レーザー資料

“光励起遠赤外同位体メチルアルコール
レーザー線の波長表”

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“Wavelength Tables of Optically Pumped Far-Infrared
Isotopic-Methylalcohol Laser Lines”

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1. はじめに

光励起遠赤外レーザーは Chang と Bridges^{a)}により CH_3F 分子気体を用いて1970年に実現されたのが最初である。それ以来約70種の分子気体から1800本以上もの光励起レーザー線が現在観測されている。これら多くの発振線のいくつかについては、その波長およびそれに関する有用な情報が既に幾人かの研究者達によりまとめられた^{b)}。しかしそれ以後の光励起遠赤外レーザーの目覚ましい進歩の故、必ずしもそれらは満足なものとはいえなくなっているのが現状である。従って、本資料においては、先ず最も多くの光励起レーザー線(全体の約1/4~1/3)が観測されているメチルアルコールのうち、その同位体を用いたものについてのみ、1981年8月までの論文に分布している情報を出来る限り詳しく整理してみることを試みた。

2. メチルアルコール

メチルアルコール分子に関しては、1938年 Borden と Barker^{c)} による赤外吸収測定による

研究が始まって以来、Woods^{d)}や Lees と Barker^{e)}や Kwan と Dennison^{f)}らにより基底状態における構造が確かめられてきた。

メチルアルコールは、僅かに非対称な偏長ゴマ (plolate top) とみなされる。そのC—O伸縮基準振動は、 CO_2 レーザーのスペクトルと重なることから、 CO_2 レーザー光励起による回転準位間での遠赤外レーザー発振が期待される。且つOHグループが CH_3 グループに対し、自由に内部回転できるとはかぎらないから (hindered rotation), メチルアルコールの回転エネルギー準位は複雑なものとなり、ゆえに数多くの光励起遠赤外レーザー線が得られる。

3. 同位体メチルアルコールの波長表

Table I から Table VI までに、それぞれ CH_3OD , CH_2DOH , CHD_2OH , CD_3OH , CD_3OD , $^{13}\text{CH}_3\text{OH}$ に関して、発振波長とそれに付随する情報を励起光 (CO_2 レーザー, $^{13}\text{CO}_2$ レーザー, N_2O レーザー) の各発振線毎に短波長から順に並べた。データは歴史的な流れを眺望でき、また測定条件を比較検討できるよう、年代の古い

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ものから順番に全て掲げてある。従って、データは全て文献に示されたとおり記してあり、偏光特性 (CO_2 レーザーの偏光方向に対する光励起レーザー線の偏光方向で示されている) のように測定者により矛盾するものがいくつか見られるものもある。また波長も測定者により異なるが、ヘテロダイン法などにより精密測定されたものではその値 (真空中での波長) を、そうでないものは最も新しい測定波長 (空気中での値) を、その代表値 (Representative Wavelength) として示してある。一方その発振波長全てを Table VII に短波長から順に示した。

遠赤外レーザーの共振器は、Table VIII で示されるように、3 種類の開放構造、2 種類の導波管構造と Stark 構造とに分類できる。Table I から Table VII では、 O_1 , W_1 , S でそれぞれその区別がなされている。表にはそれらの共振器寸法がまとめられている。但し W_3 は、共振器鏡が内部鏡か外部鏡か区別できなかったもので、本質的には W_1 あるいは W_2 に属するものである。表中最後の欄には、フレネル数が1になるときの波長が示されている。従ってこの波長より長い領域では、共振器内で導波管効果が生じることになる。

本資料より、測定は開放型共振器を用いてなされた方が導波管型のものより約1.6倍と多く、その得られた遠赤外レーザー線も約4.6倍と、前者の方が後者よりも現在のところ相当多いことがわかる。また3種の開放型共振器のうち、得られた遠赤外レーザー線はほぼ同数であるが、長波長領域では O_1 型からのものが多い傾向にある。

4. おわりに

波長表を作成するにあたり、発振波長の測定精度が研究者により異なり、測定誤差の範囲内で一致するものを1つの発振線としてまとめた。しかし同じ発振線を異なる発振線とみなし、反対に異なる発振線を同じ発振線とみなす誤りをおかしている危険性が全く無いとはいえない。また将来測定精度がよくなれば、Table VII の

発振波長の順序が異なる場合も生じるであろう。これらの点は将来の研究に待つところが大きい。

現在、イタリア、ピサ大学の Inguscio, Strumia らが中心となり、世界各国の研究者達が分担しあって、全分子についての光励起レーザー波長表がまとめられつつある。これらの結果は、"Review in Infrared and Millimeter Waves, Vol. 3" (ed. K. J. Button) に近い将来発表されるであろう。本資料はそのうちの1つであるが、より詳細にして本稿にまとめたものである。 CH_3OH 分子については、デンマーク、コペンハーゲン大学の Henningsen によりまとめられつつあるが我々もその作業を進行中である。

Table I-1 Laser lines of the optically pumped CH₃OD lasers up to August of 1981.

CO ₂ Pump Line (cm ⁻¹)	CH ₃ OD Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (JnK) → (J'n' r'K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
9R (34)	151.6	151.56			S	80	S	strongest line peak=30			0V/cm E ₀₀ ⊥ E _s	19
9R (28)	186	186			W		O ₁	threshold 6.0				18
9R (26)	106	106			W		O ₁	threshold 6.5				18
	182	182			W		O ₁	threshold 6.0				18
9R (22)	169	169			M		O ₁	threshold 6.0				18
9R (16)	70.3	70.3			~0.18	320	W ₃	10				15
9R (14)	215.4	216		⊥	W	6~10	O ₂	9P branch center=3				4
		215.37246	1391972.1		0.1		O ₃	5				7
		215			M		O ₁	threshold 1.5				18
	233	234			W	250	O ₃	<20				17
		233			W		O ₁	threshold 4				18
9R (8)	46.7	46.7			~0.6	75~150	W ₁	>15				5
	57	57		⊥	S	6~10	O ₂	9P branch center=3				4
		57		⊥	~0.6	75~150	W ₁	>15				5
		57			<1	280	W ₂	Q switch ~KW				16
		57			<5	825	W ₂	Q switch ~KW				16'

CH₃OD

Table I-2

CO ₂ Pump Line (cm ⁻¹)	CH ₃ OD Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J _{n''K''} → J _{n'K'})	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
	294.8	295		⊥	VS	6~10	O ₂	9P branch center=3				4
		292.6		⊥	~0.2	75~150	W ₁	>15				5
		294.81098	1016897.2		0.055		O ₁	2				7
	305.7	307		⊥	VS	6~10	O ₂	9P branch center=3				4
		305		⊥	~0.2	75~150	W ₁	>15				5
		305.72611	980591.6		0.015		O ₁	2				7
9R(6) 1069.014	282	282			10	320	W ₂	Q switch ~KW				16
		282			10	270	W ₂	Q switch ~KW				16'
9R(6) 69.5	69.5	69.5			~0.09	200	W ₃	10				15
9R(6) 221	221	225			~0.6	200	W ₃	10				15
		221			W		O ₁	threshold 4.5				18
9R(4) 1067.539	212	212			~1.2	150	W ₃	10				15
		212			8		O ₁	threshold 3.5				18
	330	330		⊥	~0.3	75~150	W ₁	>15				5
		330			VS		O ₁	threshold 1.5				18
9R(2) 1066.037	106	106			M		O ₁	threshold 1.5				18

CH₃OD

Table I-3

CO ₂ Pump Line (cm ⁻¹)	CH ₃ OD Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J _{up} K _{up}) → (J _{low} 'K _{low} ') FIR 13, 0, 2, 10 → 12, 0, 3, 9 ^{so} FIR 13, 0, 2, 10 → 13, 0, 3, 9 ^{so} FIR 13, 0, 3, 5 → 12, 0, 1, 4 ^{so} FIR 13, 0, 3, 5 → 13, 0, 1, 4 ^{so} FIR 13, 0, 3, 5 → 12, 0, 3, 5 ^{so}	Note E _{CO₂} ⊥ E _s E _{CO₂} ∥ E _s	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
	115.0	114.96			S		S	strongest line peak=30				19
9P(6)	134.7	134.7		⊥	~0.3	75~150	W ₁	>15				5
		134.7			5000	300	W ₂	Q switch ~KW				16
		134.7			5000	250	W ₂	Q switch ~KW				16'
	182.1	182.1				200	O ₂	<20				17
	229.1	229.1		∥	~0.7	75~150	W ₁	>15				5
		229.1			5000	300	W ₂	Q switch ~KW				16
		229.1			5000	250	W ₂	Q switch ~KW				16'
	417.1	417.1		⊥	~0.2	75~150	W ₁	>15				5
	510	510		∥	W	10	O ₂	5				20
9P(10)	134	134					O ₁	10R branch peak=30				8
		134		⊥	~2.4	200	W ₂	10				15
		133			5000	400	W ₂	Q switch ~KW				16
		133			5000	450	W ₂	Q switch ~KW				16'
		134		∥	M		O ₁	threshold 5				18
9P(22)	128.0	128.0		⊥	0.30		O ₁	10				1

CH₃OD

Table I-4

CO ₂ Pump Line (cm ⁻¹)	CH ₃ OD Laser Line			Relative polarization	FIR Output Power (mW)	CH ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J ₁ n' K' → J ₂ n'' K'')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
9P(24) 1043.163	133	136					O ₃	10R branch peak=30				8
					M		O ₁	threshold 2.5				18
9P(26) 1041.279	100.8	100.8		⊥	~1.2	200	W ₃	10				15
		101.6			VS	240	O ₃	<20				17
					M		O ₁	threshold 2.5				18
	107.8	107.67			W M	40 40	S	strongest line peak=30			4.7KV/cm E _{CO₂} ⊥ E _s 4.1KV/cm E _{CO₂} E _s	19
	117.2	117.4			20.0		O ₁	10				1
		117			M	6~10	O ₂	9P branch center=3				4
		117.22707	2557365.4			threshold 70	W ₃	threshold 1.5				6
					M		O ₁	threshold 1.5				18
9P(30) 1037.434	81.9	81.9		⊥	S	250	O ₃	<20				17
	89.6	89.6			S	250	O ₃	<20				17
	103.1	103.0			8.00		O ₁	10				1
		104		⊥	M	6~10	O ₂	9P branch center=3				4
		103		⊥	~0.2	75~150	W ₁	>15				5
		103.12463	2907088.9	⊥		threshold 50	W ₃	threshold ≪1				6

