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New wavelength measurements and laser lines in optically pumped methanol and methanol analogues

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Résumé. — Nous présentons des mesures précises des longueurs d'onde de 8 raies fréquemment utilisées en spectroscopie laser dans l'infrarouge lointain, leurs longueurs d'onde citées dans la littérature étant erronées. Nous présentons également les mesures de 8 nouvelles raies que nous avons observées.

Abstract. — We present accurate measurements of 8 frequently used CW far infrared laser lines which we found substantially in error in the literature. We also present measurements of 8 newly observed lines.

The optically pumped Far Infrared (FIR) molecular laser introduced by Chang *et al.* [1] provides a vast number of laser lines in the wavelength region from $\lambda = 30 \mu\text{m}$ to $\lambda = 3 \text{ mm}$. More than a thousand lines have been collected by Knight [2]. Cyclotron resonance studies in III-V semiconductor compounds in high magnetic fields have established the need for accurately known wavelengths in the short wavelength region $\lambda = 30 \mu\text{m}$ up to $\lambda = 200 \mu\text{m}$ [3, 4]. In a recent study of resonant polaron effect in GaInAs based heterostructures we found out that some of the published FIR lines are substantially in error [5, 6].

In this communication we present accurate wavelength measurements of these lines together with the wavelength measurements of some new laser lines we have observed. We used a PL 4 Edinburgh CW CO₂ laser. The pump radiation was chopped at typically 30 Hz and then focused into the waveguide cavity made of a 1.5 m long, 17 mm inner diameter Pyrex tube placed between two mirrors. The FIR output stability was greatly improved using the passive isolator for optically pumped far infrared lasers described by Mansfield *et al.* [7]. With such a device, the pump radiation is circularly polarized, no attempt was made to check the polarization of the emitted radiation. Depending upon the region of

interest we used two waveguide cavities. In the short wavelength region 30-70 μm , in order to obtain a good stability of the optical FIR resonator the cavity was designed with one flat and one concave mirror [8]. The fixed mirror was a flat gold plated brass mirror with a 1.5 mm central hole, the movable mirror was an aluminized glass mirror with a 3 m radius of curvature. In this region we used the in/out coupling system described by Sigg *et al.* [9]. Above 100 μm we obtained higher FIR output power using the same fixed mirror and for the FIR output a movable mirror made of a flat aluminized glass mirror with a 4 mm central hole. In the intermediate region we used either one of the two waveguide cavities.

We measured the laser lines wavelengths with a Michelson interferometer built in our workshop. The accuracy of this interferometer was checked against the wavelength of a number of precisely known laser lines ($\Delta\lambda/\lambda = 10^{-7}$). The wavelength measurements are accurate to 0.1 % except for one line (see table II).

The pressure of the lasing medium was measured with an absolute gauge independent of the nature of the gas. The FIR output power, measured with a Golay cell, is quoted using a relative scale: very weak (VW) corresponds to roughly 0.01 mW, weak (W) corresponds to 0.1 mW and medium (M) corresponds to 1 mW. The frequently quoted 46.7 μm line (9 R 8) which we measure at 47.70 μm would appear as medium on our scale.

(*) The Service National des Champs Intenses is « Laboratoire associé à l'Université Scientifique, Technologique et Médicale de Grenoble ».

Table I. — *New measurements of known FIR laser lines* (MA = CH₃OH, DME. CD₃OD, DMA. CH₃OD, MAD. CD₃OH).

Quoted (μm)	Measured (μm)	Gas	Pump
37.6	37.25	MAD	10R34
40.1	40.28	MAD	10P22
41.0 (*)	41.35	DME	10R18
	43.70	DME	10R18
46.7	47.70	DMA	9R8
57.0	57.20	DMA	9R8
81.9	81.70	DMA	9P30
89.6	89.30	DMA	9P30

(*) See text.

In table I, we present our measurements of known laser lines we found in error while table II displays wavelengths measurements of new laser lines. The line quoted at 41 μm for DME using 10 R 18 as a CO₂ pump appears to consist of two lines at 41.35 and 43.70 μm identical with the lines found with MAD with the same CO₂ pump. These lines are stronger and more stable with MAD and we believe these lines are due to MAD contained in DME. Recently Sigg *et al.* [9] published a set of 25 new CW FIR lines. We measured some of them. Our results were always within the experimental accuracy these authors quote.

Table II. — *Experimental conditions for newly observed FIR laser lines* (MA13 : methanol with C13 isotope).

FIR wavelength (μm)	FIR power	Gas	Pressure (mbar)	CO ₂ pump
51.40	W	MAD	0.5	10R38
54.65	M	MAD	0.2	10R18
68.21	VW	MAD	0.5	10R36
88.7	M	DMA	0.5	9R32
110.4	W	DMA	0.5	9P30
122.3	W	MAD	0.3	10R38
122.5	M	DME	0.5	10R28
143.6 (*)	W	MA13	0.3	9P22

(*) This line has been measured with an accuracy of 0.2 %.

In conclusion we measured with an accuracy convenient for magnetooptical experiments some frequently used FIR laser lines. The short wavelength spectrum has been improved using high performance waveguide cavities.

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