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A Model and Simulation of TEA-CO2 Laser in Consideration of H2O Molecule in Active Gas

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Abstract: ***We have developed an output power prediction method used in the design of the output power of a TEA-CO2 laser which uses carbon dioxide and nitrogen produced by industrial method. In this paper, we have commented a method of modeling the laser output power and the simulation method based on the 7- vibrational temperature model which has six vibrational temperatures including a vibrational temperature of H2O molecule and the peripheral temperature which was constant and finally proved the simulation result.***

Keywords: vibrational temperature, influence of H2O molecule, energy exchange process

1. Introduction

It is the first and foremost task to simulate exactly the energy exchange process between the particles of the active gases in a TEA-CO_2 laser for the purpose of increasing the output power and the efficiency. The more exact the output power model of a CO_2 laser reflects the oscillatory motion, the stimulated radiation, the spontaneous radiation and the loss in the resonator, the closer the simulation result is to practical experimental result. [1 to 14] The 5- vibrational temperature model for the output model of a CO_2 laser, which takes account of the CO molecule produced during gas discharge has been developed. [11 to 20] The relaxation rate from a level 100 to a level 000 of carbon dioxide through V-T process when ignoring the effect of H_2O gas is over 200 times as great as that when not ignoring it. And the relaxation rate from a level 010 to a level 000 through V-T process by H_2O molecules which play the role of collision molecules is 140 times as great as than by helium molecules. The relaxation rate by helium is 100 times and 20 times as great as nitrogen and carbon dioxide respectively. [1,7] Hence, the effect of H_2O molecules is much greater than that of helium or argon gas Consequently, we have predicted that the output power model of a TEA-CO_2 laser would be more accurate if the oscillatory motion between CO_2, N_2, CO and H_2O molecules was taken into account. In this paper, we have proposed the 6-oscillatory motion equation in consideration of the vibrational mode of H_2O molecules and set up the simulation method of the output power of a laser.

This paper is composed of as follows. Section 2 introduces the oscillatory motion equation of energy exchange relation between main components and impurity ones of the working gas in a TEA-CO_2 laser. Section 3 presents a method of modeling the output power of a laser in consideration of population inversion, stimulated radiation, spontaneous radiation and loss of resonator. Section 4 presents the simulation method of the output power model. Section 5 illustrates the result of accuracy verification. Section 6 summarizes our results and discusses further applications.

2. The Oscillatory Motion Equation of Active Gases

In order to set up the model of the output power of a laser it is essential to know the population inversion which has direct influence on the output power. And to find the population inversion, the energy exchange relation between activated molecules ought to be analyzed. Namely, the oscillatory motion equation corresponding to the kind of vibrations of the molecules must be set up. We have set up the oscillatory motion equation as follows.

The variation of an energy density E_1 accumulated in a symmetry mode of a CO_2 molecule with time is related with the following expressions:

$$\begin{aligned}
&CO_2(100) + M_t \leftrightarrow CO_2(000) + M_t\\
&CO_2(100) + M_t \leftrightarrow CO_2(020) + M_t\\
&CO_2(001) + M_t \leftrightarrow CO_2(110) + M\\
&CO(1) + CO_2(000) \leftrightarrow CO_2(110) + CO(0)\\
&CO_2(000) + e \rightarrow CO_2(100) + e
\end{aligned}$$

where M_t means the kind of molecules (such as CO_2, N_2, H_2, H_2O, CO and O_2 molecules) colliding with a level 100 of CO_2 molecules.

The variation of E_1 with time is also made when a CO_2 molecule transfers from a level 001 to a level 100 while emitting a photon of a wavelength 10.6 micrometer). In this case, the energy increase of the symmetric mode is written as $\nu_1 \Delta N_{31} W I_{\nu_0}(t)$, where ΔN_{31} is the difference of the population between the two levels, I_{ν_0} the light intensity in the center frequency and W is given as

$$W = \frac{\lambda_1^2 g(\nu)}{8\pi\nu_1\tau_{\text{self}}}$$

,where λ_1 is the wavelength corresponding to $h\nu_1$, $g(\nu)$ the normalized spectral function, τ_{self} the lifetime of spontaneous radiation.

