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# FAR-INFRARED HYDRAZINE LASER PUMPED BY AN $N_2O$ LASER

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## ABSTRACT

We have used an $N_2O$ laser to optically pump $N_2H_4$ molecules in a far-infrared cavity and observed 17 new laser lines in the wavelength range 93.0 to 374.2 μm, the 136.8 μm line pumped by 10P(16) being a doublet . We measured the frequencies of the laser lines by heterodyne mixing of the far-infrared radiation with radiation from two frequency-stabilized $CO_2$ lasers.

Key words: $N_2H_4$ , far-infrared laser, frequency measurement, $N_2O$ pump laser



## 1. Introduction

Until recently, hydrazine ($N_2H_4$) had six known far-infrared (FIR) laser lines in the wavelength range 200 to 575 μm obtained by optically pumping the molecule with an $N_2O$ laser [1,2]. We used an $N_2O$ laser to pump molecules in the 10 μm region [3], and found 17 new laser lines in the spectral range



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93.0 to 374.2 μm. We measured the wavelengths of the far-infrared laser lines by longitudinally moving one of the mirrors of the laser cavity and counting the laser modes, and their frequencies by heterodyne mixing of the far-infrared radiation with radiation from two frequency-stabilized $CO_2$ lasers.

## 2. Laser Description

The $N_2O$ pump laser is a 1.5 m long cavity, described elsewhere [3], with typical powers of about 5-6 W. The FIR cavity was a rectangular metal-dielectric waveguide also described in detail elsewhere [4].

## 3. Measurements

We determined the far-infrared wavelengths by varying the cavity length over about ten wavelengths and measuring the length span with a micrometer. The wavelength value thus obtained is accurate to about 0.05 mm. The FIR frequency measurement was accomplished by heterodyne mixing of two frequency-stabilized $CO_2$ lasers with a microwave frequency and the FIR radiation to be measured [5]. The accuracy in the wavelength estimation is enough to select the $CO_2$ laser lines for the heterodyne measurement. The radiations are mixed in a metal-insulator-metal (MIM) diode which is also used to detect the FIR radiation when searching for new lines. A beat note is generated in the diode, and the FIR frequency is obtained from the equation

$$\nu_{FIR} = |\nu_1 - \nu_2| \pm m\nu_{\mu wave} \pm \nu_{beat}, \qquad (1)$$

where $\nu_1$ and $\nu_2$ are the $CO_2$ laser frequencies, $\nu_{\mu wave}$ is the frequency of the microwave source, $\nu_{beat}$ is the beat note frequency, $\nu_{FIR}$ is the laser frequency to be measured, and the integer m is a harmonic number. The frequencies $\nu_1$, $\nu_2$ and $\nu_{\mu wave}$ are chosen so that

$$0 < |\nu_{beat}| < 1.5 \text{ GHz} \qquad (2)$$

## 4. Results and Conclusion

Table I shows the total of 23 $N_2O$ laser pumped $N_2H_4$ laser lines, known to date: 17 new lines plus six previously known lines, along with their $N_2O$ laser pump line and power, wavelength, pressure of operation, and relative intensity. The previously known 10P(11) 575.0 μm and 10P(24) 237.0 μm lines were not observed in this work. The reported wavelength values of the

six previously known laser lines were consistently lower than our measurements with differences from 3 to 19 μm.

Table II shows 15 observed far-infrared laser lines pumped by an $N_2O$ laser, along with their measured frequency, calculated wavelength, calculated wavenumber, and $N_2O$ laser pump line.The 10P(16) 136.8 μm line is a doublet. These preliminary results have shown the potential of this new pumping laser in producing many more far-infrared laser lines in hydrazine, many with wavelength less than 150 μm.

