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FREQUENCY MEASUREMENTS OF CF_2CHF AND SO_2 LASER LINES AND A NEW FAR INFRARED LASER LINE OF HDCO

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abstract: The emission frequencies of several optically pumped far infrared laser lines of CH_2CHF, SO_2 and HDCO molecules have been measured by mixing them with a harmonic of a millimeter-wave synthesizer operating in the range 78-118 GHz. A new line of HDCO at 1886 GHz has been found.

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1. Introduction

During the last years we have seen an improvement of the techniques to produce radiation in the Far infrared region (FIR) (1,2). With the use of Backward Waves Oscillators from Russia now available, one is able to work at frequencies up to 1.2 THz. Due to this technical enhancement, experiments using a FIR laser have to work at higher frequencies than 1.2 THz. Unfortunately, if we look carefully at a list of FIR lines, which are sufficiently strong to produce sidebands and to generate frequency tuneable radiation, one can see a relative lack of lines at frequencies higher than 1.5 THz (3). This is the reason for our search of FIR lines in this region.
We set up an experiment to measure the frequency of FIR laser lines. After a check of the frequency measurement precision with well know CH_2CHF lines, we present new frequency measurements of FIR lines.

2. Experimental set-up

Figure 1 presents the scheme of the experimental set-up.
The experiment consists of a generation of a beat note between the far infrared laser and a synthesizer in the range 78-118 GHz. It is a commercial device supported by KVARZ company (Nizhnii Novgorod, Russia). It delivers about 6 mW of output power and has a relative frequency stability of 10^{-8} (4). The beat note at about 350 MHz is produced by the use of submillimeter wave mixer developed at the Institute of Applied Physics, Nizhnii Novgorod (5). The FIR laser radiation is focused by a parabolic mirror with

8 mm focal length on a planar Schottky diode. The diode from the other side is glued on the open end of ridged waveguide connected at the synthesizer output. After amplification, the beat note is counted if it is strong enough and the signal to noise ratio sufficient. In fact we need a signal higher than 35 mV and a minimal signal to noise ratio of 40 dB. Otherwise the frequency beat note is measured by the spectrum analyser. In this case,the 35th harmonic of high stability 10 MHz reference signal was used for the spectrum analyser calibration.

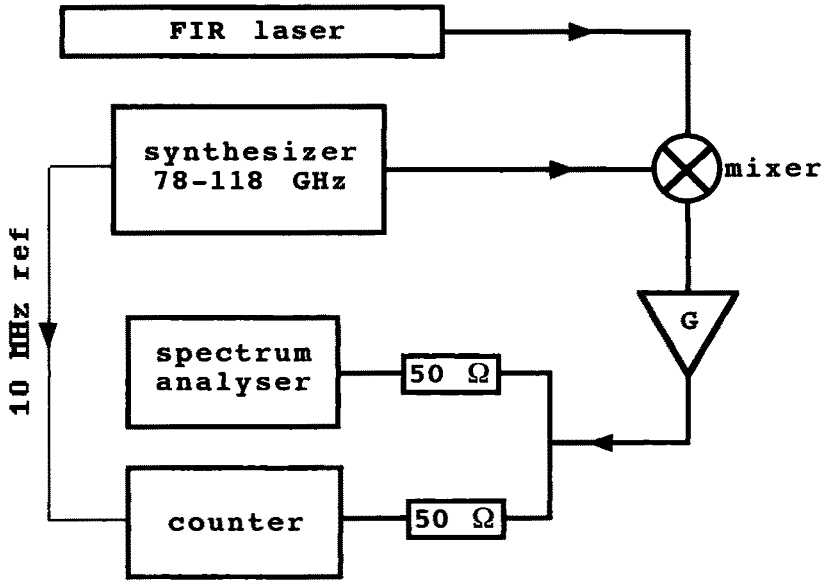

figure 1: experimental set up

The FIR laser is a labmade apparatus, 2.7 m long, pumped by a commercial CO_2 laser (PL6 model from Edinburgh Instruments). We have the possibility, using an acoustic detection fitted into the FIR laser cavity, to lock the CO_2 cavity length on the top of the absorption curve of the FIR gas medium. This detection can be easily used to find quickly the CO_2 lines which are absorbed by the gas medium. This is a necessary condition, but not sufficient to obtain an FIR emission from the gas medium. This part of the experiment has been described in detail in ref(3).

