Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

AAS21-P31 Room:Convention Hall Time:May 19 18:15-19:30

Parametric studies on temperature lidar with a multispectral detector

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Measurements of atmospheric temperature and water vapor in the troposphere are essential for studying atmospheric processes such as dynamics, thermodynamics, and cloud physics. Remote sensing techniques have obvious advantages for continuous observation of the spatial distributions of meteorological parameters. The Raman lidar is a laser-based remote sensing instrument used to quantify the distribution of water vapor mixing ratio and atmospheric temperature. We have developed several Raman lidar systems that measure water vapor by detecting the vibrational Raman scattering. Recent improvements in the performance of optical components have led to the development of better water vapor lidar systems that are portable and easy to use. More detailed spatio-temporal distributions of water vapor can be acquired by a lidar equipped with a scanning mirror system. On the other hand, the polychromator design for temperature lidar is much more complex than that for water vapor, because the temperature lidar method is based on the fact that the intensities of the lines within the rotational Raman band exhibit slightly different dependencies on temperature. Therefore, temperature lidar is used less widely than the water vapor system.

In this study, temperature lidar with a multispectral detector is proposed to construct a system that is compact, robust, and easy to align for the detection of rotational Raman signals. The multispectral detector enables 32-channel simultaneous photon counting acquisition and provides spectral and range-resolved data by applying lidar techniques. While conventional temperature lidar methods detect the ratio of two rotational Raman lidar signals of opposite temperature dependence in combination with several edge and interference filters, the multispectral lidar detector can grasp the shape of the rotational Raman spectrum. Therefore, the estimation of temperature can be accomplished by directly fitting the observed lidar signals to the shape of the theoretical values of a rotational Raman spectra that exhibit different dependencies on temperature. The use of the multispectral detector for detecting rotational Raman signals has several advantages. In particular, it can reduce uncertainties in the optical alignment of the polychromator and in the stability of the laser wavelength. Furthermore, the multispectral receiver system can be made more compact and less expensive than the conventional system with an interference-filter-based polychromator.

The accuracy of temperature derived from multispectral lidar signals depends on both the spectral resolution and spectral range of the multispectral detector. Therefore, the values of these parameters should be set appropriately to improve the accuracy of temperature estimation. In this study, we estimated the effect of both spectral resolution and spectral range on the accuracy of temperature estimation, and found the ideal combination of those optical parameters. Then, we calculated the accuracy of our proposed method for temperature estimation via a computer simulation of selected cases in combination with both the spectral resolution and spectral range of a multispectral detector.

Keywords: temperature lidar, multispectral detector