CH₃OD

Table I-5

CO ₂ Pump Line (cm ⁻¹)	CH ₃ OD Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (Jn+K) → (J' n' z' K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
		103			>1000	500	W ₂	Q switch ~KW				16
		103			>1000	825	W ₂	Q switch ~KW				16'
	111.1	111.10			M	30	S	strongest line peak=30			9.1~12.4KV/cm E ₀₀ ⊥E _s	19
	145.7	146		⊥	W	6~10	O ₂	9P branch center=3				4
		146		⊥	~0.2	75~150	W ₁	>15				5
			145.66171		0.12		O ₂	4				7
	168.1	168.1		⊥	0.10		O ₁	10		FIR 19, 0, 2, 6→18, 0, 3, 5 ²⁰		1
	320	320.0			0.10		O ₁	10				1
		320			~0.2	75~150	W ₁	>15		FIR 19, 0, 2, 6→19, 0, 3, 5 ²⁰		5
	352.5	352.5		⊥	0.05		O ₁	10		FIR 19, 0, 2, 6→18, 0, 2, 6 ²⁰		1
9P(32) 1035.474	80	80.0		⊥	0.80		O ₁					1
		80		⊥	M		O ₁	threshold 2.5				18
	108	108			M		O ₁	threshold 3.5				18
	110.7	110.7		⊥	VW	220	O ₂	<20				17
	113.8	113.8			W	220	O ₂	<20				17
	145.6	145.6			VW	220	O ₂	<20				17

CH₃OD

Table I-6

CO ₂ Pump Line (cm ⁻¹)	CH ₃ OD Laser Line		Relative Polarization	FIR Output Power (mW)	CH ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J ₁ τK) → (J ₂ τ'K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)									
	179.0	179.0	⊥	0.50		O ₁	10		FIR 24, 0, 1, 4 → 23, 0, 2, 3 ^(a)		1
		179.0	⊥	M		O ₁	threshold 2.5				18
	279	279.4	⊥	0.10		O ₁	10		FIR 24, 0, 1, 4 → 23, 0, 1, 4 ^(a)		1
		279	⊥	M		O ₁	threshold 2.5				18
	498	498.0		0.05		O ₁	10		FIR 24, 0, 1, 4 → 24, 0, 2, 3 ^(a)		1
10R(44) 989.647	110	110	⊥	W	6~10	O ₂	9P branch center=3				4
		110		S		O ₁	threshold 1.5				18
	236	236		M		O ₁	threshold 2.0				18
	241	241		M		O ₁	<20				17
10R(42) 988.647	141	141	⊥	W		O ₁	threshold 2.5				18
10R(34) 984.363	238	238		VW	230	O ₂			This line may originate from CH ₃ OH ⁽¹⁾		17
10R(22) 977.214	137.2	137		M		O ₁	threshold 4.0				18
		137.17		S	200	S	strongest line peak=30			0KV/cm E _{co} ⊥ E _s	19
	224	224		W		O ₁	threshold 10.0				18
10P(18) 945.980	280	280		VW	250	O ₁	<20				17
10P(26) 938.688	135.5	135.49		M	30	S	strongest line peak=30			8.2~14.5KV/cm E _{co} ⊥ E _s	19

CH₃OD

Table I-7

Pump Line (cm^{-1})	CH ₃ OD Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (JnrK)→(j' n' τ K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
¹³ CO ₂ Pump Line												
9R (28)	1037.167	86.7			11.6		W _s	6.25				22
9R (24)	1034.838	917			0.3		W _s	11.25				22
N ₂ O Pump Line												
R (22)	954.651, 957.056	139.9	139.85		W	30	S	9.5			0KV/cm E _{N₂O} ⊥E _s	19

Table II-1 Laser lines of the optically pumped CH₃DOH lasers up to August of 1981.

CO ₂ Pump Line (cm ⁻¹)	CH ₃ DOH Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₃ DOH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J _u rK) → (J' n' τ' K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
9R(24)	152.7	152.7			0.20	100	O ₂	31				21
9R(24)	219.1	219.1			0.13	100	O ₂	30				21
			219.09602			100	O ₂					21
	272.3	272			0.5~1	80	O ₁	strongest line peak=25				9
			272.3		0.90	100	O ₂	30				21
			272.25164			100	O ₂					21
	682.6	682.6		⊥	0.030	100	O ₂	30				21
9R(22)	182.1	182.1			0.063	70	O ₂	30				21
	171.8	171.8			0.008	40	O ₂	30				21
	218.0	218.0			0.025	45	O ₂	30				21
9R(18)	164	164			<0.5	80	O ₁	strongest line peak=25			This line may originate from CHD ₃ OH ⁽²¹⁾	9
9R(16)	216.8	216.8			0.050	110	O ₂	29				21
9R(8)	135.8	135.8		⊥	0.038	80	O ₂	26				21
			135.83350			90	O ₂					21
	164.7	164.7			0.050	70	O ₂	26				21
			164.74645			80	O ₂					21

CH₂DOH

Table II-2

CO ₂ Pump Line (cm ⁻¹)	CH ₂ DOH Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₂ DOH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J n' K' → J n'' K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
	422.2	422.2		⊥	0.015	60	O ₂	26				21
			422.15116			50	O ₂					21
9P(6) 1058.949	273.0	273.0		∥	0.025	80	O ₂	20				21
			273.00372			110	O ₂					21
9P(10) 1055.625	183.6	183.6		∥	1.0	160	O ₂	24				21
			183.62132			110	O ₂					21
					0.5~1	80	O ₁	strongest line peak=25				9
	295.4	295.4		∥	0.55	130	O ₂	24				21
			295.39666			110	O ₂					21
9P(12) 1053.924	108.8	109			0.5~1	80	O ₁	strongest line peak=25				9
		108.8		∥	0.50	180	O ₂	24				21
			108.81776			180	O ₂					21
	112.5	112.5		∥	0.80	180	O ₂	24		FIR probably J, K → J-1, K-1		21
			112.53224			210	O ₂					21
	172.8	171			0.5~1	80	O ₁	strongest line peak=25				9
		172.8		⊥	0.20	100	O ₂	24		FIR probably J, K → J, K-1		21

CH₂DOH

Table II-3

CO ₂ Pump Line (cm ⁻¹)	CH ₂ DOH Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₂ DOH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J _n K _n) → (J' _{n'} τ' _{n'} K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
		172.84619	1734446.4			80	O ₂					21
		322.5			0.5~1	80	O ₁	strongest line peak=25				9
		322.5			0.50	135	O ₂	24		FIR probably J, K → J-1, K		21
			322.45221			80	O ₂					21
9P(14)	1052.196	206.7			0.5~1	80	O ₁	strongest line peak=25				9
			206.7		0.68	100	O ₂	27				21
			206.68741			90	O ₂					21
		308.0			0.5~1	80	O ₁	strongest line peak=25				9
			308.0		0.50	110	O ₂	27				21
			308.04046			130	O ₂					21
9P(16)	1050.441	102.0		⊥	0.088	80	O ₂	30				21
			102.02349			80	O ₂					21
			2938465.1				O ₂					21
9P(18)	1048.661	87.1		⊥	0.20	145	O ₂	32				21
		100.0			0.25	160	O ₂	32				21
					0.063	130	O ₂	32				21
9P _a (10)		167.5			<0.5	80	O ₁	strongest line peak=25				9

CH₂DOH

Table II-4

CO ₂ Pump Line (cm ⁻¹)	CH ₂ DOH Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₂ DOH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J _u K _u) → (J _v 'n'ε'K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
		167.5			0.63	70	O ₂	27				21
		167.54117	1789365.9			90	O ₂					21
	396.0	396			<0.5	80	O ₁	strongest line peak=25				9
		396.0			0.15	70	O ₂	27				21
9P(20)	1046.854	140.3		⊥	0.025	90	O ₂	28				21
9P(25)	1041.279	468.2			0.5~ 1.0	80	O ₁	strongest line peak=25				9
		468.2			0.55	80	O ₂	31				21
		468.23586	640259.5			50	O ₂					21
	616.3	616			1~2	80	O ₁	strongest line peak=25				9
		616.3			0.75	80	O ₂	31				21
		616.33505	486411.5			210	O ₂					21
9P(30)	1037.434	44			0.075	180	O ₂	30				21
9P ₁ (32)	1035.474	108.9		⊥	0.050	130	O ₂	28				21
		108.94124	2751872.9			110	O ₂					21
	117.1	117.1		⊥	0.063	130	O ₂	28				21
		117.08507	2560467.0			110	O ₂					21

CH₂DOH

Table II-5

CO ₂ Pump Line (cm ⁻¹)	CH ₂ DOH Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₂ DOH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J _u K _u) → (J' _v K' _v)	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
9P ₁ (32)	167.4	167.4			0.50	150	O ₂	29				21
			1791384.9			160	O ₂					21
	266.7	266.7			0.14	95	O ₂	29				21
			266.73524			130	O ₂					21
	451.5	451.5		⊥	0.075	85	O ₂	29				21
			451.47536			110	O ₂					21
9P ₁ (36)	195.5	195.5			0.43	85	O ₂	27				21
			195.49558			110	O ₂					21
	336.2	336.2			0.40	85	O ₂	27				21
			336.24615				O ₂					21
9P ₁ (38)	42.5	42.5		⊥	0.025	210	O ₂	21				21
	200	200		⊥	0.015	70	O ₂	21				21
9P ₁ (40)	87.9	87.9		⊥	0.11	170	O ₂	19				21
9P ₁ (40)	387.6	387.6			0.20	80	O ₂	20				21
			387.55913			110	O ₂					21
	523.1	523.1			0.25	75	O ₂	20				21

CH₃DOH

Table II-6

CO ₂ Pump Line (cm ⁻¹)	CH ₃ DOH Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₃ DOH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (JnK) → (J' n' τ' K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
		523.09138	573116.8			80	O ₂					21
9P(46)	1021.057	226.3		⊥	0.38	100	O ₂	15				21
		226.29742	1324771.9			110	O ₂					21
	452.4	452.4		⊥	0.40	80	O ₂	15				21
10R(34)	984.383	150.8	151		0.5~1	80	O ₁	strongest line peak=25				9
		150.8		∥	2.0	160	O ₂	34				21
		150.81629	1987798.9			130	O ₂					21
	159.2	159.2		∥	0.80	140	O ₂	34				21
		159.21794	1882906.3			140	O ₂					21
	295.6	295			1~2	80	O ₁	strongest line peak=25				9
		295.6		∥	0.60	120	O ₂	34				21
		295.63940	1014047.7			90	O ₂					21
10R(32)	983.252	135.172	135.1718	∥	0.13	130	O ₂	29				21
		135.17175	2217863.3			100	O ₂				Experimental evidence for the existence of two lines is not conclusive. If there is one line, it appears to be split by 13.4MHz. ²¹⁾	21
	135.173	135.1726		∥	0.18	130	O ₂	29				21
		135.17256	2217849.9			100	O ₂					21