3. Measurements

3.1. CH_2CHF results

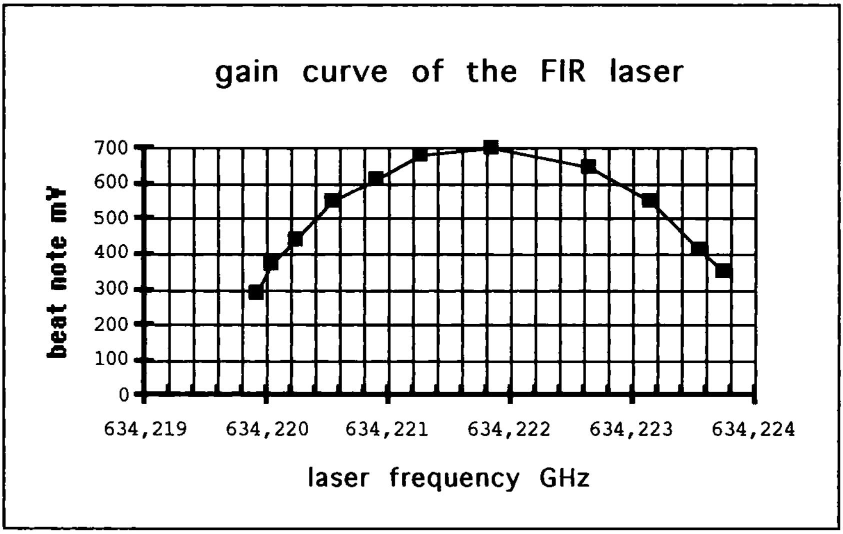

figure 2: beat note versus the laser frequency of the vinyl fluoride line pumped by the 10P20 line

We made a check of our frequency precision by measuring some well know lines of CH_2CHF.

The difficulty in measuring the frequency of a far infrared emission line of a molecular laser is due to the bandwidth of the laser gain curve . Figure 2 shows an approximation of this gain curve for the CH_2CHF line at 634 GHz pumped by the 10P20 line (3).
This curve shows the detected beat note in mV versus the laser frequency. The laser frequency is tuned by changing the far infrared laser cavity length , with a fixed frequency of the synthesizer. If we assume a flat gain curve for the amplifiers within a 4 MHz bandwidth, and a linear down conversion versus laser power for the mixer, the curve represents the gain curve of the laser. One can see that the full bandwidth at half maximum is of the order of 3.5 MHz. In this case it seems to be difficult to determine the line frequency with only one measurement. To make our frequency measurements, we adopted the following procedure: we made an average value of the frequency line over 10 measurements. Each measurement is realised after a detuning of the laser cavity and a retuning at the top of the gain curve.
The results are given in table 1.

CO_2 line	(a)	(b)	(c)	(c)-(b) kHz
10R20	673.9974(3)	673.997567(19)	673.99761(7)	43
10P36		*446.698886(30) *446.698457(46)	446.69908(15)	194 623

table 1: frequency measurements of CH_2CHF lines in GHz, 1σ rms uncertainty in parenthesis
(a) our previous work in 1994 (3)
(b) ·Bryant's work in 1995 (6)
(c) present work
**** measurements on different days***

One can see a good agreement between (a) and (c) for the line pumped by the 10R20. The (a) measurement was made with a spectrum analyser giving a 300 kHz precision.
The difference (c)-(b) is higher than 100 kHz for the line pumped by the 10P36. This could be due to the CO_2 laser which is locked in our experiment giving a good repeatability for the measurements. The difference between the two measurements on different days in (b) is of the order of 400 kHz.

3.2. New frequency determination of FIR lines

Table 2 gives the frequency measurements of 4 FIR lines.

molecule	pump line	frequency	intensity
CH_2CHF	10R20	1478.9133(1)	strong
CH_2CHF	10P22	613.0998(1)	strong
SO_2	9R14	1459.2525(3)	very weak
HDCO	10P10	1886.3583(4)	strong

table 2: frequency measurements in GHz, 1σ rms uncertainty in parenthesis

The first two lines from CH_2CHF were reported in ref(7) with a wavelength measurement at 203 μm and 490 μm. The 1479 GHz line can be referenced as strong. However, it would be difficult to work with it, due to the very strong line at 674 GHz pumped by the same CO_2 line .
The line from SO_2 was reported in ref(8) with a wavelength measurement at 205.3 μm. Unfortunately this line is very weak and unstable and it is really impossible to use it in spectroscopic applications.

To our knowledge, the line from HDCO had never been reported. It is a strong line really well adapted to our experiment. This line has been discovered using the acoustic detection.

4. Conclusion

The use of a millimeter-wave synthesizer allows us to measure the frequency of FIR laser lines, with an accuracy of the order of a few hundred kilohertz. But in fact, this accuracy is limited by the slow drift of the FIR laser cavity (due to the heat of the output coupler from the CO_2 laser).
With these conditions, we have measured two lines of CH_2CHF and one of SO_2 which were previously reported only by wavelength measurements. We found a new line of HDCO at 1886 GHz, really interesting for its high intensity and frequency useability.
The slow drift of the FIR laser frequency, combined with its gain curve, shows the drawback of this type of source, especially when used in spectroscopic applications: the impossibility to reach a frequency accuracy better than few hundred kilohertz. This suggests the use of millimeter-wave synthesizers for frequency stabilisation of FIR lasers.

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