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POLARIZATION LIDAR FOR ATMOSPHERIC MONITORING

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ABSTRACT

Aerosol plays an important role in global climate and weather changes. Polarization lidar captures parallel and perpendicular signals from atmosphere to research aerosols. The lidar system we used has three emission wavelengths and could obtain the atmospheric aerosol extinction coefficient, backscattering coefficient and depolarization ratio. In this paper, the design of the lidar is described. The methods of data acquisition and inversion are given. Some recent results are presented.

1 INTRODUCTION

Lidar is a powerful tool for atmospheric aerosols monitoring with high temporal resolution [1-4]. Aerosol plays an important role in global climate and weather changes. The traditional Mie scattering lidar technique assumes the aerosol particles are spherical and homogeneous [5]. But it is not consistent with the actual atmospheric environment. Non-spherical or inhomogeneous particles will introduce a depolarized component into the backscattering. Lidar polarization technique greatly expands the capabilities of atmospheric monitoring [6-10]. Polarization lidar transmits a linearly polarized laser pulse and uses a beam splitter to separate the perpendicular and parallel signals of the backscattered light. The ratio of these two signals can be used to analyze the physical and optical characteristics of the aerosols and clouds.

2 METHODOLOGY

The lidar system we established has three emission wavelengths and six receiving channels. It could obtain the atmospheric aerosol extinction coefficient, backscattering coefficient at 355nm, 532nm and 1064nm, and depolarization ratio at 532nm. The system layout is depicted below the figure 1.

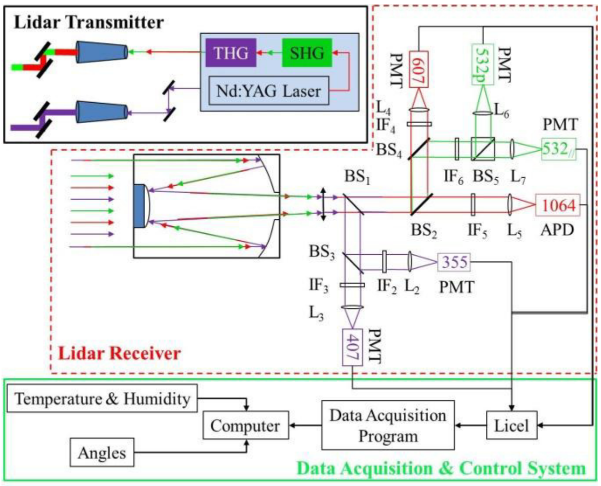

Figure 1 Design of lidar system

The system is based on a Nd:YAG laser followed by a second- and a third-harmonic generator, the whole emitting at the 355 nm, 532 nm and 1064 nm wavelengths. The receiver telescope is a Schmidt-Cassegrain telescope with 300mm diameter. The system has six receiving channels. They collect elastic scattering signals at 355nm, 1064nm, Raman scattering signals at 407nm, 607nm, and the parallel and perpendicular signals at 532nm. Signals are detected by photomultiplier tubes and APD as indicated in fig.1. This system can detect the atmospheric aerosol extinction coefficient, backscattering coefficient and depolarization ratio. System parameters and photo are showed in table 1 and figure 2, respectively.

Table 1 Lidar system parameters

Laser	Nd:YAG
Wavelength	355, 532 and 1064 nm
Single Pulse Energy	80 mJ@355 nm, 50mJ@532 nm,

	100mJ@1064 nm
Repetition Rate	20 Hz
Divergence Angle	0.15 mrad
Telescope type	Schmidt-Cassegrain
Telescope diamater	300mm
Telescope FOV	0.3mrad

Figure 2 Photo of lidar system

The range(r)-resolved volume linear depolarization ratio δ is defined as

$$\delta(r)=\frac{p_{rs}(r)/k_s}{p_{rp}(r)/k_p}=\frac{\beta_s(r)}{\beta_p(r)}\exp\{\int_0^r[\alpha_p(r')-\alpha_s(r')]dr'\} \qquad (1)$$

where $p_{rs}(r)$ and $p_{rp}(r)$ are the lidar signals with polarization perpendicular and parallel to the polarization of the transmitted laser light, respectively. k_s and k_p are the system constants of perpendicular and parallel channels. $\beta_p(r)$ and $\beta_s(r)$ are the backscatter coefficients for scattering parallel and perpendicular relative to the polarization of the transmitted laser beam. $\alpha_p(r)$ and $\alpha_s(r)$ are parallel and perpendicular components of extinction coefficient at the distance r. Normally, $\alpha_p(r)=\alpha_s(r)$ [11], so

$$\delta(r)=\frac{\beta_s(r)}{\beta_p(r)}=k\frac{P_{rs}(r)}{P_{rp}(r)} \qquad (2)$$

Where $k=k_p/k_s$, is a calibration factor.

