

PACS numbers: 42.55.Lt; 42.60.Lh; 52.80.Hc
DOI: 10.1070/QE2007v037n01ABEH013351

Parameters of a trigatron-driven low-pulse-repetition-rate TEA CO_2 laser preionised by a surface corona discharge

M. Aram, A. Behjat, M. Shabanzadeh, F. Mansori

***Abstract*. The design of a TEA CO_2 laser with UV preionisation by a surface corona discharge is described and the dependences of its average output energy on the gas-flow rate, discharge voltage and pulse repetition rate are presented. The scheme of the electric circuit and the geometry of the pre-ionisation system are considered. The electric circuit is designed to produce only impulse voltage difference between the laser electrodes. The triggering system of the trigatron is used to prevent the appearance of the arc. The dependences of the current, voltage and average output energy on the gas-mixture composition and applied voltages at a low pulse repetition rate are presented. The central output wavelength of the laser was measured with an IR spectrometer. Lasing at two adjacent vibrational – rotational transitions of the CO_2 molecule was observed, which demonstrates the possibility of simultaneous lasing at several lines.**

Keywords: *pulsed CO_2 laser, UV preionisation, surface corona discharge*.

1. Introduction

TEA CO_2 lasers emitting in the range from 9 to 12 μm have many applications including optical pumping of IR lasers [1], plasma production on solid targets [2], and remote sensing, in particular, by using differential absorption lidars [3, 4]. The conventional method of pumping TEA CO_2 lasers is the two-stage electric-discharge method [5]. A preionisation discharge near the active medium emitting UV radiation increases the energy of atoms or molecules in the active medium, and after some time the main electric discharge is produced, which excites atoms or molecules and generates the output laser pulse.

UV preionisation can be produced either by the spark array [6 – 7] or the surface corona discharge [8 – 9]. In the first case, several pairs of parallel pin arrays are placed along the gas-discharge gap from one or two sides. Upon applying the preliminary voltage, spark arrays emit UV radiation, which preionises the active medium of the laser. High temperature and also high electron density in the spark discharge cause electronic excitation of the molecules, resulting sometimes in the decomposition of CO_2 molecules, which is undesirable. The operation of a TEA CO_2 laser with UV preionisation by the spark array was studied earlier in [7].

In the second case, two parallel metal plates, separated by an isolating material such as glass or ceramic are used. A surface discharge appearing upon applying high voltage between the plates allows moving low-density, high-energy electrons along the surface (Fig. 1a). During collisions of electrons with surface atoms of the insulator, UV radiation is produced. Because of a lower electron density, fewer molecules are damaged when this method is used. In addition, the emission spectrum in this case is narrower compared to the spark array method. Advantages of the surface corona discharge are simplicity of design and high efficiency [10 – 12]. The theoretical investigations of the surface corona discharge have been published in [13].

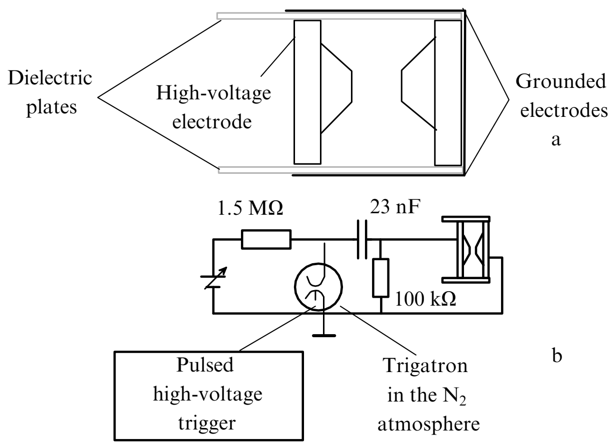

Figure 1. Laser cavity made of Perspex with steel electrodes and a glass insulator (a) and the electric discharge circuit of the laser (b).

