The pressure shift of carbon dioxide for the on-line wavelength of 1.6 μm CO_2 DIAL

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Abstract

Fundamental spectroscopic parameters of CO_2, the absorption cross section, pressure induced broadening and shift coefficient, the contamination from other gases are important for the high precision DIAL measurement less than 1 %. With regard to the vertical profile measurement using a DIAL, the broadening and the pressure shift coefficients are concerned as factors increasing the uncertainty for the precision. Using a distributed feed-back laser, the pressure induced self-broadening and shift coefficients have been measured for several absorption lines around 1.572 μm. The pressure shift coefficient of the main lobe around 1572nm is -0.25 MHz/Torr. To our knowledge, these measurements for the pressure shift coefficients are the first results given for this band.

1. Introduction

Carbon dioxide is an important trace constituent of the Earth's atmosphere and is concerned as a potent greenhouse gas. The vertical carbon dioxide distribution from ground to 10km altitude is required in the atmospheric dynamics because of more precise prediction of global carbon cycle in the future. The precision of measured carbon dioxide in the layer is needed less than 1 %. With regard to the overview including system design about the 1.572 μm CO_2 DIAL, Nagai et al. are described in reference [5].

To achieve the precise CO_2 measurement using the DIAL operated at the 1.57 μm, spectroscopic parameters, the pressure induced broadening and shift coefficients, must be considered as same as the development of the instrument. Reference 1 and 2 reported the self- or buffer-gas pressure broadening coefficients of CO_2 in 1.57 μm region. On the other hand, the pressure shift coefficients have not been almost reported. In this study, we have measured the pressure shift coefficients for the 5 absorption lines of CO_2 in the 1.57μm region with a direct absorption.

2. Experimental setup

Fig. 1 shows our experimental setup. A fiber coupled distributed feed-back (DFB) laser was used as the near-infrared light source. This laser has a built-in isolator (nominal 45dB) and the high side mode suppression ratio (over 45dB), with the linewidth less than 1 MHz. The laser driver is a low noise current source, and a temperature controller has been used to stabilize the laser wavelength within 0.003K. The operated wavelength between 1.57 μm and 1.573 μm is tuned by changing the temperature of a TEC in the laser module. The temperature coefficient of this module is 0.08nm/K. The fine turning is done by adjusting the injection current over an absorption line.

The output of the DFB laser is divided by a 10/90 splitter through a fiber optical isolator. The output of the port1 (10% of the total power) is used as a prove beam, goes through the sample cell, while the port2 is sent to the wavelength meter for the identification of the absorption line and the detector for the differential absorption detection. Both signals from photodetectors are acquired by the digital oscilloscope and then stored to the PC through a GPIB interface. The signal from wavelength meter is also stored to the PC. The room temperature was assumed constant, T = 24 degree.

The sample cell is filled with CO_2 at different pressure. The propagation length of the prove beam in the cell is about 120 cm. The pressure in the cell is monitored with a capacitive vacuum gauge, with a full scale range between 1 Torr and 825 Torr.

The pressure shift coefficients are evaluated from the fitting curve of 10 times average. The analysis is done with C++ and the MathCad 13 software package. The absorption signal is normalized with the signal of the empty cell and is fitted assuming the Voigt profile function. The pressure broadening coefficients are also determined from the Lorentzian parameter in the Voigt profile function because the temperature dependence is small during the measurements. The Doppler broadening at 24 degree is assumed 177 MHz.

3. Results

In this study, 5 absorption lines around 1.572 μm were

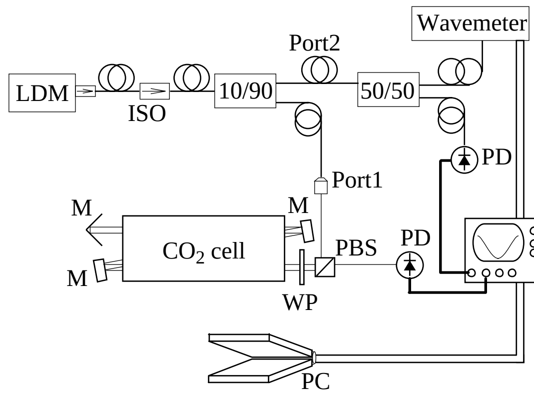

Fig. 1. The diagram of the measurement of pressure broadening and shift. LDM: laser diode module; ISO: fiber isolator; PBS: polarizing beam splitter; WP; λ/4 wave plate; M: mirror; PD: photodetector; OSC: Oscilloscope.