Eventually, the oscillatory motion equation of the symmetric model is as follows [5, 6 and 20]:

$$\frac{dE_1}{dt} = -\frac{E_1 - E_1(T)}{\tau_{10}(T)} - \frac{E_1 - E_1(T,T_2)}{\tau_{12}(T,T_2)} - \frac{h\nu_1}{h\nu_6}\cdot\frac{E_6 - E_6(T,T_1)}{\tau_{61}(T,T_1)} + \frac{h\nu_1}{h\nu_3}\cdot \frac{E_3 - E_3(T,T_1,T_2)}{\tau_{312}(T,T_1,T_2)} + \frac{h\nu_1}{h\nu_5}\cdot\frac{E_5 - E_5(T,T_1,T_2)}{\tau_{512}(T,T_1,T_2)} + \nu_1\Delta N_{31} W I_0 + P_{1E} \quad (1)$$

, where the suffixes 0,1,2 and 3 mean the ground state, the symmetric state, the deformation state, the asymmetric state of a CO_2 molecule respectively, and 4,5 and 6 does the vibrational states of N_2, CO and a level 01^10 of H_2O molecules, respectively.

And $\tau_{10}(T)$, $\tau_{12}(T,T_2)$, $\tau_{61}(T,T_1)$, $\tau_{312}(T, T_1,T_2)$, $\tau_{512}(T, T_1,T_2)$, $E_1(T,T_2)$, $E_6(T,T_1)$, $E_3(T, T_1,T_2)$, $E_5(T, T_1,T_2)$ and P_{1E} are written as

$$\tau_{V-T}^{-1}(T)=\tau_{100-000}^{-1}(T)=\tau_{10}^{-1}(T)=\sum_t N_t\chi_{100,000}^t\left[1-\exp(-h\nu_1/kT)\right]$$

$$\tau_{V-V}^{-1}(T,T_2)=\tau_{100-010}^{-1}(T,T_2)=\tau_{12}^{-1}(T,T_2)=$$
$$=\sum_t N_t\chi_{100,010}^t\exp[h(\nu_2-\nu_1)/KT]\left[\exp(h\nu_2/KT_2)-1\right]^{-1}$$
$$\times\left\{\exp[h\nu_2/KT_2-h(\nu_2-\nu_1)/KT]-1\right\}$$

$$\tau_{V-V}^{-1}(T,T_2)=\tau_{100-010}^{-1}(T,T_2)=\tau_{61}^{-1}(T,T_1)=$$
$$=\sum_t N_t\chi_{100,010}^t\exp[h(\nu_1-\nu_6)/KT]\left[\exp(h\nu_1/KT_1)-1\right]^{-1}$$
$$\times\left\{\exp[h\nu_1/KT_1-h(\nu_1-\nu_6)/KT]-1\right\}$$

$$\tau_{V-V}^{-1}(T,T_1,T_2)=\tau_{001-110}^{-1}(T,T_1,T_2)=\tau_{312}^{-1}(T,T_1,T_2)=$$
$$=\sum_t N_t\chi_{001,110}^t\cdot\exp[h(\nu_1+\nu_2-\nu_3)/kT]\cdot\left[\exp(h\nu_2/kT_2)-1\right]^{-1}\times$$
$$\times\left[\exp(h\nu_1/kT_1)-1\right]^{-1}\left\{\exp[h\nu_1/kT_1+h\nu_2/kT_2-h(\nu_1+\nu_2-\nu_3)/kT]-1\right\}$$

$$\tau_{V-V}^{-1}(T,T_1,T_2)=\tau_{1-110}^{-1}(T,T_1,T_2)=\tau_{512}^{-1}(T,T_1,T_2)=$$
$$=N_{CO_2}\chi_{1,000;0,110}^{CO-CO_2}\cdot\exp[h(\nu_1+\nu_2-\nu_5)/kT]\left[\exp(h\nu_2/kT_2)-1\right]^{-1}\times$$
$$\times\left[\exp(h\nu_1/kT_1)-1\right]^{-1}\left\{\exp[h\nu_1/kT_1+h\nu_2/kT_2-h(\nu_1+\nu_2-\nu_5)/kT]-1\right\}$$

