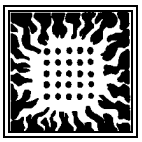


VINČA INSTITUTE OF NUCLEAR SCIENCES
Department of Physical Chemistry
Belgrade - Serbia & Montenegro

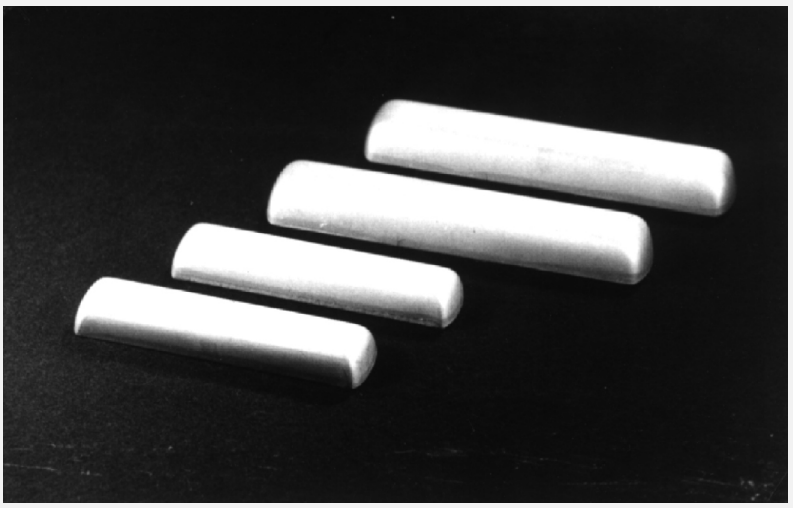
LASERS & LASER APPLICATIONS DIVISION

Pulsed CO_2 Laser Program

- Uniform field electrodes
- Mini TEA CO_2 laser head
- Mini TEA CO_2 laser

VINČA INSTITUTE OF NUCLEAR SCIENCES

UNIFORM FIELD ELECTRODES BY VINČA



Specially profiled uniform field electrodes of improved design have been developed in The VINČA Institute of Nuclear Sciences, Lasers & Applications Division within The Laboratory of Physical Chemistry. This lab has many years of experience in R&D of molecular gas lasers and their components. In the many years of practice high quality components, including electrodes as well as entire laser systems have been delivered to numerous customers, starting with those in USA. The specially profiled uniform field electrodes are computer designed and produced on a numerically controlled milling machine. The electrodes ensure a volumetrically uniform high-voltage pulsed discharge in transversely excited gas lasers (e.g. TEA carbon-dioxide, nitrogen, excimer, etc.). *Besides lasers, electrodes can be used in any unit where uniform high-voltage discharge is required.* After machining each electrode is polished[1] to eliminate all sharp edges. Standard materials offered for the electrodes are aluminium or brass. They are of modified Chang's profile[2]. This profile is superior to those of Rogowski, Bruce or Harrison for its smoothness, compactness and field uniformity.

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[1] On special request the following options can be considered: (i) sand blasting of the electrode surface, (ii) nickel coating. After this process the resistivity of electrodes to the aggressive-corrosive gases is increased. It is also possible to manufacture the electrodes from other materials, e.g. stainless steel.

[2] On request electrodes of other profiles can be considered, e.g. Stappaerts, Ernest, etc.

Standard electrode dimensions, shown in the Table 1-*Appendix*, are intended for use in efficient TEA CO_2 lasers, but they can successfully be used for other pulsed laser systems[3]. By a row arrangment of mini electrodes of the type A or B, Table 1, multiplied **A**ctive **D**ischarge **V**olume (ADV) can be obtained, e.g. ADV = n·8 cm3 or n·16 cm^3, where n is the number of standard electrode couples. Accordingly, the high output laser energy and high quality laser beam are achieved.

Other electrode dimensions[4] are available on special request. When ordering please specify length and values of the parameters: electrode critical discharge width ($2x_m$), Fig. 3. - *Appendix*, and the critical discharge height, i.e. interelectrode spacing ($2y_0$). Also, the value of the parameter δ_m[5] can be quoted. Specify the number of mounting holes, their spacing, thread size, electrode quantity, material and finishing.

