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DEVELOPMENT OF TUNABLE DIODE LASER HETERODYNE SPECTROMETERS FOR REMOTE SENSING OF ATMOSPHERIC MINOR CONSTITUENTS

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INTRODUCTION

High-resolution infrared spectroscopy offers an useful way of measuring abundance of minor constituents in the terrestrial atmosphere. The most important point of the high-resolution spectroscopy for application to trace-gas monitoring is that we can avoid interference due to other absorption matters which mask weak absorption feature to be measured. The laser heterodyne spectroscopy can achieve an ultra-high spectral resolution ($\Delta\sigma = 0.001$ cm^{-1}) and quantum-limited sensitivity in the middle infrared region ($\lambda = 8 - 11$ μm). We have developed tunable diode laser heterodyne spectrometers (TDLHSs) for remote sensing of atmospheric minor constituents from the ground.

INSTRUMENTATION

Liquid nitrogen-cooled tunable diode lasers are employed as a local oscillator. They have performance suitable for this application because of their frequency tunability and wide-selection of operating wavenumber. Moreover, use of diode lasers instead of gas lasers such as a CO_2 laser contributes to light-weight, small-size, and small energy consumption of the system. These characteristics are important in its future application for observation from a space platform.

Observations are performed in the daytime using solar infrared radiation, which is automatically tracked by a sun follower, as a light source. Data are acquired by a PC, which is also used for control of laser current, through a 12-bit A/D D/A converter. A fully-resolved absorption line profile of minor species in the terrestrial atmosphere is obtained by a laser-frequency scan of $\sim$ 8 min duration. Figure 1 shows an example of ozone absorption line spectrum obtained with one of the TDLHSs.

OBSERVATIONAL RESULTS

We have constructed three sets of TDLHSs: TDLHS-1 was firstly used for routine observations of stratospheric ozone from 1989 through 1991 in Sendai, Japan, with a short period of alternative observation of nitrous oxide in 1989. Seasonal variations of total ozone amounts in Sendai were obtained for two entire years exhibiting a good agreement with the seasonal variation of total ozone amounts observed in Tsukuba and Sapporo with Dobson spectrophotometers. A rapid ozone increase around the upper-level frontal zone associated with development of a cyclone was also detected from the TDLHS measurements.

TDLHS-2 was designed mainly aiming at field observations of ozone, nitrous oxide and methane. Campaign observations were made at Mt. Haleakala in Maui, Hawaii in October, 1991 and in February, 1993 for ozone, nitrous oxide and methane, and in Fairbanks, Alaska in September/October, 1992 for ozone and methane and in February/March, 1994 for ozone. Diurnal variations of ozone vertical profiles were obtained from the observations in Hawaii with a time resolution of 1 hour. Figure 2 shows a time-height cross section of ozone mixing ratio observed with the TDLHS at Mt. Haleakala in Hawaii in October, 1991. TDLHS-2 was also used in intensive observations of the ozone layer in Tsukuba during 1991/1992 and 1992/1993 winter periods.

The latest TDLHS-3 is an advanced and sophisticated instrument designed for observations of the Antarctic ozone hole and related minor species with the green-house effect. Test observations began at Syowa station in Antarctica in February, 1994, and several absorption line spectra of ozone and methane have so far been obtained.

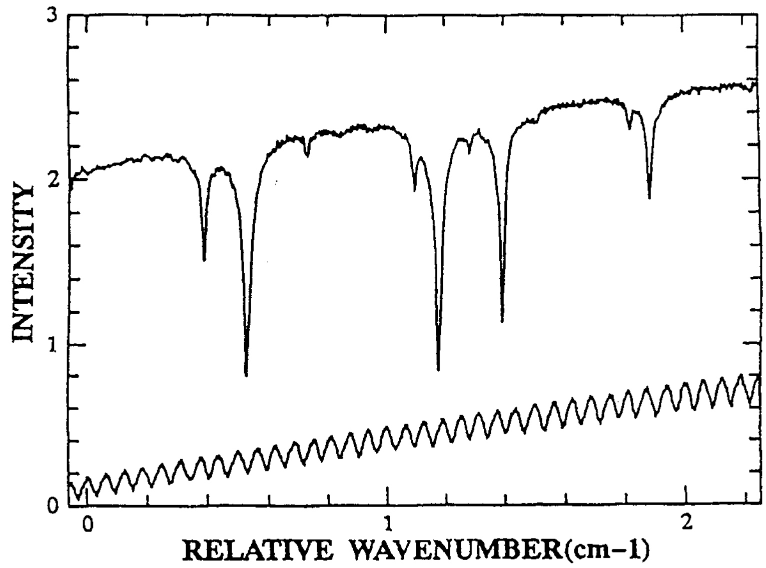

Fig. 1. An example of ozone absorption line spectrum obtained with the TDLHS.

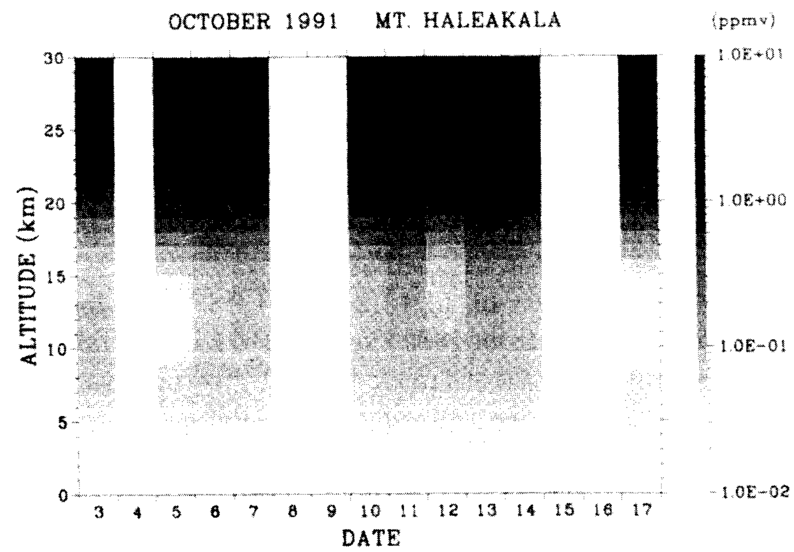

Fig. 2. A time-height cross section of ozone mixing ratio observed with the TDLHS at Mt Haleakala in Hawaii in October, 1991.