DEVELOPMENT OF A TWO-WAVELENGTH LIDAR SYSTEM WITH TWO RECEIVE CHANNELS

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ABSTRACT

A simple solution for lidar system to receive backscattering returns from both near and far distance synchronously is presented. And a two-wavelength lidar system with two receive channels is described. With which the atmospheric extinction profiles from almost ground to a high altitude can be measured. Besides, a convenient method for the lidar overlap correction is also given is this paper.

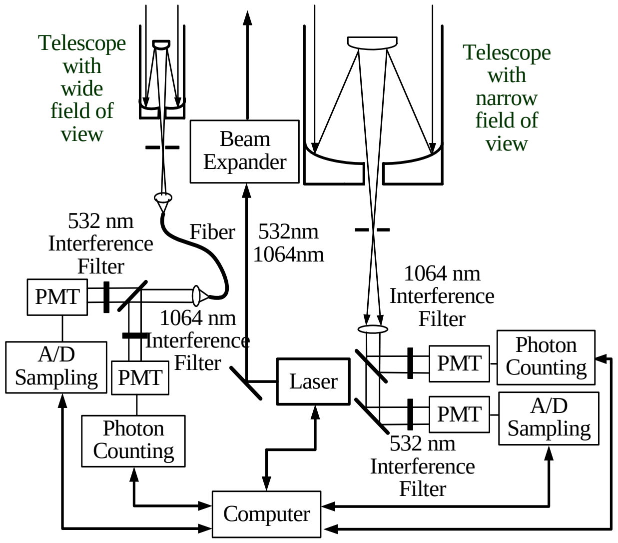

Fig. 1. Diagram of the two-wavelength two receive channels lidar system.

1. INTRODUCTION

Lidar is a stand-alone remote sensor that provides the user with range-dependent atmospheric backscattering coefficients, attenuated by the path-integrated extinction coefficients over distances as great as several tens of kilometers. One of the interesting applications of lidar is that it can measure atmospheric extinction profiles at wavelengths from the ultraviolet to the infrared. Generally, the lidar return signal is expected to be available staring from the ground to as far as possible, however, in practice this is ordinarily not the case. Usually lidar returns from near distances are suppressed in order to handle the large dynamic range, but in some instance, the signal from near distance is vital, such as the near-ground air pollution monitoring. A solution is using two detectors to receive the signals from near distance and far distance individually. This method really can handle the large dynamic range but there still is a conflict between the requests for receiving the near signal and far signal. To receive the return signal from as near as possible, the field of view (FOV) of the telescope in lidar system is expected to be as wide as possible, but in far distance the return signal is very faintness, to enhance the sensitivity and heighten the detecting distance, the FOV of the telescope must be narrow enough to suppress the background lights. To solve this problem, we developed a lidar system with two receive channels, which can deal with the return signals from both near distance and far distance faultlessly. Furthermore, to inversion the atmospheric extinction more exactly, two wavelength channels are included in this lidar system. [1]

2. EXPERIMENTAL SETUP

A schematic of the lidar system is shown in Fig. 1. The system contains two optical receivers. One is a Schmidt-Cassegrain telescope with aperture of 200 mm and FOV of 4 mrad, which is employed to receive the backscattering signal lights from near distance, the other one is also a Schmidt-Cassegrain telescope but with aperture of 400 mm and FOV of 1 mrad, which is employed to receive the backscattering signal lights from far distance. There is only one laser transmitter is the system, which is a Nd:YAG laser and emits laser beams at both 532 nm and 1064 nm wavelength. The output of the laser is expanded to decrease the divergence to approximate 0.3 mrad to enable daytime operation. A list of the main system parameters is given in Table. 1.

