

Another mobile scanning aerosol lidar system is under developing. The main task of this system is to routine measure the aerosol optical characters and its temporal evolvement at interested sites. In phase one, the laser emitter is a second harmonics Nd: YAG laser. The backscattering signals are collected by a 14-inch diameter telescope. By integrating the elastic channel and the nitrogen Raman channel, the optical characters of aerosols could be retrieved with a high level of accuracy. Also there will be a sun photometer associated with the lidar to obtain more aerosols information.

Keywords: Lidar, Aerosol, Scanning, Portable, Mobile

1. INTRODUCTION

Aerosols influence the earth observation remote sensing results by scattering and absorbing radiations and backscattering from and to active sensors, and involved in the positive sensors results by scattering and absorbing solar and earth radiation. Also aerosols play a critical role in the climate system by influencing the microphysical properties of clouds. Lidars are powerful tools to provide quantitative measurements of the aerosols optical properties with high spatial and temporal resolution and with a high level of accuracy. Aerosols and clouds at lower altitude (especially, 0~10km) are the most important element to atmosphere optical properties and effect directly the precise inversion of optics remote sensing data, therefore, it is significant to research the properties of aerosol and cloud in application of remote sense.

The Mie theory is the most common tool employed to estimate scattering properties of atmospheric particles. It describes the scattering of spherical particles with size comparable to the laser wavelength. It is applicable well to liquid aerosols, cloud and fog droplets. Although Mie scattering Lidar can obtain optical properties of aerosol and cloud with pretty good temporal and spatial resolution, it is not easy to effectively separate atmospheric Rayleigh scattering and aerosols Mie scattering. The drawback has serious influence on precision measurements and accurate correction of earth observation optical remote sense data [1].

Here, we present a single channel portable scanning lidar; the purpose to develop this system is to build an eye-safe lidar system for daily aerosol measurements. The main concern is eye-safe wavelength, fully automatic operation, lightweight and small size [2, 3].

Additionally, we introduce another under developing mobile lidar system. By adding a Raman channel, the molecule density spatial distribution could be obtained by measure the N_2 Raman return. So the molecule influence could be eliminated from the elastic return. At the same time, polarize and depolarize elastic channels will provide more information while distinguish the aerosols size and shape.

2. PORTABLE LIDAR

2.1 LIDAR TRANSCEIVER MODULE

The lidar transceiver module is a lightweight reinforced graphite epoxy structure with dimensions 12.5" x 12.5" x 16" shown in Fig. 1. The front compartment houses a 10-inch diameter primary mirror and detection optics. A cover on the rear of the unit can be removed to access the laser transmitter (Fig. 2). The transceiver box is mounted on a computer-controlled scanner (Fig. 1). A video camera mounted on the top of transceiver box allows the user to visually select a region of the atmosphere to be studied. The scanner enables lidar pointing throughout the full range of azimuth and elevation angles with an angular resolution of 0.3 mrad and maximum scanning speed of 2 rad/sec.

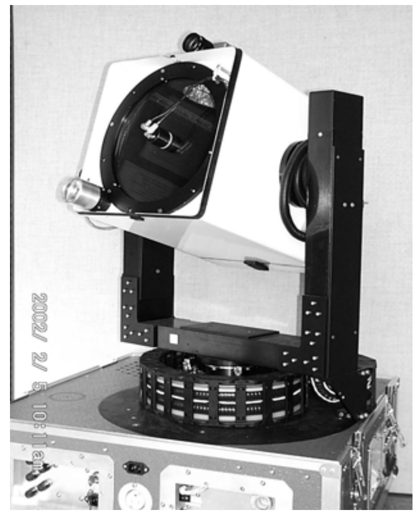


Fig.1. The portable and eye-safe Lidar

2.2 LIDAR TRANSMITTER

The pump source for the transmitter is a Continuum Surelite II Nd: YAG pump laser folded into an angle to fit in the transceiver box (Fig. 2). An optical isolator with an optical transmission of 90% protects the laser from optical reflections from the OPO. The slope efficiency for the OPO is 30% [4, 5].

