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Remote Detection of Iodine By using Differential Absorption Lidar

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1. Introduction

Remote sensing of air pollution emissions has several advantages for toxic element measurements over other methods in terms of safety. A powerful and reliable tool for range-resolved remote sensing of gas concentrations that has proven its capabilities in a variety of studies is the differential absorption lidar (DIAL), as first suggested by Schotland [1]. Differential absorption lidar (DIAL) is frequently used for atmospheric gas monitoring to detect impurities such as nitrogen dioxide, sulfur dioxide, iodine, and ozone [2]. In this paper, DIAL technique of using remote sensing experiment is performed in the previous step. Radioactive iodine emitted by nuclear plants, however, is not frequently measured using DIAL because of the difficulty in preparing samples and its dangerous characteristics. In this paper, we configurated the DIAL system in our laboratory. A head detect the iodine gas of air and detect the iodine gas of cell in the distance of 90m. To lock the frequency of Nd:YAG laser, the iodine cell was used for discriminator. We acquired the signals from iodine cell by various frequency locking ratio that were from 0.1 to 0.9 by steps of 0.1. In the paper, we confirmed that the signals from the iodine target cell was proportional to the frequency locking ratio of the laser.

2. Experimental setup

A necessary condition of the laser in the DIAL system is a narrow bandwidth. The bandwidth or linewidth of current commercially available unseeded Nd:YAG (532 nm) pulse lasers is about 30 GHz. As it is not possible for this Nd:YAG laser pulse to pass separately the iodine absorption lines, which are close to 532 nm, an injection-seeded laser is used. We used the single longitudinal mode of a continuous wave seeder laser with a bandwidth of less than 10 kHz as the injection source to obtain a pulsed laser with a bandwidth of 100 MHz at 532 nm. The laser system should also be tunable. The advantage of the seeder laser is that the tunable frequency range is 10 GHz around 532 nm. The laser radiation power (3 mW) is also several orders of magnitude higher than that of spontaneous radiation in the resonance cavity. When the seeder laser frequency is within the range of the absorption lines, a Q-switched pulsed beam also develops at the frequency of the iodine absorption lines. For the frequency-locking process, the absorption profile of the molecular iodine filter must be both stable and known. Figure 1 shows a plot of the iodine transmission ratio as a function of the tunable seeder laser wavelength for external input voltages of –1 V to +1 V varied in steps of 100 μV; to the frequency of the laser is 0.87 MHz. Figure 1 shows a plot of the iodine transmission ratio for wavelengths of approximately 532 nm indicating where the laser is locked to off- and on-line wavelengths at transmission ratios of 0.9 and 0.1, respectively. We first divide the light using a beam splitter (T90:R10) before it is transmitted through the target iodine cell. The reflected light is sent to the frequency-locking device, and transmitted light to the target iodine cell. The backscattered beam from the target iodine cell, Al mirror, and dumper is collected through two Al mirrors by a lens. The iodine cell is located about 45m away from the collecting mirror and sealed in glass. A schematic diagram of the frequency locking is shown in Figure 1. The collimated light is divided using a beam splitter (T50:R50). One path is used for monitoring the frequency shift, and the other path is used for monitoring energy. When the reflected light is frequency shifted, the variation in the laser energy through the iodine filter is detected in the two optical paths. The output of the reference channel is relayed to a computer as the proportional feedback signal. Signals from the two photodiodes (PDs) are sampled using a National Instruments data acquisition (DAQ) card (USB-6211). For minimizing fluctuations in the signal, a sample-and-holder device (LF 398) is used before the signal is transmitted to the DAQ card. In addition, the DAQ transmits a DC voltage feedback signal to the seeded laser for the frequency stabilization. The scattered beam is measured by the PMT and the A / D converter is analyzed by the counter system.

