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A Line Tuned TEM_{oo} Mode CW CO_2 Laser

A design, construction and operation of a stable frequency line-tuned, plane-polarized CW CO_2 laser are described. The maximum output power of 30W for 10P(20) V-R transitions was obtained. The line tuning of laser wavelength was achieved by using 100line/mm grating. This laser was stabilized by holding the laser cavity fixed using a low thermal expansion quartz rods.

Keywords: *CO_2 laser, CW Lasers, Line Tuning*

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1. Introduction

Since the first CO_2 laser operation by Patel in 1964 [1], the CO_2 laser had received a great deal of attention [2], since, because it has a wide range of applications such as optical pumping [3], optical radar [4], cutting and welding of metals [5], medical applications [5], spectroscopy [6] and waveguide lasers [7].

In this paper, the basic laser system design, operation and characterization, as well as line tuning, are described.

2. Experimental Work And Results

Figure (1) shows a schematic diagram of the laser system. The laser is consisting of two discharge pyrex glass tubes, cooled by cold water flow at 5°C, supplied and circulated by a commercial chiller. The discharge tubes lies on a common optical axis. The close ends of the discharge tubes were mounted and sealed onto an earthed stainless steel electrode. The far ends were connected and sealed onto the anodes, stainless steel electrodes, each anode was connected and sealed onto a stainless steel block. The port of the blocks were sealed by an NaCl crystal plates inclined at Brewster angle (θ_B) [8] which is determined by:

$$\theta_B = \tan^{-1}\frac{n_{NaCl}}{n_{gas}} = 56.13^\circ \qquad (1)$$

where n_{NaCl} and n_{gas} are refractive indices of NaCl crystal and gas, respectively.

This will allow the electric field in the plane of incidence to be transmitted only. Also, this will define the polarization of the laser output beam.

The optical resonator consisting of a grating of ~99% reflectivity, and 100line/mm (ML302, ptr optics Corporation) used as back reflector, whereas a partially transparent ZnSe mirror of 80% reflectivity, 7.5m radius of curvature and 2.54cm diameter was used as output coupler. Table (1) summarizes the optical laser beam parameters [9], for the TEM_{oo} mode, minimum spot size (w_o), beam waist (w) and far-field divergence angle (θ).

Table (1): Laser beam parameters

Parameter	Value
Laser cavity length	2.2m
Mirror radius of curvature	7.5m
Laser wavelength	10.591μm
Beam spot size at plane mirror (ω_l)	4.03mm
Beam waist at 7.5m mirror (ω_0)	3.93mm
Beam divergence (θ)	1mrad
Cavity arrangement	Hemispherical

The ZnSe mirror was mounted on a piezoelectric transducer (Burleigh PZ-90) derived by a DC power supply (P2-62) giving mirror axial movement of 7mm.K/V to control any frequency shift and to maximize the output power. The mounted ZnSe mirror was bolted onto an aluminum plate, also, the grating holder was bolted onto another aluminum plate. The two aluminum plates were placed on a ~2.3m long metal rail. A distance of ~2.2m between the two aluminum plates, which defines the optical cavity length, defined by two mirrors separation hold fixed by joining the two plates by three parallel quartz tubes. The latter tubes were fixed onto the aluminum plates. This arrangement gives frequency shift given by [5]:

$$\Delta\nu = \nu_o \alpha \Delta T \qquad (2)$$

where ν_o is the laser frequency (=2.83×10^{13}Hz), α is the quartz thermal expansion (=0.42×10^{-6}/°C) [10] and ΔT is the temperature change (=1°C). These data give frequency shift of $\Delta\nu$=11.9MHz. This is a quite small shift in the frequency compared with the doppler line width of ~60MHz for T=400K, p=10 torr for the pre-gas mixture used.

A 100line/mm grating was used for line tuning of laser wavelength. The laser blazed at littrow angle (θ_L),

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for each particular transition, according to the equation [11]:

$$\theta_L = \sin^{-1}\frac{n\lambda}{2d} \tag{3}$$

where n is the grating order, λ is the laser emission wavelength and d is the grating spacing. For n=1, λ=10.591μm and d=0.01mm, gives θ_L=31.97°. The minimum passive resolution for the grating is given by [11]:

$$\Delta\nu = \frac{c}{n\lambda N} \tag{4}$$

where c is the light velocity, and N is the number of lines covered on the grating by the laser beam. For n=1, λ=10.591μm and N=1600, gives Δν=17.7GHz. The latter frequency bandwidth is smaller than the frequency separation between two adjacent vibrational-rotational (V-R) CO_2 molecular transitions for the 10.4μm and 9.4μm bands for P and R branches, where the frequency separations are about 53GHz and 38GHz for the P and R branches for 10.4μm and 9.4μm bands, respectively [12]. The small $\Delta\nu$=17.7GHz will make single vibrational-rotational (V-R) transition oscillation for certain $\theta_L(\lambda)$ at a time. However, two line oscillation, 10P(18) and 10P(16) for free running (metal back mirror and ZnSe output coupler) was noticed due to gain equalization between the lines, and by replacing the back mirror by the grating again, single line oscillation was obtained again. The grating was rotated, such that the incident laser polarization was normal to the grating grooves to obtain maximum reflectivity for the incident polarization.