2. Experimental

A laser cavity was made of Perspex with steel electrodes (Fig. 1a). The 1.5-mm glass plates were used as an insulator to produce UV preionisation. The electric circuit of the preionisation unit of the laser is shown in Fig. 1b. A trigatron switch with a hetero-polar triggering configuration

M. Aram, M. Shabanzadeh, F. Mansori Gas Lasers Department, Laser Research Center, P.O. Box:14155-1339, Tehran, Iran;
A. Behjat Physics Department, Yazd University, P.O. Box: 89178/741, Yazd, Iran; e-mail: abehjat@yazduni.ac.ir

Received 22 November 2005, revision received 20 June
Kvantovaya Elektronika **37** (1) 60 – 62 (2007)
Submitted in English

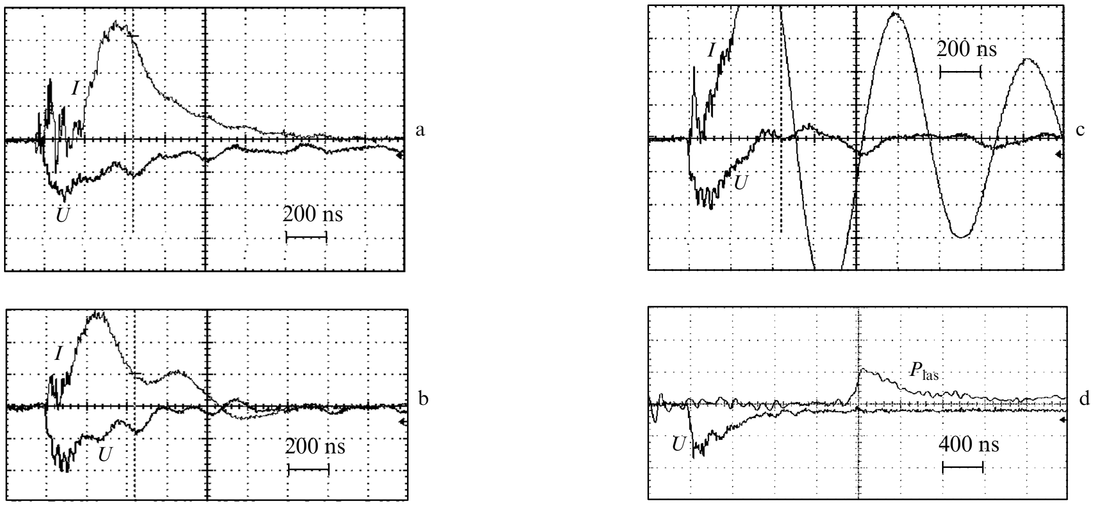

Figure 2. Oscillograms of the laser voltage and current for $V = 14$ kV (a), 16 kV(b) and 18 kV (c) [the gas-flow rates F are the same for all the three cases and are 5.2 L min^{-1} (He), 2.2 L min^{-1} (CO_2), and 0.4 L min^{-1} (N_2)] and oscillograms of the characteristic laser pulse and voltage for the main voltage of 16 kV (d).

[14], which was in the pressurised Nitrogen atmosphere served as a high voltage trigger. The main capacitor included 12 ceramic 1.9-nF TDK capacitors. The gas-flow rate was measured and controlled with three similar flow meters. The voltage and current were measured with a Tektronics p6015 voltage probe (1 : 1000) and Pearson Electronics current coil (1 : 40). The laser pulse energy was measured with a Coherent LM-P10F power meter. A Rofin-sinar 7425 Photon-Drag detector together with a Tektronics 3052 DSO oscilloscope were used to monitor and measure the output pulse.

3. Results

A gas mixture required for producing the pulsed glow discharge at a characteristic 14-kV electric voltage and 1-Hz pulse repetition rate was prepared and used in the laser. The laser voltage and current pulses were measured for dc voltages of 14, 16, and 18 kV (Fig. 2). One can see that at 18 kV, the glow discharge changes to arc and periodic oscillations of voltage and current are observed. In this situation, the laser voltage decreases rapidly to almost a zero value and the peak current increases to more than 1600 A. Therefore, main voltage was fixed at 16 kV, for which the voltage of the gas-discharge gap and peak current pulse are steady and equal to 5 kV and 1200 A, respectively. Figure 2d shows the shape of the laser pulse in this regime. The laser peak power was about 400 kW and its duration was 80 ns.

We also studied the effects of the gas mixture composition on the output pulse energy at the constant input voltage of 14 kV and constant capacity of main capacitors. Figure 3 shows the dependence of the gas-flow rate of He in the gas mixture on the laser output energy for two rates of the CO_2 flow. Figure 4 presents the dependence of the laser output energy on the gas-flow rate of CO_2 in the gas (the gas-flow rates of He and N_2 are constant). The maximum amount of He ($F = 7.2$ L min^{-1}) was used to avoid the gas-discharge nonuniformity. The effect of the applied voltage on the output energy at a constant gas mixture and the values of the main capacitors was also studied (Fig. 5).