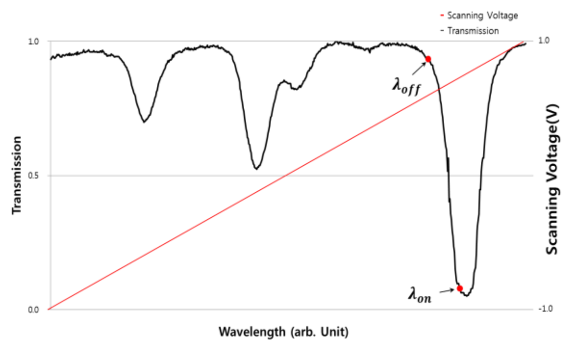

Fig. 1. The iodine transmission ratio as a function of the tunable seeder laser wavelength

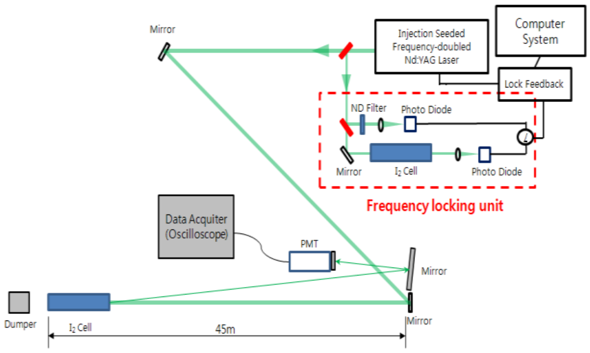

Fig. 2. The configuration of the differential absorption lidar consisting in the laboratory system

3. Experimental Results

The lidar backscattering signals from the iodine cell are shown in Fig. 3. To identify iodine molecular absorption, we obtained two backscattering signals and the signal ratio using the on- and off-line (seeded laser) wavelengths. As we can see, the signal ratios decrease after the light passes through the iodine cell. According to the ratio of frequency locking, the signal strength is relatively linearly as can be seen to appear.

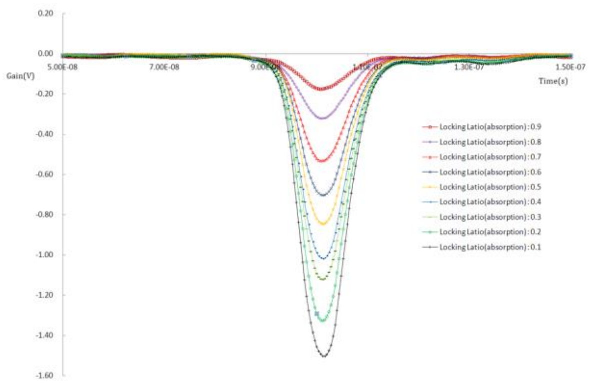

Fig. 3. Absorption of a iodine cell for located 45m from the sensor

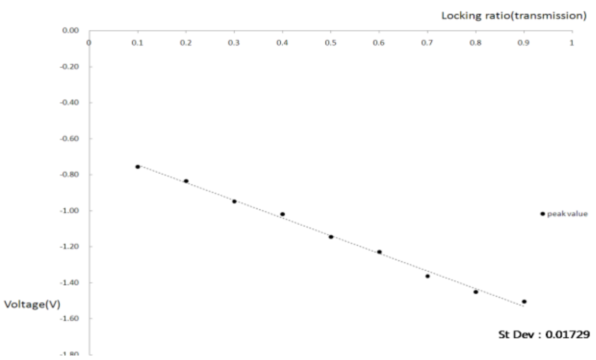

Fig. 4. The size of the differential absorption signal in accordance with the frequency shift

4. Conclusions

For the iodine measurement, the transmission ratio using the injection-seeded laser is locked to 0.9 (off line) and 0.1 (on line) on the edges of the iodine absorption line to stabilize the frequency. The DIAL measurements were performed using a target iodine cell in the laboratory. We confirmed that the on- to off-line ratio decreased after the laser passed through the iodine cell. The system of DIAL(Differential Absorption Lidar) was effective to detect the iodine gas. We obtained the signals from the iodine target cell and the lidar signal from the iodine target cell was proportional to frequency locking ratios.

REFERENCES

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[2] 1. Sungchul Choi, "Implementation of Differential Absorption LIDAR (DIAL) for Molecular Iodine Measurements Using Injection-Seeded Laser", Journal of the Optical Society of Korea, Vol. 16, Issue 4, pp. 325-330 (2012)