DEVELOPMENT OF WAVELENGTH LOCKING CIRCUIT FOR 1.53 MICRON WATER VAPOR MONITORING COHERENT DIFFERENTIAL ABSORPTION LIDAR

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ABSTRACT

We have studied a ground based coherent differential absorption LIDAR (DIAL) for vertical profiling of water vapor density using a 1.5μm laser wavelength. A coherent LIDAR has an advantage in daytime measurement compared with incoherent LIDAR because the influence of background light is greatly suppressed. In addition, the LIDAR can simultaneously measure wind speed and water vapor density.

We had developed a wavelength locking circuit using the phase modulation technique and offset locking technique, and wavelength stabilities of 0.123 pm which corresponds to 16 MHz are realized. In this paper, we report the wavelength locking circuits for the 1.5 um wavelength.

1 INTRODUCTION

Water vapor in the atmosphere affects growing cumulonimbus which cause localized heavy rainfall, therefore the measurement of water vapor density profile is required for the early prediction of this rainfall. Height profiling of water vapor measurement using incoherent DIAL technique was reported in Ref. 1 and 2. The continuous height profile measurement was demonstrated, however, the measurement accuracy was influenced by solar background light. On the other hand, coherent DIAL technique can overcome this issue and was reported in Ref. 3 and 4. Good agreement result on water vapor density in comparison with that of radiosonde soundings was shown.

Since late 1990s, we have been developing a wind sensing coherent Doppler LIDARs with 1.5 μm wavelength. The LIDAR with 1.5 μm wavelength has advantages such as its compactness and reliability by using telecom products. Here, we consider to apply this technology to DIAL, and perform preliminary study on a ground based coherent DIAL for vertical profiling of water vapor density using a 1.53 μm laser wavelength. In the followings, we discuss the concept, configuration, and simulation results of the LIDAR.

2 WAVELENGTH SELECTION

The main requirements for the ON wavelength selection in the 1.5 μm wavelength region are (i) strong line intensity and high weighting function near the ground in the region of the band of optical amplifier, and (ii) low temperature dependence of absorption. In the band of optical amplifier, the strong line intensity is in shorter wavelength for 1520 nm - 1570 nm range, and the value is 3.066×10^{-24} (cm/molecule) at 1531.374 nm wavelength.

The height dependence of the absorption coefficient k is expressed by

$$k(\nu,P,T)=S_T(T)\cdot\frac{1}{\pi}\cdot\frac{\gamma_{self}(P,T)}{\gamma_{self}(P,T)^2+(\nu-\nu_{shift}(P))^2} \quad (1)$$

where S_T is the line intensity, γ_{self} is the self-broadened harfwith at half maximum, and ν is the wavenumber in vaccume. Figure 1 shows the height dependence of the absorption coeffient at

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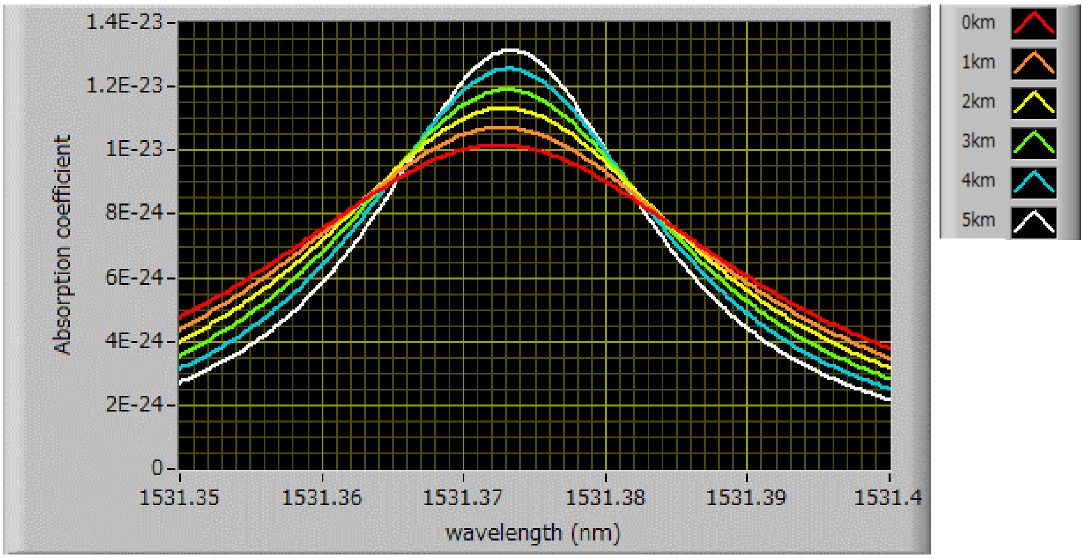

Figure 1. Height dependence absorption coeffient at 1531.374 nm wavelength.

