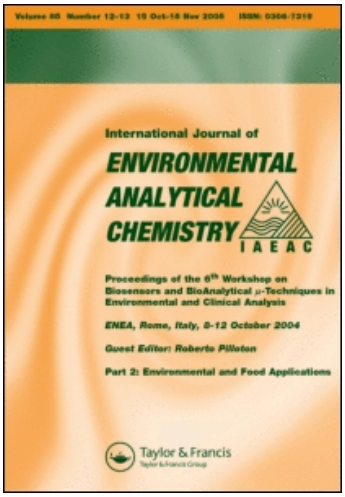

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Infrared Emission of Air Pollutants Induced by a CO_2 Laser

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KEY WORDS: CO_2 laser; air pollutants; infrared emission; sulphur hexa fluoride.

A possible method for the measurement of air pollutants is described. It is based on infrared emission from gases at specific wavelengths induced by a CO_2 laser. The emission level can be increased by adding a sensitizing gas (e.g. SF_6) to the sample gas. Although the mechanism of the emission is not fully understood experimental data indicate that the emission is of thermal origin. Spectra of some air polluting gases are included in this paper.

In 1966 Bordé *et al.*[1,2] and later Ronn[3] and Robinson and co-workers[4–6] reported on infrared emission by gases when they were irradiated by a 40-W cw CO_2 laser. The wavelengths of the emission spectra coincided with the wavelength of the infrared absorption spectra and differed from the wavelength of the exciting laser beam. The emission is specific to the gas and therefore the gas can be identified.

In the experiments described in the present paper the beam of a 55-W CO_2 laser was focussed by a concave mirror to a diameter of about 1 mm in front of the entrance slit of a monochromator (Jarrell-Ash 0.5 m). A schematic diagram of the experimental arrangement is given in Figure 1. A Golay detector (SP 50 Pye-Unicam) and a mechanical chopper (SP 52 Pye-Unicam) at a frequency of 11 Hz were used in conjunction with a synchronous amplifier (SP 51 Pye-Unicam).

Air polluting gases such as SO_2, CO, NO and NO_2 were added to a nitrogen flow of 60 l/hr and emission was observed with a focussed laser beam. A minimum laser power is required in order to observe emission; below 20 W no emission could be observed.

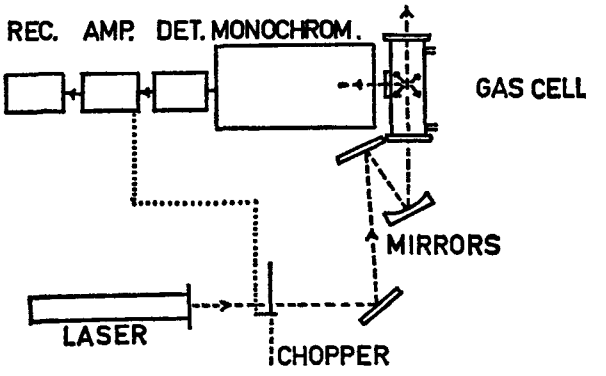

FIGURE 1 Schematic diagram of experimental arrangement.

It is known that SF_6 is a good absorber of the CO_2 laser radiation. Bailey *et al.*[7] indicated in 1971 that the intensity of the emission of gases as CO, among others, could be increased considerably by adding some SF_6, CO_2 or C_2H_4 to the gas flow. The signal did not depend strongly on the SF_6 concentration: from 0.05% to 0.2% no change in emission signal was observed.

