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# DIAL MEASUREMENTS OF NITROGEN DIOXIDE BASED ON SOLID-STATE LASERS

Ryoichi Toriumi and Hideo Tai
*Information Technology Research Institute, Tokyo Gas Co., Ltd.*
2-3, Nakase, Mihama-ku, Chiba 260-91, JAPAN
Phone: 81-43-296-5879 Facsimile: 81-43-298-1913

Nobuo Takeuchi
*Remote Sensing and Image Research Center, Chiba University*
1-33, Yayoi-cho, Inage-ku, Chiba 263, JAPAN
Phone: 81-43-290-3849 Facsimile: 81-43-290-3857

## INTRODUCTION

A differential absorption lidar (DIAL) technique has proved to be useful for remote monitoring of air pollution gases. The DIAL measurements on nitrogen dioxide which was one of major air pollution gases were made by some authors. These systems were constructed by a flashlamp-pumped dye laser [1],[2],[3], or by a Nd:YAG laser-pumped dye laser [4],[5].

Recently solid-state tunable lasers have been improved, which promises the practical applications of the DIAL systems. In the present paper, we demonstrate measurements of nitrogen dioxide with a DIAL system based on solid-state lasers.

## DIAL SYSTEM DESCRIPTION

A block diagram of the DIAL for nitrogen dioxide measurements is shown in Figure 1. Frequency mixing of a Ti: sapphire laser (130 mJ/pulse) and a Nd: YAG laser (450 mJ/pulse) is used as a light source. The Ti: sapphire laser is pumped by a frequency doubled Nd: YAG laser at a repetition rate of 10 Hz. The frequency mixing is achieved by a KDP crystal. Output energy and beam divergence are 20 mJ/pulse and 0.5 mrad, respectively, at the mixing wavelength of 453 nm. A couple of glass plates are placed on the optical path in order to divide the beam off slightly (4 % each). One divided beam is lead to a pulse wavemeter to monitor wavelength continuously. The other is divided again by a beam splitter (50%–50%). The transmitted and reflected beams by the splitter are lead to photodiodes directly and through a 10-cm calibration cell, respectively. The calibration cell is filled with 1.05 % nitrogen dioxide in 1 atm of nitrogen. The signals of the two photodiodes are integrated by a boxcar integrator. An absorption spectrum of nitrogen dioxide of the cell is given by taking ratio of the two signals as shown in Figure 2.

The wavelength of the Ti: sapphire laser is switched pulse by pulse by oscillating a tuning mirror of the resonator. As a result, the mixing wavelength is switched between 448.10 nm (absorption wavelength) and 446.90 nm (reference wavelength) pulse by pulse, as shown in Figure 3.

The received light is collected with a 30-cm-diameter Cassegrain telescope, which focuses the light on an iris for geometrical compression. After the iris, the light is parallelized and passes through an interference filter. The filter of 8.8 nm FWHM (T= 55%) is used. The filtered light is detected by a photomultiplier and the output signals are digitized after pre-amplification in a 10 bit-100 MHz transient recorder and processed by a personal computer.

## EXAMPLES OF MEASUREMENT

In the experiment, the system was directed toward a topographic target (metal fence) at a distance of about 50 m. Since the target was very close, the beam energy was attenuated to 2 mJ/pulse so that the photomultiplier was not saturated. The wavelengths of the laser pair were selected 448.20 nm (absorption wavelength) and 447.00 nm (reference wavelength). An emission of nitrogen dioxide was simulated by a 25-cm sample cell whose windows were made of quartz. The cell was placed about 30 m from the DIAL system.

Measurements were done for four situations: a sample cell filled with 0 ppm, 502 ppm, 926 ppm, and 2280 ppm nitrogen dioxide in 1 atm of nitrogen. Figure 4 shows an example of a DIAL measurement of 926 ppm nitrogen dioxide. The curve are the averaged signals from 8 pulse-pairs. Absorption cross section is calculated by the ratio of areas of signal peaks around 50 m for each wavelength. The results of the series of the cell measurements are shown in Figure 5. The concentration of the nitrogen dioxide (DIAL) in Figure 5 is calibrated by measured absorption cross section at 2280 ppm.

This system will be used to measure nitrogen dioxide from a stack plume.

