HIGH-SPECTRAL-RESOLUTION LIDAR FOR ACCURATE OBSERVATION OF AEROSOL, CIRRUS CLOUDS AND WATER VAPOR PROFILIES AT XI’AN, CHINA

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ABSTRACT

A high-spectral-resolution lidar has been developed at Xi’an, the northwest part of China for accurate observation of the aerosol, cirrus clouds and water vapor profiles simultaneously. A single frequency pulsed Nd:YAG laser at 355nm is employed as a transmitter. A high-resolution grating is used to separate the Mie-Rayleigh scattering, water vapor Raman scattering spatially and to block the solar background. The Mie and Rayleigh scattering are then accurately separated by use of a Fabry-Perot etalon with dual-pass optical layout. A polarizing prism is set at the zero-order diffraction of the grating for detection of depolarization ratio of cirrus clouds and Asian dust. The paper will describe the lidar system and show the preliminary experimental results.

1. INTRODUCTION

Aerosol, cirrus clouds and water vapor are important basic meteorological parameters of the atmosphere, which affect the Earth’s radiation budget seriously. On the other hand, aerosol and water vapor distributions are highly variable in space and time and are affected easily by nature and human activities. Accurate observation of aerosol and water vapor are essential for improvement of weather forecasting and research of mechanism of atmospheric circulation, such as, cloud formation, rainfall and so on.

Optical extinctions or the optical depths of the clouds are one of more important atmosphere optical properties, and several methods were developed for derivation of the this parameter by using a single-[1]or multi-wavelength[2-3] Mie scattering lidar. However, for general Mie lidar, in order to determine the extinctions, some assumption conditions are commonly required, which may lead to measurement uncertainties largely.

Recently, a high-spectral-resolution lidar (HSRL)[4-7] has been demonstrated to be as an effective tool for accurate observation of aerosol optical properties without prior assumptions. By using the difference on the line-width of the Mie- and Rayleigh- spectrum, generally, the HSRL employs special atomic/molecular absorption filter or narrow bandpass filter to separate the Mie- and Rayleigh- signals spectrally. Because two separated signals are detected independently, the HSRL is permitted to measure the extinction and backscatter cross-section independently and allows the backscatter coefficient to be computed accurately.

The purpose of our study is to develop a HSRL system at 355nm, which has a potential not only for accurate observation of the extinction of aerosol, Asia dust and cirrus clouds, but also for water vapor profiles simultaneously. In this paper, the HSRL built in Xi’an, China is presented and its performance will be discussed.

2. CONFIGURATION OF LIDAR SYSTEM

Figure 1 shows a spectral diagram of the backscattered lidar signals and the filter. One narrow bandpass filter located at high-frequency wing of the Rayleigh spectrum is used to detect the backscattered Rayleigh signal. For blocking the effect of Mie scattering effectively, the filter is constructed with a dual-pass optical layout optically. A schematic of the HSRL system is shown in Fig.2.

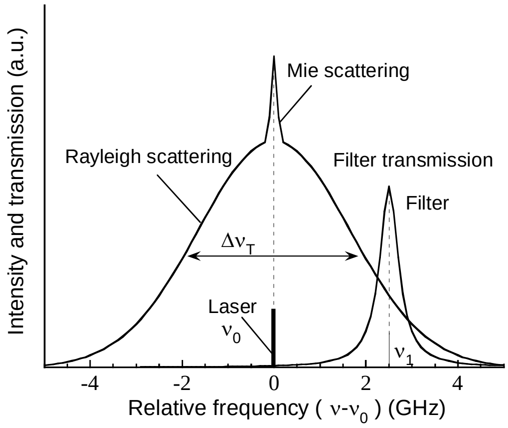

Fig.1 Spectral diagram of the backscattered lidar signals and the filter

UV output of the third harmonics of the injection seeded, pulsed Nd:YAG laser (Continuum PL8020 type) at 355-nm is collimated by the beam expander and transmitted into the atmosphere. The 25cm-dimater telescope collects the atmospheric backscattering light and couples into a multimode fiber. The fiber sets a field of view (FOV) of the telescope at 0.1mrad. The output of the fiber is collimated again and sent directly into a high-resolution grating.

