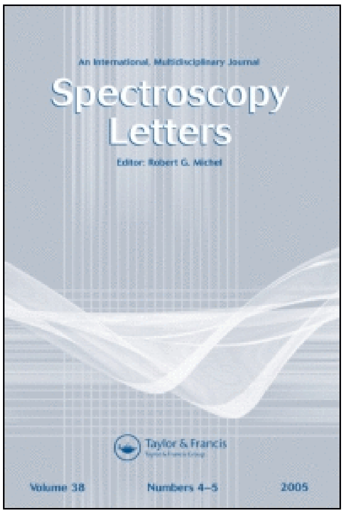

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Spectrophone Measurements of Air Pollutants Absorption Coefficients at CO_2 Laser Wavelengths II

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SPECTROPHONE MEASUREMENTS OF AIR POLLUTANTS ABSORPTION COEFFICIENTS AT CO_2 LASER WAVELENGTHS II

KEY WORDS: laser optoacoustic technique, absorption coefficients, air pollutants

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Abstract

Laser optoacoustic spectroscopy technique has been used to measure the absorption coefficients of eight gas pollutants at CO_2 laser wavelengths between 9.2 μm and 10.8 μm. All measurements were performed with pollutant at a low pressure in the presence of 1 atm of nitrogen. For outdoor long--optical path monitoring of air pollution paier of lines (detection and reference line) have been selected.

INTRODUCTION

It is well known that the absorption coefficients of various pollutant gases are of basic importance for air pollution monitoring with differential absorption technique (see e.g. ref.1). This paper reports some new results of absorption coefficients measurements at CO_2 laser wavelength and it represents the extention of our previous work[2].

EXPERIMENTAL APPRATUS

All details about the experimental technique and apparatus have been

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described in the preceeding paper[2]. Same apparatus has been used again for the measurement of absorption coefficients. The only alteration has been made with the pressure gauge. In our previous experiment for the measurement of low vapour pressure of pollutants, McLeod gauge has been used. In order to avoid possible errors in vapour pressure measurements this gauge has been replaced with a capacitance manometer (MKS Instruments, sensor head model no. 310 BHS-100).

RESULTS AND DISCUSSION

First, it has been carefully checked for all previously investigated substances[2] whether new improved technique of vapour pressure measurements could improve the accuracy or correct some systematic error in absorption coefficient measurements. It was found that, in the range of vapour pressures used in our experiment[2], there was no difference in pressure reading between McLeod and capacitance pressure gauge. Therefore, the results for absorption coefficients of ethylene, freon 12, ammonia, benzene, trichlorethylene, etanol and toluene can be used with confidence within the limits of estimated accuracy[2].

New experimental results for absorption coefficients at CO_2 laser wavelengths of vinyl chloride, monochloro-ethane, sulfur dioxide, methanol isopropanol, cyclohexane, ethyl acetate and acetonitrile are given together with the results of Mayer et al[3] in Tables 1-4. The temperature of measurement was $22 \pm 2^{o}C$.

Since the calibration of the optoacoustic cell is performed with ethylene at the wavelength of CO_2 (P 14) line whose absorption coefficient is known within $\pm 5\%$ (see discussion in ref. 2), estimated accuracy of our data is $\pm 9\%$. Here, one should point out that a very good agreement with results of Mayer et al[3] exists (see Tables 1-4). Unfortunately similar detailed comparison could, not be performed with the other authors[4,5] since the results were given only in a graphical forme. However maximum

TABLE 1.

ABSORPTION COEFFICIENTS $\alpha(\mathrm{atm\ cm})^{-1}$ OF VARIOUS POLLUTANTS, R BRANCHES OF THE $00^01\text{-}02^00$ TRANSITION

	Wavelength [μm]	Vinyl chloride		Monochloro-ethane		Sulfur dioxide		Methanol	Izopro-panol	Cyclo-hexane	Ethyl acetate	Aceto-nitrile
		meas.	ref. 3	meas.	ref. 3	meas.	ref. 3	meas.	meas.	meas.	meas.	meas
R 36	9,192	-	-	0,012	-	-	-	1,29	2,58	0,013	1,32	0,071
34	9,201	-	-	0,014	<0,01	0,079	-	1,29	2,61	0,015	1,41	0,066
32	9,210	0,43	-	0,013	<0,01	0,089	-	1,33	2,63	0,015	1,62	0,056
30	9,220	0,43	0,45	0,010	<0,01	0,072	0,11	1,33	2,65	0,015	1,72	0,051
28	9,230	0,22	0,20	0,014	<0,01	0,070	0,092	1,66	2,68	0,017	2,23	0,051
26	9,240	0,10	0,12	0,015	<0,01	0,093	0,105	1,55	2,65	0,017	2,53	0,061
24	9,250	0,054	<0,05	0,013	<0,01	0,070	0,090	1,87	2,62	0,015	2,84	0,071
22	9,261	0,054	0,05	0,012	<0,01	0,068	0,072	1,65	2,65	0,012	3,04	0,071
20	9,271	0,17	0,15	0,014	<0,01	0,087	0,088	1,78	2,77	0,010	3,04	0,101
18	9,283	0,054	<0,05	0,012	<0,01	0,044	0,068	1,83	2,74	0,012	3,44	0,071
16	9,294	0,051	<0,05	0,014	<0,01	0,044	0,056	1,92	2,74	0,014	3,54	0,076
14	9,305	0,054	<0,05	0,014	<0,01	0,043	0,054	2,33	2,79	0,011	3,85	0,086
12	9,317	0,12	0,1	0,011	<0,01	0,043	0,048	2,59	2,98	0,010	4,55	0,076
10	9,329	0,10	0,95	0,010	<0,01	0,043	0,044	2,22	2,77	0,010	5,26	0,091
8	9,342	1,48	1,50	0,011	<0,01	0,043	0,036	2,15	2,74	0,010	5,57	0,081
6	9,352	1,48	-	0,011	-	-	-	2,18	2,71	0,011	6,07	0,076

