Development of A 3-D Scanning 1.5μm Portable Aerosol Lidar

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Abstract - **In this paper, the design, testing and field measurements with a portable, eyesafe, 85mJ, 15Hz, 1.5 micron 3-D scanning aerosol lidar system is presented.**

I. INTRODUCTION

Atmospheric laser remote sensing can be a powerful motivational tool for science education. It connects a timely and compelling concern for the environment with cutting edge technologies. Its interdisciplinary nature enables students throughout the natural sciences and engineering to contribute their own unique training to a collaborative research project.

Hampton University's Center for Lidar and Atmospheric Sciences Students (CLASS) team and ITT's Advanced Engineering & Sciences Division have worked together to develop a portable, eyesafe and scanning aerosol lidar system.[1,2] The system is based on a 1.5 micron, 85 mJ, 15 Hz eye-safe Optical Parametric Oscillator (OPO). Its purpose is to remotely detect aerosols, clouds, and pollution in the lower atmosphere. The CLASS project is a 5-year undergraduate research training program funded by NASA to educate students in atmospheric science and lidar technologies. The CLASS lidar team has designed, constructed, tested, and is currently using the lidar. In this paper, we will focus primarily on the joint Hampton University-NASA-ITT design, testing and field measurements with this lidar system for student education, research training and outreach.

Figure 1: The CLASS lidar system.

The CLASS Lidar is a powerful tool to meet the goals of: (1) providing education and training in NASA-related technology and science to U.S. students who are underrepresented in areas of interest to NASA, (2) encouraging these students to achieve advanced degrees, and (3) integrating educational curriculum with research training.

II. LIDAR SYSTEM DESIGN CONSIDERATIONS

A single-wavelength elastic backscatter lidar is probably the most conceptually simple lidar system. Despite this apparent simplicity, few portable, eyesafe, scanning lidar systems exist with sufficient pulse energies to make rapid 3-dimensional mapping of the atmosphere.[3,4,5] These

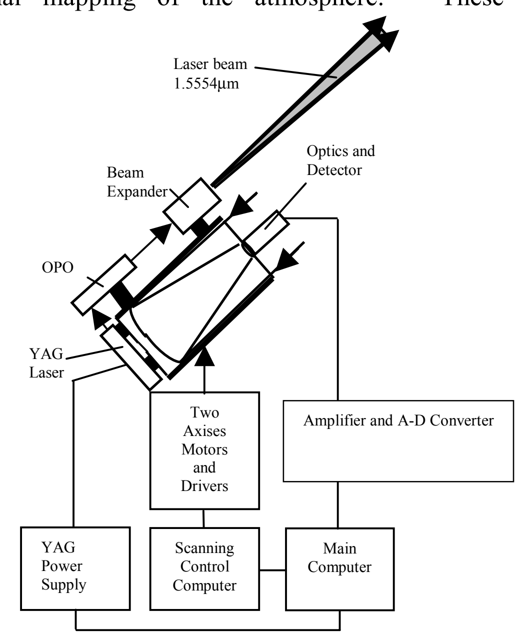


Figure 2. The Schematic Structure of the CLASS Lidar

capabilities constituted the initial general design goals. The schematic structure of the CLASS Lidar is shown in figure 2.

III. LIDAR TRANSCEIVER MODULE

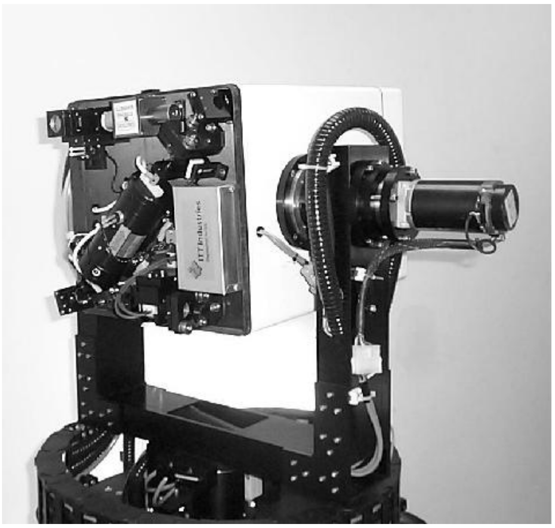


Figure 3: Laser transmitter compartment.

The lidar transceiver module is a lightweight reinforced graphite epoxy structure with dimensions 12.5” x 12.5” x 16” shown in figure 1. It was designed by Hampton University students and faculty and fabricated by ITT. 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 (Figure 3). The transceiver box is mounted on a computer-controlled scanner made by Torus Technologies (Figure 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 azimuthal and elevation angles with an angular resolution of 0.3 mrad and maximum scanning speed of 2 rad/sec.

IV. 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 (Figure 3).[6] An optical isolator with an optical transmission of 90% protects the laser from optical reflections from the OPO. The Type II KTA OPO is shown schematically in Figure 4.

