26PA11 ETL'S TRANSPORTABLE LOWER TROPOSPHERE OZONE LIDAR

Yanzeng Zhao

Cooperative Institute for Research in Environmental Sciences, University of Colorado/NOAA
NOAA/ERL/ETL R/E/ET2, 325 Broadway, Boulder, CO 80303, USA
Phone: 1-303-497-6567 Fax: 1-303-497-5318 E-mail: yzhao@wpl.erl.gov

James N. Howell and R. Michael Hardesty

NOAA/ERL/Environmental Technology Laboratory
NOAA/ERL/ETL R/E/ET2, 325 Broadway, Boulder, CO 80303, USA

1. INTRODUCTION

A very compact, transportable differential absorption lidar (DIAL) specifically designed for ozone and aerosol profiling in the lower troposphere (from near surface to about 3 km) has been developed at the National Oceanic and Atmospheric Administration's Environmental Technology Laboratory (ETL), formerly Wave Propagation Laboratory (WPL). The ETL ozone lidar[1] has the capability of measuring ozone concentration and aerosol profiles from ~100 m to ~3 km with high range resolution. The maximum detection range is comparable or greater than much bigger and more powerful ozone lidar systems. The near range coverage is unique. The efficiency and the compactness of the lidar due to the innovative hardware design and improved signal processing technique make the system not expensive, and easily transportable. The instrument has been tested in Boulder Colorado, and employed in two field experiments in California. Interesting results from the field experiments have shown that both air quality monitoring and atmospheric chemistry studies can benefit significantly from the continuous high resolution ozone-profiles observed by the ETL lidar.

2. THE OZONE DIAL SYSTEM

A. Design Considerations

- To obtain a higher range resolution for lower troposphere ozone profiling, a wavelength pair, 266 nm and 289 nm, with high differential absorption coefficient, has been selected. With such a wavelength-pair the ETL system can measure ozone profiles with a range-resolution of several tens of meters in the lower boundary layer to about 200-300 m at 3 km. The corresponding maximum detection range is restricted to ~3 km because of the strong absorption of ozone at 266 nm. Choosing 266 nm as the on-line wavelength also allows us to use a frequency-quadrupled Nd:YAG laser. The compact-sized Nd:YAG laser significantly reduces the size of the lidar system.

- To reduce the signal dynamic range and obtain a good range coverage, we have designed a multibeam transmitter.[2] This design also helps to increase the system efficiency and thus to reduce the size of the lidar, due to the fact that the detector gain can be fully utilized.

- To minimize the size of the system for better transportability, high system optical efficiency is required. Besides a multibeam transmitter, we have used the following methodologies:
  (a) Improving the optical efficiency of the detector package at UV wavelengths. The optical transmission in our system is made much higher by using a combination of a solar-blind filter (with high transmission from 240-340 nm) and a series of dichroic mirrors to reject background radiation with wavelength longer than 300 nm and separate the two wavelengths while maintaining high transmission. Thus the major limit for this filtering technique is the transmission of the solar-blind filter, typically 70-75%. This is ten times higher than that of a narrow band

interferometer.

(b) Optimizing the Raman shift optical configuration. In order to save energy at 266 nm, we choose a different configuration than is commonly employed. The Raman cell is pumped by the residual energy of the YAG laser at 532 nm. The pumping wavelength is Raman-shifted to 632.5 nm. The off-line wavelength 289 nm is then generated by sum-frequency-mixing the 632.5 and 532 nm wavelengths through a BBO crystal.

(c) Improving signal processing techniques, especially numerical differentiation.

B. System Description

The block diagram of the ozone lidar is shown in Fig. 1. The transmitter and the receiver are assembled on an optical breadboard 1.65 m long and 0.75 m wide. The height of the transmitter and receiver are about 0.6 m. The optical layout of the transmitter is shown in Fig. 2. A Continuum Nd:YAG laser (Model NY61-10) is used in the transmitter. The 10-Hz Nd:YAG laser is frequency-doubled (532 nm) and quadrupled (266 nm) and exits the output aperture as a single, three-color beam. The output energy at 266 nm is adjusted much lower than the maximum output to save the down-stream optics, within the range of 20 to 40 mJ. The energy at 289 nm is in the range of 0.5-4 mJ. The two UV beams are adjusted collinear with an angle difference less than 50 μrad. This angle is further reduced by a 3X beam expander to less than 17 μrad. The receiver consists of a well-baffled Newtonian telescope with an 8 inch diameter off-axis parabolic primary mirror and a field of view of 1.0 mrad. The output beam of the telescope is then directed into a four-wavelength detector package. The transmitted beams are precisely aligned to the receiver using lateral transfer retroreflectors and periscopes to an accuracy of better than $\pm 50 \mu$rad. Calibration of the system is carried out in horizontal direction when the atmosphere is horizontally homogeneous.

At present, a temporary data acquisition and processing system based on an IBM-486 pc is employed. Lidar signals at 532 and 1064 nm are digitized by a two-channel, 8-bit, 64 MHz digitizer, and the UV signals are digitized by a two-channel, 12-bit, 10 MHz digitizer.