1531.374 nm wavelength using the U.S. standard atmosphere 1976 model. The center of the absorption line has a large dependence on temperature and the pressure. In the absorption line wing, there is low dependence on the temperature and the pressure region exist. From these results, we have selected the absorption wavelength at 1531.3828 nm [5].

4 WAVELENGTH LOCKING CIRCUIT

Figure 2 shows the wavelength locking circuit. For the ON wavelength, we utilize two CW lasers because the absorption coefficient of water vapor in the 1.5 μm wavelength region is relatively low. One of the CW lasers is locked to the HCN R18 absorption line (1531.276 nm) by the phase modulation technique and the other CW laser is locked to the water vapor absorption line by the offset locking technique.

Figure 3 (a) schematically shows the error signal of the phase modulation technique. If the laser wavelength controlled to be at the center of the absorption line, the side-band signals which is positive and negative amplitude are canceled, and then, the amplitude of the error signal is zero. If the laser wavelength has an offset from the absorption line center, a difference appears between the positive and negative amplitude of the side-band signals, and then, the error signal has some amplitude. Therefore, the wavelength can be stabilized by controlling the laser so as to make the amplitude of the error signal to be zero.

Figure 3 (b) is the error functions of the offset locking technique. The difference of the wavelength between the HCN R18 absorption line and water vapor absorption line is 0.1068 nm which corresponds to the 13.663 GHz frequency difference. Therefore, the beat frequency of HCN locked laser and CW laser for water vapor absorption is controlled to 13.663 GHz by using the filter edge method, by stabilizing the amplitude of the beat frequency to be constant.

We had developed this wavelength locking circuit. Figure 4 shows the results of wavelength stabilities of phase modulation technique and offset locking technique. By using this locking system, the wavelength stabilities for HCN R17 absorption line attain 0.07 pm which corresponds to 9.05 MHz, and the wavelength stabililities for water vapor absorption line attain 0.13 pm which corresponds to 16.2 MHz.

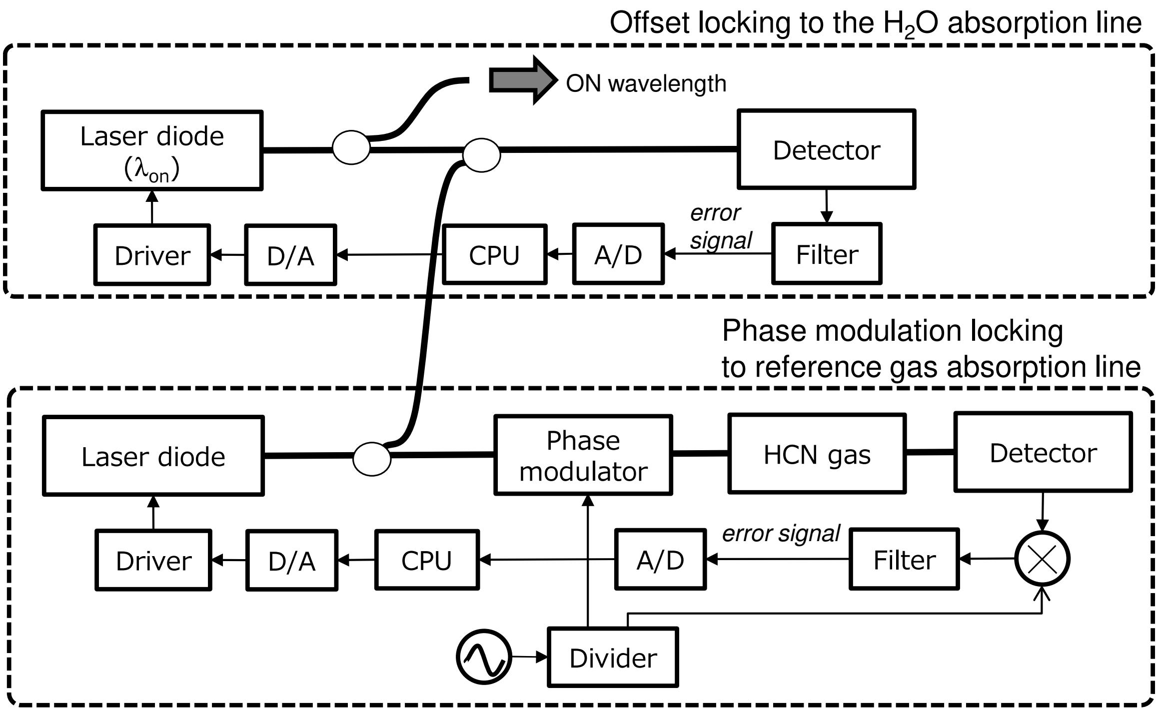

Figure 2. Schematic diagram of coherent differential absorption LIDAR.