Table I presents the relative intensity of the emission of the gases and the wavelength of the emission peak. Peak heights of the emission are compared to the peak height of the SO_2 emission at 7.26 micron (resolution 394 Å; SF_6 concentration 0.1%; time constant 10 sec). The emission peaks of CO, NO_2 and SO_2 are given in Figures 2, 3 and 4. It was possible to detect a

TABLE I

Relative intensity of the emission peaks of several gases with respect to SO_2

Gas	Relative intensity	Emission wavelength (micron)
SO_2	1	7.26
CO	0.6	4.56
CO_2	5	4.37
NO	0.3	5.30
NO_2	5	6.30
O_3	0	—
SF_6	—	5.93

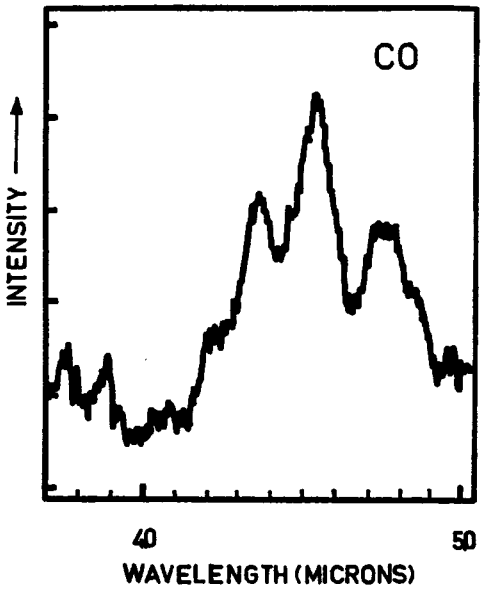

FIGURE 2 Emission spectrum of CO. [CO] = 2000 ppm. Time constant = 10 sec.

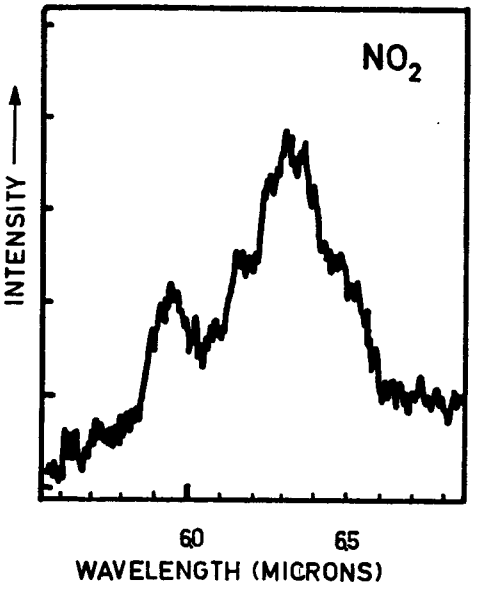

FIGURE 3 Emission spectrum of NO_2. [NO_2] = 200 ppm. Time constant = 10 sec.

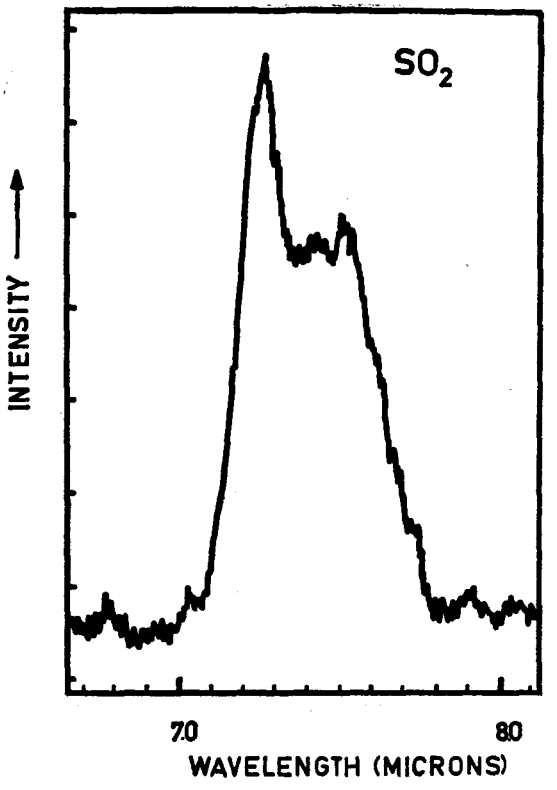

FIGURE 4 Emission spectrum of SO_2. $[SO_2]$ = 2000 ppm. Time constant = 10 sec.

sulphur dioxide concentration of 20 ppm with a time constant of 40 sec and a signal-to-noise ratio of 4.