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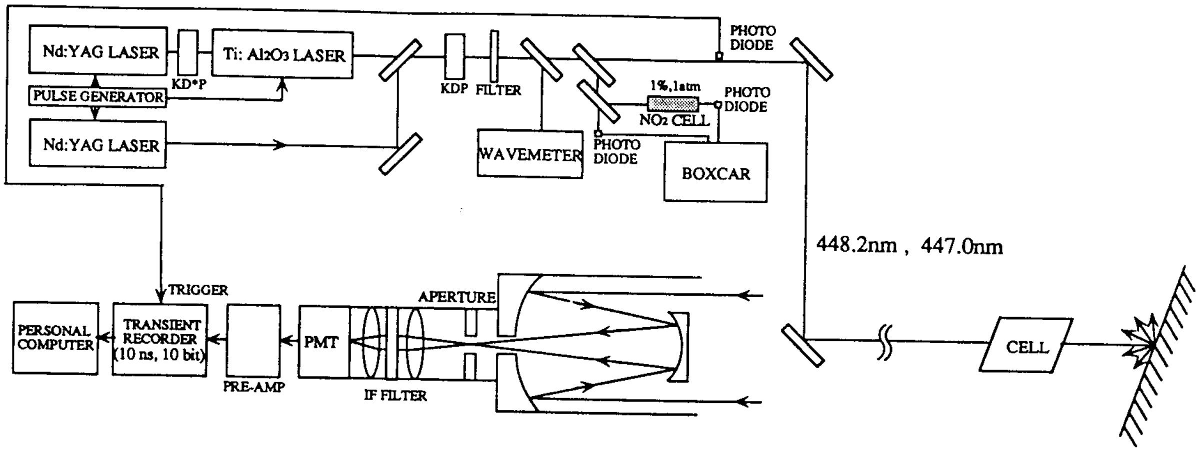


Fig.1 Schematic diagram of a differential absorption laser radar

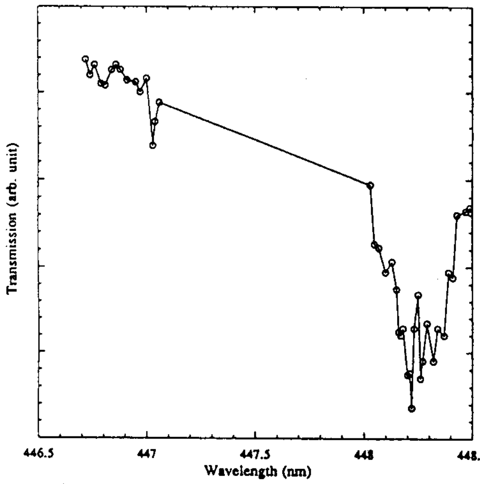


Fig.2 Transmission spectrum of nitrogen dioxide

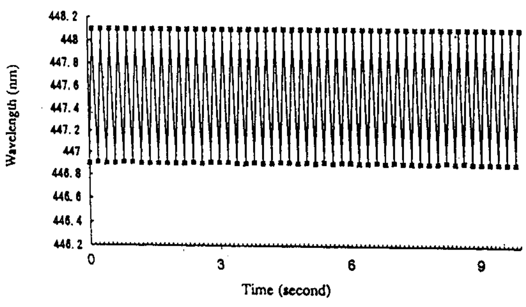


Fig.3 Wavelength stability between the laser pulses

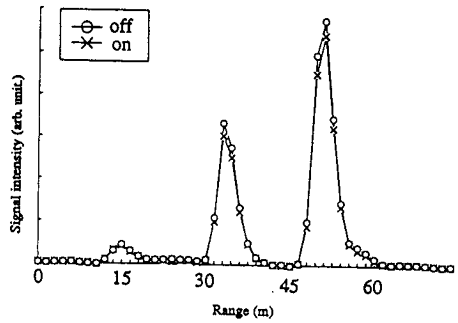


Fig.4 Plot of received signal vs range with 926 ppm nitrogen dioxide in a sample cell

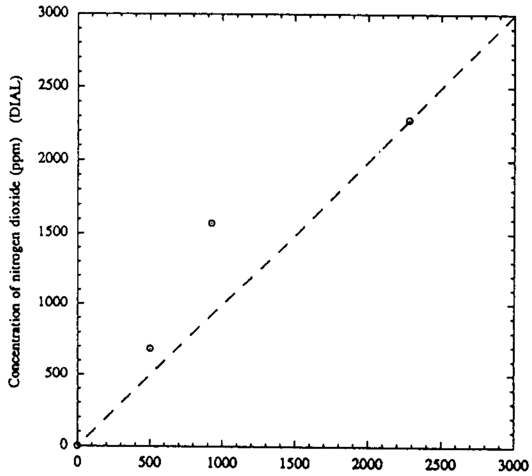


Fig. 5 Measurement of nitrogen dioxide concentration in a sample cell with a DIAL system and a NOx analyzer