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FREQUENCY MEASUREMENTS OF FAR INFRARED $^{12}CH_3OH$ LASER LINES

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We have measured the frequencies of 12 known and 3 new submillimeter laser lines obtained by pumping $^{12}CH_3OH$ with a cw waveguide CO_2 laser in a Fabry-Perot far infrared resonator. We have also measured the relative polarization and the pumping CO_2 frequency offset for each line.

Key Words: $^{12}CH_3OH$, laser frequency measurement, far infrared laser, new laser lines, CO_2 cw-waveguide laser, wavelengths, relative polarization, frequency offset measurements

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Introduction

Methanol has been the most studied optically pumped far infrared laser molecule. In the past it has been pumped mainly by conventional cw low pressure CO_2 lasers and occasionally by high pressure TEA lasers. More recently the use of waveguide CO_2 lasers to pump far infrared (FIR) lasers has led, due to its extended tunability, to the discovery of new lines. To assign CO_2 lines, the extra tunability mandates the acquisition of extra data concerning already known lines, such as the pumping CO_2 frequency offset for each line(1,2). In the present work we have used such a cw CO_2 waveguide laser to pump the $^{12}CH_3OH$ molecule.

Experiment

The CO_2 laser cavity consisted of a 1.2 m long quartz waveguide tube of 5 mm bore diameter terminated at one end by a piezoelectrically driven 80% reflectance flat dielectric mirror and at the other end by a 150 lines/mm diffraction grating. The gas mixture flowed through the cavity and its total pressure was 3.5×10^3 Pa. The typical cw power available from the strongest CO_2 laser lines was 30 W and the laser tuned over ~120 MHz around each line.

The FIR resonator described elsewhere(3) consisted of an open structure resonator 1 m long with 2 m radius of curvature concave mirrors at each end. One of the mirrors was mounted on a micrometer to tune the resonant frequency of the cavity. The FIR laser tube consisted of a copper cylinder 51 mm in diameter. Transverse as well as longitudinal pumping was used. The transverse pumping was achieved by focusing the CO_2 radiation through a side window at the Brewster angle into the tube at an angle of 75° with respect to the laser axis. The longitudinal pumping was obtained by focusing the CO_2 beam through a 1 mm hole centered at the fixed mirror. This hole was closed by a NaCℓ window at the Brewster angle. In either type of pumping the FIR radiation was coupled out through a polyethylene window located at the side of the cavity after being reflected off a variable coupler consisting of a 45° mirror, 6 mm in diameter, whose distance from the laser axis was adjustable. The FIR radiation was detected by a W-Ni metal-insulator-metal (MIM) point contact diode.

The direct frequency measurements were performed through synthesis of an appropriate local oscillator signal from the difference frequency of two saturated absorption fluorescence stabilized CO_2 lasers(4). The MIM point contact diode was used as the mixer. The pump offsets were determined by heterodyning the pumping radiation with an actively stabilized CO_2 laser.

Experimental Results and Conclusion

We have measured the frequencies of 12 already known and 3 new submillimeter laser lines obtained by pumping the normal $^{12}CH_3OH$ with the CO_2 cw waveguide laser. The data are presented in Tables I and II. Table I presents all the frequency measured lines, their relative polarizations, the $^{12}CH_3OH$ pressure for maximum power achievement, the FIR relative output power and the CO_2 pump powers. Table II lists the FIR laser lines, their measured frequencies, the corresponding vacuum wavenumbers and pump CO_2 laser lines.

The use of a cw-waveguide CO_2 pump laser and careful adjustment of the $^{12}CH_3OH$ laser pressure will most certainly produce new FIR lines in the already extensively studied methanol molecule and add to the extensive list of far infrared lasers(5).

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Table I. Summary of New Frequency Measured $^{12}CH_3OH$ Laser Lines

CO_2 Pump Line	$^{12}CH_3OH$ Laser Line $\lambda(\mu m)$	Relat. Polariz.	$^{12}CH_3OH$ Pressure Pa(mTorr)	Relative FIR Output	CO_2 Power (W)
R_I (48)	286.2	//	27(200)	200	2.4
R_I (46)	274.2	//	20(150)	1500	7
R_I (44)	251.9	//	33(250)	400	13
	120.9	⊥	33(250)	300	13
R_I (32)	242.8	//	29(220)	2000	22.5
	145.3	//	21(160)	500	22.5
	100.2a	//	21(160)	80	23
R_I (4)	493.5	⊥	35(260)	300	14
P_I (16)	99.8	⊥	36(270)	200	27.5
P_{II}(12)	448.5	//	9(70)	1000	19
	163.6	//	9(70)	600	18.5
P_{II}(36)	162.2	//	23(170)	-	14
	110.7	⊥	19(140)	-	14
P_{II}(44)	112.9a	⊥	20(150)	80	14
	196.6a	⊥	16(120)	120	14

a New Lines

TABLE II. Summary of Measured Frequencies of $^{12}CH_3OH$ Laser Lines

Wavelength, λ(μm)	Measured Frequency megahertz (uncertainty: 2×10^{-7})[a]	Vacuum Wavenumber (cm^{-1})[b]	CO_2 Laser Pump Line	CO_2 Freq. Offset (MHz)[c]
99.8	3 002 087.470	100.138859	P_I (16)	-19.8
100.2	2 992 957.046	99.834301	R_I (32)	+ 8.6
110.7	2 707 749.324	90.320795	P_{II}(36)	> -62
112.9	2 654 310.737	88.538276	P_{II}(44)	-31.1
120.9	2 479 622.153	82.711292	R_I (44)	+ 9.1
145.3	2 063 941.095	68.845664	R_I (32)	-26.1
162.2	1 848 083.325	61.645424	P_{II}(36)	> -62
163.6	1 832 768.565	61.134579	P_{II}(12)	+49
196.6	1 525 164.110	50.873999	P_{II}(44)	-31.1
242.8	1 234 490.394	41.178167	R_I (32)	-26.3
251.9	1 190 069.092	39.696432	R_I (44)	+ 9.1
274.2	1 093 154.703	36.463716	R_I (46)	+33
286.2	1 047 657.623	34.946097	R_I (48)	- 9.8
448.5	668 500.103	22.298763	P_{II}(12)	+49
493.5	607 431.171	20.261723	R_I (4)	-17.5

[a]Estimated uncertainty $\Delta\nu/\nu$ in the reproducibility of the FIR laser frequency. Other measurement uncertainties are negligible in comparison.
[b]Calculated from the measured frequency with c=299 792 458 m/s.
[c]Heterodyne frequency measurement between the CO_2 pump laser and a Doppler free stabilized CO_2 reference laser operated on the pump line.