Relevant references for R&D of electrodes:

[1] M. S. Trtica, "*A Small Scale TEA CO_2 Laser Utilizing Nonconventional Ternary $CO_2/N_2/H_2$ Gas Mixture*", SPIE Proceedings, 1276 (1990) 106.

[2] M. S. Trtica, Š. S. Miljanić, "*Compact TEA CO_2 Laser Operating with Nonconventional Hydrogen Gas Mixtures*", European Quantum Electronics Conference and 10th Nat. Quant. Elcetr. Conference, Edinburgh, August 1991, Technical Digest, p. 52.

[3] Š. S. Miljanić, M. S. Trtica, B. Radak, Lj. Petkovska (Yugoslav part of the Project), Project: *Research and Development of Novel Pulsed Gas Laser Systems CO_2 and Excimer with Kinetic Studies of Processes in Relevant Gas Mixtures*. Project No. CI1*0520-C(SMA), European Community - Brussels. (Participants in the Project: University of Strathclyde, Glasgow; Heriot-Watt University, Edinburgh; Vinča Institute of Nuclear Sciences, Belgrade), Final Report, p. 3-14, 35-37, August 1992.

[4] M. S. Trtica, G. N. Ostojić, " *Numerical Modeling of Self-sustained TEA CO_2 Laser Operation*", Proceedings of SPIE, 3612 (1999) 7.

[5] M. S. Trtica, B. M. Gakovic, B. B. Radak, S. S. Miljanic, "*Efficient Small-scale TEA CO_2 Laser for Material Surface Modifications*", Proceedings of SPIE, 4747 (2002) 44.

Ordering information a customer can get via contact persons:

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Attention: For detailed inform. please see the three page *Appendix*.

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[3] It is known from numerous sources that the Chang profile electrodes are commonly used in excimer lasers, etc.

[4] On request we produce electrodes that can ensure an active discharge volume of 450 cm^3 or more. In the case of such ADV value the critical discharge width is 3.0 cm, see Fig. 3 - *Appendix*, critical height of the discharge is 3.0 cm, while its length is about 50 cm.

[5] If this parameter is not quoted the producer will apply the value which is optimal for the ordered electrodes.

APPENDIX

Table 1. Standard electrode dimensions

Electrode type	Width[a)] (cm)	Thickness[a)] (cm)	Length[a)] (cm)	$2x_m$ [b)] (cm)	$2y_0$ [b)] (cm)	δ_m [c)]	ADV[d)] (cm^3)
A	3.2	1.6	13.0	0.8	0.8	$5 \cdot 10^{-6}$	~8
B	3.6	2.0	17.7	1.0	1.0	$1 \cdot 10^{-5}$	~16
C	6.9	3.0	60.0	2.0	2.0	$1 \cdot 10^{-5}$	~220

a) The view of the electrodes is shown in Fig. 1. - *this Appendix*. The real length of discharge (l_{eff}) is always somewhat smaller than the electrode length (Fig. 2 - *Appendix*).

b) $2x_m$ - critical value of discharge; $2y_0$ - critical height of discharge, Fig. 3 - *Appendix*. At the same time $2y_0$ is the inter-electrode spacing.

c) Parameter δ_m is defined as $|E(0) - E(x_m)|/E(0)$. It describes the maximal relative variation of the electric field which can be tolerated within the critical electrode width.

d) **A**ctive **D**ischarge **V**olume (ADV) defines the volume between specially profiled electrodes from which the gas is lasing. Generally, it is determined by products of **c**ross-**s**ection ($cs = 2x_m \cdot 2y_0$) and length of the discharge (l_{eff}).

Notes:

1 Although ADV is small, only 16 cm^3 e.g. for the electrodes of B-type, Table 1, by using the corresponding UV preionizer and optical cavity, as well as by choosing appropriate electrical circuit and gas mixture, it is possible to achieve very-high laser output energy. In our commercial *mini TEA CO_2 laser head* all these facts are put together (see technical *notification* on the *mini TEA CO_2 laser head*). So, high output energy of up to 250 mJ per pulse is obtained, i.e. specific output energy[6] is up to 16 J/l.