**Table I - FIR lines from $N_2H_4$ optically pumped by an $N_2O$ laser.**

| Pump Line | Wavelength μm | Pressure Pa(mTorr) | Rel. Int. | $N_2O$ Power W | Reference |
|---|---|---|---|---|---|
| 10R(38) | 339.4 | 19(140) | | | New |
| 10R(36) | 98.0 | 35(260) | S | 3.2 | New |
| 10R(25) | 106.19 | 19(140) | W | 5.0 | New |
| 10R(24) | 257.5 | 15(110) | W | 4.2 | New |
| 10R(11) | 330.57 | 15(110) | W | 5.2 | 1 |
| 10R(4) | 218.84 | 9(70) | VW | 2.6 | New |
| 10P(7) | 218.59 | 27(200) | VS | 5.0 | 1 |
| 10P(11) | 161.28 | 9(70) | W | 6.0 | New |
| 10P(11) | 575.0[a] | | VS | | 1 |
| 10P(15)‴ | 113.93 | 19(140) | M | 5.4 | New |
| 10P(15)″ | 232.74 | 7(50) | W | 5.8 | New |
| 10P(15)′ | 374.24 | 9(70) | M | 5.8 | 1 |
| 10P(16) | 136.79[b] | 13(100) | S | 6.0 | New |
| 10P(24) | 120.62 | 27(200) | VS | 6.0 | New |

| | | | | | |
|---|---|---|---|---|---|
| 10P(24) | 237.0[a] | | S | | 1 |
| 10P(26) | 114.2 | 21(160) | S | 4.0 | New |
| 10P(28) | 492.4 | 17(130) | M | 5.0 | 1 |
| 10P(29) | 241.6 | 16(120) | VW | 6.0 | New |
| 10P(30) | 157.58 | 8(60) | S | 4.0 | New |
| 10P(34) | 210.21 | 7(50) | S | 3.8 | New |
| 10P(34) | 287.96 | 13(100) | W | 4.4 | New |
| 10P(32) | 93.04 | 24(180) | VVS | 4.0 | New |
| 10P(45) | 106.18 | 23(170) | S | 1.8 | New |

1 Torr = 133.3 Pa.
′,″ , and ′″ indicate different $N_2O$ laser frequency offsets from line center.
[a] not observed in this work.
[b] doublets.
VW,W,M,S,VS,VVS stand for: very weak, weak, medium, strong, very strong, and very very strong, respectively.

**Table II - Frequency Measurements of an $N_2H_4$ far-infrared laser pumped by an $N_2O$ laser.**

| $N_2O$ Line | Measured Frequency MHz | Calculated Wavelength μm | Calculated Wavenumber $cm^{-1}$ |
|---|---|---|---|
| 10P(32) | 3 222 036.9 | 93.044 | 107.4756 |
| 10P(45) | 2 823 544.5 | 106.176 | 94.1833 |
| 10R(25) | 2 823 287.0 | 106.186 | 94.1747 |
| 10P(15)′″ | 2 631 380.7 | 113.930 | 87.7734 |
| 10P(24) | 2 485 511.6 | 120.616 | 82.9077 |
| 10P(16) | 2 191 609.6 | 136.791 | 73.1042 |
| | 2 191 613.7 | 136.791 | 73.1044 |
| 10P(30) | 1 902 430.3 | 157.584 | 63.4582 |

| | | | |
|---|---|---|---|
| 10P(11) | 1 858 872.0 | 161.277 | 62.0053 |
| 10P(34) | 1 426 180.2 | 210.207 | 47.5723 |
| 10P(7) | 1 371 481.5 | 218.590[b] | 45.7477 |
| 10R(4) | 1 369 893.3 | 218.844 | 45.6947 |
| 10P(15)″ | 1 288 113.7 | 232.738 | 42.9668 |
| 10P(34) | 1 041 094.2 | 287.959 | 34.7272 |
| 10R(11) | 906 899.8 | 330.568[b] | 30.2509 |
| 10P(15)′ | 801 069.7 | 374.240[b] | 26.7208 |

[a] Calculated from c= 299 792 458 m/s.

[b] Previously reported. See refence 1.

′, ″, and ′″ indicate different $N_2O$ laser frequency offsets from line center.

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