

## MEASUREMENTS OF NEW FIR LASER LINES IN CD<sub>3</sub>OD

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We report the measurement of 80 new FIR laser lines in CD<sub>3</sub>OD optically pumped by a regular continuous wave CO<sub>2</sub> laser. These lines are in the spectral range of 79 $\mu$ m to 2.9mm.

### Introduction

FIR laser action in fully deuterated methyl alcohol (CD<sub>3</sub>OD) was first reported by Kon et al. who measured eight lines optically pumped by CO<sub>2</sub> laser lines (1). Subsequently more FIR laser lines have been found using other CO<sub>2</sub> pump lines. A list of all previous lines in CD<sub>3</sub>OD was given in a recent review paper by Kon et al. (2).

We performed a careful search for new lines in CD<sub>3</sub>OD pumping over the entire range of regular CO<sub>2</sub> laser lines by varying the pressure and the output coupling of the laser in such a way that even weak lines could oscillate. Our laser was specially convenient for observing long wavelength lines. Besides making CD<sub>3</sub>OD a more attractive lasing gas for applications, this data will help in the spectroscopic assignment of its FIR lines.

### Experimental Setup

The experimental setup consist of a continuous wave CO<sub>2</sub> pump laser and a FIR cavity. The CO<sub>2</sub> laser consists of a 2m long cavity mechanically stabilized by invar rods, a 150 lines/mm grating on one side and partial reflector ZnSe mirror on the other end. The output mirror was mounted on a

PZT tube which allows for tuning the frequency of the CO<sub>2</sub> laser lines over its gain curve.

The FIR laser is a Fabry-Perot resonator formed by two concave, gold coated mirrors, both with 140cm radius of curvature and 7.5cm diameter. One of the mirrors has a hole in its center of 1.5mm diameter for coupling the CO<sub>2</sub> radiation into the cavity. This end of the cavity is sealed by a NaCl window in Brewster angle. The other mirror can be translated by a micrometer in order to tune the cavity in resonance with the CD<sub>3</sub>OD emission lines. The wavelength measurements were made by counting the modes in a calibrated 3.5mm scan. The wavelength accuracy is  $\Delta\lambda/\lambda = 10^{-3}$ . The FIR power was coupled out of the cavity by a 45° mirror by cutting and polishing a 6mm - diameter copper cylinder. The cylinder can be positioned at various distances from the laser axis to vary the coupling. The radiation exits the laser through a 1.5mm thick quartz window opposite to this coupling mirror. The line intensities were measured with a Golay cell. The relative polarization of the lines was determined by a metal mesh polarizer placed in front of the FIR detector.

### Results

The sample of CD<sub>3</sub>OD used was from Merck Sharp & Dohme with nominal isotopic purity of 99.5%. We have measured a total of 80 new lines, which are shown in table I, arranged by CO<sub>2</sub> pump line. In this table it is given the wavelengths, optimum pressures of the gas, relative polarization and intensities of the FIR laser lines. Six of the new lines have wavelength below 100 $\mu$ m where the transmission of the quartz FIR laser output window is sharply reduced. The shortest new wavelength line is 79.6 $\mu$ m pumped by the 10R(42) CO<sub>2</sub> laser line. In the 100-500 $\mu$ m range we have found 59 new lines and the other 15 are above 500 $\mu$ m. The longest wavelength line measured was at 2.9mm pumped by the 10R(24) CO<sub>2</sub> line. To our knowledge this is the longest optically pumped FIR laser line reported up to now.

The intensities of the lines were measured with a Golay detector using various attenuators, when necessary, to prevent saturation. The FIR signal divided by the pump power gives a relative intensity for each line. These numbers were then normalized with respect to the relative intensity of the 118.8 $\mu$ m line of CH<sub>3</sub>OH, on the same cavity, to which was attributed a value of 100. On this scale most lines have relative intensities close to 10. The strongest line is the 136.9 $\mu$ m line pumped by the 10R(46) which has a relative intensity value of 100.

