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New laser lines from CHD_2OH methanol deuterated isotope

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ABSTRACT Through the optical pump technique we have reinvestigated the CHD_2OH molecule as a source of far-infrared (FIR) laser lines using for the first time a CO_2 laser lasing on regular, hot, and sequence bands. As a consequence, we present here spectroscopic data of 16 new FIR laser transitions from this molecule. Furthermore, we also present a catalogue of all FIR laser lines generated from CHD_2OH.

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1 Introduction

Methanol is the most important lasing molecule in the far-infrared (FIR) spectra, and the most widely used for investigations and applications. The main reason for its success as a laser source is the excellent overlap of the strong absorbing C−O stretch mode of this molecule with the CO_2 laser lines that are the most used as pump sources. The substitution of H by D, ^{12}C by ^{13}C, or ^{16}O by ^{18}O in the molecule does not appreciably shift this absorption. As a consequence, methanol and its isotopes together have been recognized as efficient sources for generation of FIR laser lines [1–3]. Particularly, the CHD_2OH deuterated isotope has been little investigated up to now. FIR laser action optically pumped from this molecule was first reported by Ziegler and Dürr [4] in 1978 and subsequently by Facin et al. [5] in 1989. The total number of FIR lines reported was 93. For this reason we have undertaken an experimental study of this molecule in order to find new laser lines, using for the first time a CO_2 laser that lases on regular, hot, and sequence bands.

In this work we report 16 new FIR laser lines from CHD_2OH, ranging from 34.2 to 192 μm. Data relative to each line are very important for spectroscopic investigations and applications, and therefore we present here a complete catalogue of all the FIR laser lines of this molecule including the lines observed by us.

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2 Experimental results

The experimental apparatus consists of a 2-m-long cw CO_2 pump laser and a versatile Fabry–Perot FIR laser cavity. The CO_2 laser has a grating specially blazed to provide approximately 3% output coupling in the zeroth order from 9 to 11 μm. A total of 230 CO_2 laser lines from sequence, hot, and regular bands were available. A detailed description of this laser can be obtained from [6, 7].

The FIR laser cavity is formed by two gold-coated copper concave mirrors with a radius of curvature of 1.9 m and separated by ~ 2 m. One mirror is fixed, while the other is moveable and coupled to a micrometer allowing tuning of the cavity into resonance with the longitudinal modes of the FIR laser. A variable resistor biased at 1.5 VDC (output range 0 to 1.5 VDC) is coupled to the micrometer to provide an output in the x direction to an x–y plotter. For each wavelength measurement the cavity was scanned over several longitudinal modes, and the intensity was plotted as a function of cavity length. This allowed us to determine the FIR laser wavelengths with an uncertainty of approximately ± 0.5 μm. The FIR output power is coupled by a 45° mirror (radially adjustable) and was detected using a pyroelectric detector. We have used the cavity in a V-type configuration [8, 9] to perform this work.

The source gas used in this experiment had an isotopic purity of 98% at minimum. To ensure that the observed laser lines were actually of CHD_2OH we kept a little gas flow in the FIR cavity.

3 Results and comments

All of the lines observed up to now, including this work, are listed in Table 1 sorted by CO_2 pump line, with a reference to the authors who first observed the line. For the 16 new lines observed by us we give the wavelength, the polarization relative to that of the pumping CO_2 laser, the optimum pressure of operation, and the relative intensity. The intensity of each line was measured and calibrated against the intensity of the 118.8-μm line from $^{12}CH_3OH$ [8]. For the lines known before this work, we keep the intensity notation used by the authors. Ziegler et al. [4] used strong (S), medium (M), and weak (W) to denote the line intensity, considering as strong

