AUTOMATIC CORRECTION OF OPTICAL ALIGNMENT DETERIORATION OF A CONTINUOUSLY OPERATED MIE LIDAR

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Abstact -- *Alignment of the laser beam and telescope axes is crucial to the acquisition of high quality lidar data. For a continuously operated Mie lidar, a routine alignment correction is needed to ensure that its data are not influenced by the misalignment and thus truly represent the aerosol and cloud behavior. This paper describes the operation of such a lidar system with automatic correction of optical alignment.*

INTRODUCTION

A Mie-scattering lidar is an atmospheric monitoring tool suitable to observe atmospheric behavior in the troposphere and stratosphere. Continuous monitoring is especially useful for the understanding of meteorological phenomena. In the lower atmosphere, the monitoring of aerosol and cloud shows the variation of boundary layer and in the case of urban area, the condition of air pollution. When the operation is continuous and the time resolution is short enough, the information of the dynamics is also obtained from the lidar data. For the accomplishment of continuous operation, the combination of a high repetition rate, diode pumped solid-state (DPSS) laser and photon-counting detection is a desirable choice. A micro pulse lidar was actually developed [1] where the same telescope was used for both transmitting the laser light and receiving the return signal. In this configuration, however, the detector often suffers damages from the effect of the transmitted light reflected inside the telescope. In contrast, this interference is far less significant for a more conventional approach in which the laser is placed at the side of the telescope and a pair of reflectors is employed to deliver the laser beam along the telescope optical axis. For this system, in turn, care must be exerted to minimize the deterioration of optical alignment due to the change of environmental condition such as temperature and the irradiation. In this paper, we describe the automatic correction scheme of optical alignment for such a type of Mie scattering lidar.

EXPERIMENT

The continuously operated lidar (Fig. 1) has the following specifications [2]. A diode-pumped Nd:YAG laser emitting 600 mW in cw operation is Q-switched by an AOM (Fig. 2), generating pulses at 1.4 kHz with a typical output of 15 μJ/pulse (20 mW in average). The laser frequency is doubled by a KTP crystal inside the cavity. The output beam is expanded 25 times to 25 mm in diameter, and is reflected by two prisms so that the emitted beam coincides with the optical axis of the 20 cm ϕ Cassegrainian telescope. The backscattered signal, detected in photon-counting mode, is collected by the telescope, accumulated for 20 s, and stored in the computer. To frequently check the alignment of the laser and the telescope's axes, a two axes control gimbal mirror holder holding the upper prism and controlled by a step-motor is used. By varying the orientation of the prism attached to the mirror holder, the alignment of the two axes is determined.

ALIGNMENT METHOD

A computer software was made to control the acquisition of the data and the alignment of the laser and telescope's axes. The alignment is checked every 15 minutes. During the alignment procedure, the computer commands the controller to move the actuator for vertical motion backwards by 10 units, and then forward by 1 unit until it has moved a total of 20 units in the same direction. The backward movement is required to take account of the hysteresis effect of the actuator. Each unit is equal to the resolution of the actuator. Each lidar signal is stored for each step in this latter process. The computer then scans, records and stores in the memory the maximum lidar signal (A-scope) in the overlap region. It then goes back to the peak signal position and the same procedure is applied to the actuator for horizontal motion. It takes around 40s to complete the whole process. After the alignment is done, the computer continues to gather lidar data. Figure 3 shows the screen image of the software. The two windows in the lower-left hand corner show the signal around the initial peak of the lidar A-scope in the overlap region for both vertical and horizontal motions of the top prism. The upper window shows the range squared signal while the bottom window shows the three-hour time-height-intensity indication. Good alignment exists if both lower left hand windows show bell-shaped curves. Table 1 summarizes the specifications of the mirror holder that holds the prism.

RESULTS

Alignment problems arise when environmental conditions changes. When daily data are collected to study aerosol behavior in the troposphere, changes in the optical alignment present a major problem in detecting correct aerosol or boundary layer information. Figures 4 and 5 show one-day data before and after the application of the alignment corrections, respectively. Comparison between the two graphs shows that signals are noticeably improved when automatic correction of the optical alignment is applied. The effect of misalignment is evident during noontime in Fig. 4. Ordinarily, higher intensity due to background radiation is observed during noontime, which is not the case in Fig. 4. In contrast, good capture of the aerosol and cloud behavior is seen in Fig. 5.

