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Innovative extracting of optimum operational diagrams for a CW sealed CO2 laser based on the evolutionary genetic algorithm

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ABSTRACT

Some innovative diagram for the optimum parameters in operation of a sealed CW CO_2 laser was extracted by using the evolutionary genetic algorithm. By picking up an optimum value for the cavity stability parameter, geometrical factor (g), the optimum value of other parameters such as tube diameter, tube length and the coupler transmission, are resulted by these optimum diagram.

Keywords: Genetic Algorithm, CW CO2 laser

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INTRODUCTION

Recently, artificial intelligent based algorithms such as genetic algorithm (GA), particle swarm optimization (PSO), Ant and Bee colony have been used regularly in different areas of science and technology (Simon, 2013). Some works have been performed in this field, for example, optimization of quantum gas production (Lausch et al., 2016), self-optimization of an ultrafast pulse source (Woodward & Kelleher, 2016) and Laser marking Speed Optimization (Wang, Yu, & Zhang, 2015). The genetic algorithm has been the first artificial intelligence based optimization algorithm which has been used in optimization of multivariable gas laser systems such as chemical oxygen-Iodine (Carroll, 1996) and CO_2 gas lasers (Cheng, Ma, & He, 2001). In this study, the genetic algorithm has been innovatively used to extracting optimized diagram for a stable cavity of a sealed CW CO_2 laser. The diagrams have been shown and the key points have been highlighted

THEORETICAL PRELIMINARY

The formulas for the stable cavity and characteristics of active media of the sealed CW CO_2 laser have been written by relations (1) to (6) (all are in S.I units):

$$P_{out} = 0.5\pi w_0^2 \beta I_s \tag{1}$$

$$\beta = \frac{T_a T_b\left[g_0 l - 0.5\, ln\left(\frac{1}{T_a^2 T_b^2 r_1 r_2}\right)\right]}{\left(1-\sqrt{T_a^2 T_b^2 r_1 r_2}\right)\left(1+\sqrt{T_a^2 r_1 / T_b^2 r_2}\right)} \tag{2}$$

$$g_0 = 0.012 - 0.0025d \tag{3}$$

$$I_s = \frac{72}{d^2} \tag{4}$$

$$T_{a,b} = 1 - e^{-2\left(\frac{\frac{d}{2}}{w_{a,b}}\right)^2} \tag{5}$$

$$\eta = \frac{4\lambda L}{\pi d^2}\sqrt{\Gamma - 1}\left[1 + \frac{1}{3(\Gamma-1)}\right] \tag{6}$$

Which in these relations, P_{out} is the output power of the laser and used as the test function in the algorithm and the geometrical parameters of $g_1(= 1)$ and g_2 $(= g = 1 - 1/\Gamma)$ are cavity geometrical factors, $\Gamma = R/L$ which R is radius of back mirror curvature and L is the cavity length. The parameters of r_1 $(= r = 1 - T)$ and r_2 $(= 1)$ are front and back mirror reflectance, which T is transmittance of the front partial mirror, and d is tube internal diameter. The parameters of g_0 and I_s are small signal gain and saturation intensity of the sealed medium of a CW CO_2 laser, respectively (Cheng et al., 2001) which are less than that of gas flow system (Aram, Soltanmoradi, Ghafori, & Behjat, 2005). The other parameters, T_a and T_b are defined as diffractive transmission of the two side apertures of the tube (Verdeyen, 1995) and w_a and w_b are beam size at the tube ends (Milonni & Eberly, 2010). The final parameter of η is given by the overlap of cavity transverse mode (TEM_{00}) and geometrical, volume as a measure of how much of the stored energy in active media would be coupled to optical field. By the way, the cavity has no wavelength tuning element and the stable cavity CW CO_2 laser mostly operated on 10.6 μm (P (20)) line of the 10 μm transition branch (Witteman, 2013).

THE GENETIC ALGORITHM OF CASE CODEING

The genetic algorithm is an evolutional algorithm which is based on generation an initial set of guess solutions (genomes) and inserting them in the test function and sorting the results from best to the worst. Then a fraction of the best genomes, e.g., 50 %, are selected and by evolutional operations, e.g. cross-over and mutation, a new complete set of genomes are generated. These new genomes are feed in the test function and sorted again by goodness of value. Finally, the stopping condition are checked if it is satisfied or not and if the condition has not been satisfied, the process of making a new set of genomes by evolution are repeated again. But if the condition has been satisfied, the best genome of the final set are selected as the final solution of this optimization case.

The flowchart of the designed genetic algorithm is shown in fig 1. Because of its relative simplicity, the decimal based coding used for population generation of genomes as $[X1, X2, X3] = [\Gamma, T, d]$, which Γ $(2\ to\ 10)$, T $(0\ to\ 0.5)$ and d $(1\ to\ 10\ mm)$, are cavity geometrical factor, transmission of output mirror and tube internal diameter, respectively, and maximizing the output power (1) has been used as optimization assessment .Since the cavity geometrical factor $(g - 0.5)$, and η are dependent on the g, this parameter has been used as the general parameter of this work.