The grating diffracts the lidar return signals spectrally; the water vapor vibration Raman signal centered at 407.5 nm is separated and then detected by photomultiplier tube (PMT-3). The Rayleigh scattering signal, which is used for the retrieval of the water vapor density and correcting the extinctions, is filtered effectively by use of a narrow bandpass filter with a dual-pass optical layout and then detected by PMT-2. PMT-1 used as an energy monitor monitors the intensity of return signal.

The zero-order diffraction of the grating used for measuring the depolarization ratio is directed to a polarizing prism and then the two return signals in a perpendicular/parallel polarization relative to the outgoing laser light are detected by PMT-4 and PMT-5 respectively. The parameters of the lidar system are given in Table1. The etalon passband is stabilized with a highly accurate temperature controller and the laser frequency can be adjusted and locked by scanning the frequency of seed laser.

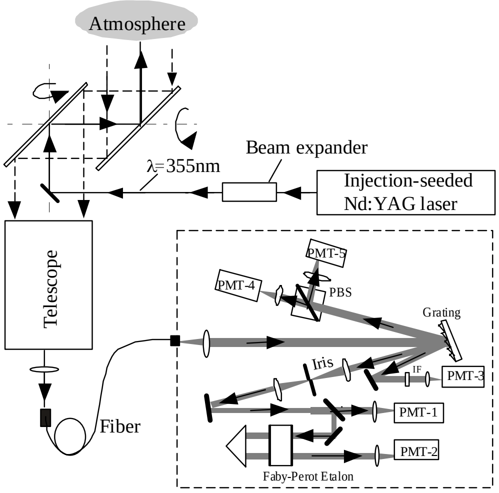

Fig. 2 Schematic of the HSRL system.

Table 1 Parameters of the HSRL

Laser: Injection-seeded Nd:YAG	
Wavelength	354.7 nm
Maximum energy per pulse	200 mJ
Pulse repetition rate	20 Hz
Optics:	
Telescope diameter	250 mm
Field of view	0.1 mrad
Grating	2400 gv/mm
Fabry-Perot Etalon (Freq. Shift, FWHM,Tpeak)	2.5 GHz, 500MHz, 60%
Detector: PMT	Hamamatsu R3896

3. MEASUREMENT METHODS

The data analysis methods for retrieval of the extinctions, optical depth and lidar ratio were described in Ref. 5 in detail, therefore, the method for the retrieval of water vapor density is described here in briefly. The calibration of system can be achieved by making a measurement over the horizontal path, in which layer the atmosphere can be assumed as a homogeneous. The Rayleigh signal detected by PMT-2 is used to eliminate the atmospheric transmission effect and the range depend- ence of lidar return. The water vapor density $D_H(z)$ is determined; $D_H(z)=k\beta_m(z)P_3(z)/P_2(z)[d\sigma_H(\pi)/d\Omega]$, where k is a system constant, $\beta_m(z)$ is the molecular backscatter coefficients, $P_2(z)$ and $P_3(z)$ are the output power of PMT-2 and 3, respectively. $d\sigma_H(\pi)/d\Omega$ is the differential cross section of the water vapor Raman scattering.

Figure 3 shows a result of numerical calculation based on standard atmosphere model in case of daytime measurement, and the main calculation conditions used are also described in Fig.3. The simulated results showed that the system is capable of measuring the extinction coefficient of cirrus clouds up to a height of 20 km and the water vapor density near to a height of 5km within 5min observation time.

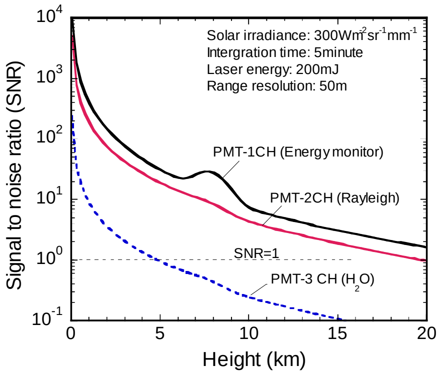

Fig. 3 Signal to noise ratio versus height calculated with the parameters as shown for daytime measurement.

4. SUMMARY

HSRL system at 355nm wavelength is built at Xi'an, China for observation of aerosol, cirrus clouds, Asia dust and water vapor density profiles simultaneously. Using of small FOV of receiver, UV transmitter, grating and FP etalon lead to achieve a high rejection rate for solar background interference and ensure the system to be run effectively under daytime measurement. Numerical calculation shows that the system has the capability to make measurement in daytime up to 20km height for extinctions and near to 5km height for water vapor. The measurement data will be reported in the conference.

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