The bigger telescope is stationary and upward looking vertically, the backscattering signal lights collected by it is focused through a field-stop iris and collimated by lens, then a dichroic beam splitter is used to separate it into the 532 nm and 1064 nm channels with each

Table. 1. Main System Parameters for the Lidar

	532 channel	1064 channel
Transmitter:		
Pulse energy (mJ)	120	90
Pulse Length (ns)	7	7
Repetition rate (Hz)	10	10
Beam divergence (after expanding) (mrad)	0.3	0.3
Receiver:		
Telescope aperture (mm)	200	400
Interference filter bandwidth (FWHM) (nm)	0.25	0.5
Field of view (mrad)	4	1
Spatial resolution (m)	30	

channel followed by a interference filter and a photon multiplier tube (PMT). Subsequently, a photon counting system composed of preamplifier, discriminator, and multichannel analyzer is used to gather the signal pulses in 1064 nm channel. Considering the greater signal level and higher quanta efficiency of the PMT, an A/D sampling system is adopted instead in 532 nm channel.
The smaller telescope can be pointed to both vertical and horizontal directions, the subsequence optics and detecting system following it is almost the same with the bigger one but an optic fiber is employed to couple the signal lights, which allows flexibility of changing the looking direction. The ability of horizontally directing of the lidar is essential for retrieving the atmospheric horizontal visibility, furthermore it can let the correction of the overlap factor for lidar returns from near distance be easy.

3. OVERLAP FACTOR CORRECTION

To inverse the atmospheric extinction from the backscattering signal at near distance correctly, the overlap factor of the lidar must be amended. In this system, the overlap factor can be corrected conveniently. For the nonabsorbing, elastic scattering atmosphere a monostatic single-scattering lidar equation is given as:

$$P(z) = C\eta(z)\frac{\beta(z)}{z^2}\exp\left[-2\int_0^z \sigma(z')dz'\right] \quad (1)$$

where *P(z)* is the return signal from the range z, *C* is the lidar system constant, *η(z)* is the overlap factor at a distance *z*, *β(z)* and *σ(z)* are the volume backscatter and extinction coefficients of the atmosphere at distance *z* respectively. With the logarithmic range-corrected signal which is defined as [2]:

$$S(z) = \ln[z^2 P(z)] \quad (2)$$

the lidar equation can be expressed in form of:

$$S(z) = \ln[C\beta(z)] + \ln[\eta(z)] - 2z\sigma(z) \quad (3)$$

Supposed that the signals are without impact of the overlap factor (namely $\eta=1$), there will be:

$$S_m(z) = \ln[C\beta(z)] - 2z\sigma(z) \quad (4)$$

This is the truth when $z > z_R$, where z_R is the distance that the laser beam is overlapped with the FOV of telescope entirely. Considering the horizontal atmosphere is homogeneous, when the lidar is operated horizontally, the backscatter and extinction coefficients are both constant, and S_m is a liner function of the range *z*. So $S_m(z)$ at $z < z_R$ can be obtained by liner fit of the actual signal *S(z)* at $z > z_R$. According to the Eq. 3 and Eq.4, the lidar overlap factor is given by:

$$\eta(z) = \exp[S(z) - S_m(z)] \quad (5)$$

In our lidar system, the overlap factor obtained by this mean is for the smaller telescope, the bigger telescope is used to receive the returns from far distance, so it does not need an overlap correction.

4. CONCLUSION

In this paper a two receive channels solution of the lidar system is presented, by which the atmospheric extinction profiles staring from almost the ground to a high altitude can be measured easily both in nighttime and daytime. The key point of this lidar system is using two telescopes with different FOV to receive the backscattering lights from near distance and far distance individually. A convenient method for correcting the overlap factor of the near distance lidar returns is also given. There is an overlapping effective region of the signal received by the two telescopes, so the lidar can be calibrated by itself, which is great helpful for the veracity of the atmospheric parameters inversion.

5. REFERENCE

1. Gerard J. Kunz, Two-wavelength lidar inversion algorithm, *Appl. Opt*. Vol. 38, 1015–1020, 1999.
2. James D.Klett, Stable analytical inversion solution for processing lidar returns, *Appl.Opt*.Vol.20, 211-220, 1981.