The computer software also records the positions of maximum signals in the overlap region for both horizontal and vertical movements of the mirror holder. Inspection of the horizontal and vertical positions of the maximum lidar signal in the overlap shows that the variation is at most +/-2 units from the mean position. During daytime, when the surrounding temperature increases due to increase of solar radiation, the alignment position also changes. Without automatic correction of optical alignment, there is no guarantee that the alignment stays fixed. The automatic correction of the optical alignment implies that for optimum alignment to occur, the change in the alignment position should follow the change in the temperature. This relationship is seen in Fig. 6, which shows the 24-hour changes of the horizontal position and the corresponding 24-hour temperature change.

The present set of data shows interesting atmospheric phenomena. One of these is the observation of the development of the mixing layer height. Downdraft and updraft movement of air are also observed. Very often, cloud base becomes very low and probably situates near the ground when it rains. When this happens, very thick extinction profiles are observed. Cloud generation of the on the top of the boundary layer is frequently observed.

CONCLUSIONS

This study has shown that the installation of the automatic correction of optical alignment in a continuously operated Mie scattering lidar system significantly improves the quality of the lidar data. Routine correction of optical alignment is a necessary way to produce reasonable lidar data. This improvement paves way to a more accurate description of aerosol activities in the atmosphere. Atmospheric observable phenomena like the existence of the boundary layer can be assessed with higher accuracy. With better data quality, studies are in progress on boundary layer characterization, optical description of the annual Asian dust, the correspondence of between lidar and ground aerosol measurement, and cloud formation in the urban atmosphere.

REFERENCES

[1] J. Spinhirne, “Micro Pulse Lidar ”, *IEE Transactions on Geoscience and Remote Sensing*, **Vol. 13**, p.48, 1993

[2] N. Lagrosas, Y. Yoshii, N. Takeuchi, H. Kuze, S. Naito, J. Okazaki, A. Sone, and H. Kan, “Development of a continuously operated and remote monitored lidar using a diode pumped solid-state laser”, *23rd Annual Meeting of the Laser Society of Japan’s Digest of Technical Papers*, p.149, (2003)

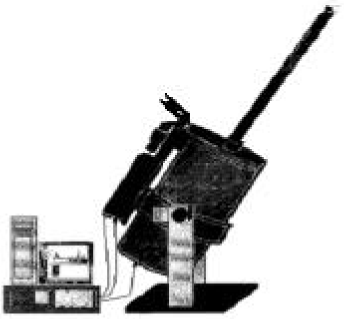

Fig. 1 Set-up of the Mie-scattering lidar.

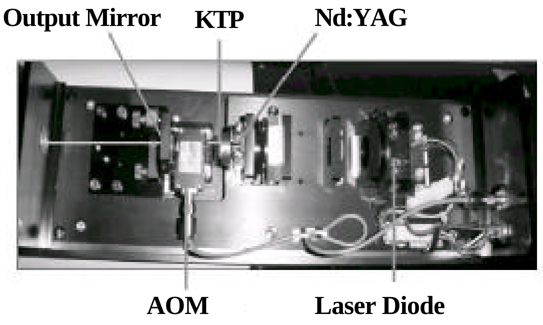

Fig. 2 Cavity configuration of the diode pumped Nd:YAG laser.

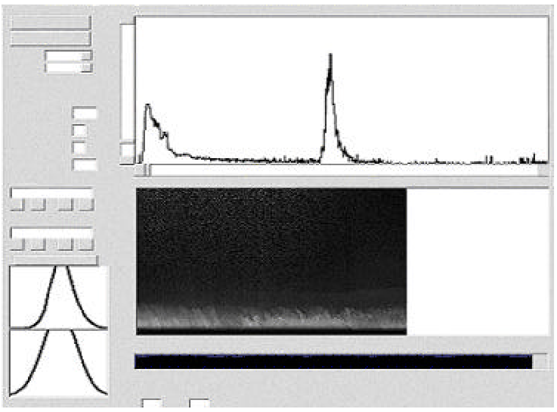

Fig. 3 Screen image of PC for data acquisition and alignment control.

