S5-2 Improvement in 1.67 micro meter DIAL for Methane Leakage Detection

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Abstract

Differential absorption lidar(DIAL) at 1.67 μm for the detection of methane gas leakage is developed. The leakage of 6000 ppm·m at the distance of 130 m was detected with the distance resolution of 30 m in the preliminary experiment. Some improvements are considered in the receiving system for a better sensitivity. Additionally, a light source based on an optical parametric oscillator and amplifier is developed for increasing the efficiency and improving the system compactness.

1 Introduction

Methane(CH_4) is widely used in our daily life as a prime material for the source of energy. Therefore, from the view point of safety, the detection of CH_4 leakage is important. Especially, a wide area and quick monitoring is required at hazardous areas such as an earthquake affected region. Such a wide area monitoring in a short period of time is difficult with usual wet chemical sensors.

While, DIAL is useful for remote monitoring of trace gases. Using DIAL technique, a fast remote monitoring from one point can be conducted. Based on the theoretical simulation, it is possible to construct a sensing system using DIAL system for CH_4 leakage monitoring in the region of about 1 km diameter[1]. Although the absorption around 3.39 μm is higher than 1.67 μm, 1.67 μm absorption is employed in our system since fast photo detectors and high energy light sources are easily available in this region. The absorption at 1.67 μm is about 2% of the 3.39 μm however, it is enough to detect a highly concentrated leakage more than about 1000 ppm·m, which is well below the danger limit.

In the following sections, system setup and the results of the preliminary experiment are reported. Additionally, some improvements for a better sensing and development of a light source are also mentioned.

2 System setup

Figure 1 shows a schematic of the proposed DIAL system. As a light source, optical parametric oscillator and amplifier based on KTP($KTiOPO_4$) crystals is considered. Using a spectrally narrowed second harmonic generation of a Nd:YAG laser(532 nm) as a pump source and considering a

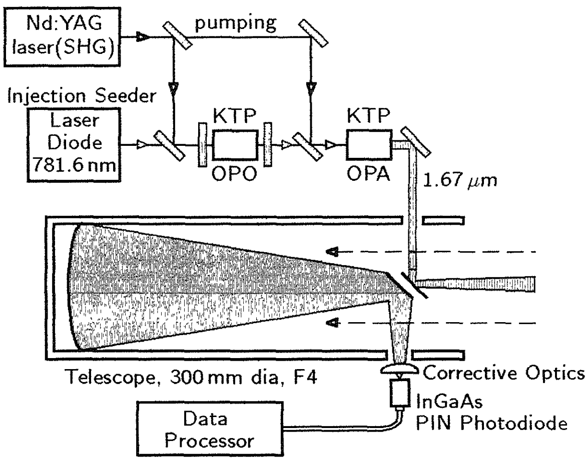

Figure 1:Schematic of DIAL system

single-mode laser diode(781.6 nm) as a signal-wave injection seeder, a narrowed idler-wave output at 1.67 μm is expected. This allows a compact and an efficient system with higher output energy at 1.67 μm.

In the receiving system, 300 mm diameter Newtonian telescope(F=4) and an InGaAs PIN photodiode with a diameter of 1 mm are considered. The response speed of the detector is expected to be 5 MHz which corresponds to the distance resolution of 30 m. To increase a geometrical form factor which represent the backscattered intensity gathering capacity, corrective optics in front of the detector is also considered. This allows a considerable improvement in the short range measurements.

3 Experiment and results

First, we performed a preliminary field experiment for a CH_4 leakage at the distance of 130 m from the receiving point. In the experiment, 3 mm diameter InGaAs PIN photodiode was used. As a transmitting light source, a Ti:sapphire laser in combination of a Raman shifter filed with deuterium gas was used. Figure 2 shows the CH_4 distribution observed in the experiment using the system.

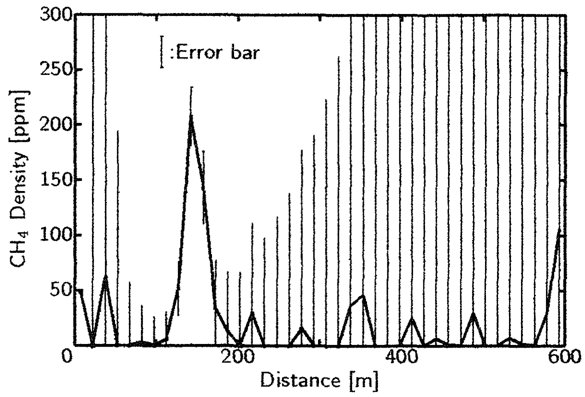

Figure 2:Observed CH_4 distribution

A peak with a high concentration of CH_4 was observed at the distance of 130 m corresponds to the experiment. The distance resolution of the system was estimated to be 30 m based on the full width at half maximum of the peak. The concentration of the leakage was about 6000 ppm·m. Although the distance resolution was enough, in the system, the detectable range of a CH_4 leakage was limited within about 300 m region due to the large electrical noise caused by the pre-amplifier used in the receiving system.

4 System improvements

The preliminary field experiment clearly indicated some scope for improvement [2]. In the receiving system, we had used a 3 mm diameter InGaAs PIN photodiode with a fast response speed pre-amplifier as a detector. However, this detector has a considerably large noise equivalent power(NEP) and it is estimated to be 2.0×10^{-11} W/$\sqrt{\text{Hz}}$. Therefore, an InGaAs PIN photodiode that has a built in amplifier with a small NEP(4.0×10^{-13} W/$\sqrt{\text{Hz}}$) is preferable. Although the NEP is improved by using this detector, the detector diameter is limited to 1 mm only. This limits the geometrical form factor in the short range measurements. Therefore, we are considering corrective optics in front of the detector to enhance the geometrical form factor. Figure 3 shows theoretical Mie scattering echo signals with and without corrective optics. As a corrective optics, a SQ plano-convex lens whose focal length is 5 cm is considered. A significant improvement

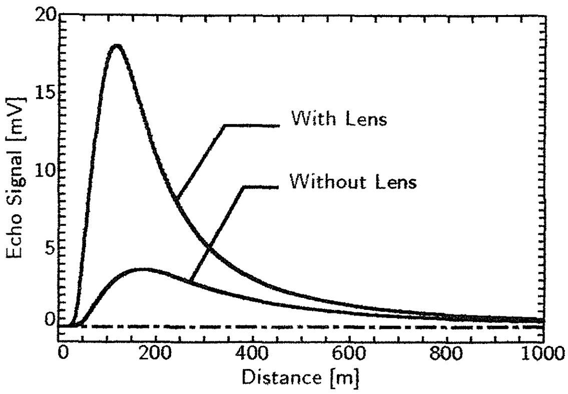

Figure 3:Theoretical Mie scattering echo waveforms

in the sensitivity is expected as an effect of this method, since the signal intensity is increased as shown in Fig. 3 and the NEP is decreased from 2.0×10^{-11} to 4.0×10^{-13} W/$\sqrt{\text{Hz}}$.

Additionally, in the transmitting system, the output efficiency of the light source was low and the system was bulky. To overcome these problems, a compact light source based on an optical parametric oscillator and an optical parametric amplifier is developed. At present, the idler output energy of 4 mJ per pulse and the spectral width of 0.2 cm^{-1} is obtained. The output energy and spectral width are sufficient enough to detect the CH_4 leakage at the short distance.

5 Conclusion

Using DIAL technique, a remote monitoring system for the detection of CH_4 leakage within a region of about 300 m was developed. The sensitivity and the compactness of the system is expected to be increased with some improvements in the receiving and transmitting systems.

References

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