CH₂DOH

Table II-7

CO ₂ Pump Line (cm ⁻¹)	CH ₂ DOH Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₂ DOH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (Jn,K) → (J'n',K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
	149.6	149.6			0.063	150	O ₂	29				21
			149.61284			190	O ₂					21
	340.4	340.4			1.00	165	O ₂	29				21
			340.35664			130	O ₂					21
10R (16) 973.289	212.5	212.5				80	O ₂					21
	363	363			<0.5	80	O ₂	strongest line peak=25			This line may originate from CHD ₂ OH ²¹⁾	9
			363 ?		0.010	70	O ₂	33				21
10P (18) 945.980	238	238			0.5~1	80	O ₂	strongest line peak=25			This line may originate from CHD ₂ OH ²¹⁾	9
10P (26) 938.688	150.6	150.6		⊥	0.31	110	O ₂	31				21
			150.57167				O ₂					21
	188.4	188.4			0.70	110	O ₂	31				21
			188.41100				O ₂					21
10P (28) 936.804	189.3	189.3			0.018	120	O ₂	31				21
	196.1	196.1			0.025	120	O ₂	31				21
10P (30) 934.894	90.4	90.4			0.25	210	O ₂	34				21
	162.7	162.7		⊥	0.003	70	O ₂	34				21

CH₂DOH

Table II-8

CO ₂ Pump Line (cm ⁻¹)	CH ₂ DOH Laser Line			Relative Polarization	FIR Output Power (mW)	CH ₂ DOH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J _u K _u) → (J _v 'K _v ') (MHz)	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
10P (34)	124.4	125			1~2	80	O ₁	strongest line peak=25				9
		124.4			1.88	160	O ₂	24				21
			124.43170			160	O ₂					21
	248.1	248.1		⊥	0.75	115	O ₂	24				21
		248.12204				140	O ₂					21
	249.7	250			<0.5	80	O ₁	strongest line peak=25				9
		249.7			0.43	115	O ₂	24				21
		249.72035	1200512.7			160	O ₂					21
10P (36)	149.4	149.4			0.020	100	O ₂	24				21
		149.38792	2006805.2			190	O ₂					21
	224.2	224.2			0.050	100	O ₂	24				21
		224.22562	1337012.5			160	O ₂					21
	427.2	427.2		⊥	0.004	150	O ₂	24				21
10P (46)	374.1	374			0.5~1	80	O ₁	strongest line peak=25				9
		374.1			0.045	90	O ₂	6				21
		374.08611	801399.6			90	O ₂					21

Table III Laser lines of the optically pumped CHD₃OH lasers up to August of 1981.

CO ₂ Pump Line (cm ⁻¹)	CHD ₃ OH Laser Line			FIR Output Power (mW)	CHD ₃ OH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J _u K _u) → (J' _{u'} K' _{u'})	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)								
9R(18)	1077.303	165	165	0.5~1	80	O ₁	strongest line peak=25				9
9P(6)	1058.949	483	483	<0.5	80	O ₁	strongest line peak=25				9
9P(20)	1046.854	346	346	<0.5	80	O ₁	strongest line peak=25				9
9P(30)	1037.434	518	518	0.5~1	80	O ₁	strongest line peak=25				9
10R(38)	986.567	168	168	0.5~1	80	O ₁	strongest line peak=25				9
		426	426	0.5~1	80	O ₁	strongest line peak=25				9
10R(20)	975.930	260	260	1~2	80	O ₁	strongest line peak=25				9
10R(16)	973.289	179	179	0.5~1	80	O ₁	strongest line peak=25				9
		363	363	1~2	80	O ₁	strongest line peak=25				9
10P(18)	945.980	238	238	1~2	80	O ₁	strongest line peak=25				9
		355	355	0.5~1	80	O ₁	strongest line peak=25				9

Table IV-1 Laser lines of the optically pumped CD₃OH lasers up to August of 1981.

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OH Laser Line			Relative Polarization	FIR Output Power (mW)	CD ₃ OH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (Jn'K') → (J'n'τ'K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
9R(44)	1092.007	407	407		0.2		O ₁	strongest line peak=10				2
9R(34)	1086.870	52.9	52.9	⊥	VS	225	O ₃	average 10				11
		60.8	60.8		VS	225	O ₃	average 10				11
		232	232		0.4		O ₁	strongest line peak=10				2
		409	409	⊥	0.06		O ₁	strongest line peak=10				2
9R(32)	1085.765	336	336		0.02		O ₁	strongest line peak=10				2
		554	554		0.6		O ₁	strongest line peak=10				2
9R(28)	1083.479	49.8	49.8	⊥	VS	150	O ₃	average 10				11
		158	158		S	150	O ₃	average 10				11
		352	352		0.1		O ₁	strongest line peak=10				2
9R(26)	1082.296	277	277		0.15		O ₁	strongest line peak=10				2
		370	370		2.0		O ₁	strongest line peak=10				2
		745	745		0.08		O ₁	strongest line peak=10				2
9R(22)	1079.852	483	483		0.5		O ₁	strongest line peak=10				2
		583	583		0.9		O ₁	strongest line peak=10				2
		583	583		W	90	O ₃	average 10				11

CD₃OH

Table IV-2

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OH Laser Line			Relative Polarization	FIR Output Power (mW)	CD ₃ OH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (Jn ₁ K ₁) → (J' n' K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
9R (20)	1078.591	968	968		0.15		O ₁	strongest line peak=10				2
9R (18)	1077.303	297	297	⊥	0.15		O ₁	strongest line peak=10				2
9R (16)	1075.988	321	321	⊥	0.04		O ₁	strongest line peak=10				2
		472	472		0.03		O ₁	strongest line peak=10				2
9R (14)	1074.646	179	179	⊥	S	150	O ₃	average 10				11
		236	236		M	150	O ₃	average 10				11
		346	346		M	150	O ₃	average 10				11
		352	352		1.0		O ₁	strongest line peak=10				2
		553	553		4.5		O ₁	strongest line peak=10				2
9R (8)	1070.462	184	184	⊥	0.2		O ₁	strongest line peak=10				2
9R (6)	1069.014	299	299		0.02		O ₁	strongest line peak=10				2
9R (?)		353	353		0.2		O ₁	strongest line peak=10				2
9P (6)	1058.949	222	222		0.1		O ₁	strongest line peak=10				2
		680	680		0.02		O ₁	strongest line peak=10				2
9P (8)	1057.300	223	223	⊥	W	98	O ₃	average 10				11
		508	508		0.1		O ₁	strongest line peak=10				2

CD₃OH

Table IV-3

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OH Laser Line			Relative Polarization	FIR Output Power (mW)	CD ₃ OH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (Jn ₂ K) → (J'n ₂ 'K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
	711	711			0.15		O ₁	strongest line peak=10				2
9P(10)	1055.625	695			1.5		O ₁	strongest line peak=10				2
9P(12)	1053.924	1100			0.2		O ₁	strongest line peak=10				2
9P(14)	1052.196	268			0.1		O ₁	strongest line peak=10				2
9P(16)	1050.441	386		⊥	0.5		O ₂	strongest line peak=10				2
		480		⊥	0.03		O ₁	strongest line peak=10				2
9P(18)	1048.661	455			0.2		O ₁	strongest line peak=10				2
9P(20)	1046.854	266			0.25		O ₁	strongest line peak=10				2
		422			0.5		O ₁	strongest line peak=10				2
9P(22)	1045.022	551		⊥	0.3		O ₁	strongest line peak=10				2
9P(24)	1043.163	702			0.4		O ₁	strongest line peak=10				2
		1146			0.1		O ₁	strongest line peak=10				2
9P(28)	1039.369	370			0.2		O ₁	strongest line peak=10				2
		435		⊥	VW	135	O ₂	average 10				11
9P(30)	1037.434	385		⊥	0.01		O ₁	strongest line peak=10				2
		774			0.01		O ₁	strongest line peak=10				2

CD₃OH

Table IV-4

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OH Laser Line			Relative Polarization	FIR Output Power (mW)	CD ₃ OH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J ₁ K ₁) → (J ₂ K ₂)	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
3P (32) 1035.474	351	350			0.4		O ₁	strongest line peak=10				2
		351			VW	150	O ₂	average 10				11
	410	410			0.2		O ₁	strongest line peak=10				2
9P (40) 1027.382	201	201			M	150	O ₂	average 10				11
	285	285			0.3		O ₁	strongest line peak=10				2
10R (36) 985.488	253.2	253.2		⊥	S	200	O ₂	10R branch average 10		FIR 12, 0, 3, 9 → 11, 0, 1, 8 ⁸⁰		10
	419.0	420		⊥	3.8		O ₁	strongest line peak=10		FIR 12, 0, 3, 9 → 12, 0, 1, 8 ⁸⁰		2
		419.0			W	200	O ₂	10R branch average 10				10
	646	646		⊥	1.3		O ₁	strongest line peak=10		FIR probably 12, 0, 3, 9 → 11, 0, 3, 9 ⁸⁰		2
	703	703		⊥	1.2		O ₁	strongest line peak=10				2
10R (34) 984.383	37.6	37.6			M	200	O ₂	10R branch average 10				10
	102.6	102.6		⊥	W	150	O ₁	10R branch average 10				10
	112.3	112.3		⊥	~0.001	150	O ₂	10R branch average 10				10
	128.7	128.7			~0.001	150	O ₂	10R branch average 10				10
	182.4	182.4		⊥	W	150	O ₂	10R branch average 10				10
	191.9	191.9			M	150	O ₂	10R branch average 10				10

CD₃OH

Table IV-5

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OH Laser Line			Relative Polarization	FIR Output Power (mW)	CD ₃ OH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J''K'') → (J' n' τ' K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
	266.2	265			0.6		O ₁	strongest line peak = 10				2
		266.2		⊥	M	150	O ₃	10R branch average 10				10
	297	297			0.5		O ₁	strongest line peak = 10				2
	498	498			M	150	O ₃	10R branch average 10				10
	685	685			0.08		O ₁	strongest line peak = 10				2
10R(32) 983.252	421	421		⊥	0.5		O ₁	strongest line peak = 10				2
10R(30) 982.096	336	336		⊥	0.1		O ₁	strongest line peak = 10				2
	351	351		⊥	0.1		O ₁	strongest line peak = 10				2
10R(28) 980.913	310	310		⊥	0.6		O ₁	strongest line peak = 10				2
	398	398			0.5		O ₁	strongest line peak = 10				2
10R(24) 978.472	278	278			0.15		O ₁	strongest line peak = 10				2
10R(20) 975.930	1290	1290			0.1		O ₁	strongest line peak = 10				2
10R(18) 974.622	41.8	41.8		⊥	VS	400	O ₃	10R branch average 10		FIR 9, 1, 1, 3 → 9, 0, 3, 4 ²⁰		10
	43.9	43.9			VS	400	O ₃	10R branch average 10		FIR 9, 1, 1, 3 → 10, 0, 3, 4 ²⁰		10
	219.9	219.9			W	150	O ₃	10R branch average 10				10
	495	495			0.5		O ₁	strongest line peak = 10				2