Table 1. Specifications of the Gimbal holder with step motor

MODEL	LMHA-300MEB
Travel of Elevation	±4°
Travel of Azimuth	±4°
Min. Resolution of Elevation	0.003°
Min. Resolution of Azimuth	0.003°
Driving Force	29.5N
Positional Accuracy	0.012 mm
Positional Repeatability	0.002 mm
Resolution	0.001 mm
Operating Temperature	0-60°C

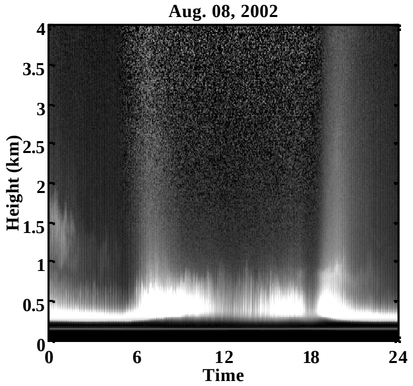

Fig. 4 Time-height indiecation of a 24-hour lidar data without alignment checking.

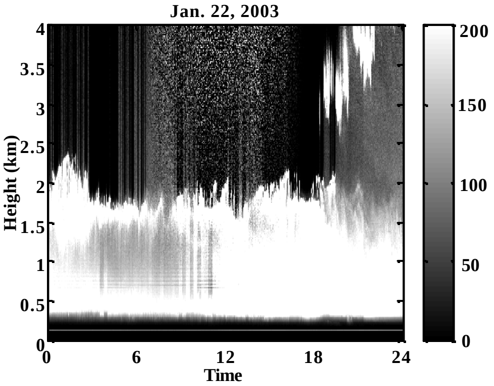

Fig. 5 Time-height indiecation of a 24-hour lidar data with periodically checked alignment.

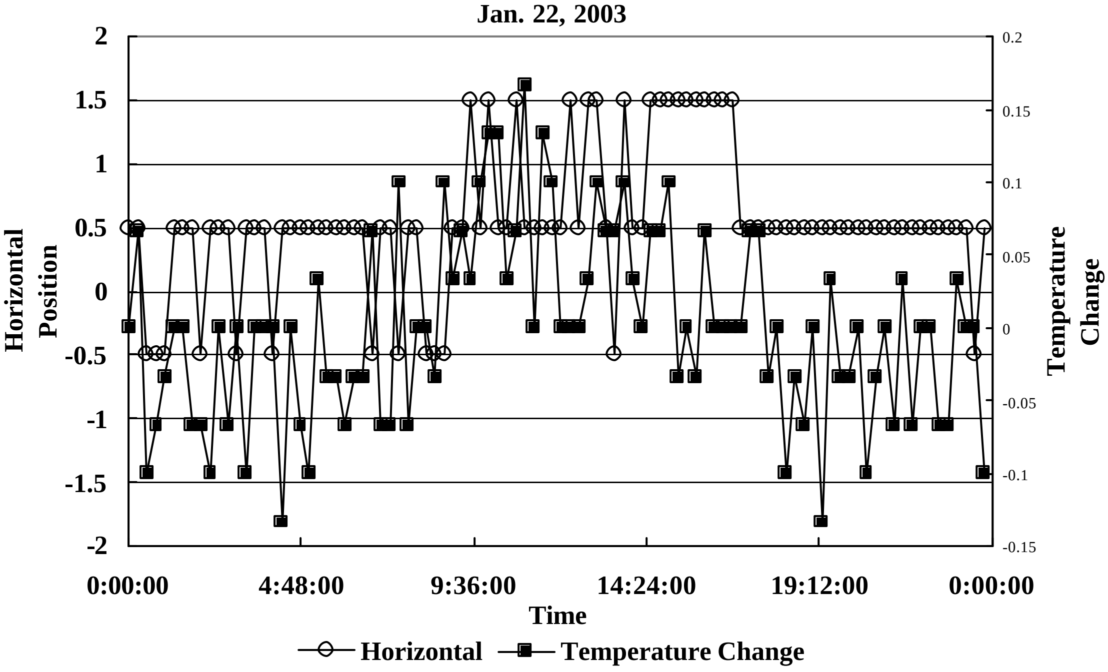

Fig. 6 The 24-hour change in temperature and the corresponding change of horizontal position.