2 Width, thickness and length of any electrode type, Table 1, can be reduced. That is a so-called modification-type electrode. In this treatment $2x_m$ and $2y_0$ values, as well as the discharge length remain unchanged. For example, in the case of modification-type of the B electrode, the active volume remains ~16 cm3 (i.e. $2x_m$ = 1 cm, $2y_0$ = cm; discharge length ≅ 16 cm) while the other electrode's dimensions, Table 1, are reduced. Thus, width = 3.0 cm, thickness = 1.5 cm and length = 17.0 cm.

3 Standard electrodes A, B and C can be fixed by screws (Fig. 4 - *Appendix*). All standard electrodes use M6 screws. Spacing (*d*) between the hole centers are 80 and 120 mm for A and B type, respectively. For the C type the customer gives the spacing between the hole centers as well as their number.

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[6] The specific laser output energy is the output energy normalized to the ADV of 1 liter.

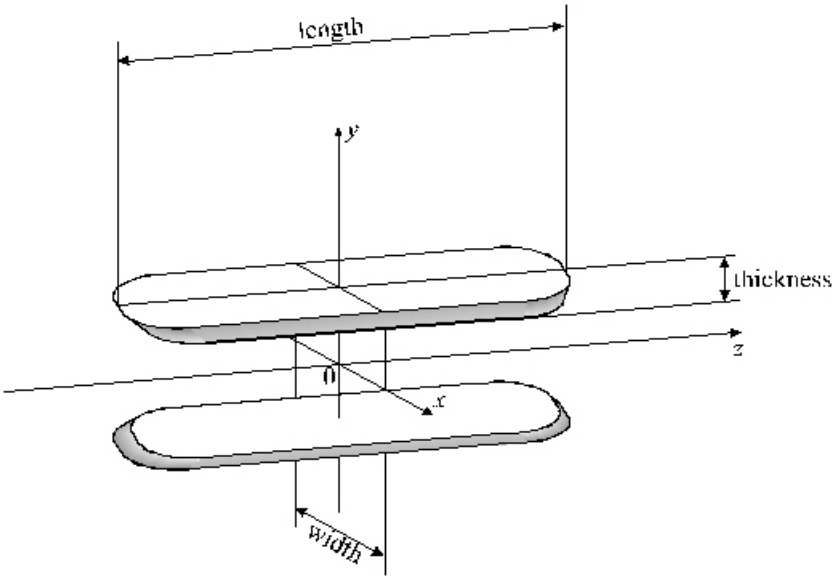

Figure 1. Three-dimensional view of the specially profiled electrodes.

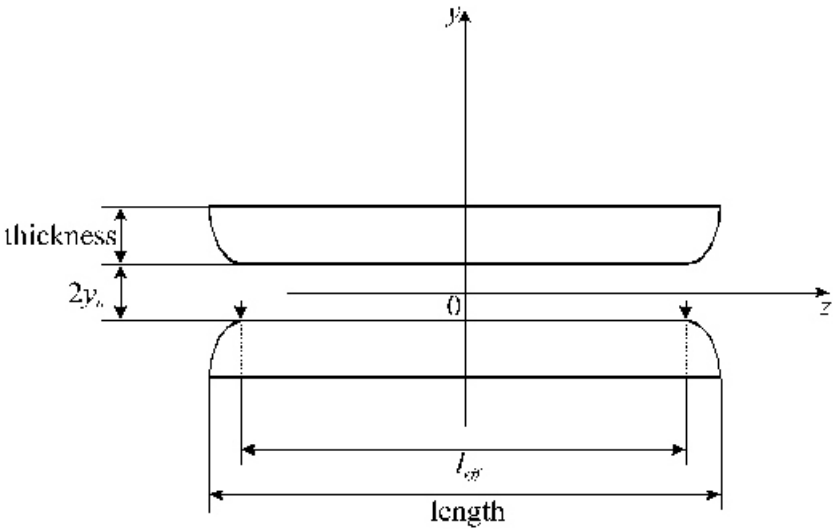

Figure 2. The view of the specially profiled electrodes in the $x = 0$ plane.

