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The study on the lidar's detection limit for Iodine Gas

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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) [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] DIAL can measure air pollutant concentrations with a high spatial resolution by adopting two laser systems with different degrees of absorption between the two different wavelengths. The absorption of the reference wavelength is very weak, while the absorption of the other wavelength is very strong. In this paper, we measured the limit of detection capability of our designed DIAL system. It was possible to adjust the concentration of the iodine gas to use the designed iodine gas cell. The concentration of iodine gas was detected by ppb units.

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 30GHz. 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. 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. Figure 1 show the iodine transmission ratio for wavelengths of approximately 532 nm indicating where the laser is locked to wavelengths at transmission ratios of 1.0 and 0.05, respectively. 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 9m away from the collecting mirror and sealed in glass. A schematic diagram of the frequency locking is shown in Figure 2. The collimated two light is added using a beam splitter. 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. These signals are detected by a photomultiplier tube with a maximum amplification. The iodine vapor filter must be temperature controlled because the spectral absorption profiles depend on pressure and temperature. Figure 2 is configured for change in the transmitted signal as the temperature (partial pressure of iodine) of the iodine cell changes.

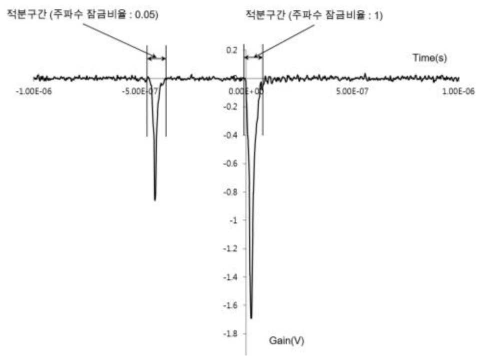

Fig. 1. Signal ratio of dial according to the frequency locking ratio

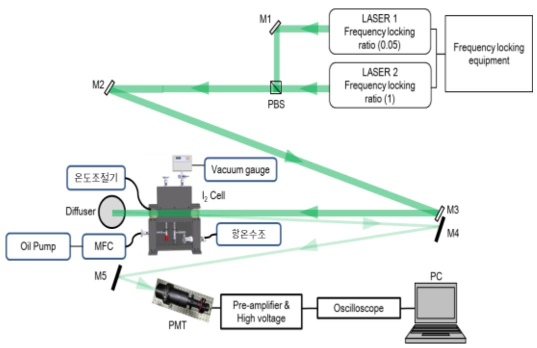

Fig. 2. Configured schematic for measurement of iodine gas with concentration using DIAL

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 Locking ratio using the 0.05 and 1.0 (seeded laser) wavelengths. As we can see, the signal ratios decrease after the light passes through the iodine cell. In order to change the concentration of iodine gas, we used the MFC and Oil pump. As shown in Figure 4, we could measure the concentration of iodine gas of 0.64 ppb.

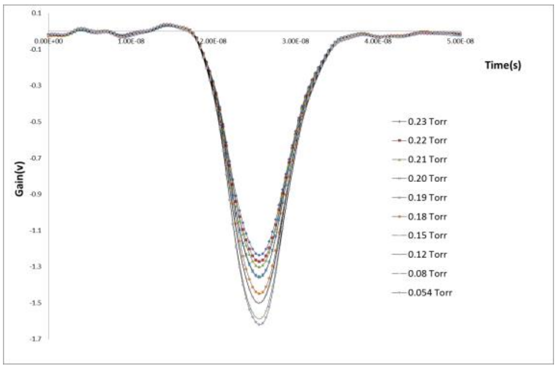

Fig. 3. PMT Signal for measurement of iodine gas with pressure using DIAL

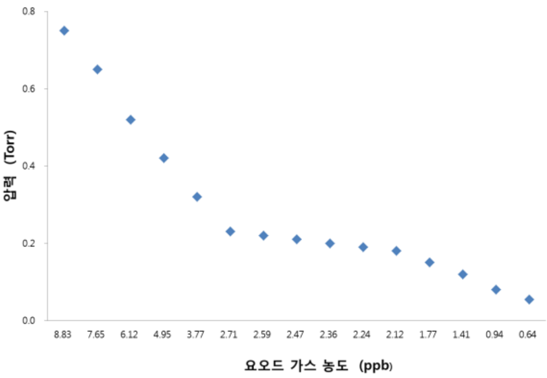

Fig. 4. Graph for measurement of pressure with concentration using DIAL

4. Conclusion

For the iodine measurement, the transmission ratio using the injection-seeded laser is locked to 0.05 and 1.0 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 concentration of iodine gas ratio increased 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. Although we did not measure molecular iodine under atmospheric conditions owing to its toxicity, from a theoretical point view, we were able to design a simple and less expensive iodine measuring DIAL system and we confirmed that our dial system can detect the iodine gas of 0.64ppb.

REFERENCES

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