During the experiments a delay time of about 15 msec was observed between the emitted infrared radiation and the scattered laser light (Figure 5). During the experiments pressure variations with the same frequency as the chopped laser beam were observed in the gas cell.

These two observations suggest that the emission is of thermal origin. The delay time was demonstrated in a modified set-up where the emitted radiation was detected directly with an InSb detector (RPY 77, Mullard; rise time 100 *n*sec) and the mechanical chopper was replaced by an electronic modulator coupled to the laser. A second detector (CdHgTe, 77°K, S.A.T.) was placed in the laser beam after the gas cell. The signals of both detectors were fed to an oscilloscope and recorded with a video recorder (Philips EL 3402)

in order to have slow-motion pictures of the fast-changing signals. Square-wave laser pulses of 10 msec and of 100 msec duration each with repetition times of 1 sec were applied. The signals of both detectors are presented in Figure 6. It can be seen that the signal due to emission rises slowly. At the end of the laser pulse the emission signal falls slowly. At shorter pulses the emission signal is lower. These observations support the assumption that the emission is mainly thermal.

The method looks promising for the measurement of common air pollutants, such as SO_2, NO, NO_2, CO and CO_2.

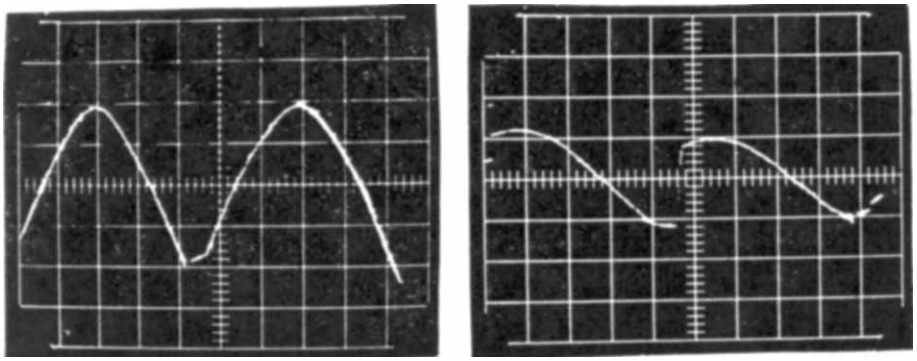

FIGURE 5*a* Direct detector signal due to emission of acetone with optimal adjustment of the phase of the chopper blades (x-axis: 10 msec/cm).

FIGURE 5*b* Direct detector signal due to scattered radiation of the laser beam with the same chopper phase as under *a* (x-axis: 10 msec/cm).

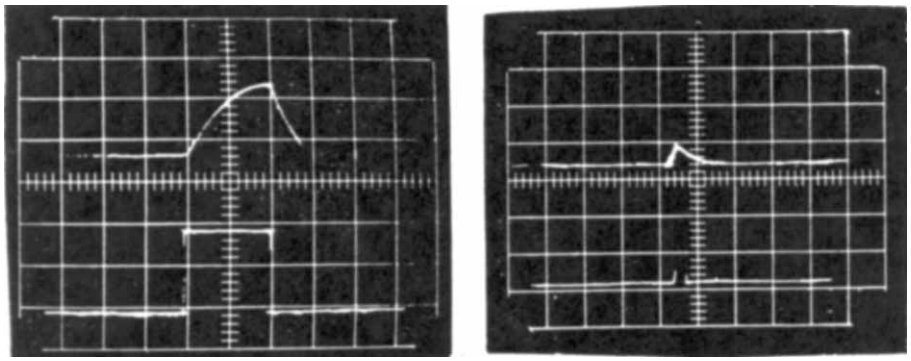

FIGURE 6*a* Emission signal compared to the laser pulse signal (pulse duration 100 msec).

FIGURE 6*b* Same as 6*a* but with a laser pulse of 10 msec.

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