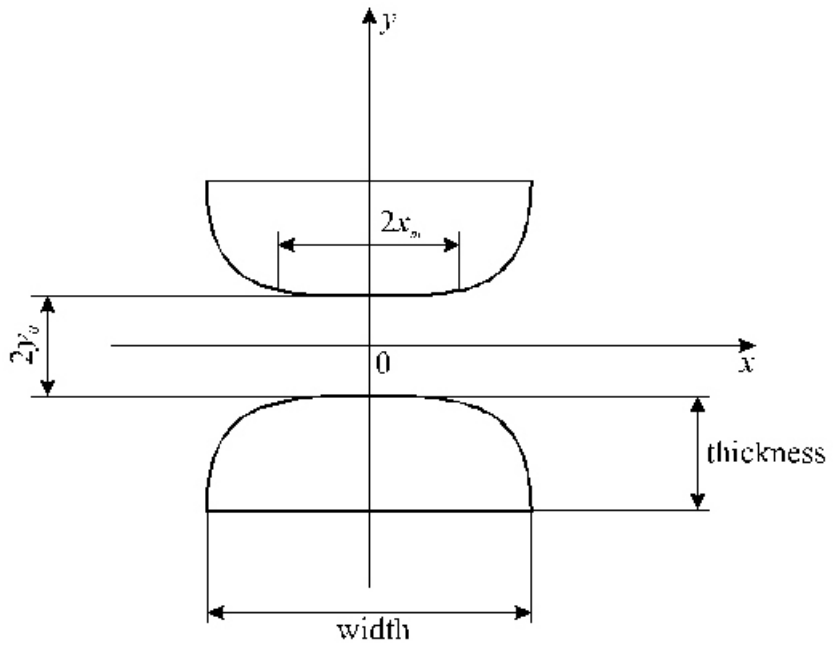

Figure 3. The view of the specially profiled electrodes in the $z = 0$ plane.

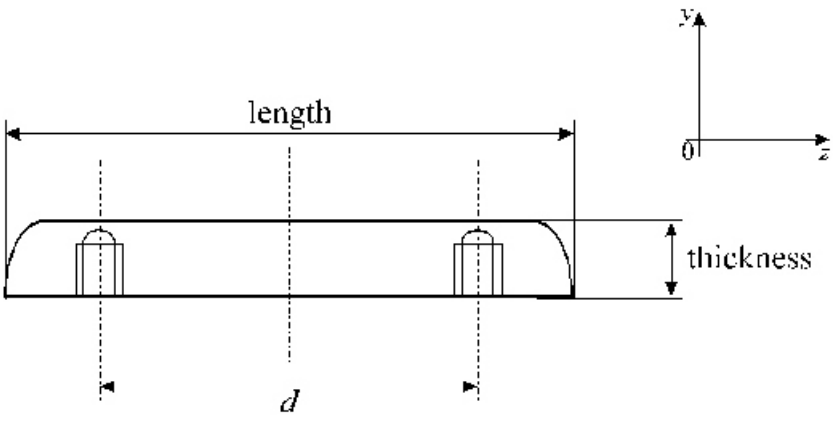

Figure 4. The manner of mounting of the specially profiled electrodes; *d* is the spacing between the centers of mounting holes.

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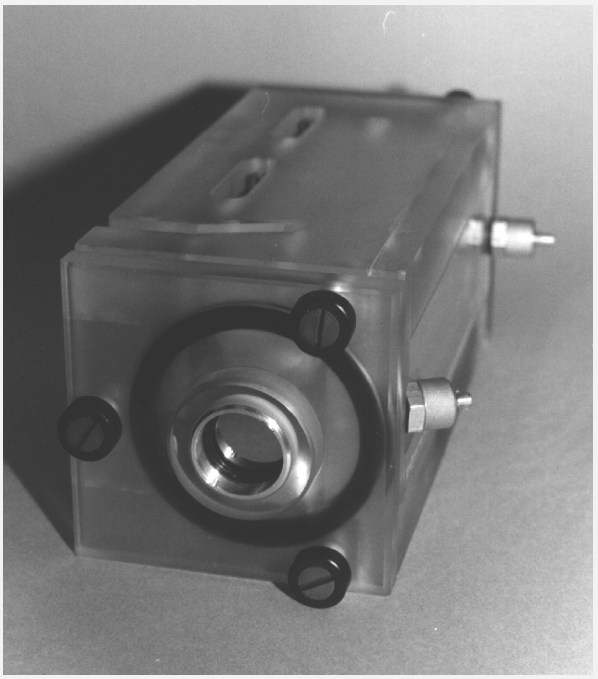
PULSED MINI TEA CO_2 LASER HEAD



Lasers & Laser Applications Division within the Department of Physical Chemistry of the Vinča Institute of Nuclear Sciences, which has long time experience in R&D of the molecular gas lasers and their components, a *mini TEA CO_2 laser head* has been developed. Also high quality laser products, including *mini TEA CO_2 lasers*, have been delivered to numerous customers, even in USA.