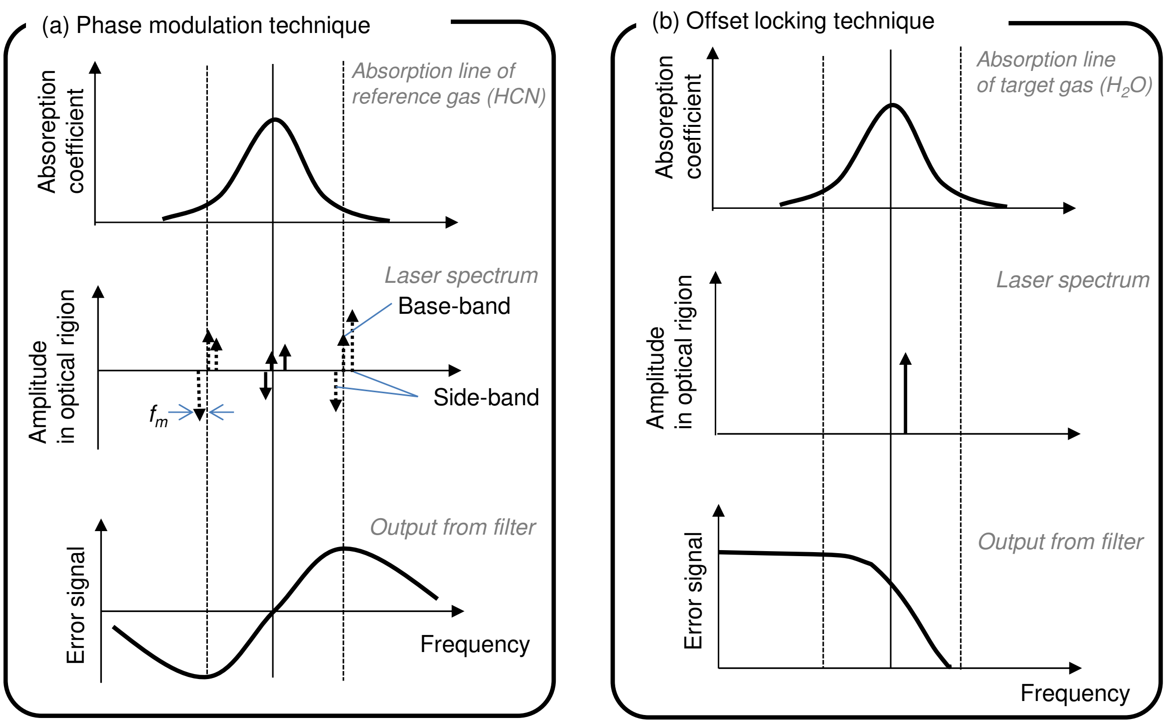

Figure 3. Error signal of the wavelength locking circuits.

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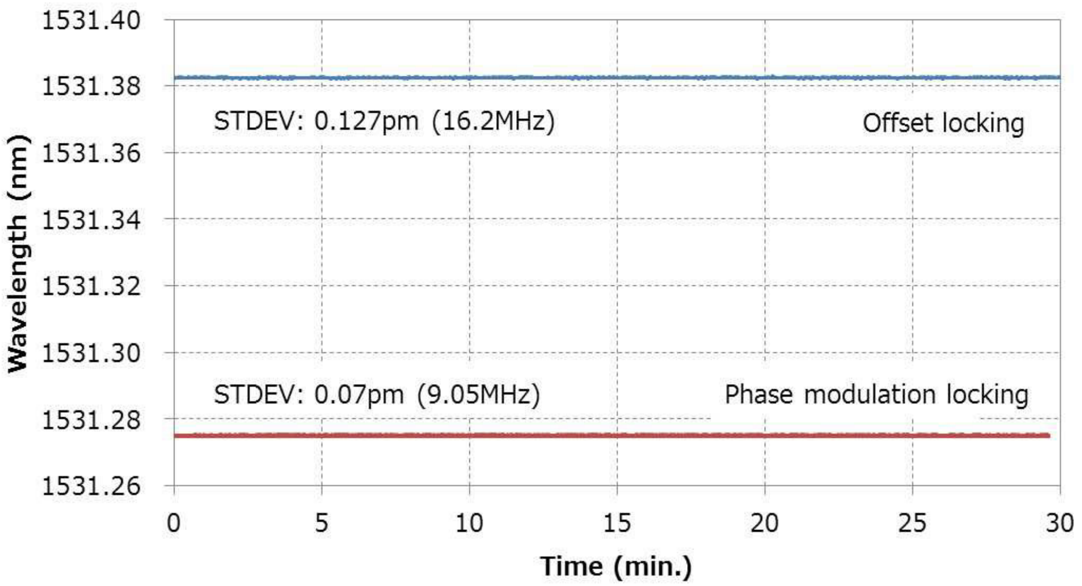

Figure 4. The data of wavelenght locking.

5 CONCLUSION

In conclusions, we reported on the result of the wavelength locking circuit for ground based coherent DIAL for vertical profiling of water vapor density using 1.5 µm laser wavelength.

Future work is the development of a benchtop model of coherent DIAL system, and demonstration of water vapor measurements.

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