TABLE 2.

ABSORPTION COEFFICIENTS α(atm cm^{-1}) OF VARIOUS POLLUTANTS, P BRANCHES OF THE 00^01-02^00 TRANSITION

	Wavelength [μm]	Vinyl chloride		Monochloro-ethane		Sulfur dioxide		Methanol	Izopro-panol	Cyclo hexane	Ethyl acetate	Aceto-nitrile
		meas.	ref. 3	meas.	ref. 3	meas.	ref. 3	meas.	meas.	meas.	meas.	meas.
P 6	9,443	0,048	<0,05	0,033	-	-	-	2,29	1,89	0,051	-	0,091
8	9,458	0,17	0,15	0,033	0,03	-	-	2,37	1,76	0,061	12,16	0,093
10	9,473	0,32	0,30	0,038	0,04	0,007	0,010	2,70	1,60	0,083	11,75	0,113
12	9,488	0,645	0,65	0,072	0,07	0,005	0,005	3,18	1,34	0,096	11,44	0,129
14	9,504	0,052	0,05	0,018	0,02	0,004	0,005	3,67	1,10	0,106	11,34	0,111
16	9,520	0,55	0,57	0,017	0,02	0,004	0,005	4,26	1,04	0,101	11,15	0,157
18	9,536	0,77	0,75	0,019	0,02	0,004	0,005	4,51	0,96	0,101	10,43	0,096
20	9,553	2,04	2,05	0,043	0,04	<0,004	<0,005	5,00	0,86	0,081	9,32	0,111
22	9,570	1,63	1,65	0,11	0,09	<0,004	<0,005	5,19	0,73	0,081	8,51	0,099
24	9,586	1,46	1,45	0,013	<0,01	<0,004	<0,005	5,93	0,66	0,126	7,09	0,106
26	9,604	1,77	1,70	0,11	0,1	<0,004	<0,005	6,00	0,56	0,134	6,08	0,111
28	9,621	1,37	1,35	0,11	0,11	<0,004	<0,005	6,67	0,44	0,405	4,86	0,122
30	9,640	1,21	1,20	0,15	0,13	<0,004	<0,005	7,71	0,44	0,246	4,66	0,111
32	9,658	0,87	0,85	0,057	0,06	<0,004	<0,005	8,34	0,36	0,153	3,14	0,097
34	9,676	1,47	1,45	0,012	0,01	<0,004	0,005	8,90	0,36	0,128	2,23	0,091
36	9,695	0,64	0,65	0,012	-	-	-	10,61	0,32	0,122	1,72	0,086

TABLE 3.

ABSORPTION COEFFICIENTS $\alpha(atm^{-1}cm^{-1})$ OF VARIOUS POLLUTANTS, R BRANCHES OF THE 00^01-10^00 TRANSITION

	Wavelength |μm|	Vinyl chloride		Monochloro-ethane		Sulfur dioxide		Methanol	Izopro-panol	Cyclo-hexane	Ethyl acetate	Aceto-nitrile
		meas.	ref. 3	meas.	ref. 3	meas.	ref. 3	meas.	meas.	meas.	meas.	meas.
R 36	10,147	0,77	0,75	2,34	-	<0,004	<0,005	2,98	0,56	0,021	0,152	0,061
34	10,158	0,12	1,10	2,35	2,37	<0,004	<0,005	3,29	0,68	0,018	0,152	0,054
32	10,170	0,73	0,75	2,32	2,30	<0,004	<0,005	2,74	0,74	0,015	0,152	0,056
30	10,182	1,83	0,80	2,31	2,33	<0,004	<0,005	2,52	0,86	0,015	0,202	0,058
28	10,194	1,27	1,25	2,11	2,14	<0,004	<0,005	1,74	0,98	0,015	0,202	0,053
26	10,207	0,93	0,95	1,89	1,85	<0,004	<0,005	1,87	1,08	0,013	0,152	0,056
24	10,220	1,62	1,60	1,59	1,57	<0,004	<0,005	1,70	1,44	0,018	0,152	0,061
22	10,233	1,02	1,00	1,36	1,34	<0,004	<0,005	1,66	1,77	0,015	0,303	0,058
20	10,247	1,47	1,45	0,94	0,97	<0,004	<0,005	2,03	1,95	0,011	0,202	0,056
18	10,260	1,21	1,20	0,82	0,78	<0,004	<0,005	1,37	2,43	0,011	0,152	0,051
16	10,274	1,02	1,00	3,34	3,34	<0,004	<0,005	1,74	2,53	0,010	0,152	0,051
14	10,289	1,27	1,25	2,17	2,14	<0,004	<0,005	2,29	2,91	0,013	0,202	0,056
12	10,303	1,12	1,10	1,29	1,25	<0,004	<0,005	1,48	3,02	0,020	0,202	0,056
10	10,318	1,63	1,60	1,64	1,65	<0,004	<0,005	1,55	3,09	0,015	0,101	0,056
8	10,334	1,03	1,05	1,69	1,67	<0,004	<0,005	1,59	3,13	0,015	0,101	0,058
6	10,349	3,51	3,50	1,76	1,77	<0,004	<0,005	2,00	3,15	0,013	0,101	0,058