The commercial *mini TEA CO_2 laser head* is a miniature and compact one. It involves transversal electrical excitation of the gas mixture at atmospheric pressure (TEA laser). High quality and efficient *mini TEA CO_2 laser head* consists of a body, Fig.1- *Appendix*, in which (i) specially profiled electrodes, (ii) an ultraviolet preionizer and (iii) optical cavity are situated. The component (i) ensures homogeneous distribution of the electrical field. In association with the component (ii) it enables maximal plasma density without arcing, hence (iii) permits laser effects.

The commercial *mini TEA CO_2 laser head*[7] of high efficiency is a compact source of infrared radiation, which can be applied in the following areas:

[7] Together with corresponding electronics.

- **Research in Physics, Chemistry, Biology etc. (**IR spectroscopy, Optical pumping, Photophysics, Photochemistry, Isotope separation, Remote sensing studies, Tissue ablation etc.)
- **Ecology** (LIDAR- remote detection of atmospheric pollutants, etc.)
- **Military uses** (Ranging, Target marking, Laser radars, Detector calibration, IR countermeasures etc.)
- **Industry** (Marking, Micro-drilling without thermal effects etc.)
- **Electronics**
- **Medicine etc.**

BASIC OPERATING PERFORMANCES OF THE MINI LASER HEAD

Lasing material[7]:	Gas mixture $CO_2/N_2/He$ (typical)
Operating pressure:	Atmospheric
Wavelength8:	10.6 μm
Active discharge volume:	1cm · 1cm · 16cm, (i.e. 16 cm^3)
Output energy per pulse[9]:	0.25 J/0.20 J- typical (multimode operation)
Specific output energy[10]:	16 J/l (typical)
Pulse width[11]:	about 100 ns (initial spike)
Pulse power:	about 1 MW
Repetition rate:	0.5-2 Hz (typically 1Hz)
Dimension of the laser beam[12]:	1cm · 1cm (multimode operation)
Optics:	Gold coated flat total reflector; about 85% R/AR germanium (or ZnSe) output coupler, 5 m radius of curvature.
Resonator length:	21 cm.
External dimensions of the *mini head*:	width-9 cm · height-9 cm · length-22.5 cm.
Weight:	~2.5 kg.

Line arrangement of several mini laser heads can provide higher active discharge volume and thus higher laser output energy than a single head one.

---

7 *The mini TEA CO_2 laser head* operates in a "slow flow" regime, as the majority of the TEA CO_2 lasers on the market. Typical consumption of the gas mixture is $\leq$ 0.4 l/min. (Notice: Consumption was measured with an air flow-meter).

8 The standard *mini laser head* contains a nondispersive resonator. On request addition of a dispersive element (grating) can be considered.

9 This output energy is recorded under 1 Hz repetition rate. The *mini head* can be connected in the electrical circuitry as shown in Fig. 2 - *Appendix*. The laser can also operate in the fundamental mode (TEM_{00}) by inserting an aperture (about 6 mm in diameter) into the resonator. Under these conditions the output energy is 1/3 of that obtained in multimode operation. The aperture can be delivered on request.

10 In extreme conditions the specific laser output energy is ~30 J/l. In this case the extracted laser output energy is 440 mJ (from only 16 cm^3), with a nonconventional $CO_2/N_2/He/H_2$ gas mixture.

11 With a typical gas mixture $CO_2/N_2/He$.

12 Diameter of the laser beam in TEM_{00} mode is about 6 mm. Beam divergence is of the order of several miliradians.

References relevant to R&D of the *mini TEA CO_2 laser head*:

[1] M. S. Trtica, "*A Small Scale TEA CO_2 Laser Utilizing Nonconventional Ternary $CO_2/N_2/H_2$ Gas Mixture*", SPIE Proceedings, 1276 (1990) 106.

[2] M. S. Trtica, Š. S. Miljanić, "*Compact TEA CO_2 Laser Operating with Nonconventional Hydrogen Gas Mixtures*", European Quantum Electronics Conference and 10th Nat. Quant. Electr. Conference, Edinburgh, August 1991, Technical Digest, p. 52.