Pump line	Laser line (μm)	Laser line (cm^{-1})	Rel. pol.	Press. (Pa)	Rel. int.	CO_2 power (W)	Ref.
9R50	54.8	182.48	⊥	21	0.5		New
9R38	109.3	91.49	⊥	19	12.9	8.5	5
	111.4	89.77	⊥	19	6.4	8.5	5
	117.3	85.25	⊥	19	8.5	8.5	5
	172.4	58.00	∥	16	1.3	8.5	5
9R34	279.0	35.84	∥	9	0.3	12	5
	290.2	34.46	∥	9	0.4	12	5
9R32	145.3	68.82	⊥	15	5.4	14	5
	179.8	55.62	∥	16	5.2	14	5
9R30	120.9	92.71	∥	24	12.1	15	5
	132.2	75.64	⊥	13	3	15	5
9R26	135.0	74.07	⊥	15	1.2	15	5
	144.8	69.06	⊥	15	0.6	15	5
	202.6	49.36	∥	15	3	15	5
9R24	164.4	60.83	∥	12	4.8	15	5
9R20	249.6	40.06	∥	11	0.7	17	5
9R18	140.7	71.07	∥	27	3		New
	165	60.61		11	M		4*
9R16	217.9	45.89	∥	21	52.1	16	5
9R14	280.8	35.61	∥	19	18.1	15	5
	317.0	31.55	∥	16	36.2	16	5
	598.3	16.71	∥	16	11.3	16	5
9R10	221.2	45.21	∥	19	0.4	13	5
9R04	45.6	219.30	⊥	25	2.7		New
	78.2	127.88	∥	27	2.7		New
	165.1	60.57	∥	15	21.1	12	5
9P04	246.8	40.52	∥	15	34	8	5
	512.8	19.50	∥	16	11.3	8	5
9P06	34.2	292.40	∥	12	2.3		New
	483	20.70	∥	11,15	W,24.9	8	4,5
9P08	196.8	50.81	∥	16	6	9	5
9P16	226.8	44.09	∥	16	2	10	5
9P18	104.6	95.60	∥	16	9.9	11	5
	165.1	74.02	∥	8	0.1		New
9P20	346	28.90		11	W		4
	246.1	40.63	∥	15	1.4	10	5
	254.3	39.35	∥	13	90.6	12	5
	501.9	19.92	∥	13	0.9	10	5
9P22	484.4	20.64	∥	13	1.5	12	5
9P24	203.1	49.24	∥	24	6.6	12	5
9P26	128.5	77.82	⊥	16	5.6	13	5
	204.7	48.85	∥	21	3.8	14.5	5
	255.3	39.17	⊥	9	1.7	13	5
	437.4	22.86	∥	11	2.5	10	5
9P28	404.6	24.72	∥	11	10.5	10	5
9P30	518	19.31		11	M		4
	385.4	25.95	∥	13	63.4	10	5
9P34	137.0	72.99	∥	11	9.1	10	5
	606.7	16.48	⊥	13	6.3	10	5
	607.3	16.47	∥	11	5.1	10	5
9P36	249.7	40.05	∥	15	1.7	11	5
9P38	123.9	80.71	⊥	16	19.9	10	5
	187.5	53.33	∥	15	6.6	11	5
9P50	60.5	165.29	⊥	20	0.5		New
	158.5	63.09	⊥	17	0.1		New
	192.0	52.08	∥	17	0.3		New
10R40	111.6	89.61	∥	8	16.1	9	5
	80.0	125.00	⊥	16	3.6	10	5
10R38	168	59.52		11	M		4
	426	23.47		11	M		4
10R36	278.4	35.92	∥	21	2.8	13	5
10R34	111.9	89.37	∥	16	9	12	5
10R32	83.9	119.19	⊥	11	1.3	14	5
	93.0	107.53	∥	15	2.5	14.5	5
10R28	227.5	43.96	∥	15	1.1	17	5
10R26	41.8	239.23	⊥	11	0.5	11	5
	45.1	221.73	∥	11	1.8	11	5
	136.2	73.42	∥	12	4.2	13	5
10R24	107.4	93.1	∥	19	0.6	12.5	5
10R22	288.3	25.75	∥	19	2.5	11	5
10R20	172.1	58.11	∥	24	4	18	5
	260	38.46		11	S		4
10R18	55.6	179.86	∥	15	20.1	18	5
	127.4	78.49	∥	21	22.4	17	5
	259.9	38.48	∥	21	7.7	15	5
10R16	55.8	179.21	∥	16	0.6		New
	179	55.87		11	M		4
	363	27.55		11	S		4*
10R14	83.7	119.47	⊥	25	3.7	17	5
10R10	228.7	43.73	∥	16	10.7	17	5
	270.0	37.04	∥	13	0.5	17	5
10R08	305.6	32.72	∥	16	27.8	15	5
	452.5	22.10	∥	21	33.1	17.5	5
10R06	105.0	95.24	∥	27	2.8	16	5
10R04	74.1	134.95	∥	16	0.3	12	5
10R02	344.9	28.99	∥	11	0.9	8	5
10P04	57.9	172.71	⊥	15	4.5	13	5
10P08	123.8	80.78	∥	12	19.3	15	5
	152.6	65.53	⊥	15	30.2	15	5
10P10	517.8	19.31	∥	12	1.2	16.5	5
10P12	171.1	58.45	∥	13	42.7	17	5
10P14	103.0	97.09	⊥	25	66.1	17	5
10P16	103.0	97.09	∥	27	85.3	17	5
10P18	46.8	213.68	∥	17	0.3		New
	174.9	57.18	⊥	27	0.1		New
	238	42.02		11	S		4*
	355	28.17		11	M		4
	212.9	46.97	⊥	21	102	17	5
10P20	291.3	34.33	∥	15	45.3	18	5
	427.1	23.41	∥	15	40.3	18	5
10P28	74.8	133.69	⊥	15	1.2	18	5
	124.4	80.39	⊥	15	6	18	5
	558.8	17.90	⊥	16	10.1	18	5
10P40	125.4	79.74	∥	16	2.7	10	5
	142.9	69.98	⊥	16	2.7	10	5
10SR11	53.3	187.62	∥	7	0.2		New
10SP11	128.2	78.00	∥	10	0.1		New
10HP16	143.4	69.74	∥	20	0.3		New
	150.7	66.36	∥	20	0.1		New