$$E_1(T,T_2)=\frac{N_{CO_2}h\nu_1}{\exp[h\nu_2/kT_2-h(\nu_2-\nu_1)/kT]-1}$$

$$E_6(T,T_1)=\frac{N_{CO_2}h\nu_6}{\exp[h\nu_1/kT_1-h(\nu_1-\nu_6)/kT]-1}$$

$$E_3(T,T_1,T_2)=\frac{N_{CO_2}h\nu_3}{\exp[h\nu_1/kT_1+h\nu_2/kT_2-h(\nu_1+\nu_2-\nu_3)/kT]-1}$$

$$E_5(T,T_1,T_2)=\frac{N_{CO_2}h\nu_5}{\exp[h\nu_1/kT_1+h\nu_2/kT_2-h(\nu_1+\nu_2-\nu_5)/kT]-1}$$

$$P_{1E}=n_e(t)N_{CO_2}h\nu_1\chi_1^e(T)$$

, where P_{1E} is the energy received while the CO_2 molecules transfer from a level 000 to a level 100 by collision in unit volume in unit time, $n_e(t)$ the electron density, $\chi^e_1(T)$ the coefficient of travel rate, f the degree of dissociation of the CO_2 molecules and N_{CO_2} the density of CO_2 molecules. Eq.1. represents the interaction between the symmetry mode of a CO_2 molecule and the deformation mode of a H_2O molecule. Similarly, we can describe the variation of an energy density E_2 of the deformation mode and an energy density E_3 of the asymmetric mode as follows.

$$\frac{dE_2}{dt}=-\frac{E_2-E_2(T)}{\tau_{20}(T)}-\frac{h\nu_2}{h\nu_6}\cdot\frac{E_6-E_6(T,T_2)}{\tau_{62}(T,T_2)}+\frac{h\nu_2}{h\nu_3}\cdot\frac{E_3-E_3(T,T_1,T_2)}{\tau_{312}(T,T_1,T_2)}+ \quad (2)$$
$$+\frac{E_1-E_1(T,T_2)}{\tau_{12}(T,T_2)}+\frac{h\nu_2}{h\nu_5}\cdot\frac{E_5-E_5(T,T_1,T_2)}{\tau_{512}(T,T_1,T_2)}+\frac{h\nu_2}{h\nu_3}\cdot\frac{E_3-E_3(T,T_2)}{\tau_{32}(T,T_2)}+P_{2E}$$

$$\frac{dE_3}{dt}=-\frac{E_3-E_3(T,T_1,T_2)}{\tau_3(T,T_1,T_2)}-\frac{E_3-E_3(T,T_2)}{\tau_{32}(T,T_2)}+\frac{h\nu_3}{h\nu_4}\frac{E_4-E_4(T,T_3)}{\tau_{43}(T,T_3)}+ \quad (3)$$
$$+\frac{h\nu_3}{h\nu_5}\frac{E_5-E_5(T,T_3)}{\tau_{53}(T,T_3)}+P_{3E}-\nu_3\Delta N_{31}WI_0(t)$$

And the variations of the energy densities of N_2 and CO molecules are written as

$$\frac{dE_4}{dt}=-\frac{E_4-E_4(T)}{\tau_{40}(T)}-\frac{E_4-E_4(T,T_3)}{\tau_{43}(T,T_3)}+\frac{h\nu_4}{h\nu_5}\frac{E_5-E_5(T,T_4)}{\tau_{54}(T,T_4)}+P_{4E} \quad (4)$$

$$\frac{dE_5}{dt}=-\frac{E_5-E_5(T)}{\tau_{50}(T)}-\frac{E_5-E_5(T,T_3)}{\tau_{53}(T,T_3)}-\frac{E_5-E_5(T,T_1,T_2)}{\tau_{512}(T,T_1,T_2)} \quad (5)$$
$$+\frac{h\nu_5}{h\nu_4}\frac{E_4-E_4(T,T_5)}{\tau_{45}(T,T_5)}+P_{5E}$$

And the equation for a level 01^10 which is the deformation mode of a H_2O molecule is written as

$$\frac{dE_6}{dt}=P_{6E}+\frac{h\nu_1}{h\nu_6}\cdot\frac{E_6-E_6(T,T_1)}{\tau_{61}(T,T_1)}+\frac{h\nu_2}{h\nu_6}\cdot\frac{E_6-E_6(T,T_2)}{\tau_{62}(T,T_2)}-\frac{E_6-E_6(T)}{\tau_{60}(T)} \quad (6)$$

, where the terms in the right side mean the energy exchange relation in the following processes and H_2O molecules play the same role as helium and argon.