Table I - New FIR Laser Lines Obtained from CD<sub>3</sub>OD

CO <sub>2</sub> Pump Line	CD <sub>3</sub> OD Laser Line λ(μm)	Relat. Polar.	Pres. (mT)	CO <sub>2</sub> Pump Power (W)	CD <sub>3</sub> OD Relat. Power (W)
9R(40)	567.8		( 60)	15.5	1.0
9R(38)	111.3		(180)	17.5	16.9
9R(34)	289.6		( 60)	18.0	0.4
	411.6		( 60)	18.0	0.2
9R(32)	80.1		(130)	19.5	1.5
	456.1		( 90)	19.5	2.1
9R(28)	550.1		( 60)	22.5	4.0
9R(24)	102.2		(100)	23.0	4.2
9R(22)	312.7		(105)	23.5	12.6
	494.1		( 90)	23.5	6.3
	585.5		( 90)	23.5	10.5
9R(18)	82.6		(110)	23.0	6.4
OR(16)	150.5		( 90)	23.0	21.4
	319.4 *		(110)	23.0	65.2
	457.5 *		(130)	23.0	53.6
9R(12)	141.7		(120)	21.5	2.3
9R(10)	552.4		(100)	21.5	3.6
9R(08)	491.2		(110)	23.0	17.2
9R(06)	249.7		( 90)	20.0	12.5
	482.5		(100)	20.0	49.4
	497.2		(150)	20.0	45.4
9R(02)	178.6		( 80)	9.5	0.5
9P(04)	247.5		(110)	15.0	23.2
9P(06)	342.8		(100)	19.5	7.7
	558.5		( 70)	20.5	1.6
9P(08)	256.4		(100)	21.5	5.0
9P(10)	184.2		(120)	22.5	26.7
	651.9		(120)	22.5	8.7
9P(12)	353.8		(105)	23.0	8.7

CO <sub>2</sub> Pump Line	CD <sub>3</sub> OD Laser Line λ(μm)	Relat. Polar.	Pres. (mT)	CO <sub>2</sub> Pump Power (W)	CD <sub>3</sub> OD Relat. Power (W)
9P(14)	356.4*		(150)	23.0	8.7
9P(16)	210.5		( 90)	25.0	1.2
	342.7		(100)	25.0	27.9
9P(18)	329.2		( 80)	25.5	19.5
	453.6		( 80)	25.5	16.4
9P(20)	373.4		(110)	26.0	19.1
9P(22)	663.0		( 60)	25.0	0.2
9P(24)	294.6		( 90)	26.0	3.4
9P(26)	139.5		(180)	28.0	24.9
	356.5		( 95)	26.0	4.5
9P(28)	348.1		(150)	26.5	19.3
9P(30)	453.1		( 90)	26.0	13.3
9P(32)	272.5		( 60)	25.0	1.0
9P(34)	684.7		(100)	24.0	2.0
9P(38)	236.1		(170)	22.5	13.1
9P(40)	404.3		(100)	21.0	14.1
	684.3		( 80)	21.0	0.7
9P(42)	129.6		(200)	18.0	4.3
9P(44)	152.3		(160)	14.0	56.4
9P(46)	172.0		(150)	10.0	51.3
9P(48)	255.0		( 90)	6.0	6.7
10R(46)	136.9		(200)	10.0	128.3
	391.3		( 90)	13.5	4.3
10R(44)	87.1		(150)	11.5	6.0
	314.3		(130)	11.0	15.2
10R(42)	79.6		(180)	16.5	4.1
10R(32)	131.5		(130)	21.5	4.6
10R(26)	222.0		(120)	23.0	4.2
	340.7		( 90)	23.0	2.6
	670.4		(100)	23.0	0.5

CO <sub>2</sub> Pump Line	CD <sub>3</sub> OD Laser Line λ(μm)	Relat. Polar.	Pres. (mT)	CO <sub>2</sub> Pump Power (W)	CD <sub>3</sub> OD Relat. Power (W)
10R(24)	598.4		(205)	24.0	69.9
	972.0		(190)	24.0	41.1
	2923.0		(150)	24.5	20.1
10R(18)	408.8		( 60)	23.5	13.4
	494.7		( 60)	23.5	12.6
10R(14)	289.5		(195)	23.0	47.2
	372.0		(120)	23.0	12.8
	438.8		(120)	23.0	21.4
	1162.2		(140)	23.0	21.4
10R(08)	208.3		(100)	23.0	19.3
10R(04)	577.8		(190)	19.5	12.6
10R(02)	202.0		(180)	14.0	70.5
10P(06)	235.7		(100)	23.0	1.7
10P(08)	161.3		(130)	23.0	1.3
10P(10)	151.3*		(150)	24.5	44.3
	311.0		(100)	24.5	2.0
10P(14)	165.3		(100)	27.0	7.4
10P(16)	329.9		(200)	26.5	16.8
10P(20)	216.9		(100)	25.5	31.0
10P(30)	83.6		(150)	26.5	0.5
10P(32)	242.9		(150)	24.5	32.2
	375.3		(130)	23.5	8.4
10P(38)	85.5		(190)	23.5	12.6
10P(46)	105.4		(180)	15.0	32.9
10P(48)	262.1		(100)	10.0	1.5

Lines with \* are previously observed, but without polarization measurements.

|| Parallel

| Perpendicular

\*Dr. F.R.Petersen has passed away during the final preparation of this work.

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