* Lines also observed from CH_2DOH by the same author. S. Kon et al. in [1] (p. 169) observed that these lines may be from CHD_2OH

More information:

Ziegler and Dürr [4]: cw CO_2 laser; wavelengths were measured to an accuracy of $\pm 0.5\ cm^{-1}$

Facin et al. [5]: cw CO_2 laser with 75 MHz of tuning; the intensity was normalized with respect to the 118.8-cm^{-1} line of $^{12}CH_3OH$ oscillating in the same cavity

TABLE 1 FIR laser lines from CHD_2OH

that line that provides a power of approximately 1–2 mW, and as weak that line with a power of about 0.5 mW or less. All the lines reported by Facin et al. [5] had their intensities normalized with respect to the intensity of the 118.8-μm line of $^{12}CH_3OH$ oscillating in the same cavity. Other important information about the FIR and CO_2 laser lines is presented at the end of Table 1.

All the 16 new lines reported here have a wavelength smaller than 200 μm, due to the Fabry–Perot laser cavity having a diffractive loss less than 0.5% at wavelengths below 150 μm. In Table 2 we compare the wavelength spectrum repartition of the FIR lines obtained by us and by other authors. The number of laser lines observed by us with a wavelength below 150 μm represents an increase of 32% with respect to the total observed before this work. Moreover, we can also observe that most FIR laser lines from CHD_2OH present

Reference	FIR line number	Lines < 150 µm	Lines 150–300 µm	Lines > 300 µm
4	11		5	6
5	82	34	32	16
Our results	16	11	5	
Total	109	45	42	22

TABLE 2 Wavelength spectral repartition of FIR laser lines from CHD_2OH

a short wavelength. From 109 lines, 87 of them have wavelengths smaller than 300 µm.

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