TABLE 4.

ABSORPTION COEFFICIENTS $\alpha(\text{atm cm})^{-1}$ OF VARIOUS POLLUTANTS, P BRANCHES OF $00^{0}1$-$10^{0}0$ TRANSITION

	Wavelength |μm|	Vinyl chloride		Monochloro-ethane		Sulfod dioxide		Methanol	Izopro-panol	Cyclo-hexane	Ethyl acetate	Aceto-nitrile
		meas.	ref. 3	meas.	ref. 3	meas.	ref. 3	meas.	meas.	meas.	meas.	meas.
P 6	10,453	1,33	1,35	1,05	1,02	0,004	0,005	1,87	3,55	0,015	0,101	0,054
8	10,476	1,02	1,00	0,66	0,63	0,004	0,005	1,87	3,67	0,010	0,202	0,056
10	10,494	1,35	1,35	0,45	0,41	0,004	0,005	1,83	3,78	0,018	0,304	0,056
12	10,513	1,32	1,30	0,25	0,22	0,004	0,005	1,70	3,55	0,021	0,456	0,053
14	10,532	1,79	1,78	0,19	0,17	0,004	0,005	1,66	3,17	0,025	0,506	0,059
16	10,551	1,74	1,72	0,064	0,06	0,004	0,005	1,42	3,02	0,020	0,506	0,063
18	10,571	2,06	2,05	0,062	0,06	0,004	0,005	1,18	3,02	0,020	0,709	0,063
20	10,591	2,32	2,30	0,062	0,06	0,004	0,005	1,14	2,87	0,010	0,810	0,066
22	10,611	8,82	8,80	0,15	0,12	0,004	0,005	1,09	2,74	0,020	0,861	0,069
24	10,632	3,43	3,42	0,165	0,17	0,004	0,005	1,29	2,63	0,020	0,861	0,071
26	10,653	2,52	2,50	0,172	0,17	0,004	0,005	0,81	2,51	0,020	0,963	0,099
28	10,674	2,01	2,00	0,22	0,20	0,004	0,005	0,42	2,23	0,021	0,912	0,101
30	10,696	2,12	2,10	0,163	0,16	0,004	0,005	0,57	1,95	0,021	1,01	0,111
32	10,718	1,52	1,50	0,20	0,18	0,004	0,005	0,66	1,62	0,021	1,11	0,122
34	10,741	1,89	1,90	0,21	0,19	0,004	0,005	0,64	1,44	0,023	1,11	0,111
36	10,763	3,13	3,15	0,21	-	0,004	0,005	0,81	1,07	0,025	-	0,117
38	10,787	1,77	1,75	-	-	-	-	-	-	-	-	-

TABLE 5.

SUGGESTED WAVELENGTHS FOR AIR POLLUTION MONITORING

G A S	Measure				Reference			
	Line	wavelength |μm|	α |$atm^{-1}cm^{-1}$|	α ref. 3	Line	wavelength |μm|	α |$atm^{-1}cm^{-1}$|	α ref.3
Vinyl chloride	P 22	10,612	8,82	8,80	R 18	9,282	0,054	0,05
Monochloro-ethane	R 16	10,275	3,34	3,3	P 20	10,591	0,062	0,06
Sulfur dioxide	R 26	9,240	0,093	0,105	P 18	9,536	0,004	0,005
Methanol	P 36	9,695	10,61	-	P 28	10,674	0,42	-
Izopropanol	P 10	10,494	3,78	-	P 36	9,695	0,32	-
Cyclohexane	P 28	9,621	0,405	-	R 12	9,317	0,010	-
Ethyl acetate	P 8	9,458	12,16	-	R 10	10,318	0,101	-
Acetonitrile	P 16	9,520	0,157	-	R 28	10,194	0,053	-

values and wavelength dependence of absorption coefficients are in good agreement with these authors[4,5] as well.

Finally on the basis of our and other experimental results[3-5] in Table 5 we have selected pairs of lines (detection and reference line) which should be used for outdoor long-optical path air pollution monitoring.

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