CD₃OH

Table IV-6

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OH Laser Line			Relative Polarization	FIR Output Power (mW)	CD ₃ OH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (JnrK)→(J'n'ε'K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
	862.0	857			6.2		O ₁	strongest line peak=10		FIR 9, 1, 1, 3→8, 1, 1, 3 ²⁰		2
		862.0			M	150	O ₃	10R branch average ₁₀				10
10R(16)	973.289	81.2			M	220	O ₃	10R branch average ₁₀				10
		86.4		⊥	W	220	O ₃	10R branch average ₁₀				10
		599			0.1		O ₁	strongest line peak=10				2
10R(14)	971.930	267			0.09		O ₁	strongest line peak=10				2
10R(12)	970.547	412			0.1		O ₁	strongest line peak=10				2
10R(8)	967.707	41.5		⊥	M	225	O ₃	10R branch average ₁₀				10
		71.0			M	150	O ₃	10R branch average ₁₀				10
		553			2.2		O ₁	strongest line peak=10				2
		648			0.9		O ₁	strongest line peak=10				2
10P(18)	945.980	144.0			M	200	O ₃	10R branch average ₁₀		FIR 27, 0, 3, 13→26, 0, 1, 12 ²⁰		10
		287.4			4.4		O ₁	strongest line peak=10		FIR 27, 0, 3, 13→26, 0, 3, 13 ²⁰		2
		287.4			M	200	O ₃	10R branch average ₁₀				10
		290.0		⊥	M	200	O ₃	10R branch average ₁₀		FIR 27, 0, 3, 13→27, 0, 1, 12 ²⁰		10
		760			0.07		O ₁	strongest line peak=10				2

CD₃OH

Table IV-7

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OH Laser Line			Relative Polarization	FIR Output Power (mW)	CD ₃ OH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J' n' K' → J'' n'' K'')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
10P(20)	944.194	309	309		0.06		O ₁	strongest line peak=10				2
		722	722	⊥	0.05		O ₁	strongest line peak=10				2
10P(22)	942.383	34.8	34.8		M	350	O ₃	10R branch average 10		FIR 30, 1, 1, 4 → 29, 0, 2, 3 ²⁰		10
		40.1	40.1	⊥	M	350	O ₃	10R branch average 10		FIR 30, 1, 1, 4 → 30, 0, 2, 3 ²⁰		10
		258.7	260		0.9		O ₁	strongest line peak=10		FIR 30, 1, 1, 4 → 29, 1, 1, 4 ²⁰		2
		258.7	258.7		W	250	O ₃	10R branch average 10				10
10P(24)	940.548	238.3	238.3	⊥	W	200	O ₃	10R branch average 10				10
		286.6	286		2.3		O ₁	strongest line peak=10				2
		286.6	286.6		W	200	O ₃	10R branch average 10				10
10P(26)	938.688	483	483		0.1		O ₁	strongest line peak=10				2
10P(28)	936.804	276	276		0.8		O ₁	strongest line peak=10				2
10P(32)	932.960	76.1	76.1		M	250	O ₃	10R branch average 10				10
10P(42)	922.914	517	517		0.15		O ₁	strongest line peak=10				2
¹³ CO ₂ Pump Laser												
9R(34)	1040.447	234.7	234.7		1.0		W ₃	10.5				22
9P(16)	900.369	309.8	309.8		1.3		W ₃	10				22

Table IV-8

$^{13}\text{CO}_2$ Pump Line (cm^{-1})	CD ₃ OH Laser Line			FIR Output Power (mW)	CD ₃ OH Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (JnK) → (J' n' r' K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)								
9P(18)	143.4	143.4		2.6		W ₅	13.9				22
9P(20)	530.4	530.4		0.9		W ₅	11.2				22
9P(36)	221.0	221.0		0.44		W ₅	6				22

Table V-1 Laser lines of the optically pumped CD₃OD lasers up to August of 1981.

CO ₂ Pump Line (cm^{-1})	CD ₃ OD Laser Line			FIR Output Power (mW)	CD ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (JnK) → (J' n' r' K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)								
9R(38)	64.4	64.4		0.002	75	O ₂	13				23
		63.1			170	S	5	0		0V/cm E _{coy} ⊥ E _s	24
9R(28)	327	327.8		0.005	45	O ₂	20				23
		327			120	S	5	0		65V/cm E _{coy} ⊥ E _s	24
9R(26)	316	316			120	S	17	-10		0V/cm E _{coy} ⊥ E _s	24
9R(16)	316	316			200	S	18	-20		0V/cm E _{coy} ⊥ E _s	24
	454	454			200	S	18	-20		0V/cm E _{coy} ⊥ E _s	24
9R(8)	141.3	141.3		0.01	50	O ₂	18				23
	270.7	270.7		0.02	75	O ₂	18				23

CD₃OD

Table V-2

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OD Laser Line			Relative Polarization	FIR Output Power (mW)	CD ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (JnrK) → (J'n'τ'K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
		270.73258	1107337.9 ± 0.6			55	O ₂					23
		269				140	S	12	0		50V/cm E _{co} ⊥ E _s	24
9P(4) 1067.539	124.5	124.5		⊥	0.002	40	O ₂					23
	152.5	152.5		⊥	0.003	40	O ₂					23
9P(14) 1052.196	353	353				150	S	20			0V/cm E _{co} ⊥ E _s	24
9P(16) 1050.441	129	129				180	S	23	0		90V/cm E _{co} ⊥ E _s	24
9P(26) 1041.279	137	137				260	S	21	+15		0V/cm E _{co} ⊥ E _s	24
9P(28) 1039.369	62.7	62.7				250	S	24	-20		0V/cm E _{co} ⊥ E _s	24
9P(34)	96.6	96.6				250	S	20	-10		0V/cm -break down E _{co} ⊥ E _s	24
	113	113				250	S	20	-10		0V/cm -break down E _{co} ⊥ E _s	24
	114	114				250	S	20	-10		0V/cm E _{co} ⊥ E _s	24
10R(40) 987.620	210.5	210.5			0.01	45	O ₂	26				23
	255.3	255.3		⊥	0.03	45	O ₂	26				23
10R(36) 985.488	255	255		⊥	S	10	O ₂	10R branch peak=3			(This line probably originate from CD ₃ OH ²³)	3
	255	255		⊥			O ₂	10R branch peak=30				8
10R(34) 984.383	181.5	181.5 ± 0.5			0.16		W ₃	27				22

CD₃OD

Table V-3

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OD Laser Line			Relative Polarization	FIR Output Power (mW)	CD ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (Jn'K) → (J'n'τ'K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
10R(30)	982.096	150	150		0.1		O ₂	10R branch peak=30				8
10R(30)		192.5	192.5	⊥	0.03	105	O ₂	38				23
10R(30)		232.4	232.4	∥	0.01	90	O ₂	38				23
10R(28)	980.913	35	35		4.0		O ₂	10R branch peak=30				8
10R(28)		122.3	122.3	⊥	0.2	130	O ₂	25				23
			122.30421			130	O ₂					23
		122				420	S	16	0		280V/cm E _{co} ⊥E _s	24
10R(28)		73.8	73.8	∥	0.005	100	O ₂	25				23
		80.5	80.5	∥	0.007	100	O ₂	25				23
10R(26)	979.705	183	183			150	S	15	+35		115V/cm, 28.1±0.7MHz/KV/cm, E _{co} ⊥E _s	24
		297	297			150	S	15	+35		0V/cm E _{co} ⊥E _s	24
10R(26)		119.1	119		0.2		O ₂	10R branch peak=30				8
		119.1	119.1	⊥	0.03	180	O ₂	32				23
		119.13700	251867.7			105	O ₂					23
		119	119			300	S	20			130V/cm E _{co} ⊥E _s	24
		124.8	124.8	⊥	0.008	130	O ₂	32				23

CD₃OD

Table V-4

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OD Laser Line			Relative Polarization	FIR Output Power (mW)	CD ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J''K'') → (J' n' r' K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
		124.75788	2402224.0			120	O ₂					23
10R ₄ (26)	97.5	97.5		⊥	0.03	115	O ₂					23
		96.8				300	S	20			250V/cm E _{coo} ⊥ E _s	24
10R(24)	184.8	184		⊥	VS	10	O ₂	10R branch peak=3				3
		184		⊥	~0.1	75~150	W ₁	>15				5
		184		⊥			O ₂	10R branch peak=30				8
		184.8		⊥	2	155	O ₂	37				23
		184.76565	1622555.2			105	O ₂					23
		183				380	S	20	+30		27.2 ± 1.0 MHz/KV/cm E _{coo} ⊥ E _s 140V/cm 26.4 ± 0.7 MHz/KV/cm	24
	298.7	299		⊥	VS	10	O ₂	10R branch peak=3				3
		299		⊥	~0.1	75~150	W ₁	>15				5
		299		⊥	0.8		O ₂	10R branch peak=30				8
		298.7			0.4	155	O ₂	37				23
		298.73586	1003536.6			85	O ₂					23
		297				380	S	20	+30		0V/cm	24
	486.5	495			0.8		O ₂	10R branch peak=30				8
		486.5		⊥	0.01	155	O ₂					23

Table V-5 CD_3OD

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OD Laser Line		Relative Polarization	FIR Output Power (mW)	CD ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (J ₁ τK) → (J ₂ τ'K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)								
10R(22)	165.6	165		0.05		O ₂	10R branch peak=30				8
		165.6		0.08	85	O ₂	32				23
		165.60426	1810294.3		40	O ₂					23
		163			190	S	21	-25		30V/cm E _{CO₂} ⊥ E _S	24
10R(20)	80.5	80.5		0.2	135	O ₂					23
10R(18)	41	41		M	10	O ₂	10R branch peak=3				3
		41		~0.2	75~150	W ₁	>15			These lines probably originate from CD ₃ OH ²³⁾	5
		41		⊥		O ₃	10R branch peak=30				8
	869	869		0.1	80	W ₁	~4	-20			12
10R(16)	52.4	52.4		0.02	75	O ₂	30				23
	82.2	82.2		0.006	55	O ₂	30				23
	354.2	354		0.5		O ₃	10R branch peak=30				8
		354.2		0.2	85	O ₂	30				23
		354.17610	846450.3		70	O ₂					23
		351			270	S	18	-25		0V/cm E _{CO₂} ⊥ E _S	24
	355.5	355.5		13		W ₁	37				22
10R ₂ (16)	87.3	87.3		0.006	65	O ₂	30				23