$H_2O(000) + e \rightarrow H_2O(010) + e$

$H_2O(000) + CO_2(100) \leftrightarrow H_2O(010) + CO_2(000)$ $H_2O(000) + CO_2(020) \leftrightarrow H_2O(010) + CO_2(000)$ $H_2O(010) + M_t \leftrightarrow H_2O(000) + M$

The equations(1 to 6) are the basis of modeling of the output power model of a laser.

3. Output Power Model of Laser Authors

The output power is directly related with the population inversion. The population inversion ΔN is written as[15, 16 and 20]

$$\Delta N=N_{001}\cdot P(J)-N_{100}\cdot P(J+1) \quad (7)$$

$$N_{001}=N_{CO_2}\exp\left(-\frac{h\nu_3}{kT_3}\right)z,\quad N_{100}=N_{CO_2}\exp\left(-\frac{h\nu_1}{kT_1}\right)z$$

$$z=\left[1-\exp\left(\frac{h\nu_1}{kT_1}\right)\right]\cdot\left[1-\exp\left(-\frac{h\nu_2}{kT_2}\right)\right]^2\cdot\left[1-\exp\left(-\frac{h\nu_3}{kT_3}\right)\right]$$

$$P(J)=\left(\frac{2hcB}{kT}\right)Q_J\exp\left[-\frac{hcBJ(J+1)}{kT}\right]$$

, where B is the rotation constant of a CO_2 molecule, c the velocity of light and Q_J is the degeneracy of a rotation state. Then, we should find the relation between the population inversion and the light intensity in the resonator. As it is known, the increase of radiation density by stimulated radiation per unit time is written as [2]

$$\frac{h\nu c^3\Delta(\nu)g(\nu)d\nu}{8\pi h\nu^3\tau_{\text{self}}}\equiv\frac{h\nu c^2\Delta NI(\nu)\delta(\nu-\nu_0)g(\nu)d\nu}{8\pi h\nu^3\tau_{\text{self}}}$$

From this, the increase velocity of the light intensity is written as follows

$$\left(\frac{dI_{\nu_0}}{dt}\right)_{\text{inc}}=\frac{\Delta Nc^3I_{\nu_0}g(\nu_0)}{8\pi\nu_0^2\tau_{\text{self}}}$$

, where ν_0 is the center frequency in the spectral function. Meanwhile, all losses in the mirrors can be specified by a single parameter τ_{res} which is the lifetime of the resonator, and therefore we can write as follows

$$\left(\frac{dI}{dt}\right)_{\text{손}}=\frac{I}{\tau_{\text{공}}}$$

The minimum threshold of the population inversion is given at the maximum value of the spectral function $g(\nu_0)$.

So the temporal change of the light intensity in the resonator is as follows [6]:

$$\frac{dI_{\nu_0}}{dt}=-\frac{I_{\nu_0}}{\tau_{\text{res}}}+\frac{c^3\Delta N\,I_{\nu_0}}{4\pi\nu_0^2\Delta\nu\tau_{\text{self}}}=-\frac{I_{\nu_0}}{\tau_{\text{res}}}+c\nu_0\Delta N\frac{\lambda_0^2}{4\pi^2\nu_0\tau_{\text{self}}}\cdot I_{\nu_0}$$

Now the spontaneous radiation ought to be taken into

account. From the general relation between stimulated radiation and spontaneous radiation, the term related to spontaneous radiation is written as [3]

$$\frac{chvN_{0,0,1}P(\mathrm{J})}{\tau_{\mathrm{self}}}\cdot G$$

, where G is the portion of the photons emitted spontaneously. Because these photons emits at a stereoangle β which corresponds to the spread angle of the laser beam, the remainder in the resonator does at a certain angle with the optical axis of the resonator which is β/4π. The spectral width dv of such photons is close to the center of the rotation transition line.

