Additional cw FIR laser lines from optically pumped CH$_2$F$_2$

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Twenty-five new, cw, FIR lines from CH$_2$F$_2$, optically pumped by a CO$_2$ laser, have been found, using a variable-coupling, open-structure resonator. Accurate wavelength measurements have been made on the 47 known CH$_2$F$_2$ lines. The new lines are fairly uniformly distributed over a wide range, from 105 to 1448 μm.

This Letter reports 25 new, cw, FIR laser lines from CH$_2$F$_2$, optically pumped by a CO$_2$ laser, ranging in wavelength from 105 to 1448 μm. These 25 lines were discovered while performing accurate wavelength determination of the 22 CH$_2$F$_2$ FIR lines found previously. Thus, wavelengths of these 47 lines accurate to about ±0.1 μm are reported here. Many of the new lines are strong and in optimized waveguide cavities should yield high-output powers, as is the case for other CH$_2$F$_2$ lines. This one laser medium itself nearly doubles the number of the very strong, optically pumped FIR laser lines in the 100–700-μm region.

A Fabry–Perot resonator formed by two concave mirrors separated by 105 cm, with radii of curvature R = 200 cm and diameters of 12.5 cm, was used. The input pump radiation, from a grating and piezoelectric tunable CO$_2$ laser, is focussed by an R = 200-cm mirror through a 1-mm-diameter hole. The hole was sealed by a ZnSe window, at the center of the stationary copper mirror. This coupling design has proved to be convenient and effective over the whole submillimeter range. Irises in front of both mirrors provide coupling mirror. The cavity itself has less than 1% losses. We have measured the absolute FIR power of two strong lines: the 184.7-μm line pumped by 9R(32), which is the strongest FIR line in CH$_2$F$_2$, and the 289.4-μm pumped by 9P(4), which is the strongest of the new lines. The values measured by a cone calorimeter with a nearly flat spectral response are 4 mW and 2.5 mW, respectively. These numbers were checked with another power meter, Scientech Model 3600, and the values agree within 10%. The 289.4-μm line has the highest quantum efficiency of all lines for this open structure laser. Its value relative to the 184.3 μm is

$$\frac{(QE)_{289.4}}{(QE)_{184.3}} = \frac{2.4 \text{ mW}}{4.0 \text{ mW}} = \frac{289.4 \text{ μm}}{184.3 \text{ μm}} \approx 1.5,$$

and it may be the most quantum efficient FIR laser line yet discovered. To check this, one has to measure its power in a laser optimized for maximum power output, such as the waveguide laser used to measure other strong lines in the preceding paper. The lines at wavelength longer than 500 μm are somewhat undercoupled and should yield more power with a larger coupling mirror. The cavity itself has less than 1% diffraction loss at wavelengths less than 1 mm. The 1448-μm line also suffers from high diffraction loss, and its relative strength probably would be much greater than the value measured from this particular cavity.

Finally, it is worth mentioning that most of the lines of CH$_2$F$_2$ are very strong compared with those from...
### Table 1. Submillimeter Laser Lines Obtained from CH₂F₂

<table>
<thead>
<tr>
<th>CO₂ Pump</th>
<th>FIR (μm)</th>
<th>Relative Polarization</th>
<th>Pressure for Maximum Power, Pascal (mTorr)</th>
<th>Intensity (Relative)</th>
<th>CO₂ Power (W)</th>
<th>Ref.</th>
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<tr>
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² and " indicated different CO₂ laser frequency offsets.

³ This power was measured with a cone calorimeter and found to be 4 mW.
other submillimeter laser gases, and, also, they are uniformly spread throughout the spectrum from 105 to 725 μm. Thus, CH₂F₂ is probably the most useful FIR laser molecule discovered up to now and will be particularly useful for numerous applications.⁵,⁷

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References

6. Commercial equipment is identified in this Letter in order to specify adequately the experimental procedure. This identification does not imply recommendation or endorsement by NBS, nor does it imply that the equipment is the best available for the purpose.