An eye-safety analysis for the system led to the atmospheric transmission window at 1.5554 microns to be chosen for the OPO wavelength [6, 7]. The bandwidth of the OPO is approximately 0.6 nm (FWHM). The beam is transmitted biaxially through the beam expander assembly shown in the lower left corner of the front of the transceiver box in Fig. 2.

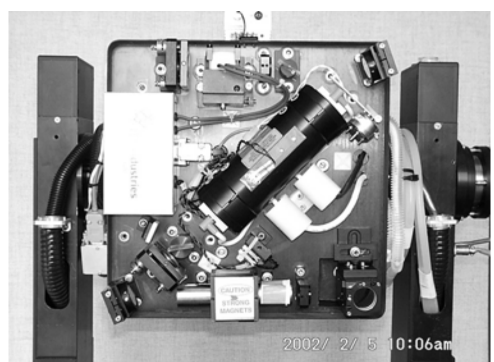


Fig2. Laser Transmitter Compartment

2.3 LIDAR RECEIVER

The optical layout of the receiver is a series of lenses housed in the central 1.25" diameter tubular obscuration along with an optical filter for solar background rejection. These lenses collimate the beam reflected from the 10" primary mirror in order for it to pass normally through the interference filter and then focus it on the 200 micron-diameter active area of an APD. For a source at infinity, the optical throughput onto the detector active area is calculated by ray trace to be ~96%, also there is about ~70% transmission of the optical filter. Preliminary results for our system, assuming an elliptical Gaussian laser beam, indicate that the far-field efficiency should be >97% and the distance to 90% overlap should be under 500 m.

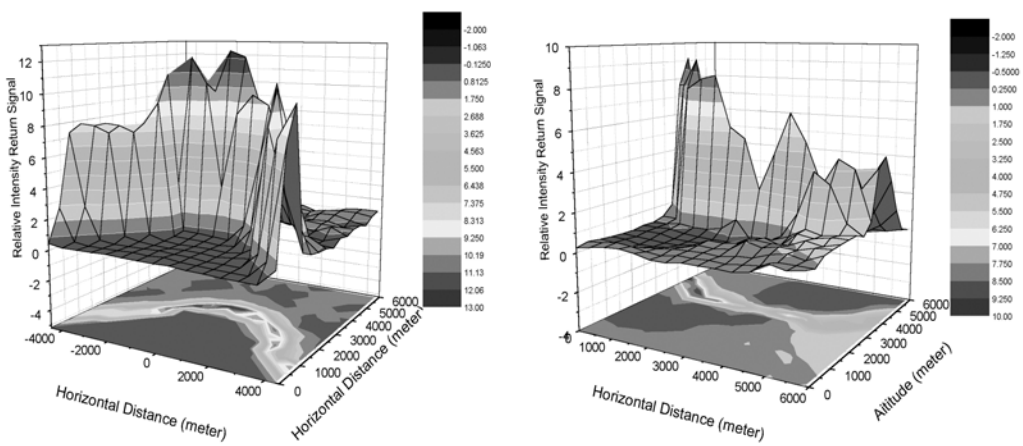
2.4 DATA ACQUISITION SYSTEM

A single-chip computer controls the scanner while an onboard computer controls the single-chip computer, laser, data acquisition, processing and display. The laser control and data acquisition is performed with Multifunction I/O board. The system software is rewritten so that a laptop computer performs data analysis, plotting, and top-level control. This will free the onboard computer to be dedicated to system control and data acquisition.

2.5 LIDAR ATMOSPHERIC DETECTION

Fig. 3 shows the actually cloud lidar detection return signal vs. scanning elevation angle. Fig. 3 shows the azimuth and elevation angle scans of a cloud layer at Hampton, Virginia, USA. From the figure, the structure of the cloud layer can be easily obtained.

A real time 4-D (3-Dimentinal plus false color data) lidar data display program is being developed. Fig. 4 shows the 3-D false color lidar data display combined with 3-D field map. Further programming work on time frame will be continued to generate the virtual reality lidar display.