The portion of the radiation energy portion whose center value is v_0 and spectral width is dv is written as

$$g(v_{\mathrm{o}})dv \approx \frac{2dv}{\pi\Delta v}$$

In our case the magnitude of Δv is more important than its detailed expression. In the standard condition, it is as follows [5]

$$\Delta v \backsim 4\mathrm{GHz}, \qquad dv \backsim (2\pi\tau_{\mathrm{c}})^{-1}$$

Hence,

$$G = \frac{\beta}{4\pi}\cdot\frac{2dv}{\pi\Delta v}$$

Then, the term related to the spontaneous radiation is as follows

$$\frac{chv_0N_{0,0,1}P(J)\beta dv}{2\pi^2\tau_{\mathrm{self}}\Delta v}$$

Therefore, the light intensity in the resonator is determined by the following equation

$$\frac{dI_{v_0}}{dt} = -\frac{I_{v_0}}{\tau_{\mathrm{res}}} + chv_0\left[\frac{\Delta NWI_{v_0}}{h} + N_{0,0,1}P(J)S\right] \qquad (8)$$

, where

$$S = \frac{\beta dv}{2\pi^2\tau_{\mathrm{self}}\Delta v}$$

In order to apply Eq.8 in the calculation of the laser output, it is necessary to find the detailed expression of τ_{res}.

Assume that there is a stable resonator of a length L, the optic axis coincide with *z* axis, which is filled up with homogeneous active material of a gain through a length ℓ.

In this case the following relation comes into being.

$$\alpha = -(1/2\ell)\ln[R(1-\delta)] \qquad (9)$$

, where R is the reflectivity of the output mirror and δ the sum of all the losses in the output mirror

Finally, the output power of the laser can be expressed as follows

$$\mathrm{P}_{\mathrm{out}} = A(1-R-\delta+\delta R)I_{v_0} \qquad (10)$$

, where A is the area of the cross section of the output mirror and I_{v0} the light intensity in it. It is impossible to calculate the flux density of radiation energy *I*(z) in static method but it's possible to do the average light intensity. i.e.

$$\langle I_{v_0}\rangle = \frac{1}{\ell}\int_0^{\ell} I(z)dz = \frac{1}{\ell}\int_0^{\ell}(1-\delta)RI_{v_0}\left(e^{\alpha z} + e^{\alpha(2\ell-z)}\right)dz =$$
$$= -\frac{(1-\delta)RI_{v_0}}{\alpha\ell} + \frac{(1-\delta)RI_{v_0}}{\alpha\ell}e^{2\alpha\ell}$$

Considering Eq.8, we obtain

$$\langle I_{v_0}\rangle = -\frac{2[1-R(1-\delta)]}{\ln[R(1-\delta)]}I_{v_0} \qquad (11)$$

, and substituting I_{v0} into eq.10

$$P_{\mathrm{out}} = -\frac{A}{2}\ln[R(1-\delta)]\langle I_{v_0}\rangle\frac{1-R-\delta+\delta R}{1-R(1-\delta)} \qquad (12)$$

The above-mentioned method is one of calculating the laser output power.

Now, the magnitude of τ_{res} in eq.8 is calculated as follows. The sum of losses such as diffraction loss and the other ones in eq.12 is the same as

$$P_{\mathrm{loss}} = -\frac{A}{2}\ln[R(1-\delta)]\langle I_{v_0}\rangle\frac{\delta}{1-R(1-\delta)}$$

Therefore, the rate of the variation of the light intensity in the output mirror due to the effective loss and the ineffective ones is written as

$$\left(\frac{d\langle I_{v_0}\rangle}{dt}\right)_{\mathrm{loss}} = \frac{P_{\mathrm{out}}+P_{\mathrm{loss}}}{A\ell}\cdot C = \frac{C}{\ell}(1-R+\delta R)I_{v_0} = \frac{\langle I_{v_0}\rangle}{\tau_{\mathrm{res}}}$$

Hence, τ_{res} is

$$\tau_{\mathrm{res}} = -\frac{2l}{C\ln[R(1-\delta)]} \qquad (13)$$

4. Simulation of Laser Output Power

The simulation is composed of three steps: initialization of input parameters, solving, and optimization. In the first step, we input the reference data for the calculation of the output power.

