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References


A NEW EFFICIENT FAR INFRARED LASING MOLECULE: "CDOH"

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Thirty-six new cw laser lines ranging from 32 to 109 μm are obtained by pumping for the first time the isotope of methyl alcohol $^{13}$CD$_2$OH. The new laser line at 107.0 μm is one with the highest efficiency ever reported. Direct frequency measurements are reported for eleven new lines.

Introduction

Methyl alcohol was one of the first molecules which was optically pumped by CO$_2$ lasers to produce CW FIR laser radiation (1). At the present time 384 FIR laser lines have been observed to lase in normal CH$_3$OH pumped by the bands of

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Dr. F.R. Petersen passed away during the final preparation of this manuscript. We authors would like to dedicate this paper to our close friend and colleague.

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Key words: Methyl Alcohol isotopic substitute, new FIR laser lines, frequency measurements.
the normal or isotopically substituted or sequence CO₂ laser (2). More than 400 FIR lines are added to the list of 12CO₂ or 23CO₂, CH₃CO, CH₂OH (4,5) isotopic methyl alcohol molecules are considered. The success of methyl alcohol as an active FIR medium derives from the excellent overlap which exists between the strongly absorbing C-O stretch band and the CO₂ laser emissions and from the complexity of the rotational spectrum. Furthermore the contribution of the internal rotation (G1 group torsion) to the transition energy makes possible the generation of very short wavelength lines. As a matter of fact, laser lines at wavelengths shorter than 90 μm have been obtained only from CH₃OH or its isotopic species. Recently by means of a special design of the resonator several laser lines around 35 μm were reported in normal CH₃OH (6, 7).

The spectral coverage is impressively broad considering that lines up to 1200 μm are also obtained from normal methyl alcohol.

Direct frequency measurements were reported for about 200 lines, contributing to making this laser a unique and efficient source with a wide application in laser frequency synthesis, laser magnetic resonance spectroscopy and spectroscopy of the active medium itself.

In the present work we have pumped for the first time the isotopic species 13CO₂OH searching for the generation of new strong emissions, hence further increasing the abundance of lines available from the methanol laser. We report 36 new cw laser lines, many of them at wavelengths shorter than 100 μm.

Experimental arrangement

The FIR resonator, described elsewhere (8), consisted of a 1 m long open structure resonator. The CO₂ pump power in general was coupled into the resonator through a 1 mm hole in one copper end mirror (2 m radius). A transverse pumping scheme could also be used for the strong lines. In this case the amplitude stability of the system improved markedly due to the absence of 10 μm radiation back reflected into the CO₂ laser.

FIR power was coupled out using a variable coupler consisting of an elliptical mirror formed by cutting and polishing a 6 mm diameter copper cylinder at 15°. The mirror was moved perpendicular to the cavity axis to optimize the output coupling at each wavelength. The output radiation was transmitted through a polyethylene window in the side of the vacuum chamber of the laser. A flat gold coated pyrex mirror at the other end was adjusted by a calibrated micrometer to change the resonant frequency of the cavity. By scanning the cavity length accurate wavelength measurements (with fractional uncertainties between 10⁻⁸ and 10⁻⁹) could be made easily since higher order transverse modes could be controlled by lines at each end of the FIR resonator.

As a pump source a 1 m long high pressure CW quartz waveguide CO₂ laser was used. More than 30 watts were available on the strongest lines and about 10 watts on the weakest ones. For some of the new emissions, direct frequency measurements were performed with the technique, introduced in (9), of synthesizing an appropriate local oscillator signal from the difference frequency of two saturated absorption fluorescence stabilized CO₂ lasers. A conical Ni metal-insulator-metal point contact diode was used as mixer (10) and the laser beams were focused on the diode by parabolic mirrors.

Pump offset were determined by heterodyning the pumping radiation with an actively stabilized CO₂ laser.

Results and discussion

The new FIR laser emissions, or derived by pump line, are summarized in Table I. The values of pressure, measured with a thermocouple gauge calibrated with a capacitance manometer,
are indicative for optimum output. The laser lines whose frequency has been measured are listed in Table II, ordered by increasing frequency.

Confirming the efficiency of methyl alcohol as FIR active medium, many of the observed emissions are "strong." More precisely, power levels higher than 1 mW are obtained, even though the FIR resonator was designed for clean mode structure operation rather than for high power.

We performed a quantitative analysis of the efficiency on the strongest new emission at 127.0 μm. The optimized FIR output power was measured by means of the absolute power meter described in (11). The data as a function of the 308 μm pump power available are reported in Fig. 1. For a comparison, also the results obtained with the same apparatus on the CH₃OH well known line at 119 μm (9P36 CO₂ pump) are shown. The higher efficiency measured at 127.0 μm suggests that ¹³C₂H₅OH could become competitive with normal CH₃OH in applications, like plasma diagnostics, where high power is required.

