PACS numbers: 42.55.Ks; 42.60.Lh
DOI: 10.1070/QE2007v037n07ABEH013617

# Test bench for studying the outlook for industrial applications of an oxygen – iodine laser

A.A. Adamenkov, V.V. Bakshin, A.V. Bogachev, E.V. Buryak, L.A. Vdovkin, S.D. Velikanov, B.A. Vyskubenko, S.G. Garanin, E.V. Gorbacheva, S.V. Grigorovich, S.P. Ilyin, R.I. Il'kaev, Yu.N. Ilyushin, A.M. Kalashnik, Yu.V. Kolobyanin, M.L. Leonov, V.V. Svishchev, M.V. Troshkin

***Abstract*. We report the development and tests of a chemical oxygen – iodine laser test bench based on a twisted-aerosol-flow singlet-oxygen generator and a supersonic laser model for studying the outlook for industrial applications of this laser. The maximal output power of the laser is ~65 kW (the average power is ~50 kW), corresponding to a specific output power of ~110 W cm$^{-2}$. The maximal chemical efficiency is ~34 %.**

***Keywords***: *chemical oxygen – iodine laser, twisted-aerosol-flow singlet-oxygen generator, radiation power, chemical efficiency.*

A high-power 30 – 50-kW chemical oxygen – iodine laser (COIL) [1] in combination with optical fibres for radiation transfer is very convenient for industrial applications such as remote cutting and welding of metals and surface machining [2 – 5]. The high output power of the COIL allows its use for dismantling the nuclear equipment that became obsolete [2]. Due to the short output wavelength (1.315 μm) and an excellent optical quality of its beam, the COIL can produce very narrow cuts, which reduces the secondary waste stream. The COIL radiation can be delivered through optical fibres to numerous remote working places. The laser radiation is controlled with the help of robots, which reduces the risk of personnel irradiation and accompanying expenses. The COIL combines the advantages of high-power $CO_2$ lasers and $Nd^{3+}$ : YAG lasers from the point of view of the possibility of energy transfer through optical fibres and the cutting efficiency [3].

In this paper, we report the results of testing a 50-kW supersonic COIL model based on a twisted-aerosol-flow singlet-oxygen generator (TA SOG) on a test bench built for working off units and systems of industrial COILs (Fig. 1).

**A.A. Adamenkov, V.V. Bakshin, A.V. Bogachev, E.V. Buryak, L.A. Vdovkin, S.D. Velikanov, B.A. Vyskubenko, S.G. Garanin, E.V. Gorbacheva, S.V. Grigorovich, S.P. Ilyin, R.I. Il'kaev, Yu.N. Ilyushin, A.M. Kalashnik, Yu.V. Kolobyanin, M.L. Leonov, V.V. Svishchev, M.V. Troshkin** Russian Federal Nuclear Center – All-Russian Scientific Research Institute of Experimental Physics, prosp. Mira 37, 607188 Sarov, Nizhnii Novgorod region, Russia;
e-mail: vyskub@otd13.vniief.ru; kolob@otd13.vniief.ru

Received 14 May 2007
*Kvantovaya Elektronika* **37** (7) 601 – 602 (2007)
Translated by M.N. Sapozhnikov

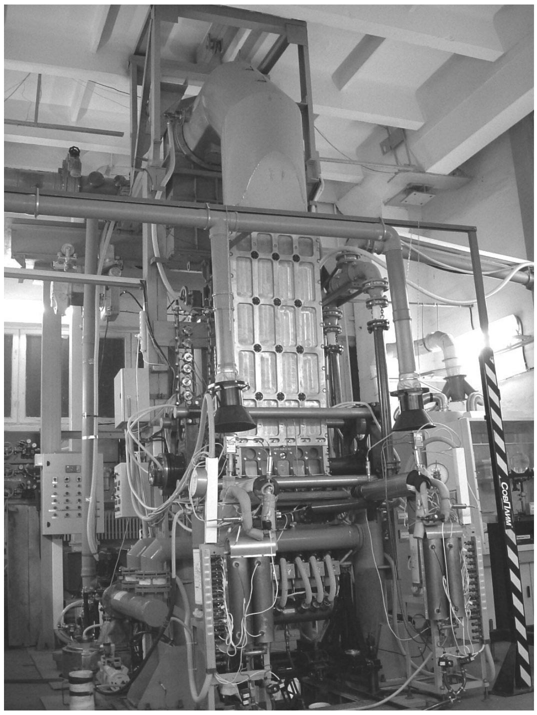

**Figure 1.** Test bench for studying chemical oxygen – iodine lasers.

We used a supersonic scheme for mixing working gases – energy-carrying [singlet oxygen (SO) with buffer nitrogen] and emitting (vapour mixture of iodine and nitrogen) [4, 5]. Iodine mixed with the carrier gas (nitrogen) was supplied through a tube injector into the supersonic part of a nozzle unit of size $60 \times 10$ cm consisting of 42 flat nozzles for the calculated Mach number M = 3, where it was mixed with gases from the TA SOG.

