P1-12 Efficient UV Rotational Raman Lidar for Accurate Temperature Profiling

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1. Introduction

Temperature profiling of the atmosphere by rotational Raman spectrum scattered by N_2 and O_2 was firstly proposed by Cooney[1)]. Both Stokes and anti-Stokes lines of the spectrum have been used for temperature determination[2,3)]. In this paper we suggest a 355nm laser and using anti-Stokes lines of rotational Raman backscattered spectrum to measure the temperature in the low troposphere. Comparing with the previous experimental results by using a 532nm rotational Raman lidar[4,5)], the simulation of the 355nm lidar shows high temperature accuracy, 2K up to the height of 4km.

2. Rotational Raman Lidar system

A block diagram of the rotational Raman lidar system is shown in Fig.1. The characteristics of the lidar system are given in Table 1. The wavelength of the emitted radiation is the third (355nm) and second (532nm) harmonic of a Nd:YAG laser. The backscattered light is incident into a doubled monochromator. Gratings are used to separate anti-Stokes branches of N_2+O_2 and reject stray light. To reduce the strong background light due to the Rayleigh and Mie backscattering, two-grating construction produces a rejection factor of at least 10^6 at the center wavelength of 355nm. This value is enough to eliminate the effect of stray light and background light. Two line signals spectrally centered at the 6th (near end) and 14th (far end) lines of the anti-Stokes branches are coupled into two bundled fibers, then to detectors, respectively. A two-channel photon counter by Optech Inc. and a Pentium 200 are used for data processing and temperature retrieval.

3. Measurements of Stokes and anti-Stokes lines

The rotational Raman spectral measurement with 532nm laser was made. From the results as shown in Fig.2, the Stokes branch in Fig.2(a) have little strong background noise described as aerosol fluorescence noise by Ref.4. The noise at 1km height becomes significant. The anti-Stokes branch presents high signal-to-noise ratio, even up to 1km. The anti-Stokes and Stokes lines present with about equal intensity, as a result the anti-Stokes lines may obtain the high signal-to-noise ratio compared to Stokes lines.

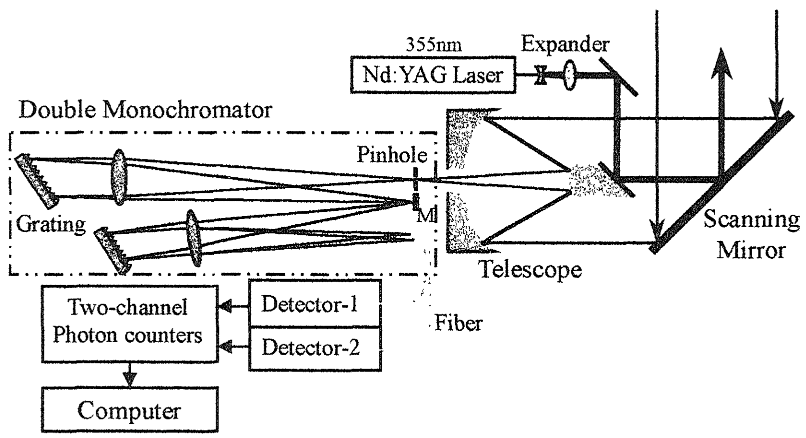

Fig.1 Schematic of UV rotational Raman lidar system

Table1 Parameters of UV rotational Raman Lidar

Laser	Nd: YAG(THG)
Wavelength	355nm
Energy	30mJ, 300mJ
PRF	20HZ
Optics	
Telescope diameter	250mm
FOV	0.1mrad
Total transmission	0.15
Monochromator	
Linear dispersion	1.3nm/mm
Band width	0.4nm
Transmission	0.23
Detector	PMT
Quantum	0.25

4. Analysis of performance at 532nm and 355nm

The serious difficulty of rotational Raman lidar for temperature measurement is to suppress the background light caused by Mie and Rayleigh backscattering. Fig.3 shows the backscatterings coefficients of rotational Raman, Rayleigh and Mie components, respectively. The Raman backscattering coefficient at short wavelength is large, this is useful to increase signal-to-noise ratio. The ratio of Raman to Mie and Rayleigh backscattering increases for short wavelength, so selecting 355nm operation wavelength offers high rejection to stray light in the troposphere.

With the same system parameters as table 1 except the wavelength, the calculation of lidar measurement accuracy has been made with using anti-Stokes branch. The monochromator band width uses the unit of wave number because the rotational Raman frequency shift is same in this case for various wavelengths. The temperature accuracy of 355nm lidar system is almost two times of the 532nm lidar system at the height of 1km, as shown in Fig.4. The temperature accuracy with the change of height is also shown in Fig.5. The simulation shows that the UV system presents better performance than the 532nm system.