The maximum laser output power of 30W for the 10P(20) vibrational-rotational (V-R) transition line was obtained using (12.3:14.3:73.2) CO_2:N_2:He pre-gas mixture. The pressure of 14 torr and 9 torr at the input and output of the discharge tubes was controlled by needle valves, and a fast gas flow in the discharge tube was achieved by using a 30m^3/hr rotary pump. The optical cavity was consisting of 100Line/mm grating (back reflector) and 80% reflectivity ZnSe output coupler of 7.5m radius of curvature. However, other vibrational-rotational (V-R) transition lines for all branches were obtained and summarized in Table (2).

Table (2): Laser vibrational-rotational (V-R) transition lines range

9.4μm band	
R branch	R(26)-R(12)
P branch	P(12)-P(36)
10.4μm band	
R branch	R(12)-R(28)
P branch	P(8)-P(36)

3. Conclusions

A 30W CW CO_2 laser was designed, constructed and characterized. The laser is line tuned, plane polarized and covering wide range of vibrational-rotational (V-R) transition lines. However, the main problem with the laser was the mirror and grating damages when a high reflectivity (90%) output coupler was used. The reflectors damages were avoided by using lower reflectivity mirror, such as 80% or 62% reflectivity. The high reflectivity mirror was used only when tuning the low gain lines emission, such as 9R(22) and 10P(38). This laser is quite useful for applications as optical pumping for FIR laser emission.

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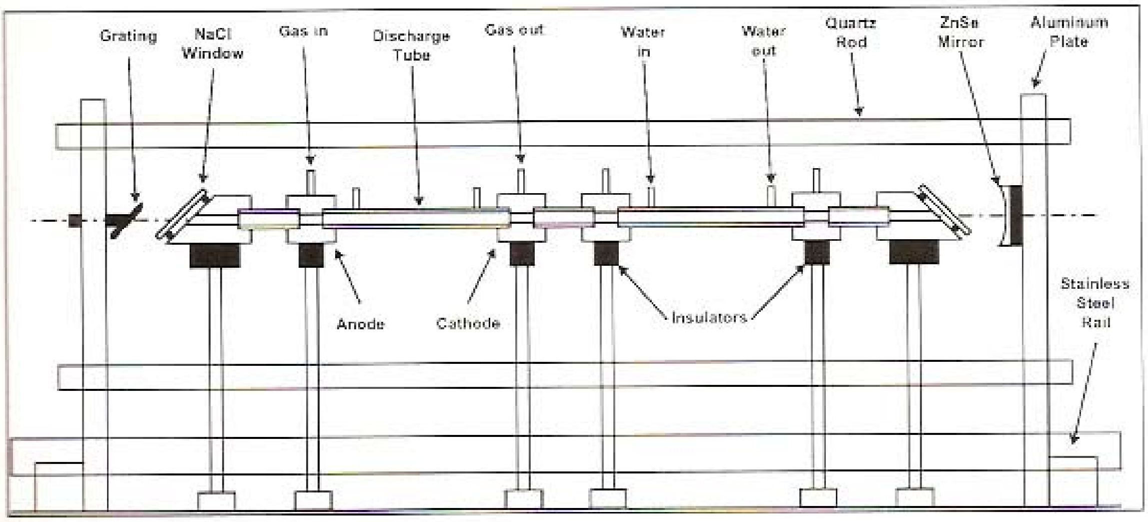

Fig. (1): Schematic diagram for the laser system

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ليزر ثنائي أوكسيد الكاربون مستمر الموجة المولف خطياً وبالنمط TEM_{00}

تم تصنيع وتركيب وتشغيل ليزر ثنائي أوكسيد الكاربون مستمر الموجة بالذبذبة المستقرة والمولف خطيا وبالاستقطاب المستوي. حصلنا على أعلى قدرة خرج ليزري مقداره 30 واط للخط 10P(20) للانتقال الاهتزازي-الدوراني. أجريت عملية التوليف للأطوال الموجية لليزر بوساطة محزز (100line/mm)، وقد تم الحصول على ليزر بذبذبة مستقرة من خلال تثبيت فجوة الليزر بوساطة أنابيب الكوارتز ذي معامل التمدد الحراري الواطئ.