CD₃OD

Table V-6

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OD Laser Line			Relative Polarization	FIR Output Power (mW)	CD ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (Jn ₁ K ₁ → J'n ₂ 'K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
10R(12) 970.547	104.3	104.3			0.2	160	O ₂	37				23
	107.5	107.5			0.3	180	O ₂	37				23
		107.53770	278789.4			90	O ₂					23
	108.7	108.7			0.2	125	O ₂	37				23
10R ₄ (12)	410.7	406		⊥	VS		O ₂	10R branch peak=3				3
		406		⊥	~0.1		W ₁	>15				5
		414			1.0		O ₂	10R branch peak=30				8
		410.7			0.5	115	O ₂	37				23
		410.71241	729332.8			115	O ₂					23
		410				200	S	16	-20		E _{co} ⊥ E _s 60.5 ± 1.3 MHz/KV/cm E _{co} // E _s not split	24
10R(10) 969.140	86.5	86.5			0.2	105	O ₂	42				23
	227.7	229		⊥	VS	10	O ₂	10R branch peak=3				3
		229		⊥	0.5		O ₃	10R branch peak=30				8
		227.7		⊥	0.2	105	O ₂	42				23
		227.66072	1316838.7			75	O ₂					23
	314.8	312		⊥	VS	10	O ₂	10R branch peak=3				3

CD₃OD

Table V-7

CO ₂ Pump Line (cm ⁻¹)	CD ₃ OD Laser Line			Relative Polarization	FIR Output Power (mW)	CD ₃ OD Laser Pressure (mTorr)	FIR Resonator O : Open W : Waveguide S : Stark	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition (JnτK) → (J'n'τ'K')	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
		312		⊥	0.1		O ₃	10R branch peak=30				8
		314.8		∥	0.2	75	O ₂	42				23
		311				170	S	19	-20		30V/cm E _{coo} ⊥ E _s	24
		314.84059	952203.9			85	O ₂					23
10R(6)	966.250	130.5		∥	0.008	85	O ₂	30				23
10R(4)	964.769	344.8		⊥	M	10	O ₂	10R branch peak=3				3
		339		⊥	0.5		O ₃	10R branch peak=30				8
		344.8		∥	0.6	95	O ₂	27				23
		344.77818	869522.7			70	O ₂					23
10P(10)	952.881	78			2.0		O ₃	10R branch peak=30				8
		149				180	S	10			0V/cm E _{coo} ⊥ E _s	24
¹³ CO ₂ Pump Line												
9P(12)	1007.798	182.0			5.2		W ₃	6				22
9P(14)	1006.053	167.5			2.6		W ₃	8.5				22
9P(16)	1004.280	310.0			2.6		W ₃	13				22
9P(18)	1002.478	374.6			0.20		W ₃	10				22
9P(20)	1000.647	533.0			0.12		W ₃	7.5				22

Table VI-1 Laser lines of the optically pumped $^{13}\text{CH}_3\text{OH}$ lasers up to August of 1981.
 *The FIR lines are numbered consecutively in order of decreasing strength for each pump line.

CO ₂ Pump Line (cm ⁻¹)	$^{13}\text{CH}_3\text{OH}$ Laser Line			Relative Polarization	FIR Output Power (mW)	$^{13}\text{CH}_3\text{OH}$ Laser Pressure (mTorr)	FIR Resonator	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
9P(8)	87.9	87.90		⊥		300	O ₃	strongest line peak=6		Pump 30,1,1,3→31,1,1,3		13
9P(10)	86.1	86.111796	3481433.2	∥	3*	300		strongest line peak=6	+25	FIR 31,1,1,3→30,1,2,2		13, 14
	146.1	146.09739	2052004.1	⊥	1*	300	O ₃ , W ₃	strongest line peak=30	+25	FIR 31,1,1,3→31,1,2,2		13, 14
	208.4	208.41204	1438460.3	∥	2*	300			+25	FIR 31,1,1,3→30,1,1,3		13, 14
9P(12)	157.9	157.92848	1898279.9	∥	3*	180		strongest line peak=6	-20	FIR 27,0,3,4→26,0,1,3		13, 14
	238.5	238.52288	1256871.9	∥	1*	180	O ₃ , W ₃	strongest line peak=30	-20	FIR 27,0,3,4→26,0,3,4	Pump 26,0,3,4→27,0,3,4	13, 14
	461.4	461.39484	649766.6	⊥	2*	180			-20	FIR 27,0,3,4→27,0,1,3		13, 14
9P ₄ (12)	63.1	63.094		∥	6*	180	O ₃		+25			13
	237.5	237.5230		∥	4*	180	O ₃	strongest line peak=6	+25			13
	628.8	628.8443		∥	5*	180	O ₃		+25			13
9P(22)	103.5	103.48082	2897082.4	∥	1*	240		strongest line peak=6	+15	FIR 19,0,1,9→18,0,2,8		13, 14
	149.3	149.27226	2008360.1	⊥	3*	240	O ₃ , W ₃	strongest line peak=30	+15	FIR 19,0,1,9→19,0,2,8	Pump 18,0,1,9→19,0,1,9	13, 14
	339.0	338.96379	884438.0	∥	5*	240			+15	FIR 19,0,1,9→18,0,1,9		13, 14
9P ₄ (22)	85.3	85.317292	3513853.4	∥	4*	240			-15	FIR 21,1,3,10→20,1,1,9		13, 14
	118.0	118.013148	2540331.0	⊥	2*	240			-15	FIR 21,1,3,10→21,1,1,9		13, 14
	307.8	307.78		∥	6*	240			-15	FIR 21,1,3,10→20,1,3,10		13, 14

$^{13}\text{CH}_3\text{OH}$

Table VI-2

CO ₂ Pump Line (cm^{-1})	$^{13}\text{CH}_3\text{OH}$ Laser Line			Relative Polarization	FIR Output Power (mW)	$^{13}\text{CH}_3\text{OH}$ Laser Pressure (mTorr)	FIR Resonator	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
9P(30)	148.0	147.97		$\perp$		180	O ₃	strongest line peak=6	-25			13
9P(36)	291.6	291.62		$\parallel$	1*	130	O ₃	strongest line peak=6	-20			13
	325.2	325.17		$\parallel$	2*	130	O ₃	strongest line peak=6	-20			13
9P(40)	168.8	168.84		$\parallel$	1*	110	O ₃	strongest line peak=6	+35			13
	358.9	358.92		$\perp$	2*	110	O ₃	strongest line peak=6	+35			13
10R(28)	85.8	85.79		$\perp$	2*	300	O ₃	strongest line peak=6	-5			13
	121.2	121.20		$\parallel$	1*	300	O ₃	strongest line peak=6	-5			13
10R(26)	77.5	77.4894		$\parallel$	1*	230	O ₃	strongest line peak=6	+40	FIR 21, n, τ , K-20, n, τ , K-1	Pump K-14 J 22-21	13
	103.6	103.5863		($\perp$)	2*	230	O ₃	strongest line peak=6	+40	FIR 21, n, τ , K-21, n, τ , K-1		13
10R(22)	34.8	34.79		$\parallel$		460	O ₃	strongest line peak=6				13
10R(18)	105.1	105.1472		($\parallel$)	2*	200	O ₃	strongest line peak=6	+25			13
	110.4	110.4324		($\parallel$)	1*	200	O ₃	strongest line peak=6	+25			13
	171.8	171.7576		$\perp$	2*	200	O ₃	strongest line peak=6	+25			13

$^{13}\text{CH}_3\text{OH}$

Table VI-3

CO ₂ Pump Line (cm^{-1})	$^{13}\text{CH}_3\text{OH}$ Laser Line			Relative Polarization	FIR Output Power (mW)	$^{13}\text{CH}_3\text{OH}$ Laser Pressure (mTorr)	FIR Resonator	CO ₂ Pump Power (W)	Pump Offset (MHz)	Transition	Note	Reference
	Representative Wavelength (μm)	Measured Wavelength (μm)	Measured Frequency (MHz)									
10R(16)	973.289	115.8	115.82325	2588361.7		2*	150		+20	FIR 24, 0, 2, 7→23, 0, 3, 6		13, 14
		148.6	148.59041	2017576.1					+20	cascade		14
		152.1	152.07569	1971337.2				strongest line peak=6	+20	cascade		14
		203.6	203.63579	1472195.3	⊥	1*	150		+20	FIR 24, 0, 2, 7→24, 0, 3, 6	Pump 25, 0, 2, 7→24, 0, 2, 7	13, 14
		268.6	268.57216	1116245.5		3*	150		+20	FIR 24, 0, 2, 7→23, 0, 2, 7		13, 14
		280.22	280.21826	1069853.4				strongest line peak=30	+20	cascade		14
		280.24	280.23974	1069771.4					+20	cascade		14
		332.6	332.60338	901351.2					+20	cascade		14
10P ₁ (16)	947.742	41.9	41.90		⊥		150	strongest line peak=6	-10			13
10P ₂ (16)		123.3	123.26				290	strongest line peak=6	+40			13

Table VII-1 Laser lines of the optically pumped CH_3OD , CH_2DOH , CHD_2OH , CD_3OH , CD_3OD and $^{13}\text{CH}_3\text{OH}$ lasers up to August of 1981.

*Frequency measured and showed in Tables I~VI.

Wavelength (μm)	Active Medium	Pump Laser and Pump Line	FIR Resonator O : Open W : Waveguide S : Stark	Reference
34.79	$^{13}\text{CH}_3\text{OH}$	CO_2 10R(22)	O_3	13
34.8	CD_3OH	CO_2 10P(22)	O_3	10
35	CD_3OD	CO_2 10R(28)	O_3	8
37.6	CD_3OH	CO_2 10R(34)	O_3	10
40.1	CD_3OH	CO_2 10P(22)	O_3	10
41	$\text{CD}_3\text{OD? (CD}_3\text{OH}^{23})$	CO_2 10R(18)	O_2 W_1 O_3	3 5 8
41.5	CD_3OH	CO_2 10R(8)	O_3	10
41.8	CD_3OH	CO_2 10R(18)	O_3	10
41.9	$^{13}\text{CH}_3\text{OH}$	CO_2 10P _I (16)	O_3	13
42.5	CH_2DOH	CO_2 9P(38)	O_2	21
43.9	CD_3OH	CO_2 10R(18)	O_3	10
44	CH_2DOH	CO_2 9P(30)	O_2	21
46.7	CH_3OD	CO_2 9R(8)	W_1	5
49.8	CD_3OH	CO_2 9R(28)	O_3	11
52.4	CD_3OD	CO_2 10R _I (16)	O_2	23
52.9	CD_3OH	CO_2 9R(34)	O_3	11
57	CH_3OD	CO_2 9R(8)	O_2 W_1 W_2	4 5 16 16'
60.8	CD_3OH	CO_2 9R(34)	O_3	11
62.7	CD_3OD	CO_2 9R(28)	S	24
63.1	$^{13}\text{CH}_3\text{OH}$	CO_2 9P _{II} (12)	O_3	13
64.4	CD_3OD	CO_2 9R(38)	O_2 S	23 24
69.5	CH_3OD	CO_2 9R _I (6)	W_3	15
70.3	CH_3OD	CO_2 9R(16)	W_3	15
71.0	CD_3OH	CO_2 10R(8)	O_3	10
73.8	CD_3OD	CO_2 10R _{II} (28)	O_2	23
76.1	CD_3OH	CO_2 10P(32)	O_3	10
77.5	$^{13}\text{CH}_3\text{OH}$	CO_2 10R(26)	O_3	13
78	CD_3OD	CO_2 10P(10)	O_3	8
80	CH_3OD	CO_2 9P(32)	O_1	1 18
80.5	CD_3OD	CO_2 10R _{II} (28)	O_2	23
80.5	CD_3OD	CO_2 10R(20)	O_2	23
81.2	CD_3OH	CO_2 10R(16)	O_3	10
81.9	CH_3OD	CO_2 9P(30)	O_3	17
82.2	CD_3OD	CO_2 10R _I (16)	O_2	23
85.3*	$^{13}\text{CH}_3\text{OH}$	CO_2 9P _{II} (22)	O_3 W_3	13 14
85.8	$^{13}\text{CH}_3\text{OH}$	CO_2 10R(28)	O_3	13
86.1*	$^{13}\text{CH}_3\text{OH}$	CO_2 9P(10)	O_3 W_3	13 14
86.4	CD_3OH	CO_2 10R(16)	O_3	10
86.5	CD_3OD	CO_2 10R(10)	O_2	23