An eyesafety analysis for the system led to the atmospheric transmission window at 1.5554 microns to be chosen for the OPO wavelength, as shown in Fig.5. The slope efficiency for the OPO is 30%, as shown in Fig.6. The bandwidth of the OPO is approximately 0.6 nm (FWHM). The OPO is resonant on the idler wavelength in the 3-micron spectral region. The beam is transmitted biaxially through the beam expander assembly shown in the lower left corner of the front of the transceiver box in Figure 7.

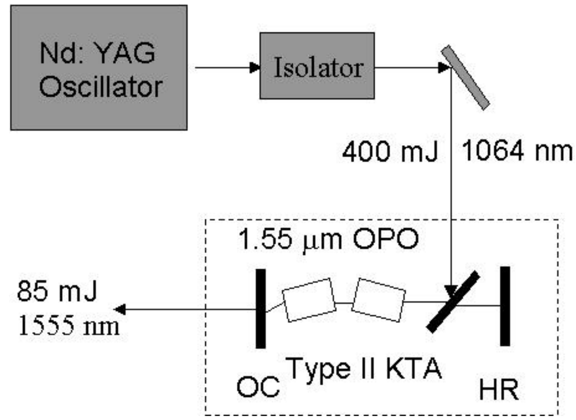


Figure 4. The Eyesafe Laser Transmitter

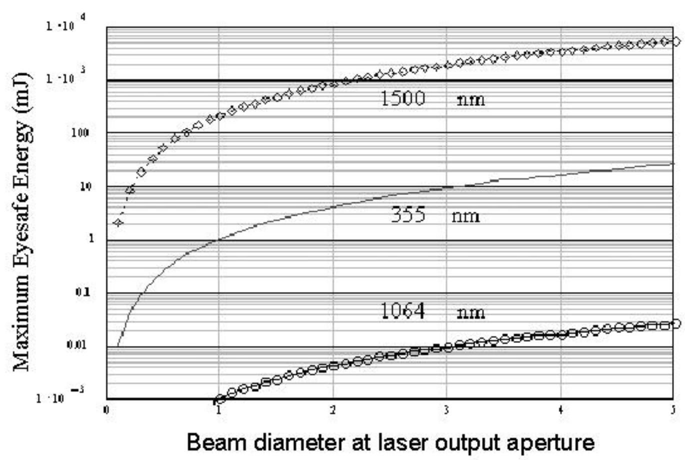


Figure 5. Maximum permissible exposure vs. laser beam diameter

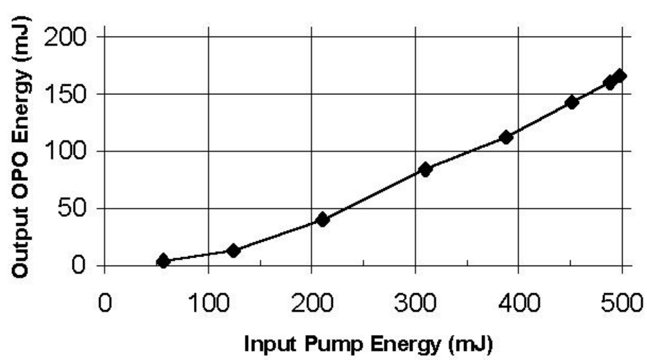


Figure 6. Conversion efficiency of the OPO transmitter.

After integration into the transceiver box, the OPO was recharacterized. Its pulse-to-pulse energy stability was also measured and the relative energy fluctuations (standard deviation/mean for 100 shots) was 2%. Approximately 5% of the total energy emanating from the OPO output coupler (OC) was found to be a combination of 532 nm (due to parasitic doubling), 1064 nm and 3 microns (the idler). The dominant contribution was 1064 nm. An additional filter has been included in the beam expander to ensure eyesafety.

V. LIDAR RECEIVER

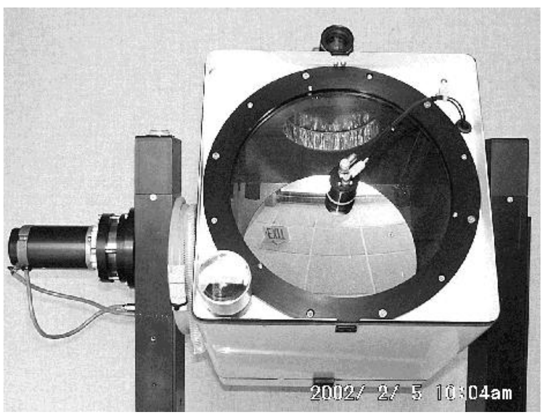


Figure 7. Lidar Receiver

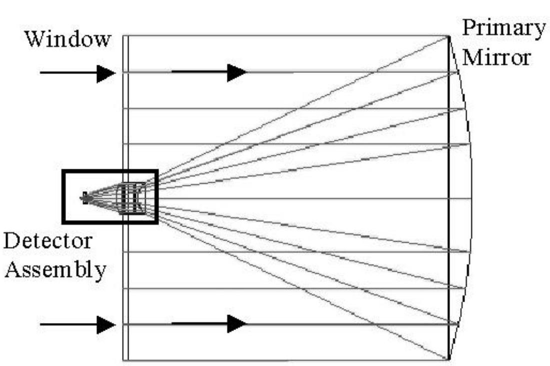


Figure 8. Receiver Optical Layout: Major Components.