3 RESULTS

Examples of the measurement results are depicted in figure 3, figure 4 and figure 5. They all show 24-hour continuous monitoring of volume depolarization ratio on different days in September, 2015. Clouds exist between 6 and 9 kilometers in figure 3, between 8 and 10 kilometers in figure 4. In figure 5, clouds exist at above 10 kilometers and dropped to about 7 kilometers gradually. Figure 6 shows aerosol extinction coefficient profile at 3:01am on September 18th. It seems that extinction coefficient increases between 10 and 12km at 3:01am, which has the same trend with figure 5.

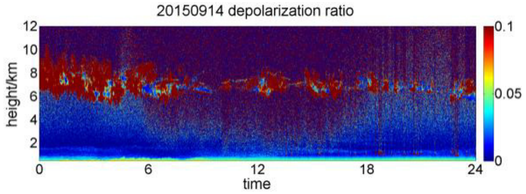

Figure 3 The depolarization ratio on September 14th,2015

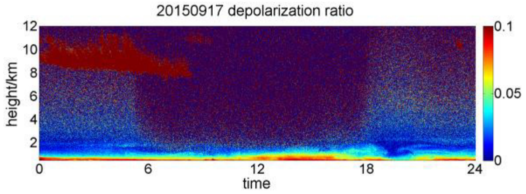

Figure 4 The depolarization ratio on September 17th,2015

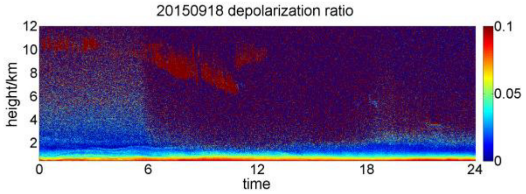

Figure 5 The depolarization ratio on September 18th,2015

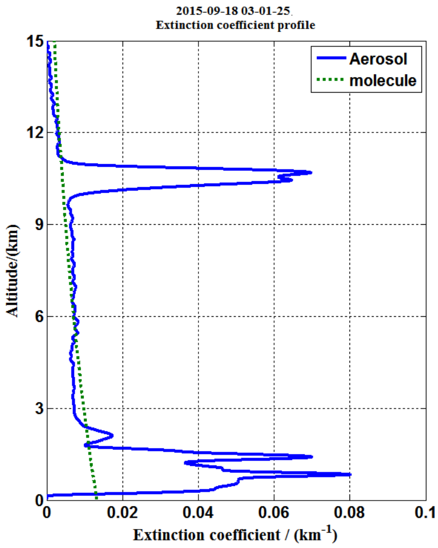

Figure 6 The aerosol extinction coefficient profile at 3:01am on September 18th

4 CONCLUSIONS

A polarization lidar system has been developed for atmospheric monitoring. Designs of the lidar system and the inversion method used to obtain depolarization ratio are discussed. Some recent results measured are also presented. Further research and analysis should to be done to get more understanding about the non-spherical particles and clouds in the atmosphere.

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References

[1] Measures, R.M., 1984. Laser Remote Sensing, Fundamentals and Applications, pp. 259-269, John Wiley and Sons, New York.

[2] Bates T., Huebert B., Gras J., Griffiths F., Durkee P., 1998. International global atmospheric chemistry (IGAC) projects's first aerosol characterization experiment (ACE 1): overview, Journal of Geophysical Research, 103(D13), pp. 16297-16318.

[3] H. Takahashi, H. Naoe, Y. Igarashi, Y. Inomata and N. Sugimoto, 2010. Aerosol concentrations observed at Mt. Haruna, Japan, in relation to long-range transport of Asian mineral dust aerosols, Atmospheric Environment, 44(36), pp. 4638-4644.

[4] J. N. PORTER, B. R. LIENERT et al, 2002: A Small Portable Mie–Rayleigh Lidar System to Measure Aerosol Optical and Spatial Properties , Journal of Atmospheric and oceanic Technology, VOL 19, 1873

[5] Klett J D, 1981: Stable analytical inversion solution for processing lidar returns, Appl Opt., 20(2), 211

[6] Allen, R.J., and C.M.R. Platt, 1977: Lidar for multiple backscattering and depolarization observations. Appl. Opt., 16,3193

[7] G.P.Gobbi: Polarization Lidar return from aerosols and thin clouds: a framework for the analysis. Applied Optics, 1998, vol.37, No.24, pp5505-5508.

[8] O.Uchino, I.Tabata, K.Kai and Y.Okada: Polarization Properties of Middle and High Lever Clouds Observed by Lidar. J. Meteor. Soc. Japan, 1988, vol.66, pp607-616

[9] R.M.Schotland, K.Sassen and R.Stone: Observation by Lidar of Linear Depolarization Ratios for Hydrometeors. J. Appl. Meteor. 1971, Vol.10, pp1011-1017

[10] Pal, S.R., and A.I. Carswell, 1973: Polarization properties of lidar backscattering from clouds. Appl. Opt.,12,1530.

[11] K.Sassen: Lidar Backscatter Depolarization Technique for Cloud and Aerosol Research. pp.393-416.