Table VII-2

Wavelength (μm)	Active Medium	Pump Laser and Pump Line	FIR Resonator O : Open W : Waveguide S : Stark	Reference
86.7	CH ₃ OD	¹³ CO ₂ 9R(28)	W ₃	22
87.1	CH ₂ DOH	CO ₂ 9P ₁ (18)	O ₂	21
87.3	CD ₃ OD	CO ₂ 10R ₁₁ (16)	O ₂	23
87.9	CH ₂ DOH	CO ₂ 9P ₁ (40)	O ₂	21
87.9	¹³ CH ₃ OH	CO ₂ 9P(8)	O ₃	13
89.6	CH ₃ OD	CO ₂ 9P(30)	O ₃	17
90.4	CH ₂ DOH	CO ₂ 10P(30)	O ₂	21
96.6	CD ₃ OD	CO ₂ 9P(34)	S	24
97.5	CD ₃ OD	CO ₂ 10R ₁₁ (26)	O ₂ S	23 24
100.0	CH ₂ DOH	CO ₂ 9P ₁ (18)	O ₂	21
100.8	CH ₃ OD	CO ₂ 9P(26)	W ₃	15
101.6	CH ₃ OD	CO ₂ 9P(26)	O ₃ O ₁	17 18
102.0*	CH ₂ DOH	CO ₂ 9P(16)	O ₂	21
102.6	CD ₃ OH	CO ₂ 10R(34)	O ₃	10
103.1*	CH ₃ OD	CO ₂ 9P(30)	O ₁ O ₂ W ₁ W ₂ W ₃	1 4 5 6 16 16'
103.5*	¹³ CH ₃ OH	CO ₂ 9P ₁ (22)	O ₃ W ₃	13 14
103.6	¹³ CH ₃ OH	CO ₂ 10R(26)	O ₃	13
104.3	CD ₃ OD	CO ₂ 10R ₁ (12)	O ₂	23
105.1	¹³ CH ₃ OH	CO ₂ 10R(18)	O ₃	13
106	CH ₃ OD	CO ₂ 9R(26)	O ₁	18
106	CH ₃ OD	CO ₂ 9R(2)	O ₁	18
107.5*	CD ₃ OD	CO ₂ 10R ₁ (12)	O ₂	23
107.8	CH ₃ OD	CO ₂ 9P(26)	S	19
108	CH ₃ OD	CO ₂ 9P(32)	O ₁	18
108.7	CD ₃ OD	CO ₂ 10R ₁ (12)	O ₂	23
108.8*	CH ₂ DOH	CO ₂ 9P(12)	O ₁ O ₂	9 21
108.9*	CH ₂ DOH	CO ₂ 9P ₁ (32)	O ₂	21
110	CH ₃ OD	CO ₂ 10R(44)	O ₂ O ₁	4 18
110.4	¹³ CH ₃ OH	CO ₂ 10R(18)	O ₃	13
110.7	CH ₃ OD	CO ₂ 9P(32)	O ₃	17
111.1	CH ₃ OD	CO ₂ 9P(30)	S	19
112.3	CD ₃ OH	CO ₂ 10R(34)	O ₃	10
112.5*	CH ₂ DOH	CO ₂ 9P(12)	O ₂	21
113	CD ₃ OD	CO ₂ 9P(34)	S	24
113.8	CH ₃ OD	CO ₂ 9P(32)	O ₃	17
114	CD ₃ OD	CO ₂ 9P(34)	S	24
115.0	CH ₃ OD	CO ₂ 9R(2)	S	19
115.8*	¹³ CH ₃ OH	CO ₂ 10R(16)	O ₃ W ₃	13 14
117.1*	CH ₂ DOH	CO ₂ 9P ₁ (32)	O ₂	21
117.2*	CH ₃ OD	CO ₂ 9P(26)	O ₁ O ₂ W ₃	1 4 6 18
118.0*	¹³ CH ₃ OH	CO ₂ 9P ₁₁ (22)	O ₃ W ₃	13 14

Table VII-3

Wavelength (μm)	Active Medium	Pump Laser and Pump Line	FIR Resonator O : Open W : Waveguide S : Stark	Reference
119.1*	CD ₃ OD	CO ₂ 10R ₁ (26)	O ₃ O ₂ S	8 23 24
121.2	¹³ CH ₃ OH	CO ₂ 10R(28)	O ₃	13
122.3*	CD ₃ OD	CO ₂ 10R ₁ (28)	O ₂ S	23 24
123.3	¹³ CH ₃ OH	CO ₂ 10P _{II} (16)	O ₃	13
124.4*	CH ₂ DOH	CO ₂ 10P(34)	O ₁ O ₂	9 21
124.5	CD ₃ OD	CO ₂ 9R(4)	O ₂	23
124.8*	CD ₃ OD	CO ₂ 10R ₁ (26)	O ₂	23
128.0	CH ₃ OD	CO ₂ 9P(22)	O ₁	1
128.7	CD ₃ OH	CO ₂ 10R(34)	O ₃	10
129	CD ₃ OD	CO ₂ 9P(16)	S	24
130.5	CD ₃ OD	CO ₂ 10R(6)	O ₂	23
133	CH ₃ OD	CO ₂ 9P(24)	O ₃ O ₁	8 18
134	CH ₃ OD	CO ₂ 9P(10)	O ₃ W ₃ W ₂ O ₁	8 15 16 16' 18
134.7	CH ₃ OD	CO ₂ 9P(6)	W ₁ W ₂	5 16 16'
135.172*	CH ₂ DOH	CO ₂ 10R(32)	O ₂	21
135.173*	CH ₂ DOH	CO ₂ 10R(32)	O ₂	21
135.5	CH ₃ OD	CO ₂ 10P(26)	S	19
135.8*	CH ₂ DOH	CO ₂ 9R(8)	O ₂	21
137	CD ₃ OD	CO ₂ 9P(26)	S	24
137.2	CH ₃ OD	CO ₂ 10R(22)	O ₁ S	18 19
139.9	CH ₃ OD	N ₂ O R(22)	S	19
140.3	CH ₂ DOH	CO ₂ 9P(20)	O ₂	21
141	CH ₃ OD	CO ₂ 10R(42)	O ₁	18
141.3	CD ₃ OD	CO ₂ 9R(8)	O ₂	23
143.4	CD ₃ OH	¹³ CO ₂ 9P(18)	W ₃	22
144.0	CD ₃ OH	CO ₂ 10P(18)	O ₃	10
145.6	CH ₃ OD	CO ₂ 9P(32)	O ₃	17
145.7*	CH ₃ OD	CO ₂ 9P(30)	O ₂ W ₁ O ₃	4 5 7
146.1*	¹³ CH ₃ OH	CO ₂ 9P(10)	O ₃ W ₃	13 14
148.0	¹³ CH ₃ OH	CO ₂ 9P(30)	O ₃	13
148.6*	¹³ CH ₃ OH	CO ₂ 10R(16)	O ₃ W ₃	14
149	CD ₃ OD	CO ₂ 10P(10)	S	24
149.3*	¹³ CH ₃ OH	CO ₂ 9P _I (22)	O ₃ W ₃	13 14
149.4*	CH ₂ DOH	CO ₂ 10P(36)	O ₂	21
149.6*	CH ₂ DOH	CO ₂ 10R(32)	O ₂	21
150	CD ₃ OD	CO ₂ 10R(30)	O ₃	8
150.6*	CH ₂ DOH	CO ₂ 10P(26)	O ₂	21
150.8*	CH ₂ DOH	CO ₂ 10R(34)	O ₁ O ₂	9 21
151.6	CH ₃ OD	CO ₂ 9R(34)	S	19
152.1*	¹³ CH ₃ OH	CO ₂ 10R(16)	O ₃ W ₃	14
152.5	CD ₃ OD	CO ₂ 9R(4)	O ₂	23
152.7	CH ₂ DOH	CO ₂ 9R _I (24)	O ₂	21
157.9*	¹³ CH ₃ OH	CO ₂ 9P _I (12)	O ₃ W ₃	13 14