[3] Š. S. Miljanić, M. S. Trtica, B. Radak, Lj. Petkovska (Yugoslav part of the Project), Project: *Research and Development of Novel Pulsed Gas Laser Systems CO_2 and Excimer with Kinetic Studies of Processes in Relevant Gas Mixtures*. Project No. CI1*0520-C(SMA), European Community (Brussels), (Participants in the Project: University of Strathclyde, Glasgow; Heriot-Watt University, Edinburgh; Vinča Institute of Nuclear Sciences Vinča, Belgrade), Final Report, p. 3-14,35-37, August 1992.

[4] M. S. Trtica, G. N. Ostojić, " *Numerical Modeling of Self-sustained TEA CO_2 Laser Operation*", Proceedings of SPIE, 3612 (1999) 7.

[5] M. S. Trtica, B. M. Gakovic, B. B. Radak, S. S. Miljanic, "*Efficient Small-scale TEA CO_2 Laser for Material Surface Modifications*", Proceedings of SPIE, 4747 (2002) 44.

Ordering information a customer can get via contact persons:

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***Attention*:** For detailed information please see the two page *Appendix*.

APPENDIX:

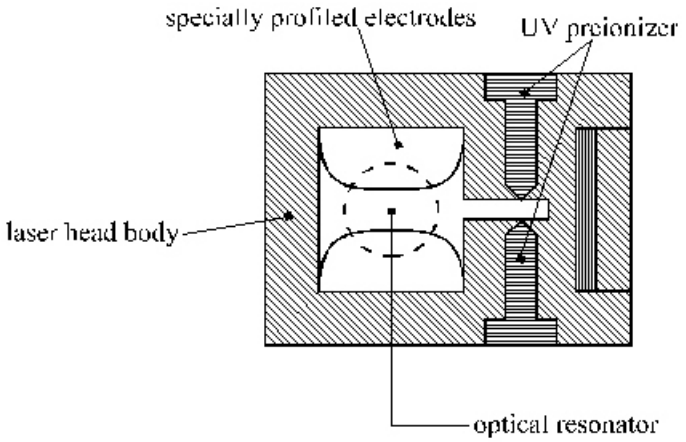

Figure 1. T*he mini TEA CO_2 laser head* cross section.

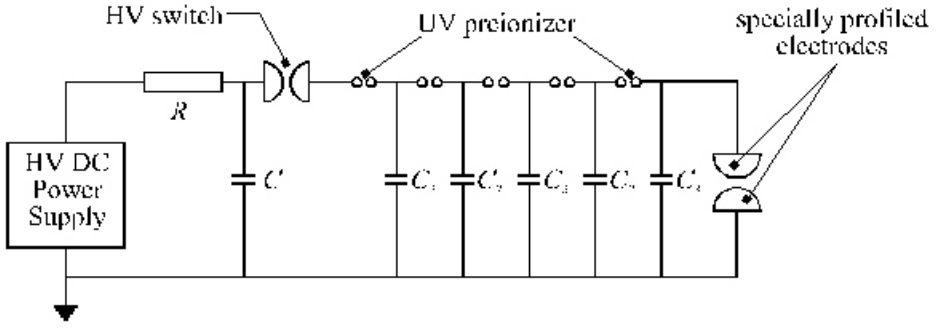

Figure 2. Connection of the *mini TEA CO_2 laser head* in one of possible electrical circuits.. R - surge limiting resistor (MΩ order of magnitude), C_1 - main capacitance (typically of nF value), C_2 - capacitance of the UV preionizer (typically in the pF range), C_3 - peaking capacitance (typically hundreds of pF).

(The accurate values of the electrical parameters, as well as the gas mixture composition, will be sent on special request.)

Additional information: *Mini TEA CO_2 laser head* enclosure is manufactured from a perspex block. Specially profiled electrodes (SPE) and ultraviolet (UV) preionizer are mounted inside, Fig.3 - *Appendix*. SPE are computer designed, fabricated on a numerically controlled milling machine and finally high quality treated. UV preionizer is of the sparking type, Fig.1- *Appendix*. Small distance between UV preionizer and SPE along with the electrical circuitry, Fig.2.- *Appendix*, enables efficient preionization of the gas mixture (the delay between the preionization and the main discharge is short and typically about 100 ns), and thus the efficient operation of the *mini TEA CO_2 laser head*. On the front and rear panel of the enclosure, the holders with the laser mirrors inside are mounted, Fig. 3. Fine adjustment of the laser mirrors can be performed by precision screws. Gas inlet and outlet are of small dimensions and are built in the enclosure.

