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DEVELOPMENT OF A LASER HETERODYNE SPECTROMETER FOR OBSERVATION OF THE ANTARCTIC OZONE HOLE

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INTRODUCTION

Tunable diode laser heterodyne spectrometers (TDLHSs) have been developed in Tohoku University for observations of minor constituents of the atmosphere. TDLHS is an infrared spectrometer operating in the middle infrared region around $\lambda \sim 10$ μm, achieving ultra-high spectral resolution and quantum limited sensitivity. We have been succeeded in obtaining vertical profiles of ozone, nitrous oxide and methane in the troposphere and the stratosphere from solar absorption spectra measured by using this instrument. The latest TDLHS (TDLHS-3) has been developed for observation of minor constituents related to the Antarctic ozone hole. One of the purposes of spectroscopic observations with this instrument is to obtain temporal variations of vertical profiles of ozone and nitric acid in developing and diminishing phases of the Antarctic ozone hole. Another purpose is to obtain vertical profiles of greenhouse gases such as nitrous oxide, methane and water vapor above Antarctica where they are free from anthropogenic emission sources.

INSTRUMENTATION

Figure 1 shows a block diagram of TDLHS-3, of which the performance parameters are listed in Table 1. TDLHS-3 is an advanced version of TDLHS-2 which is currently operating for observations of atmospheric minor constituents at Sendai, Japan. TDLHS-2 has only one large liquid-nitrogen dewar vessel which contains an MCT photomixer and two diode lasers, whereas, in TDLHS-3, a photomixer and a set of four diode lasers are equipped in separate vessels to make adjustment of optical alignment easier. The dewar which contains diode lasers has two Ge vacuum windows. Two lasers are placed inside of each window. One of the four diode lasers is selected as a local oscillator for a specific wavenumber region by using a resettable mirror and moving a translational stage on which a collimator lense is mounted. The lasers are operating in the wavenumber regions of $\sim$ 900 cm^{-1}, $\sim$ 1100 cm^{-1}, $\sim$ 1190 cm^{-1}, and $\sim$ 1220 cm^{-1}, which correspond to absorption bands of nitric acid, ozone, nitrous oxide, and methane, respectively. The instrumental bandwidth is $\sim$ 0.001 cm^{-1} yielding a resolving power of $\sim 10^6$. A Ge solid etalon or a gas cell is used for frequency calibration and identification of absorption substance.

TDLHS-3 is now operating at Syowa station, Antarctica (69.0°S, 39.6°E). An absorption line spectrum obtained during the test observation period in March 1994 is shown in Figure 2. The three strong absorption lines seen in Figure 2 are due to methane. Intensive observations will begin in August 1994 after the end of the polar night.

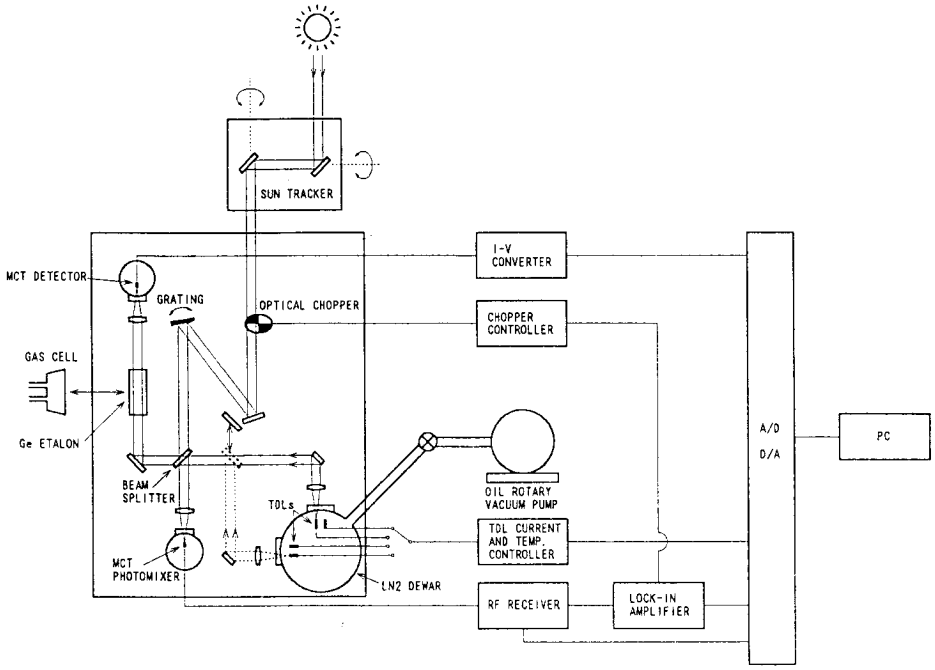

Fig. 1. A block diagram of TDLHS-3.

Table 1. Performance parameters of TDLHS-3

Size	1400 mm × 600 mm × 500 mm
Weight	120 kg
Spectral region	900, 1100, 1190, 1220 cm^{-1}
Bandwidth	40 MHz (0.0013 cm^{-1})
Resolving power	6.9 – 9.4 × 10^5
Temperature range	65 – 90 K
Temperature stability	< 0.01 K
Liquid N_2 holding time	> 2 days
Scan time	9 min/spectrum

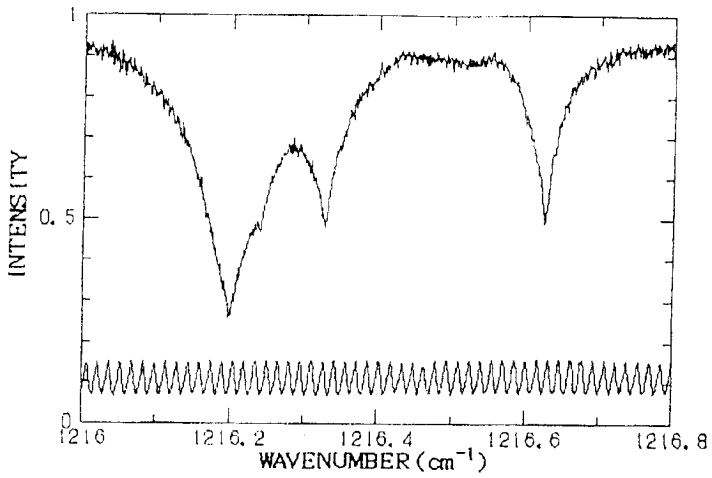

Fig. 2. An example of absorption line spectrum of methane obtained with TDLHS-3 on March 22, 1994 at Syowa station in Antarctica.