Table VII-4

Wavelength (μm)	Active Medium	Pump Laser and Pump Line	FIR Resonator O : Open W : Waveguide S : Stark	Reference
158	CD ₃ OH	CO ₂ 9R(28)	O ₃	11
159.2*	CH ₂ DOH	CO ₂ 10R(34)	O ₂	21
162.7	CH ₂ DOH	CO ₂ 10P(30)	O ₂	21
164	CH ₂ DOH(CHD ₂ OH? ²¹⁾	CO ₂ 9R(18)	O ₁	9
164.7*	CH ₂ DOH	CO ₂ 9R(8)	O ₂	21
165	CHD ₂ OH	CO ₂ 9R(18)	O ₁	9
165.6*	CD ₃ OD	CO ₂ 10R(22)	O ₃ O ₂ S	8 23 24
167.4*	CH ₂ DOH	CO ₂ 9P _{II} (32)	O ₂	21
167.5*	CH ₂ DOH	CO ₂ 9P _{II} (18)	O ₁ O ₂	9 21
167.5	CD ₃ OD	¹³ CO ₂ 9P(14)	W ₃	22
168	CHD ₂ OH	CO ₂ 10R(38)	O ₁	9
168.1	CH ₃ OD	CO ₂ 9P(30)	O ₁	1
168.8	¹³ CH ₃ OH	CO ₂ 9P(40)	O ₃	13
169	CH ₃ OD	CO ₂ 9R(22)	O ₁	18
171.8	CH ₂ DOH	CO ₂ 9R(22)	O ₂	21
171.8	¹³ CH ₃ OH	CO ₂ 10R(18)	O ₃	13
172.8*	CH ₂ DOH	CO ₂ 9P(12)	O ₁ O ₂	9 21
179.0	CH ₃ OD	CO ₂ 9P(32)	O ₁	1 18
179	CHD ₂ OH	CO ₂ 10R(16)	O ₁	9
179	CD ₃ OH	CO ₂ 9R(14)	O ₃	11
181.5	CD ₃ OD	CO ₂ 10R(34)	W ₃	22
182	CH ₃ OD	CO ₂ 9R(26)	O ₁	18
182.0	CD ₃ OD	¹³ CO ₂ 9P(12)	W ₃	22
182.1	CH ₃ OD	CO ₂ 9P(6)	O ₃	17
182.1	CH ₂ DOH	CO ₂ 9R(22)	O ₂	21
182.4	CD ₃ OH	CO ₂ 10R(34)	O ₃	10
183	CD ₃ OD	CO ₂ 10R(26)	S	24
183.6*	CH ₂ DOH	CO ₂ 9P(10)	O ₂	21
184	CD ₃ OH	CO ₂ 9R(8)	O ₁	2
184.8*	CD ₃ OD	CO ₂ 10R(24)	O ₂ O ₃ W ₁ S	3 5 8 23 24
186	CH ₃ OD	CO ₂ 9R(28)	O ₁	18
188.4*	CH ₂ DOH	CO ₂ 10P(26)	O ₂	21
189.3	CH ₂ DOH	CO ₂ 10P(28)	O ₂	21
191.9	CD ₃ OH	CO ₂ 10R(34)	O ₃	10
192.5	CD ₃ OD	CO ₂ 10R _I (30)	O ₂	23
195.5*	CH ₂ DOH	CO ₂ 9P(36)	O ₂	21
196.1	CH ₂ DOH	CO ₂ 10P(28)	O ₂	21
200	CH ₂ DOH	CO ₂ 9P(38)	O ₂	21
201	CD ₃ OH	CO ₂ 9P(40)	O ₃	11
203.6*	¹³ CH ₃ OH	CO ₂ 10R(16)	O ₃ W ₃	13 14

Table VII-5

Wavelength (μm)	Active Medium	Pump Laser and Pump Line	FIR Resonator O : Open W : Waveguide S : Stark	Reference
206.7*	CH ₃ DOH	CO ₂ 9P(14)	O ₁ O ₂	9 21
208.4*	¹³ CH ₃ OH	CO ₂ 9P(10)	O ₃ W ₃	13 14
210.5	CD ₃ OD	CO ₂ 10R(40)	O ₂	23
212	CH ₃ OD	CO ₂ 9R(4)	W ₃ O ₁	15 18
212.5	CH ₃ DOH	CO ₂ 10R(16)	O ₂	21
215.4*	CH ₃ OD	CO ₂ 9R(14)	O ₂ O ₃ O ₁	4 7 18
216.8	CH ₃ DOH	CO ₂ 9R(16)	O ₂	21
218.0	CH ₃ DOH	CO ₂ 9R(22)	O ₂	21
219.1*	CH ₃ DOH	CO ₂ 9R _n (24)	O ₂	21
219.9	CD ₃ OH	CO ₂ 10R(18)	O ₃	10
221	CH ₃ OD	CO ₂ 9R _n (6)	W ₃ O ₁	15 18
221.0	CD ₃ OH	¹³ CO ₂ 9P(36)	W ₃	22
222	CD ₃ OH	CO ₂ 9P(6)	O ₁	2
223	CD ₃ OH	CO ₂ 9P(8)	O ₃	11
224	CH ₃ OD	CO ₂ 10R(22)	O ₁	18
224.2*	CH ₃ DOH	CO ₂ 10P(36)	O ₂	21
226.3*	CH ₃ DOH	CO ₂ 9P(46)	O ₂	21
227.7*	CD ₃ OD	CO ₂ 10R(10)	O ₂ O ₃	3 8 23
229.1	CH ₃ OD	CO ₂ 9P(6)	W ₁ W ₂	5 16 16'
232	CD ₃ OH	CO ₂ 9R(34)	O ₁	2
232.4	CD ₃ OD	CO ₂ 10R _n (30)	O ₂	23
233	CH ₃ OD	CO ₂ 9R(14)	O ₃ O ₁	17 18
234.7	CD ₃ OH	¹³ CO ₂ 9R(34)	W ₃	22
236	CH ₃ OD	CO ₂ 10R(44)	O ₁	18
236	CD ₃ OH	CO ₂ 9R(14)	O ₃	11
237.5	¹³ CH ₃ OH	CO ₂ 9P _n (12)	O ₃	13
238	CH ₃ OD? (CH ₃ OH ¹⁷)	CO ₂ 10R(34)	O ₃	17
238	CH ₃ DOH (CHD ₂ OH ²¹)	CO ₂ 10P(18)	O ₁	9
238	CHD ₂ OH	CO ₂ 10P(18)	O ₁	9
238.3	CD ₃ OH	CO ₂ 10P(24)	O ₃	10
238.5*	¹³ CH ₃ OH	CO ₂ 9P _i (12)	O ₃ W ₃	13 14
241	CH ₃ OD	CO ₂ 10R(44)	O ₃	17
248.1*	CH ₃ DOH	CO ₂ 10P(34)	O ₂	21
249.7*	CH ₃ DOH	CO ₂ 10P(34)	O ₁ O ₂	9 21
253.2	CD ₃ OH	CO ₂ 10R(36)	O ₃	10
255	CD ₃ OD? (CD ₃ OH ²³)	CO ₂ 10R(36)	O ₂ O ₃	3 8
255.3	CD ₃ OD	CO ₂ 10R(40)	O ₂	23
258.7	CD ₃ OH	CO ₂ 10P(22)	O ₁ O ₃	2 10
260	CHD ₂ OH	CO ₂ 10R(20)	O ₁	9

Table VII-6

Wavelength (μm)	Active Medium	Pump Laser and Pump Line	FIR Resonator O : Open W : Waveguide S : Stark	Reference
266	CD ₃ OH	CO ₂ 9P(20)	O ₁	2
266.2	CD ₃ OH	CO ₂ 10R(34)	O ₁ O ₃	2 10
266.7*	CH ₂ DOH	CO ₂ 9P _{II} (32)	O ₂	21
267	CD ₃ OH	CO ₂ 10R(14)	O ₁	2
268	CD ₃ OH	CO ₂ 9P(14)	O ₁	2
268.6*	¹³ CH ₃ OH	CO ₂ 10R(16)	O ₃ W ₃	13 14
270.7*	CD ₃ OD	CO ₂ 9R(8)	O ₂ S	23 24
272.3*	CH ₂ DOH	CO ₂ 9R _{II} (24)	O ₁ O ₂	9 21
273.0*	CH ₂ DOH	CO ₂ 9P(6)	O ₂	21
276	CD ₃ OH	CO ₂ 10P(28)	O ₁	2
277	CD ₃ OH	CO ₂ 9R(26)	O ₁	2
278	CD ₃ OH	CO ₂ 10R(24)	O ₁	2
279	CH ₃ OD	CO ₂ 9P(32)	O ₁	1 18
280	CH ₃ OD	CO ₂ 10P(18)	O ₃	17
280.22*	¹³ CH ₃ OH	CO ₂ 10R(16)	O ₃ W ₃	14
280.24*	¹³ CH ₃ OH	CO ₂ 10R(16)	O ₃ W ₃	14
282	CH ₃ OD	CO ₂ 9R(6)	W ₂	16 16'
285	CD ₃ OH	CO ₂ 9P(40)	O ₁	2
286.6	CD ₃ OH	CO ₂ 10P(24)	O ₁ O ₃	2 10
287.4	CD ₃ OH	CO ₂ 10P(18)	O ₁ O ₃	2 10
290.0	CD ₃ OH	CO ₂ 10P(18)	O ₃	10
291.6	¹³ CH ₃ OH	CO ₂ 9P(36)	O ₃	13
294.8*	CH ₃ OD	CO ₂ 9R(8)	O ₂ W ₁ O ₃	4 5 7
295.4*	CH ₂ DOH	CO ₂ 9P(10)	O ₁ O ₂	9 21
295.6*	CH ₂ DOH	CO ₂ 10R(34)	O ₁ O ₂	9 21
297	CD ₃ OH	CO ₂ 9R(18)	O ₁	2
297	CD ₃ OH	CO ₂ 10R(34)	O ₁	2
297	CD ₃ OD	CO ₂ 10R(26)	S	24
298.7*	CD ₃ OD	CO ₂ 10R(24)	O ₂ W ₁ O ₃ S	3 5 8 23 24
299	CD ₃ OH	CO ₂ 9R(6)	O ₁	2
305.7*	CH ₃ OD	CO ₂ 9R(8)	O ₂ W ₁ O ₃	4 5 7
307.8	¹³ CH ₃ OH	CO ₂ 9P _{II} (22)	O ₃ W ₃	13 14
308.0*	CH ₂ DOH	CO ₂ 9P(14)	O ₁ O ₂	9 21
309	CD ₃ OH	CO ₂ 10P(18)	O ₁	2
309.8	CD ₃ OH	¹³ CO ₂ 9P(16)	W ₃	22
310	CD ₃ OH	CO ₂ 10R(28)	O ₁	2
310.0	CD ₃ OD	¹³ CO ₂ 9P(16)	W ₃	22
314.8*	CD ₃ OD	CO ₂ 10R(10)	O ₂ O ₃ S	3 8 23 24
316	CD ₃ OD	CO ₂ 9R(16)	S	24
316	CD ₃ OD	CO ₂ 9R(26)	S	24
320	CH ₃ OD	CO ₂ 9P(30)	O ₁ W ₁	1 5

