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New short-wavelength laser emissions from partially deuterated methanol isotopes

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ABSTRACT The partially deuterated isotopes of methanol, CH_2DOH and CHD_2OH, have been reinvestigated as sources of far-infrared (FIR) laser emissions using an optically pumped molecular laser (OPML) system recently designed for wavelengths below 150 µm. With this system, 10 new FIR laser emissions from these isotopes ranging from 32.8 to 174.6 µm have been discovered. This includes the shortest known OPML emission from CHD_2OH, at 32.8 µm. These lines are reported with their operating pressure, polarizations relative to the CO_2 pump laser and wavelengths, measured to ±0.5 µm. In addition, polarizations for three previously observed FIR laser lines from CHD_2OH were measured for the first time.

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1 Introduction

The first observation of optically pumped far-infrared (FIR) laser emissions from CH_2DOH and CHD_2OH was by Ziegler and Dürr in 1978 [1]. In their work, 30 laser emissions were discovered from these isotopes with wavelengths ranging from 109 to 616 µm. Since then, over 140 FIR laser emissions have been discovered for these isotopes, with wavelengths ranging from 41.8 to 762.5 µm [2–5].

In this work, these isotopes were reinvestigated using an optically pumped molecular laser (OPML) system designed for the discovery of short-wavelength ($\lambda < 150$ µm) laser emissions [6, 7]. By use of this cavity with these partially deuterated isotopes of methanol, 10 new OPML emissions have been discovered and three previously unknown polarizations were measured.

2 Experimental details

The experimental apparatus used to search for new FIR laser lines (described in detail elsewhere [6, 7]) consisted of a tunable Fabry–Perot cavity optically pumped with an X–V geometry by a CO_2 laser [8]. The FIR cavity utilized a nearly confocal mirror system with one end mirror mounted on a micrometer to tune the cavity into resonance with the FIR laser radiation. Laser wavelengths were measured by scanning over 20 adjacent longitudinal modes for a particular laser emission. Using this method, FIR laser wavelengths were measured with an uncertainty of ±0.5 µm. Figure 1 illustrates a portion of a typical cavity scan with the intensity plotted as a function of cavity length. The intensities of the laser lines were measured with a pyroelectric detector using various filters that attenuate CO_2 laser radiation and help distinguish different FIR wavelengths [6]. The relative polarizations of the FIR laser emissions with respect to the CO_2 laser lines were measured with a multi-Brewster-angle polarization selector as well as a gold-wire-grid polarizer (1000 lines per inch). The samples of CH_2DOH, 98% D enriched, and CHD_2OH, 98% D_2 enriched, were obtained from Cambridge Isotope Laboratories.

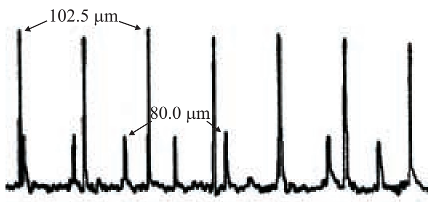

FIGURE 1 Portion of a cavity scan illustrating adjacent longitudinal modes of the 80.0- [3] and 102.5-µm laser emissions. The FIR laser medium was CHD_2OH and the CO_2 pump line was 10*R*40

3 Results and conclusions

The newly discovered FIR laser emissions from optically pumped CH_2DOH and CHD_2OH are listed in Table 1 and are arranged by molecule in order of their CO_2 pump line. This work reports the discovery of 10 new laser emissions ranging from 32.8 to 174.6 µm along with their polarizations with respect to the CO_2 pump laser and their operating pressure and relative intensity, when available. The discovery of these emissions, which includes the discovery of the shortest known laser emission from optically pumped CHD_2OH at 32.8 µm, illustrates the effectiveness of the X–V pumping geometry on short-wavelength FIR laser

This paper is dedicated to the memory of Dr. K.M. Evenson, a pioneer in the field for his role in the development of optically pumped molecular lasers and their use in laser frequency measurements and the laser magnetic resonance technique. His scientific expertise, guidance, mentoring and friendship will be greatly missed.

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Pump	Wavelength (µm)	Rel. pol.	Pressure (Pa)	Rel. int.[a]
CH_2DOH				
9*P*32	56.0[b]	⊥	14.5	W
9*P*40	86.5[b]	⊥	26.5	W
10*P*46	49.0[b]	⊥	13.5	M
	56.9[b]	∥	13.5	M
CHD_2OH				
9*R*18	165[c]	∥	26.5	M
10*R*44	157.4[b]	∥	33.5	M
10*R*40	102.5[b]		17.5	W
10*R*38	53.1[b]	∥	24.0	M
	168[c]	∥	31.5	M
10*R*26	32.8[b]		21.5	W
10*R*20	174.6[b]	∥	15.5	W
10*R*16	47.9[b]	⊥	22.0	M
	179[c]	∥	32.5	M

[a] The 118.8-µm line of CH_3OH is considered to be VVS (designated for powers greater than 10 mW) [6]
[b] New laser emission
[c] Wavelength previously reported in [1]

TABLE 1 Far-infrared laser emissions from optically pumped CH_2DOH and CHD_2OH

emissions. Table 1 also lists the relative polarizations of three previously observed OPML emissions, measured for the first time from CHD_2OH. These new laser emissions will be useful for filling the gaps in the short-wavelength portion of the FIR region and will help provide a more complete picture of these isotopes. The OPML emissions can also serve as a source of strong coherent FIR radiation for a number of spectroscopic applications including laser magnetic resonance and laser Stark spectroscopy.

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