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 (not currently installed) 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 EG&G C30662 series InGaAs APD, as shown in Fig.8 and

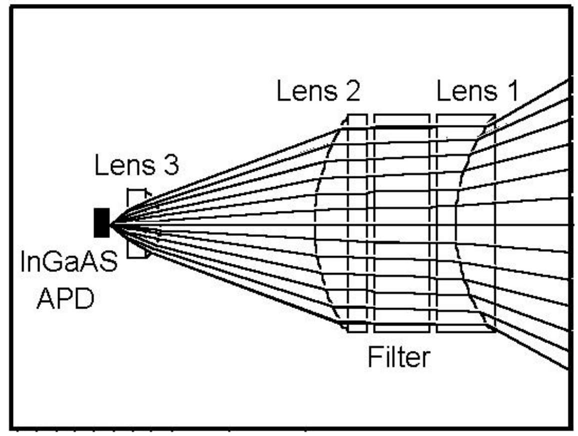


Figure 9. Receiver optical layout: detector assembly

Fig.9. For a source at infinity, the optical throughput onto the detector active area is calculated by ray trace to be ~96%, with 2% of the loss arising from the central obscuration. This calculation does not take into account the ~70% transmission of the optical filter.

The effective focal length of the receiver was calculated with a commercial ray-tracing program (ZEMAX®) to be 166 mm. For a 0.20 mm detector area, this yields a FOV of 1.2 mrad. 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.

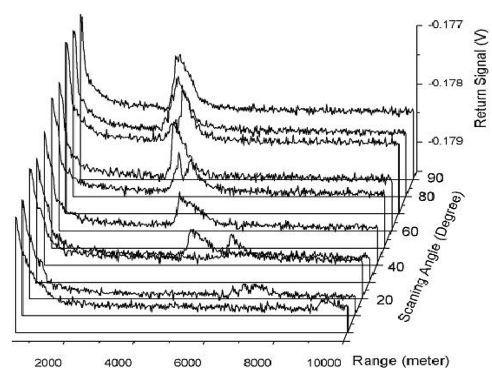
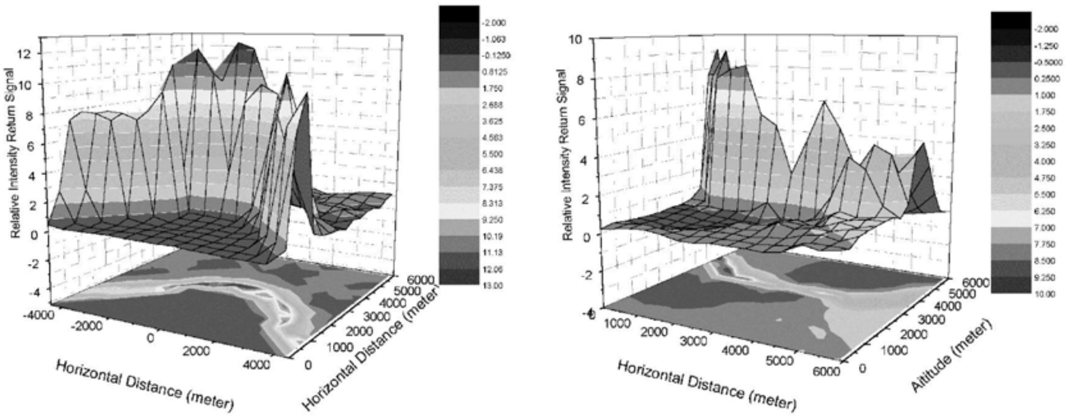


Figure 10. Lidar Return Signal vs. Elevation Angle

VI. DATA ACQUISITION SYSTEM

A singlechip computer runs LYNX to control the scanner while an onboard computer running LabVIEW controls the singlechip computer, laser, data acquisition, processing and display. The laser control and data acquisition is performed with a National Instruments Multifunction I/O board (sample rate = 5MHz). The



(A) (B)

Figure 11. Scanning Lidar Backscatter Signal After Background Subtraction and Range Correction
(A) Jan-02-2002, Hampton, USA, azimuthal scanning of a cloud with 70 degrees elevation angle,
(B) Jan-02-2002, Hampton, USA, elevation scanning of a cloud

system software is currently being 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.

VII. LIDAR ATMOSPHERIC DETECTION

Fig.10 shows the actual cloud lidar detection return signal vs. scanning elevation angle. Fig.11 shows the azimuthal and elevation angle scans of a cloud layer at Hampton, Virginia, USA. From the figure, the structure of the cloud layer can easily be obtained.

VIII. CONCLUSIONS

We are developing a portable, scanning, eyesafe, backscatter lidar system for investigations of troposphere aerosols, plumes and clouds. 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. With two persons, the system can be transported by van, unloaded and set up within 15 minutes. It is powered by a portable gas generator. Preliminary scanning measurements of a cloud layer have been made.

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