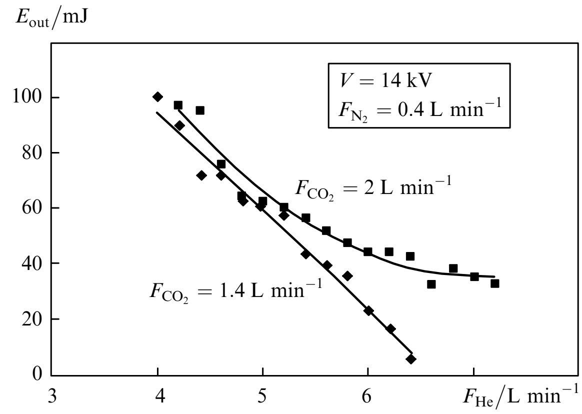

Figure 3. Dependence of the output pulse energy on the gas-flow rate F of He in the gas mixture at the input voltage of 14 kV and constants main capacitors.

Finally, the output energy as a function of the pulse repetition rate was measured (Fig. 6).

Figure 7 shows the dependence of the average output power on the pulse repetition rate for the input electric

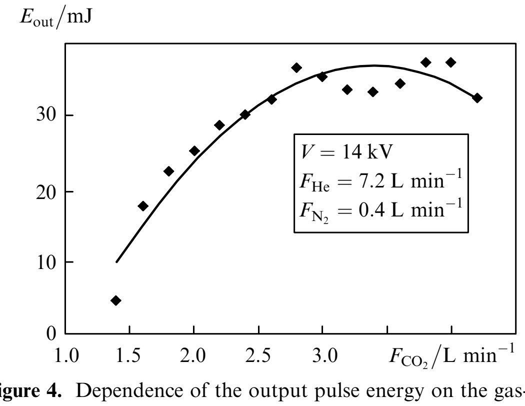

Figure 4. Dependence of the output pulse energy on the gas-flow rate F of CO_2 in the gas mixture at the input voltage of 14 kV and constants main capacitors.

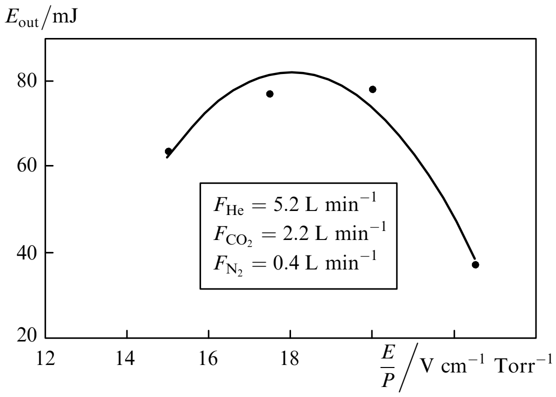

Figure 5. The effect of reduced electric field strength on the laser output energy under conditions of the constant gas mixture composition and the value of the main capacitors.

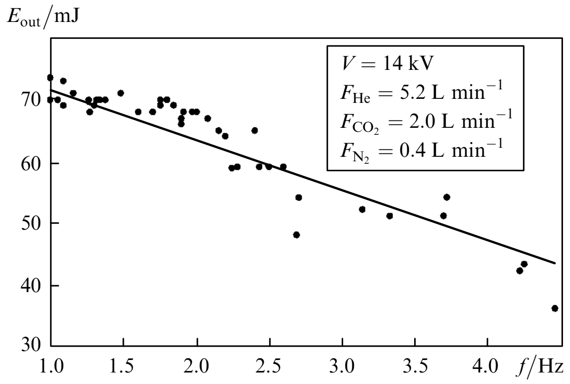

Figure 6. Dependence of the laser output energy on the pulse repetition rate *f*.

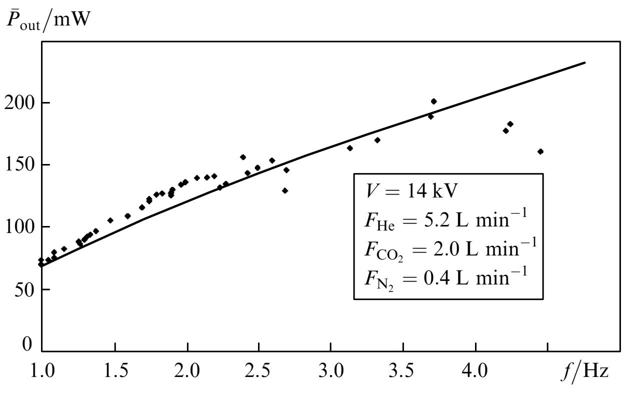

Figure 7. Dependence of the calculated average output power $\bar{P}_{out}$ of the laser on the pulse repetition rate *f*.

voltage of 14 kV and the gas-flow rates of 5.2 L min^{-1} (He), 0.4 L min^{-1} (N_2) and 2 L min^{-1} (CO_2). One can see that at a low pulse repetition rate the average output energy increases linearly up to 4 Hz. Figure 8 shows the dependence of the total efficiency of the laser on the pulse repetition rate. The conversion efficiency of the laser under the best conditions was about of 3.3 %.