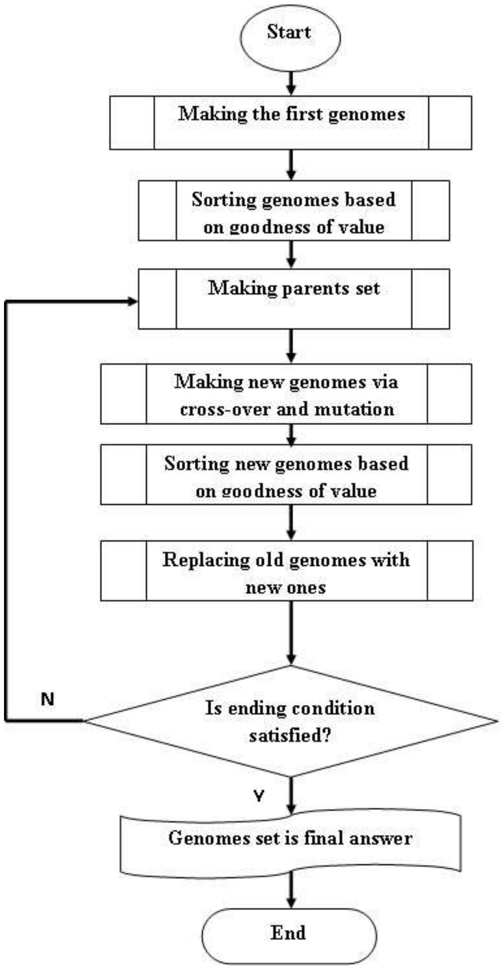

Fig1. Flowchart of the GA based evolutional algorithm.

RESULTS AND DISCUSSION

At first, g has been selected between 0.5 and 0.5+0.001, then by using the genetic algorithm, the best genome for maximizing the output power is extracted from the above interval. Then the upper limit of the g has been increased by 0.001, again and the new best genome extracted, too. This loop has been repeated until the upper limit is reached to the 1. The result of the described loop on $P(g), d(g), T(g)$ and $\eta(g)$, are shown in figs 2-5, respectively. The important note is that the diagrams are the changing of the optimum value, i.e. all of points on the curves, figs 3-5, and make a set that accompanies by the related optimum output power in fig. 2, and all of these are depended on what interval is allowed for the optimum value of g. As it is expected, the maximum value for the optimized value of output power takes place when the optimum value of g tends to the upper limit. Also, this behavior occurs similarly for d and η. For T, the condition is reversed and the optimum value of T has been decreased when optimum of g tends to the upper limit. As we can see from figs 2-5, the parameters of $Pout, d, \eta$ and T are increased, nonlinearly, when g is increased. When g is equal to 0.9, the output of energy is reached to 8.5W.

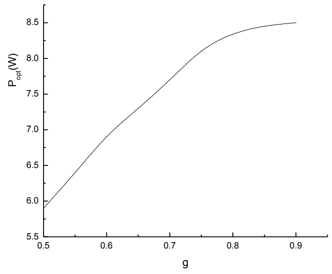

Fig 2. The optimum output power versus g

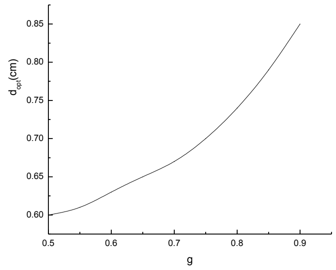

Fig 3. The optimum tube internal diameter versus g

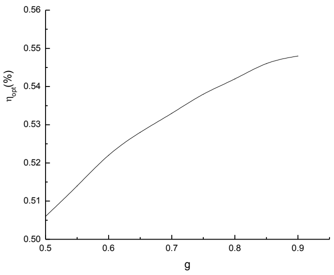

Fig 4. The optimum η versus g

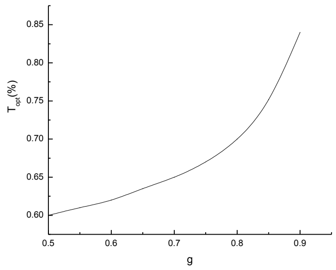

Fig 5. The optimum T versus g

CONCLUSION

The physical relations between parameters of a sealed CW CO_2 laser and the genetic based evolutional algorithm for extracting the maximum laser's output power, has been described. Our main innovation, as it has been pointed out, is extracting the diagram for the track of the optimum value for parameters related to the maximum of the output power. So, by picking up an optimum value for main cavity geometrical factor, *g*, the optimum values of other parameters such as tube diameter and tube length will be resulted from these optimum value diagrams. Therefore, a (sealed) CW CO_2 laser can be designed where the other important macroscopic parameters of laser system have got their optimum value beside the output power. For example, when g is selected as 0.9, i.e. the length of laser tube become equal to 0.1 of curvature radius of coupler mirror, the maximum output power of laser will be obtained. The similar research for designing of an optimized gas flow CW CO_2 laser with this method can be performed, too.

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