(A) (B)

Fig.3. Scanning Lidar Backscatter Signal after Background Subtraction and Range Correction

(A) Hampton, USA, azimuthal scanning of a cloud with 70 degrees elevation angle,

(B) Hampton, USA, elevation scanning of a cloud

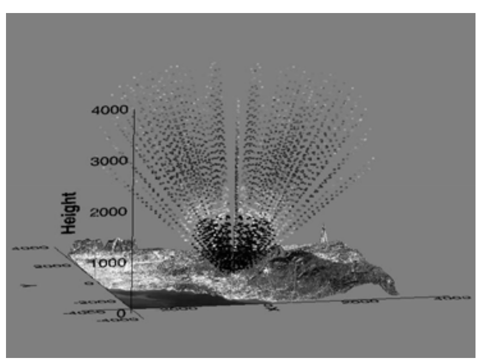


Fig.4. 3-D False Color Lidar Data Display

3 MOBILE RAMAN LIDAR

Since this system is under developing, here we briefly introduce its design consideration.

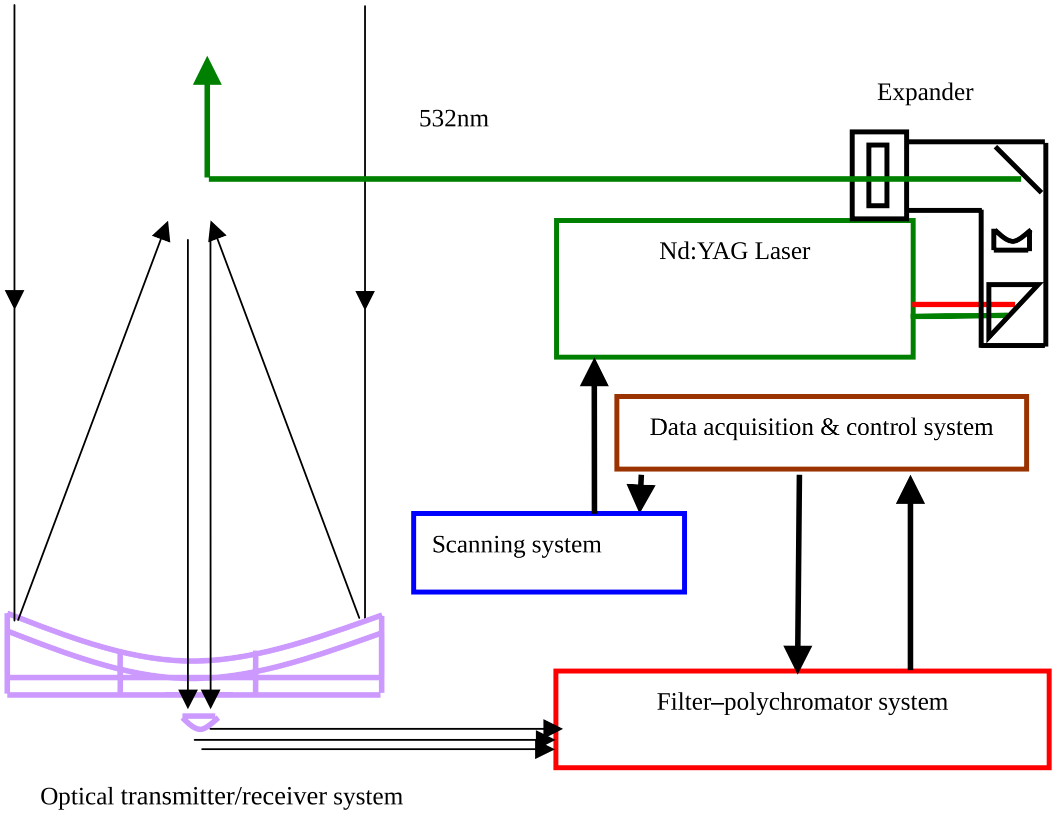


Fig.5. Mobile lidar diagram

The LIDAR system transmits double frequency Nd: YAG laser, 532nm. Since it is a scanning system, it could emit laser beam into the atmosphere at any desire direction, the backscattered light are collected by reflecting telescope and then separates into three optics channels. The mix return of atmosphere molecule and aerosol are collected by polarize and depolarize 532nm Mie channels respectively, while atmosphere molecule (N_2) signal is collected by 607nm Raman channel. The data acquisition & control system will implement filtering 、photoelectric transforming 、sampling/counting and storing the results to a computer. The lidar receiver is based on a 350mm diameter, f/4 telescope. The receiver field of view (FOV) can be adjusted from 0.5 to 3.5mrad by exchangeable diaphragms. This mirror is aluminum coated, and flat to λ/10 p-v at 607 nm. The initial spectral separation of the optical signals is carried. The initial spectral separation of the optical signals is carried out by a modified version of the filter–polychromator as described in fig.6.