The lidar is installed in a mobile laboratory, modified from a 20-foot sea-container. Thus the lidar is transportable. A movable temporary scanning mirror set can be installed on top of the sea-container to steer the beams in the horizontal direction (with a $\pm 15°$ scanning capability) for horizontal and low-elevation observations and system calibrations. The system will have a full elevation and azimuth scanning capability next year.

3. FIELD EXPERIMENTS OF THE OZONE LIDAR

The ETL ozone lidar was first tested in horizontal direction in early 1993 in Boulder, Colorado. The observations have demonstrated the unique features of this lidar and verified the design concepts. Very good agreements (less than 5 ppb) on surface ozone mixing ratio between the ozone lidar and an UV ozone analyzer were obtained.

The lidar was then employed in two field experiments sponsored by the California Air Resources Board. The first was an intercomparison experiment between the ozone lidar and an airborne UV ozone analyzer from the University of California-Davis, carried out near Davis, California during July 1993. A very preliminary data analysis for one case shows that the differences of the ozone mixing ratio between the *in situ* measurements (courtesy of J. Carroll of UC-Davis) and the lidar measurements are less than 10 ppb. The second field experiment involving the ozone lidar was *the Free Radical Study* experiment in the Los Angeles basin during September 1993. The lidar and other instruments were located at a site (433 m MSL) approximately 60 km east of downtown Los Angeles, in Claremont, California. Under high pressure weather systems, the prevailing surface wind is southwestly in the afternoon, carrying polluted air from the west and central part of Los Angeles inland to the site. The pollutants are trapped in a shallow marine boundary layer, and become stagnant. During the experiment period, we experienced the highest surface ozone episode observed during 1993 in the Los Angeles basin. Examples of the results will be presented. One of the ozone profile at the peak and the balloon measured temperature profile are shown in Fig. 3.

4. REFERENCES

1. Yanzeng Zhao, James N. Howell, and R. Michael Hardesty, "Transportable Lidar for the Measurement of Ozone Concentration and Aerosol Profiles in the Lower Troposphere," A&WMA/SPIE *International Symposium on Optical Sensing for Environmental Monitoring*, October 11-14, 1993, Atlanta, Georgia. (Will be published in SPIE Proceedings Vol. 2112)

2. Yanzeng Zhao and R. Michael Hardesty, "A Multibeam Transmitter for Signal Dynamic Range Reduction in Incoherent Lidar Systems," *Appl. Opt.* **31** 7623-7632 (1992).

BLOCK DIAGRAM OF THE OZONE LIDAR

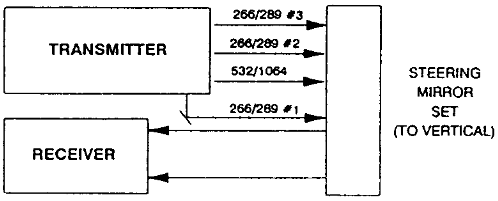


Fig. 1

OPTICAL LAYOUT OF THE OZONE LIDAR TRANSMITTER

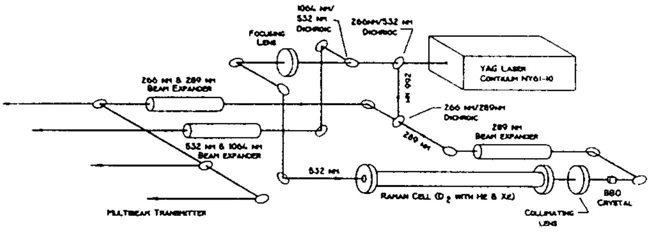
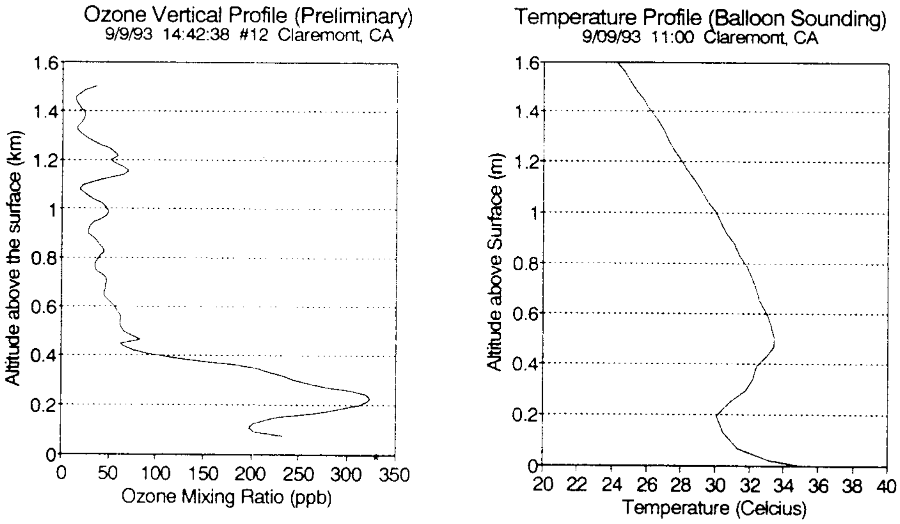


Fig. 2


Ozone Vertical Profile (Preliminary)
9/9/93 14:42:38 #12 Claremont, CA

Temperature Profile (Balloon Sounding)
9/09/93 11:00 Claremont, CA

Fig. 3