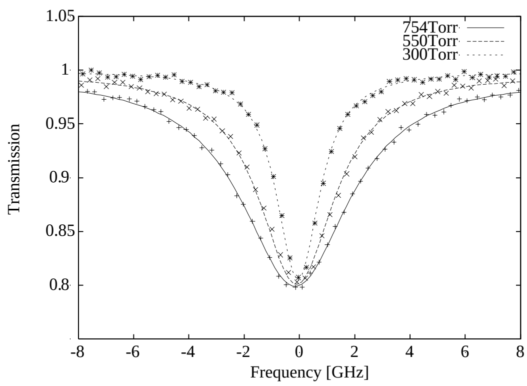

Fig. 2. The absorption profiles observed for the absorption line (1572.018nm[†]) for sample pressure from 300Torr to 754Torr. Each points show experimental transmittance. Solid, dotted, dashed lines are the fitting curve at 754, 550, 300 Torr, respectively. [†)]Center wavelength value is form HITRAN2004 database

observed for three pressures.

In the case of CO_2 the Lorentzian half-width Γ and the center wavelength shift Δ are assumed to vary linearly as a function of the pressure *p*,

$$\Gamma_L = \gamma_L p \quad (1)$$

$$\Delta = \delta p \quad (2)$$

where γ_L and δ are the pressure broadening and shift coefficients, respectively. The observed spectrum at the 1.572018 μm showed in Fig. 2 as transmittance. The spectrum recorded in three sample pressures. The Voigt profile function was used as the profile function to analyze the observed spectrum.

The broadening and shift coefficients, γ_L, δ for the 5 absorption lines evaluated by the Voigt profile are plotted in Fig. 3. Both coefficients are average value, and error bars for the both parameters are standard deviations within 10 times measurements.

To our knowledge, pressure shift coefficients around 1.572 μm are the first measured value, therefore no comparison with early studies is possible. However, at least for the pressure broadening, a comparison can be made with data from HITRAN molecular database, where self broadening coefficients are reported for each line. The γ_L values between our measurements and HITRAN data show generally good agreement. Our measurements are smaller than HITRAN data, which the average of difference between our γ_L value and HITRAN is 0.41 MHz/Torr. Reference 3 indicated that the Doppler width have a dependence on the pressure, the coefficient is about -1.0×10^{-5} cm^{-1} (0.3 MHz/Torr) with increase of the pressure. Consequently, the offsets of measured γ_L are evaluated as results of the dependence of the Doppler width on the pressure.

As far as the pressure shift coefficients are concerned, no previous data are available for the absorption lines here studied. In the 1.575-1.579 μm, Rosa et al. measured the pressure induced shift and broadening coefficient for 11 absorption lines [2]. Reported shift coefficients were -0.3 ~ -0.8 MHz/Torr, which the dependence on the rotational quantum number J was

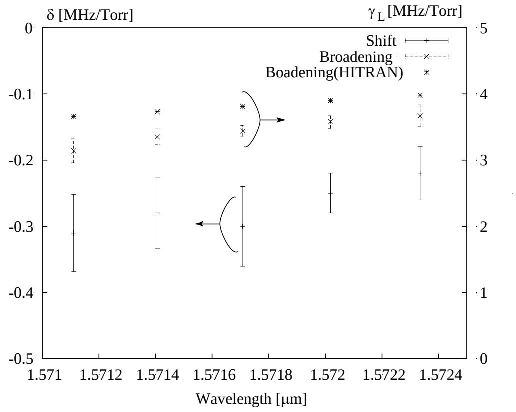

Fig. 3.. Measured pressure induced broadening and shift coefficient of CO_2 at different pressure. The error bars indicate 10 times standard deviations obtained for each profile analysis.

found. Our δ values also indicate the negative and small increases with the wavelength decreases.

4. Conclusion

By using DFB diode laser, we measured fundamental spectroscopic parameters for 5 absorption lines of CO_2 due to the target of the precise CO_2 DIAL measurements. The pressure induced broadening and shift coefficients have been measured. The broadening coefficients are compared with the data from HITRAN database, and a generally good agreement is found. The pressure shift coefficients are -0.25 ~ -0.32 MHz/Torr, which increase inverse proportion to the wavelength decrease. To our knowledge, the pressure shift coefficients in 1.57 ~ 1.573 μm are shown for the fist time.

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ACKNOWRIDGEMENT

This work is financially supported by the Japan EOS (Earth Observing System) Promotion Program (JEPP) promoted by the Ministry of Education, Culture, Sports, Science and Technology of Japanese Government.