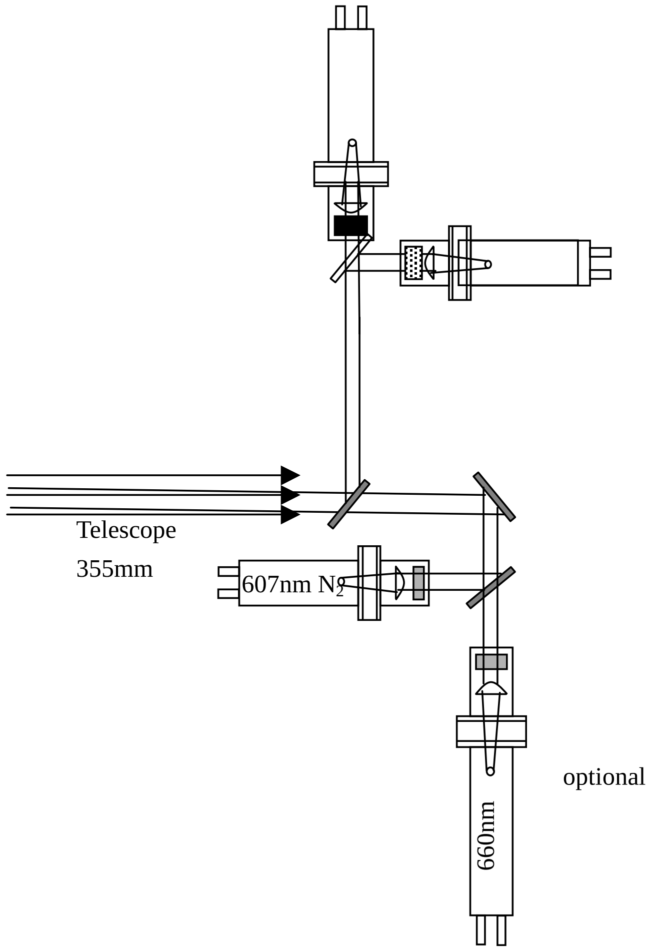


Fig.6. the filter–polychromator system

4. SUMMARYS AND CONCLUSIONS

We have developed a portable, scanning, eye-safe, backscatter lidar system for investigations of troposphere aerosols, plumes and clouds. A mathematical lidar model program was developed to enables the user to analyze the performance of this lidar. Preliminary tests of the entire lidar system have been conducted. The system behavior compares favorably with model results. A single computer utilizing LabView controls the scanner, laser, and data acquisition system. An IDL program for 3-D false color lidar data display combined with 3-D field map was developed. Two persons can transport the whole system by hand. It can be easily unloaded from a van, and within 15 minutes it begins its fieldwork powered by a gas generator. Preliminary field scanning measurements of a cloud layer have been made. Through the analysis of lidar returns, the lidar obtains spatial distribution and temporal evolution of a series of atmosphere optical parameters such as scattering, absorption and extinction coefficient of atmosphere molecular, aerosols and cloud particles, providing important information for satellite precise correction in ground-based remote sensing. Besides, the integration of the laser radar with other spectrum devices （sun photometer etc）could provide a experimental hardware platform for satellite verification and correction in ground-based remote sensing[8].

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