Next, we get the vibrational temperatures T_i(i=1 to 6). [20]

$$T_i = \frac{h\nu_i}{\mathrm{k}\times\ln(1+N_ih\nu_i/E_i)}$$

, where *i*=1 to 6 correspond to the vibrational modes of the CO_2, N_2 and H_2O molecules. And we calculate from eq.7 to eq.13.

In this case the initial conditions is as follows

$$E_1(0) = (1-f)N_{CO2}h\nu_1/(\exp(h\nu_1/kT)-1)$$
$$E_2(0) = (1-f)N_{CO2}h\nu_2/(\exp(h\nu_2/kT)-1)$$
$$E_3(0) = (1-f)N_{CO2}h\nu_3/(\exp(h\nu_3/kT)-1)$$
$$E_4(0) = N_{N2}h\nu_4/(\exp(h\nu_4/kT)-1)$$
$$E_5(0) = ((fN_{CO2}+N_{CO})h\nu_5/(\exp(h\nu_5/kT)-1)$$
$$E_6(0) = (N_{H2O}h\nu_6/(\exp(h\nu_6/kT)-1)$$
$$E(0) = 0, \quad T = 300K, \quad I_v(0) = 1E-9$$

Because of the good cooling condition, the value of T is constant.

Table.1 shows the coefficients and the constants used in the calculation. [1 to 15]

We used the result of [4 and 7] as an electron density Ne(t). Fig.1 shows the calculation result of the output power related to the amount of H2O. In fig.1, the curves from 1 to 5 correspond to the cases CO2: N2: H2O=1:9:0.02, CO2: N2: H2O=1:9:0.08, CO2: N2: H2O=1:9:0.14, CO2: N2: H2O=1:9:0.2, CO2: N2: H2O=1:9:0.26, respectively. From the fig.1 it is noted that the output power increases and then decreases while increasing the amount of H2O. This means that there is an optimal value in the amount of H2O and it is the same as CO2: N2: H2O=1:9:0.2.

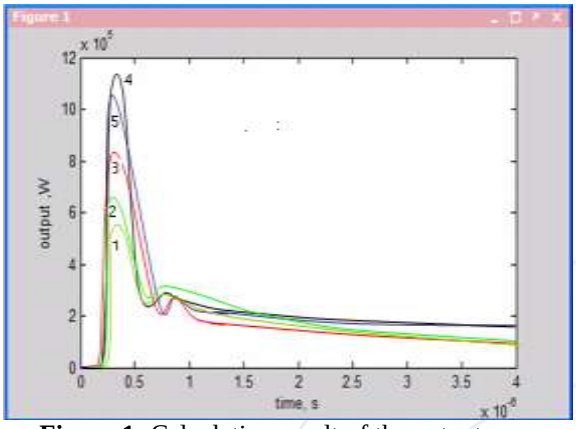

Figure 1: Calculation result of the output power corresponding to the amount of H2O (1-CO2:N2:H2O =1:9:0.02, 2-CO2:N2:H2O=1:9:0.08, 3-CO2:N2:H2O =1:9:0.14, 4-CO2:N2:H2O=1:9:0.2, 5-CO2:N2:H2O =1:9:0.26)

Table 1: Coefficients and constants

symbol	size	symbol	size
$h\nu_1$	1388 cm^{-1}	h	6.625×10^{7}erg/s
$h\nu_2$	667 cm^{-1}	J	18
$h\nu_3$	2349 cm^{-1}	c	2.998×10^{10}cm/s
$h\nu_4$	2330 cm^{-1}	τ_{sti}	0.2 μs
$h\nu_5$	2150 cm^{-1}	λ	10.6 μm
$h\nu_6$	1595 cm^{-1}	k	1.38×10^{-6}erg/K
χ_1^e	$5\times10^{-9}cm^3/s$	p	760Torr
χ_2^e	$3\times10^{-9}cm^3/s$	B_{CO_2}	0.4 cm^{-1}
χ_3^e	$8\times10^{-9}cm^3/s$	R	0.65
χ_4^e	$2.3\times10^{-}cm^3/s$	δ	0.001
χ_5^e	$3\times10^{-9}cm^3/s$	CO_2:N_2:H_2O	1:9:0.02-0.26
χ_6^e	$5\times10^{-10}cm^3/s$	f	0.2

5. Verification of Simulation of Laser Output Power

We compared the simulation result with the experimental one showed in [15]. In the simulation, the initial data coincide with the experimental ones in [15] which is shown in Tab.2.