5. Conclusion

Experimental results have shown the anti-Stokes lines of rotational Raman spectrum offer high signal-to-noise ratio than the Stokes lines for a large distance. By theoretically analyzing the system performances which give better temperature accuracy for the 355nm lidar system, a UV temperature lidar system has being built up. The system is expected to measure temperature profiling with the accuracy of 2K up to 4km height.

References

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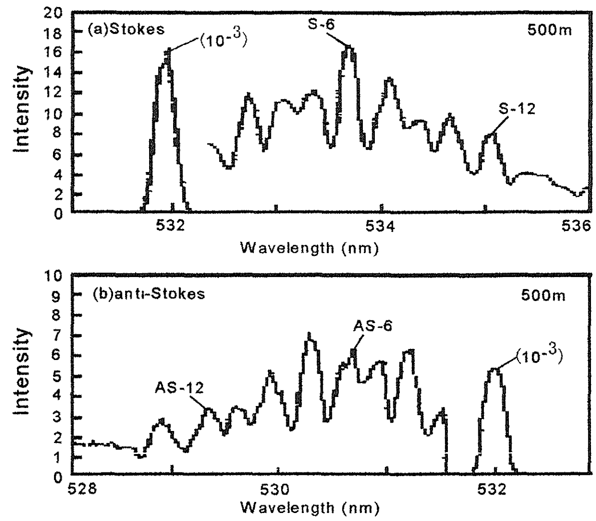

Fig.2 Rotational Raman spectrum with 532nm laser.

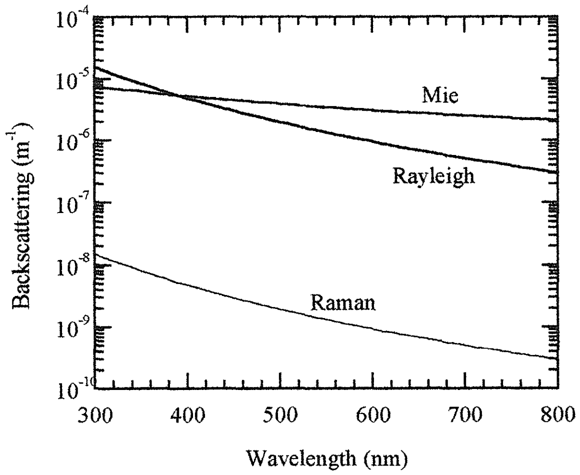

Fig.3 Backscattering coefficient vs laser wavelength

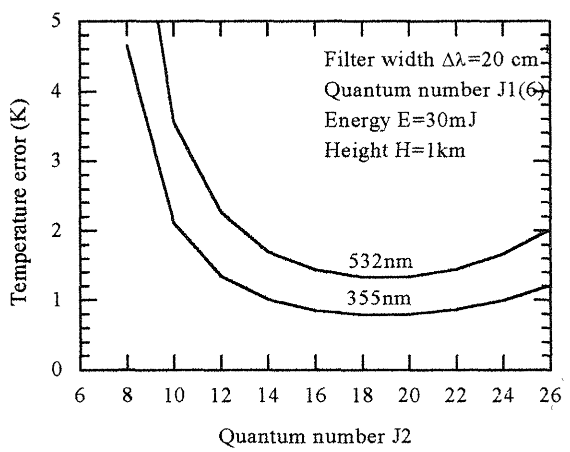

Fig.4 Temperature accuracy vs. anti-Stokes lines for 355nm and 532nm at the height of 1km.

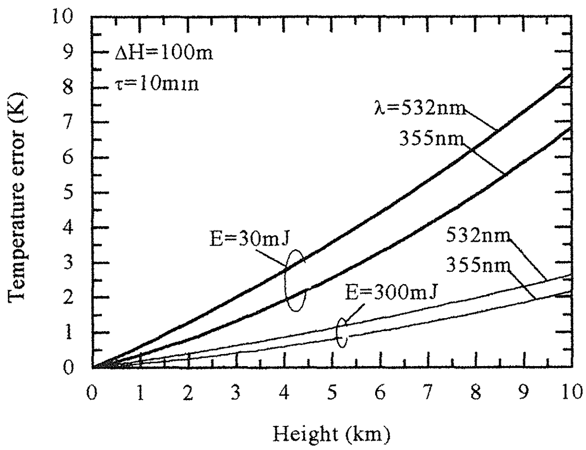

Fig.5 Temperature error vs height for 355nm and 532nm lidar systems.