HIGH PRECISION LINE PROFILE MEASUREMENT ON ^{13}C-ACETYLENE USING AN OPTICAL FREQUENCY COMB

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A line profile of ^{13}C acetylene in NIR has been measured with very high precision using a diode laser locked to an optical comb. Observed profile data have been analyzed by the generalized Voigt function to determine the Doppler width precisely: at the present we realized a precision of 10^{-3}.

I. Introduction

A spectral line profile obtained experimentally provides not only the line center position but also the intensity and the width. The intensity and the width carry the thermodynamical information of the molecules in the sample cell: temperature and pressure. Among them the Doppler width is directly related to the temperature T ; the half width at (1/e) maximum of the Gaussian contribution of the line profile Γ_G is expressed as $\nu_0(2kT/Mc^2)^{1/2}$, where ν_0 is the line center position, k the Boltzmann constant, M the molecular mass. In other words, the k can be determined from the observed Γ_G, ν_0, and T. In the present study we have measured a ^{13}C acetylene line, P(16) of the $\nu_1+\nu_3$ band in NIR (1.5 μm), for which the line center position is known with a very high accuracy: 194 369 569 383.6(1.3) kHz[a)]. The Γ_G of the line at zero pressure has been obtained as 271.31(32) MHz, which should be compared to 271.12 MHz calculated at 294.65(10)K with the most accurate value of k.

II. Experimental Procedure

To increase the precision of measurement as high as possible, we recorded the line profile by an external cavity laser diode (ECLD) locked to an optical frequency comb signal, which is produced by a fiber-based frequency comb system developed at NMIJ(AIST)[b)]. A frequency scan of ECLD for 2 GHz, required to measure the Doppler broadened line profile, is realized by tuning the repetition frequency f_{rep} of the comb system; f_{rep} is scanned by locking it to a synthesizer-sweeper (~54 MHz).

The ECLD output level is stabilized using a fiber-amplifier by a feed-back loop, in order to keep the power level of the incident radiation for the sample cell constant as much as possible. The 150 mm sample cells (THORLABS Co.) are sealed by wedged quartz windows, which contain the sample of $^{13}C_2H_2$ with different pressures: about 0.3, 1, 3, and 5 Torr.

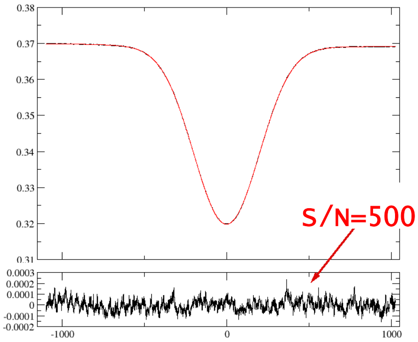

Fig. 1. The observed line profile is reproduced with the calculated one. The observed – calculated values are displayed in the bottom with an enlarged scale.

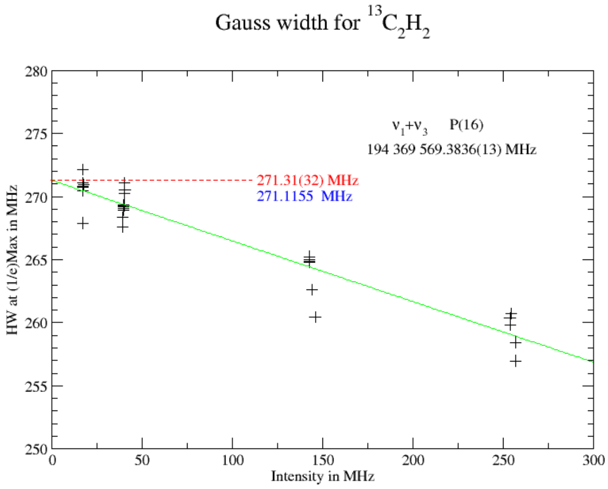

Fig. 2. The Gaussian width obtained from the analysis using generalized Voigt function is plotted as a function of intensity. The value at the zero intensity corresponds to the “Doppler” width.

III. Analysis and Results

The observed line profiles have been analyzed by a least-squares-fit procedure using the generalized Voigt function to determine four parameters for each profile: line center, line intensity, Gaussian width, and Lorentzian width. A typical result of the fit is presented in Fig. 1 for a spectrum measured for the sample of 1 Torr. Because of the Dicke narrowing effect, it is important to use the generalized Voigt function, where the Doppler (Gaussian) width is also handled as a parameter to be adjusted. The Lorentzian width was not well determined for the 0.3 and 1 Torr samples, because the observed line profile is almost Gaussian and the Lorentzian contribution is very small. Presently the Lorentzian width for these pressures are estimated from those for 3 and 5 Torr samples by a linear extrapolation, and are fixed in the analysis.

The results are represented in Fig. 2, where the obtained Gaussian widths are plotted as a function of the observed intensities. The sample pressure in the cell was not known with high accuracy, we use the observed intensities as the measure of pressure. As shown in the figure, we have observed the Dicke narrowing effect significantly. The thermodynamically defined Doppler width has been evaluated by extrapolating to zero intensity (pressure).

[a)]F.-L. Hong *et al.*, *Opt. Lett.*, **28**, 2324 (2003).
[b)]H. Inaba et al., Opt. Express 14, 5223 (2006).