Table 2: Experimental data in [15]

Parameter	Comment	Value	Unit
χ_1^e	Coefficient of excitation velocity(CO_2 (100))	5.0×10^{-10}	cm^3/s
χ_2^e	Coefficient of excitation velocity (CO_2 (010))	3.0×10^{-9}	cm^3/s
χ_3^e	Coefficient of excitation velocity (CO_2 (001))	8.0×10^{-9}	cm^3/s
χ_4^e	Coefficient of excitation velocity (N_2 (v=1))	2.3×10^{-8}	cm^3/s
χ_5^e	Coefficient of excitation velocity (CO (v=1))	3.0×10^{-8}	cm^3/s
J	Rotational quantum number	18	-
L	Length of resonator	120	cm
ℓ	Length of active material	100	cm
R	Reflection coefficient of output mirror	0.65	-
δ	Loss coefficient of resonator	0.001	-
f	Degree of dissociation of CO_2 molecule	0.2	-
A	Area of output mirror	0.7	Cm^2
CO_2:N_2: He	Mixed ratio of active gas	1: 1: 8	

Fig.2 shows the simulation result of the laser output power and fig.3 the experimental result in [15].

In comparison of fig.2 with fig.3, it is clear that the simulation result is so close to the experimental one for the maximum pulse power and the pulse width. And the trend of the simulation result is similar to that in [20].

Consequently, it is available to design a high-power TEA-CO_2 laser using the model of calculating the output power and the code. In other words, the model and the simulation method helps to predict the energy of laser pulse, the peak power, the average power, the pattern of the pulse, the composition ratio, the total pressure, the effective loss and ineffective losses and get the optimal basic parameters of a TEA-CO_2 laser demanded for the desired output power.

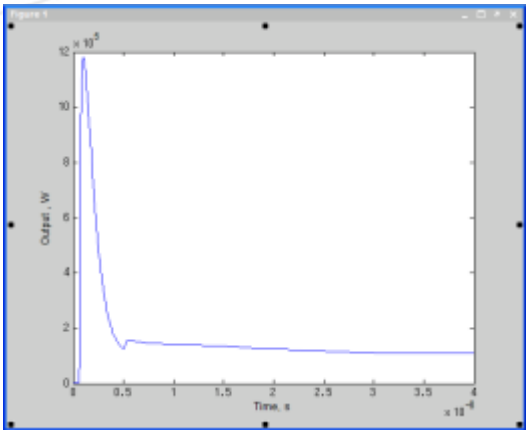

Figure 2: Simulation result

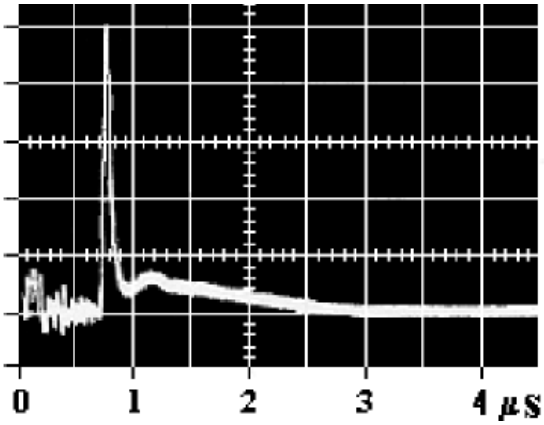

Figure 3: Experimental result in [15].

6. Conclusion

In this paper, we have developed an available model of the output power of a TEA-CO_2 laser which uses carbon dioxide and nitrogen produced by industrial method. Through the simulation, it was verified that the result from this model coincided approximately with the experimental result. The developed model and simulation method can be used for designing the main generator and the amplifier of a TEA-CO_2 laser using carbon dioxide and nitrogen produced by industrial method.

7. Acknowledgment

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