We think that the new discovered lines can expedite spectroscopic investigation in regions were no alternative sources to FIR lasers are available. For instance the new line at 127.6 μm (2348438.4 kHz) has already been applied to the laser Magnetic Resonance detection of atomic Silicon (12).

As a final remark, the present investigation should be considered not complete. We think that the results in the present paper demonstrate that ¹³C₂H₅OH is an efficient source in the far infrared and even more strong lines can be generated after a more systematic investigation.

**Table I**

<table>
<thead>
<tr>
<th>PUMP LINE</th>
<th>FIR WAVELENGTH</th>
<th>REL.POL. PRESS 1</th>
<th>PASCAL(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9R46</td>
<td>177.6</td>
<td>// 24 W</td>
<td></td>
</tr>
<tr>
<td>9R50(b)</td>
<td>187.2</td>
<td>// 19 MW</td>
<td></td>
</tr>
<tr>
<td>9R58</td>
<td>185</td>
<td>// 27 W</td>
<td></td>
</tr>
<tr>
<td>9R32</td>
<td>98.5</td>
<td>// 24 MW</td>
<td></td>
</tr>
<tr>
<td>9R32</td>
<td>55.8</td>
<td>// 27 M</td>
<td></td>
</tr>
<tr>
<td>9R30</td>
<td>150.2</td>
<td>// 30 VS</td>
<td></td>
</tr>
<tr>
<td>9R28(b)</td>
<td>153.69</td>
<td>// 27 8</td>
<td></td>
</tr>
<tr>
<td>9R18</td>
<td>356.5</td>
<td>// 27 W</td>
<td></td>
</tr>
<tr>
<td>9R14</td>
<td>119.4</td>
<td>// 13.5 M</td>
<td></td>
</tr>
<tr>
<td>9R10</td>
<td>65.4</td>
<td>// 16 M</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1: Measured efficiency for the new laser line at 127.02 μm
| Frequency measurements for 11 cw FAR infrared laser transitions of $^{13}$CD$_2$OH pumped by a CO$_2$ laser |
|---|---|---|---|---|
| LASER LINE $\lambda$(nm) | MEASURED FREQUENCY (MHz) | VACUUM WAVE NUMBER $\nu$ (cm$^{-1}$) | PUMP LINE $\nu$ (cm$^{-1}$) | CO$_2$ FREQ. OFFSET (MHz) |
| 73.47 | 4080637.8 | 136.114905 | 10820 | +16 |
| 84.41 | 3558085.8 | 118.475490 | 10822 | -8 |
| 127.02 | 2860174.8 | 78.726051 | 1028 | 0 |
| 127.66 | 2338438.1 | 78.339473 | 10822 | +12 |
| 145.56 | 2059933.6 | 68.608770 | 10824 | +12 |
| 146.32 | 2048803.8 | 68.340472 | 10326 | -12 |
| 153.69 | 1950581.6 | 65.063198 | 9828 | +2 |
| 197.04 | 1521430.9 | 50.757403 | 10826 | -30 |
| 333.36 | 809771.7 | 30.006484 | 10P16 | -15 |
| 340.62 | 880120.4 | 29.537655 | 10P16 | -17 |
| 468.96 | 639264.6 | 21.323570 | 10826 | -20 |

*Calculated from the measured frequency $c = 299792458$ m/s*
MODE CONVERSION IN HELIX LOADED WAVEGUIDE

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Forward coupling of a fast TE-like mode is an interesting and desirable option in the gyro-TWT amplifier. We consider in this paper a mode conversion at the abrupt junction of two infinitely long sheath-helix-loaded waveguides. A helix mode traveling from the left to the right side excites fast TE-like modes at the waveguide junction. The conversion rates of helix mode into TE-like modes are numerically calculated by taking dominant terms in the eigenmode-expansion method. The bandwidth (3 dB) for TE-mode-like coupling in the second (right-hand-side) waveguide is found to be over 40%.

Keywords: Mode conversion, helix-loaded waveguide, gyro-TWT

I. Introduction

The gyrotron [11-21] produces high power microwaves by utilizing the resonant coupling between the waveguide mode and electron cyclotron mode. Recently some efforts have been made to increase the bandwidth of the gyrotron traveling wave amplifier (gyro-TWT) [13-14]. In order to maintain the high resonant coupling in the wide frequency range, the waveguide is tapered and the input signal wave is coupled in the backward direction from the output port. This so-called reflection type amplifier causes undesired oscillations and pulsates some complexity in the separation of input and output waves. Due to these difficulties, a two stage tapered gyrotron has been proposed [5] that will have forward injection of signal from the first stage. This two-stage circuit in general requires high-quality electron beam with a low velocity spread typically less than 2.5% in rms value.

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