The output radiation of the CO_2 laser was studied with an Optical Engineering spectrum analyser, the central output wavelength being 10.58 μm. By slightly varying the back mirror, lasing at 10.56 and 10.58 μm was observed.

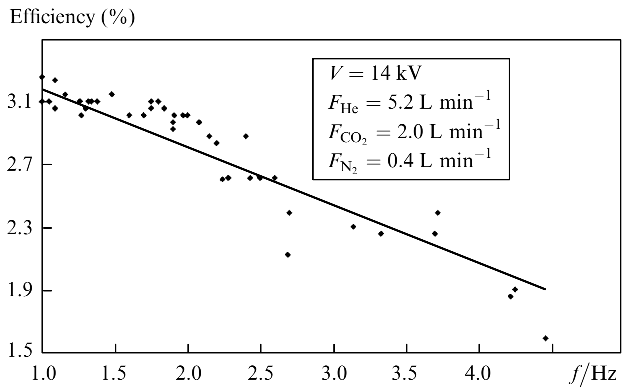

Figure 8. Dependence of the total laser efficiency on the pulse repetition rate *f*.

4. Conclusions

The TEA CO_2 laser with a surface corona preionisation (through the glass surface) and a gas-flow system has been presented. Some experimental data on the output energy of the laser at low pulse repetition rates have been given. Dependences of the average output energy and output efficiency of the laser on the gas mixture composition, applied voltage and pulse repetition rate have been studied. Simple operation and stability of the output parameters of the laser make this laser suitable for the laboratory research. In addition, simultaneous lasing and amplification at two wavelengths is possible.

Acknowledgements. The authors thank S.H.Fakhraei, G.Azizabadi, G.Mokhtari and K.Shiraghazadeh for their technical assistance. This work was supported by the Laser Research Center of the AEOI.

References

1. Behjat A., Soltanmoradi F., Silakhori K., Montazerolghaem M., Fathi V., Saifi A., Sadr R. *Proc. SPIE Int. Soc. Opt. Eng.*, **5777** (2), 535 (2004).
2. Dyer P.E., Ramsden S.A., Sayers J.A., Skipper M.A. *J. Phys. D.*, **9**, 375 (1976).
3. Carts Y.A. *Laser Focus World*, 71-82, Oct 1990.
4. Cooke B., Schmitt M., Goeller R., Czuchlewski S., Fuller K., Olivas N., Laubscher B., Sander R. *Proc. SPIE Int. Soc. Opt. Eng.*, **2702**, 2, (1996).
5. Judd O.P., Wada J.Y. *IEEE. J. Quant.Electron.*, **10** (1), 12 (1974).
6. Soltanmoradi F., Naeimi S.A. *Sci. Bull. AEOI*, No. 7, 61 (1988).
7. Aram M., Soltanmoradi F., Behjat A. *Proc. SPIE Int. Soc. Opt. Eng.*, **5483**, 43 (2003).
8. Ernst G.J., Boer A.G. *Opt. Commun.*, **34**, 221 (1989).
9. Behjat A., Aram M., Soltanmoradi F., Shabanzadeh M. *Proc. SPIE Int. Soc. Opt. Eng.*, **6263**, 626305-1-05-6 (2005).
10. Marchetti R., Penco E., Salveti G. *IEEE. J. Quantum Electron.*, **19**, 1488 (1983).
11. Marchetti R., Penco E., Salvetti G. *J. Appl. Phys.*, **56**, 3163 (1984).
12. Soltanmoradi F., Jelvani S., Behroozinia S., Aram M. *Sci. Bull. AEOI*, No. 11–12, 57 (1993).
13. Ashraf Ganjavi A., Bahrampor A. *Proc. 9th Photon. Gath. Phys. Soc. Iran* (5-6 Feb. 2003) p.6.
14. Aram M. *J. Nucl. Sci. Technol. AEOI*, **2** (34), 33 (2005).