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► To cite this version:

S. Marchetti, R. Simili. A GHz SINGLE MODE TUNABLE CO2 RADIOFREQUENCY LASER. Journal de Physique IV Proceedings, 1991, 01 (C7), pp.C7-711-C7-714. 10.1051/jp4:19917193 . jpa-00250873

HAL Id: jpa-00250873

<https://hal.science/jpa-00250873>

Submitted on 1 Jan 1991

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A GHz SINGLE MODE TUNABLE CO₂ RADIOFREQUENCY LASER

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Abstract- a nearly gigahertz mode tunable CO₂ WG laser is briefly described. The laser operates at high pressure He free mixtures (0.4 bar) ,driven by 1KHz 1kW radiofrequency pulses. A full FSR tuning is obtained over 40 lines at 150 W peak power and 0.3 W mean power.

1. Introduction

High power single mode GHz tunable CO₂ lasers are very interesting in many experiments as LIDAR, optical pumping, high resolution spectroscopy . To achieve this result the free spectral range (FSR) must be increased (the cavity length reduced) ,and the operating pressure must be increased so that the excitation power density is increased squarely to obtain the same laser gain. By using moderate voltages the energy deposition can be increased by using WG discharges. A similar CW GHz mode tuned laser is reported in (1) but the WG section is too small to allow grating tuning to other lines than the strongest 10P20 one, and the power is small. On the contrary the WG pulsed TEA lasers can have large power (100W) and KHz repetition frequency but they have the same tuning problems(2). By using a mini-TEA laser an effective 0.7 GHz tuning with 0.5 MW and few Hz is obtained over some lines(3) but these devices have not great power and frequency stability. On the contrary the TE Radiofrequency excitation allows to operate in CW at high pressures in large section WG, and a tuning over many CW lines has been observed(4), but the power is small. In fact at high energy density there is a limit in the laser cooling and the gas must be flowed very fast. Besides at high pressure a RF discharge becomes ionic after few μ s ,so that only a small part of a CW RF energy can be converted in the CW laser emission . To avoid these effects smaller pressures in He rich mixtures are used (4). On the contrary by pulsing a high power RF discharge both the peak power than the mean power can be increased at larger pressures (5). The only problem is the frequency chirp (due to gas heating in the pulse time,) which acts as a mean linewidth enlargement. At 1bar and 1kW this enlargement is expected lower than 30 MHz in standard mixtures ,and 20 μ s time pulse(6), so this approach is very interesting.

2. Experiment

Our RF laser design has been reported previously (7) and described in fig 1. The WG tube is dressed with two copper tubes (E) with internal water circulation (W) allowing both the transverse discharge and the laser cooling. A 29 MHz RF pulse generator (power=0-1 KW, pulse duration= 3 μ s -continuous) is matched to the laser by means of the matching box MB. To obtain a larger repetition frequency , the gas (g) is inserted at the WG ends and ejected(pumped) at the WG centre , also to avoid the windows/mirror thermal damage . The

(+) work supported by the Progetto Finalizzato Tecnologie Elettroottiche del CNR

Fig1. A)experimental set-up (see text).B)WG section (W=water)

circular WG radius = 1.4 mm allows a beam dimension enough large to ensure grating line separation also for the weaker lines. The discharge length is $l=103\text{mm}$ while the cavity length(L) is 16 cm about corresponding to $L/(2c) = 940\text{ MHz FSR}$. (c the light velocity). The mode tuning is achieved by means of a PZT (V) grating (G) translation.

The coupling mirror M has 7% transmission and the total cavity loss per trip is about 15%.

The emitted power can be sent to two optoacoustic cells (O), to a monochromator (S), to a fast detector (F) and finally it is sent through a reference cavity (with D distance), to a pyroelectric P , so that, by means of the transmission interferences, we can measure the mode tuning vs. the PZT voltage and the mean laser linewidth from the fringes visibility vs. the cavity distance D . At 10 liter. atm /min gas flow a KHz repetition frequency is obtained at the maximum peak power. This is a large flow and to reduce the laser running expenses the He-free mixture $\text{CO}_2:\text{N}_2=1:2$ is used at about 0.4 atm. With 0.4 atm 1:2 mixture the laser gain $g(v)$ is enlarged by collisions as

$$g(v) = 1/(1+(v-v_0)^2/\Delta p^2) \quad (1)$$

Fig2. 10P20 pulsed emission. time scale $5\mu\text{s}$, power scale 30W. O is RF pulse onset, E the RF end of pulse

Fig3. The mode tuning through the reference cavity (see text)

with $\Delta_p = 1\text{GHz}$ so that the FSR pulling reduction is expected lower than 40 MHz (7).

3. Results

A standard laser pulse is reported in fig 2. The laser pulse has a 7- 10 μs build-up time and the laser gain turn off 20 μs after the RF onset due to the fast ionic degeneration so that the RF pulse is ended at this time. More than 150 W peak pulse is obtained with 300 μJ energy pulse. The effective mode tuning vs. the PZT voltage (v) is reported in fig 3 for the 9P22 (a) and 9P28 (b) lines. The fringe spacing was 67 MHz and the effective FSR about .92 GHz. The PZT non linearity is well shown, while the pulling is lower than expected.

The fringes are not detectable with $D > 4\text{ m}$ (fig.4) so that according with the Rayleigh criterion, the laser linewidth is smaller than $c/(2 \cdot 4\text{m}) = 40\text{MHz}$.

Fig 4. The visibility $(I_{\max} - I_{\min}) / I_{\max}$ vs. the D distance

**Fig 5. The 10R28 scan in He free (a) and He rich mixture (b).
(see text). V=PZT voltage, O=zero power**

When a 1:1:3 He rich mixture is used at 1 bar both the full tunable line number and the mean power are increased. Fig 5 shows this effect on the 10R26 line.

4. Conclusion

A RF CO₂ laser, nearly GHz mode tunable over many lines is reported. High peak power and good mean power are obtained in unexpensive He free mixtures at 0.4 atm. The frequency chirp enlarges the laser mean linewidth but it is always subdoppler (<40MHz)

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