The entire *mini TEA CO_2 laser head*[13] is fabricated with high accuracy. The volumetrically homogeneous discharge process can be observed through the transparent side wall of the enclosure.

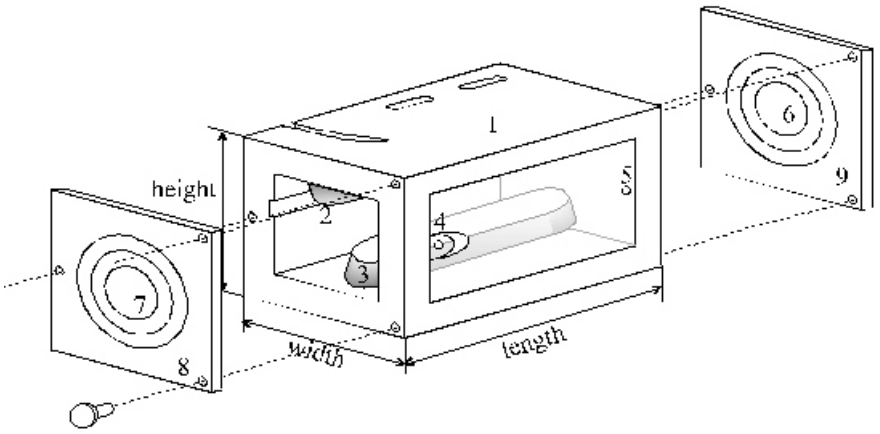

Figure 3. The external view of the *mini TEA CO_2 laser head*.
1 - enclosure; 2, 3 - specially profiled electrodes; 4,5 - inlet and outlet of the gas mixture; 6,7 - laser mirrors; 8, 9 - mirror holders. Total length of the head, including the mirror holders, is 22.5 cm.

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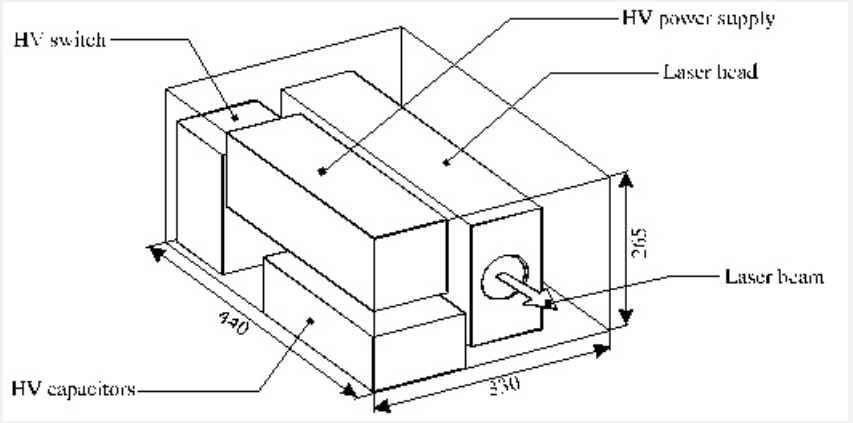
[13] On special request the following options, can be considered: (i) vacuum-tight *mini TEA CO_2 laser head*; (ii) very small *mini TEA CO_2 laser head*, but with similar laser output parameters; (iii) large *TEA CO_2 laser head*.

MINI TEA CO_2 LASER



dimension in mm.

In the Vinča Institute of Nuclear Sciences, Lasers & Applications Division within the Laboratory of Physical Chemistry, which has many years of experience in R&D of the molecular gas lasers and their components, a *mini TEA CO_2 laser* has been improved. In the many years of practice high quality laser products, including *mini TEA CO_2 lasers*, have been delivered to numerous customers, starting with those in USA.

