Appendix 1 25 mm Sample of Paper and Technical Note

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Paper

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Analysis of SO_2 Measurement Accuracy by Multiwavelength DIAL

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Taro Denshi*[a] Member, Hanako Denki** Non-member

If the ORCID iD is to be included, an identifier (16-digit ID) should be inserted in the name of the author using the annotation function.

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(Manuscript received Jan. 00, 2000, revised May 00, 2000)

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This paper presents two multiwavelength methods to improve the accuracy of a DIAL system for measuring SO_2 in the lower atmosphere: a dual-DIAL method using three or four wavelengths, and a curvefitting method using five wavelengths. By the selection of appropriate wavelengths, these methods can eliminate the effects of ozone and aerosols. Since there is no significant difference in accuracy between the four wavelength dual-DIAL and curvefit methods, the former is advantageous for SO_2 detection in view of the measurement and data processing speeds.

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Keywords : laser radar, SO_2, DIAL, multiwavelength differential absorption

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Use 2 lines for the heading

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1. Introduction

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LIDAR (LIght Detection And Ranging) has been used for measurement of atmospheric pollutants by Raman scattering, resonant fluorescence, and differential absorption(1). Fig. 1 is a schematic diagram of a LIDAR system. This apparatus transmits laser radiation into the atmosphere, collects light backscattered by atmospheric molecules and particulates using a receiving telescope, and converts it to an electric signal using a photodetector such as a photomultiplier tube. The measurement height is obtained from the time delay between illumination and detection. Therefore, to measure the height profile one measures the received photon counts as a function of time delay relative to illumination using a multichannel scaler. The measurement range resolution ΔR is determined by the time width of the channel Δt=$2\Delta R/c$, where c is the speed of light. The smaller the time Δt, the better the range resolution, but the photon count per channel becomes less and the relative error larger.

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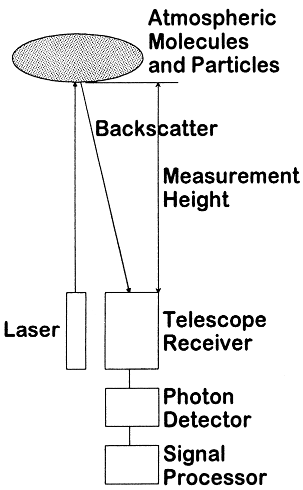
This paper examines DIAL (DIfferential Absorption Lidar), a method to obtain the concentration profile of the measurement target molecule from the backscatter intensity at two or more illumination wavelengths. The measurement target is atmospheric SO_2, which is a substance causing acid rain. Until now, measurements of atmospheric SO_2 have been limited mainly to cases of localized SO_2 concentrations, e.g. smokestack exhaust and volcanic eruptions(2)-(4). In these cases, the SO_2 concentration is over 100 ppb, therefore the measurement was relatively easy and the measurement accuracy was not a problem. However, when measuring SO_2 in the ambient atmosphere, its concentration is of ppb order, and the measurement accuracy



Do not fill the blank space around the figures with text

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Fig. 1. Schematic diagram of a LIDAR system

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becomes an issue. We performed a theoretical analysis of the measurement accuracy of conventional two-wavelength DIAL, and other substances which cause measurement error(5). In this paper, we examined the measurement accuracy of dual-DIAL methods using three or four wavelengths.

2. Multiwavelength Differential Absorption

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2.1 Fundamentals of DIAL The received energy for a LIDAR is given by the following LIDAR equation:

〔An equation starts at two-stroke indent〕

$$E_r(R,\lambda_i)=[E_0\eta A]\frac{\Delta R}{R^2}\beta_\pi(R)\times\exp\left[-2\int_0^R(\alpha_0+\alpha_x)dR'\right] \quad \cdots\cdots (1)$$

Here $E_r(R,\lambda_i)$ is the backscattered photon energy received from range between R and $R+\Delta R$ from the illumination laser, λ_i the illumination wavelength, E_0 the illumination energy, η the optical efficiency of the

4. Conclusion

In this paper, we calculated the error due to ozone and aerosols in measurement of SO_2 concentrations of ppb order using DIAL. The statistical error of the return signal and background noise can

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Table should be prepared to fit one-column; within 75 mm, or two-column; within 165 mm

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Table 2. Nominal parameters and rated values of tested DC servo motor

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rated output	0.8 kW	K_t	0.48 N・m/A
rated current	11 A	L	1.8 mH
rated speed	1,750 rpm	R	0.66 Ω
K_e	0.48 V・s/rad	J	9.8×10^{-3} kg・m^2

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be overcome by improving the system constant (laser output, receiver area, optical efficiency of the receiver). On the other hand, systematic errors due to ozone and erosols are inherent in the measurement method, and cannot be eliminated solely by improving the system constant. In conentional two-wavelength DIAL, the systematic error is over 1.5 ppb and the measurement accuracy is insufficient. In order to improve the measurement accuracy, a multiwavelength differential absorption method using three or more wavelengths is effective. In this paper we have considered dual-DIAL methods using three or four wavelengths and a curvefit method using five wavelengths, and indicated that the measurement errors due to ozone and aerosols can be reduced relative to conventional DIAL or eliminated. When these methods are compared, four-wavelength dual-DIAL is superior in view of measurement accuracy and measurement/processing speeds.

Acknowledgement

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