Table VII-7

Wavelength (μm)	Active Medium	Pump Laser and Pump Line	FIR Resonator O : Open W : Waveguide S : Stark	Reference
321	CD_3OH	CO_2 9R(16)	O_1	2
322.5*	CH_2DOH	CO_2 9P(12)	O_1 O_2	9 21
325.2	$^{13}\text{CH}_3\text{OH}$	CO_2 9P(36)	O_3	13
327.8	CD_3OD	CO_2 9R(28)	O_2 S	23 24
330	CH_3OD	CO_2 9R(4)	W_1 O_1	5 18
332.6*	$^{13}\text{CH}_3\text{OH}$	CO_2 10R(16)	O_3 W_3	14
336	CD_3OH	CO_2 9R(32)	O_1	2
336	CD_3OH	CO_2 10R(30)	O_1	2
336.2*	CH_2DOH	CO_2 9P(36)	O_2	21
339.0*	$^{13}\text{CH}_3\text{OH}$	CO_2 9P ₁ (22)	O_3 W_3	13 14
340.4*	CH_2DOH	CO_2 10R(32)	O_2	21
344.8*	CD_3OD	CO_2 10R(4)	O_2 O_3	3 8 23
346	CHD_2OH	CO_2 9P(20)	O_1	9
346	CD_3OH	CO_2 9R(14)	O_3	11
351	CD_3OH	CO_2 9P(32)	O_1 O_3	2 11
351	CD_3OH	CO_2 10R(30)	O_1	2
352	CD_3OH	CO_2 9R(28)	O_1	2
352	CD_3OH	CO_2 9R(14)	O_1	2
352.5	CH_3OD	CO_2 9P(30)	O_1	1
353	CD_3OH	CO_2 9R(?)	O_1	2
353	CD_3OD	CO_2 9P(14)	S	24
354.2*	CD_3OD	CO_2 10R ₁ (16)	O_3 O_2 S	8 23 24
355	CHD_2OH	CO_2 10P(18)	O_1	9
355.5	CD_3OD	CO_2 10R ₁ (16)	W_3	22
358.9	$^{13}\text{CH}_3\text{OH}$	CO_2 9P(40)	O_3	13
363	$\text{CH}_2\text{DOH}(\text{CHD}_2\text{OH}^{21})$	CO_2 10R(16)	O_1 O_2	9 21
363	CHD_2OH	CO_2 10R(16)	O_1	9
370	CD_3OH	CO_2 9R(26)	O_1	2
370	CD_3OH	CO_2 9P(28)	O_1	2
374.1*	CH_2DOH	CO_2 10P(46)	O_1 O_2	9 21
374.6	CD_3OD	$^{13}\text{CO}_2$ 9P(18)	W_3	22
385	CD_3OH	CO_2 9P(30)	O_1	2
386	CD_3OH	CO_2 9P(16)	O_1	2
387.6*	CH_2DOH	CO_2 9P _{II} (40)	O_2	21
396.0	CH_2DOH	CO_2 9P _{II} (18)	O_1 O_2	9 21
398	CD_3OH	CO_2 10R(28)	O_1	2
407	CD_3OH	CO_2 9R(44)	O_1	2
409	CD_3OH	CO_2 9R(34)	O_1	2
410	CD_3OH	CO_2 9P(32)	O_1	2
410.7*	CD_3OD	CO_2 10R _{II} (12)	O_2 W_1 O_3 S	3 5 8 23 24

Table VII-8

Wavelength (μm)	Active Medium	Pump Laser and Pump Line	FIR Resonator O : Open W : Waveguide S : Stark	Reference
412	CD ₃ OH	CO ₂ 10R(12)	O ₁	2
417.1	CH ₃ OD	CO ₂ 9P(6)	W ₁	5
419.0	CD ₃ OH	CO ₂ 10R(36)	O ₁ O ₃	2 10
421	CD ₃ OH	CO ₂ 10R(32)	O ₁	2
422	CD ₃ OH	CO ₂ 9P(20)	O ₁	2
422.2*	CH ₂ DOH	CO ₂ 9R(8)	O ₂	21
426	CHD ₂ OH	CO ₂ 10R(38)	O ₁	9
427.2*	CH ₂ DOH	CO ₂ 10P(36)	O ₂	21
435	CD ₃ OH	CO ₂ 9P(28)	O ₃	11
451.5*	CH ₂ DOH	CO ₂ 9P _{II} (32)	O ₂	21
452.4*	CH ₂ DOH	CO ₂ 9P(46)	O ₂	21
454	CD ₃ OD	CO ₂ 9R(16)	S	24
455	CD ₃ OH	CO ₂ 9P(18)	O ₁	2
461.4*	¹³ CH ₃ OH	CO ₂ 9P _I (12)	O ₃ W ₃	13 14
468.2*	CH ₂ DOH	CO ₂ 9P(26)	O ₁ O ₂	9 21
472	CD ₃ OH	CO ₂ 9R(16)	O ₁	2
480	CD ₃ OH	CO ₂ 9P(16)	O ₁	2
483	CHD ₂ OH	CO ₂ 9P(6)	O ₁	9
483	CD ₃ OH	CO ₂ 9R(22)	O ₁	2
483	CD ₃ OH	CO ₂ 10P(26)	O ₁	2
486.5	CD ₃ OD	CO ₂ 10R(24)	O ₃ O ₂	8 23
495	CD ₃ OH	CO ₂ 10R(18)	O ₁	2
498.0	CH ₃ OD	CO ₂ 9P(32)	O ₁	1
498	CD ₃ OH	CO ₂ 10R(34)	O ₃	10
508	CD ₃ OH	CO ₂ 9P(8)	O ₁	2
510	CH ₃ OD	CO ₂ 9P(6)	O ₂	20
517	CD ₃ OH	CO ₂ 10P(42)	O ₁	2
518	CHD ₂ OH	CO ₂ 9P(30)	O ₁	9
523.1*	CH ₂ DOH	CO ₂ 9P _{II} (40)	O ₂	21
530.4	CD ₃ OH	¹³ CO ₂ 9P(20)	W ₃	22
533.0	CD ₃ OD	¹³ CO ₂ 9P(20)	W ₃	22
551	CD ₃ OH	CO ₂ 9P(22)	O ₁	2
553	CD ₃ OH	CO ₂ 9R(14)	O ₁	2
553	CD ₃ OH	CO ₂ 10R(8)	O ₁	2
554	CD ₃ OH	CO ₂ 9R(32)	O ₁	2
583	CD ₃ OH	CO ₂ 9R(22)	O ₁ O ₃	2 11
599	CD ₃ OH	CO ₂ 10R(16)	O ₁	2
616.3*	CH ₂ DOH	CO ₂ 9P(26)	O ₁ O ₂	9 21
629.8	¹³ CH ₃ OH	CO ₂ 9P _{II} (12)	O ₃	13
646	CD ₃ OH	CO ₂ 10R(36)	O ₁	2

Table VII-9

Wavelength (μm)	Active Medium	Pump Laser and Pump Line	FIR Resonator O : Open W : Waveguide S : Stark	Reference
648	CD ₃ OH	CO ₂ 10R (8)	O ₁	2
680	CD ₃ OH	CO ₂ 9P (6)	O ₁	2
682.6	CH ₂ DOH	CO ₂ 9P ₁₁ (24)	O ₂	21
685	CD ₃ OH	CO ₂ 10R(34)	O ₁	2
695	CD ₃ OH	CO ₂ 9P(10)	O ₁	2
702	CD ₃ OH	CO ₂ 9P(24)	O ₁	2
703	CD ₃ OH	CO ₂ 10R(36)	O ₁	2
711	CD ₃ OH	CO ₂ 9P (8)	O ₁	2
722	CD ₃ OH	CO ₂ 10P(20)	O ₁	2
745	CD ₃ OH	CO ₂ 9R(26)	O ₁	2
760	CD ₃ OH	CO ₂ 10P(18)	O ₁	2
762.5	CH ₂ DOH	CO ₂ 9P ₁ (18)	O ₂	21
774	CD ₃ OH	CO ₂ 9P(30)	O ₁	2
862.0	CD ₃ OH	CO ₂ 10R(18)	O ₁ O ₃	2 10
869	CD ₃ OD	CO ₂ 10R(18)	W ₁	12
917	CH ₃ OD	¹³ CO ₂ 9R(24)	W ₃	22
968	CD ₃ OH	CO ₂ 9R(20)	O ₁	2
1100	CD ₃ OH	CO ₂ 9P(12)	O ₁	2
1146	CD ₃ OH	CO ₂ 9P(24)	O ₁	2
1290	CD ₃ OH	CO ₂ 10R(20)	O ₁	2

Table VIII Types of FIR resonators and their dimensions.

<div style="display: flex; align-items: center;"> <div style="margin-right: 20px;">Type O₁</div> </div>							
Reference Number	Size of Resonator						Wavelength at Fresnel No. = 1 (μm)
	L (cm)	R ₁ (cm)	R ₂ (cm)	D (cm $^\phi$)	ϕ_1 (mm $^\phi$)	ϕ_2 (mm $^\phi$)	
1	120	200	200	5.6	1.5	4	653
2	120	100	100	10	1.5	4	2083
9	100	100	100	9	1.5	4	2025
18	200	250	250	10	1.5	2	1250

<div style="display: flex; align-items: center;"> <div style="margin-right: 20px;">Type O₂</div> </div>							
Reference Number	Size of Resonator						Wavelength at
	L (cm)	R ₁ (cm)	R ₂ (cm)	D (cm ^φ)	φ ₁ (mm ^φ)		Fresnel No. = 1 (μm)
3 , 4 , 20	250	500	500	8	3		640
21 , 23	105	200	200	12.5	1		3720

<div style="display: flex; align-items: center;"> <div style="margin-right: 20px;">Type O₃</div> </div>					
Reference Number	Size of Resonator				Wavelength at
	L (cm)	R ₂ (cm)	D (cm ^φ)	φ ₁₂ (mm ^φ)	Fresnel No. = 1 (μm)
7	100	200	5	3	625
8	100	280	7.5	3	1406
10 , 11	80	200	10	3	3125
13 , 14	100	—	10	—	2500
17	75	200	10	3	3333

<div style="display: flex; align-items: center; justify-content: center;"> <div style="margin-right: 20px;">Type W₁</div> </div>						
Reference Number	Waveguide Material	Size of Resonator				Wavelength at Fresnel No. = 1 (μm)
		L (cm)	D (cm ^φ)	φ ₁ (mm ^φ)	φ ₂ (mm ^φ)	
5	metal	—	2.5	2	2	—
12	copper	70	2	1	0.7, 1.0 1.25, 2.5	143

<div style="display: flex; align-items: center; justify-content: center;"> <div style="margin-right: 20px;">Type W₂</div> </div>						
Reference Number	Waveguide Material	Size of Resonator				Wavelength at Fresnel No. = 1 (μm)
		L (cm)	D (cm ^φ)	φ ₁ (mm ^φ)	φ ₂ (mm ^φ)	
16 , 16'	quartz or Metal	100	1.3 or 2.5	1	2	42 or 156

<div style="display: flex; align-items: center; justify-content: center;"> <div style="margin-right: 20px;">Type W₃</div> </div> <p style="text-align: center;">It is not sure whether the resonator mirrors are inner or external ones.</p>						
Reference Number	Waveguide Material	Size of Resonator				Wavelength at Fresnel No. = 1 (μm)
		L (cm)	D (cm ^φ)	φ ₁ (mm ^φ)	φ ₂ (mm ^φ)	
6 , 14	copper	200	1.4	1	2.5	24.5
15	glass	100	3.8	3	4	361
22	brass	150	2.4	1	5	96

Reference Number	Waveguide Material		Size of Resonator				
	Plate	Side Wall	L (cm)	W (cm)	d (cm)	ϕ_1 (mm $^\phi$)	ϕ_2 (mm $^\phi$)
19	aluminium	Plexiglass	120	4	0.5	1.4	2.5
24	aluminium	acrylite	130	4	1	2	2

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