The commercial *mini TEA CO_2 laser* is a miniature and compact one. It involves transversal electrical excitation of the gas mixture at atmospheric pressure (TEA laser). High quality and efficient *mini TEA CO_2 laser* consists of (i) laser head, (ii) HV power supply unit, (iii) HV capacitors unit, (iv) HV switch and (v) gas system.

The commercial *mini TEA CO_2 laser* of high efficiency is a compact source of infrared radiation, which can be applied in the following areas:

- **Research in Physics, Chemistry, Biology etc. (**IR spectroscopy, Optical pumping, Photophysics, Photochemistry, Isotope separation, Remote sensing studies, Tissue ablation etc.)
- **Ecology** (LIDAR - remote detection of atmospheric pollutants, etc.)
- **Military uses** (Ranging, Target marking, Laser radars, Detector calibration, IR countermeasures etc.)
- **Industry** (Marking, Micro-drilling without thermal effects etc.)
- **Electronics**
- **Medicine etc.**

BASIC OPERATING PERFORMANCES OF THE MINI TEA CO_2 LASER

Lasing material[14]:	Gas mixture CO_2/N_2/He (typical)
Operating pressure:	Atmospheric
Wavelength1[5]:	10.6 μm
Active discharge volume:	1cm · 1cm · 16cm, (i.e. 16 cm^3)
Output energy per pulse[16]:	0.25 J/0.20 J- typical (multimode operation)
Pulse width[17]:	about 100 ns (initial spike)
Pulse power:	about 1 MW
Repetition rate:	0.5-2 Hz (1Hz typical)
Dimension of the laser beam[18]:	1cm · 1cm (multimode operation)
Optics:	Gold coated flat total reflector; about 85% R/AR germanium (or ZnSe) output coupler, 5 m radius of curvature.
Resonator length:	21 cm.
External dimensions of the *mini laser*[19]:	width-33 cm · height-26.5 cm · length-44 cm.
Weight:	~10 kg.
Controls:	Gas: Gas-Built-In flowmeters20 Power: HV on-off switch, HV control knob continuously adjustable from 25 to 30 KV. Trigger: Rotary mode selector; manual repetitive external; repetition rate control linearly calibrated 0-2 pps, manual triggering push-button, sync output, external trigger input.
Power input:	110 V, 60 Hz (220 V, 50 Hz) mains voltage or 24 V DC.

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14 *The mini TEA CO_2 laser* operates in a "slow flow" regime, as the majority of the TEA CO_2 lasers on the market. Typical consumption of the gas mixture is $\leq$ 0.4 l/min. (Notice: Consumption was measured with an air flow-meter).

15 The standard *mini TEA CO_2 laser* contains a nondispersive resonator. On request addition of a dispersive element (grating) can be considered.

16 This output energy is recorded under repetition rate of 1 Hz. The laser can also operate in the fundamental mode (TEM_{00}) by inserting an aperture (about 6 mm in diameter) into the resonator. Under these conditions the output energy is 1/3 of that obtained in multimode operation. The aperture can be delivered on request.

17 With a typical gas mixture CO_2/N_2/He.

18 Diameter of the laser beam in TEM_{00} mode is about 6 mm. Beam divergence is of the order of several miliradians.

19 The laser is placed in the metal box. Its external dimensions are previously given. These dimensions can be reduced on special request.

20 Gas control consists of two mini-flowmeters. One is for "pre-mixed" CO_2/N_2/He gas mixture, and the other for HV switch, i.e. spark gap (SG). Standard version of the *mini laser* operates with a spark gap (with pressurized N_2 flow). Building-in SG (sealed-off type) of other manufactures can be considered on request.

Small consumption of gases enables utilizing of small gas-cylinders, which makes the laser system more mobile. Mini-gas cylinders are not included in the laser unit. On the special request this option can be considered.

References relevant to R&D of the *mini TEA CO_2 laser*:

[1] M. S. Trtica, "*A Small Scale TEA CO_2 Laser Utilizing Nonconventional Ternary $CO_2/N_2/H_2$ Gas Mixture*", SPIE Proceedings, 1276 (1990) 106.

[2] M. S. Trtica, Š. S. Miljanić, "*Compact TEA CO_2 Laser Operating with Nonconventional Hydrogen Gas Mixtures*", European Quantum Electronics Conference and 10th Nat. Quant. Electr. Conference, Edinburgh, August 1991, Technical Digest, p. 52.

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