We used the concept of a modular unit of a SO reactor consisting of 12 TA SOG modules [5]. The design of a TA SOG module is described in detail in papers [6, 7]. Experiments were performed with alkali solutions of hydrogen peroxide at concentrations $M_{KOH} = 6$ mole L$^{-1}$ and $M_{H_2O_2} = 6$ mole L$^{-1}$. A system for preparation and supply of the working solution into the reactor unit provided ~200 L of solution which was cooled with the help of a Freon refrigerator approximately for three hours. In experiments, the working solution was replaced from a service tank under the action of atmospheric pressure through the reactor unit to a receiving tank. The running time was ~7 s. The working solution in the reactor unit interacted with gaseous chlorine supplied from a chlorine system. This system consisted of vertical tube receivers from which the required amount of gaseous chlorine was replaced to the reactor unit by a gas piston.

Crystalline iodine was heated up to 100 – 150 °C in the evaporator of an iodine system, the iodine vapour was mixed with nitrogen and supplied into the nozzle unit injector. Wasted gases were removed through a vacuum line into a vacuum receiver of volume 110 $m^3$ and were discharged into atmosphere after neutralisation.

The test bench was controlled according to the specified program by an automated system connected with a computer. This system controls the actuating devices of the test bench and their state and records and processes the output signals of detectors, protecting and control devices. During the operation of the program and after the end of experiments, the system forms data files containing complete information on its state and experimental parameters.

The gas pressure at different points of the gas-dynamic channel of the laser was measured with IKD and MIDA sensors. The Mach numbers in the supersonic flow of the laser were determined from the known relation for the isoentropic gas flow [8].

The energy parameters of the supersonic COIL were studied by using a stable flat-spherical resonator with mirrors of diameter 160 mm and the reflectivities 99.9 % and 85 % of the highly reflecting and output mirrors, respectively.

The optical scheme for measuring the energy parameters of the COIL is presented in Fig. 2. The output energy was measured with calibrated L1500W-LP laser power meters (Ophir Optronics, USA) and TPI-2A calorimeters. The shape of laser pulses was measured with InGaAs photodiodes recording radiation scattered by the receiving elements of calorimeters.

Figure 3 shows the time dependences of the radiation power, chemical efficiency, the chlorine and iodine flow rates, and the Mach number of the supersonic COIL obtained in one of the experiments. The Mach number of the supersonic flow was 2.7 – 2.8. The increase in the output power of the laser in time corresponded to the increase in the chlorine flow rate. The maximum output power of the laser for the total gas pressure at the input to the nozzle unit equal to ~75 Torr was ~65 kW (the average power was ~50 kW), which corresponds to the specific radiation power of ~110 W $cm^{-2}$ and the chemical efficiency of ~30 %. As the gas pressure was reduced down to 55 – 60 Torr, the chemical efficiency of the laser increased up to 33 % – 34 %.

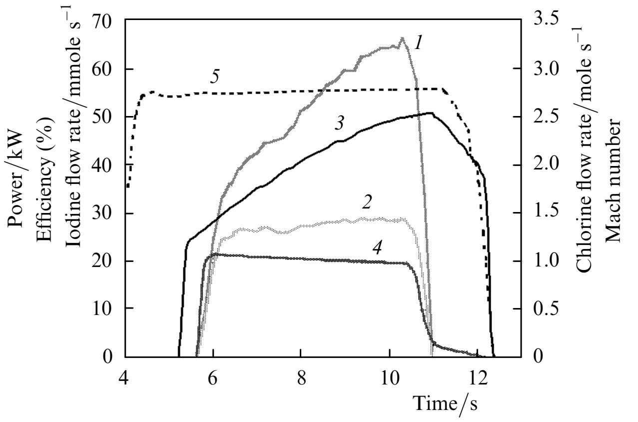


**Figure 3.** Experimental time dependences of the radiation power (*1*), chemical efficiency (*2*), chlorine (*3*) and iodine (*4*) flow rates, and the Mach number (*5*) of the supersonic flow for the COIL.

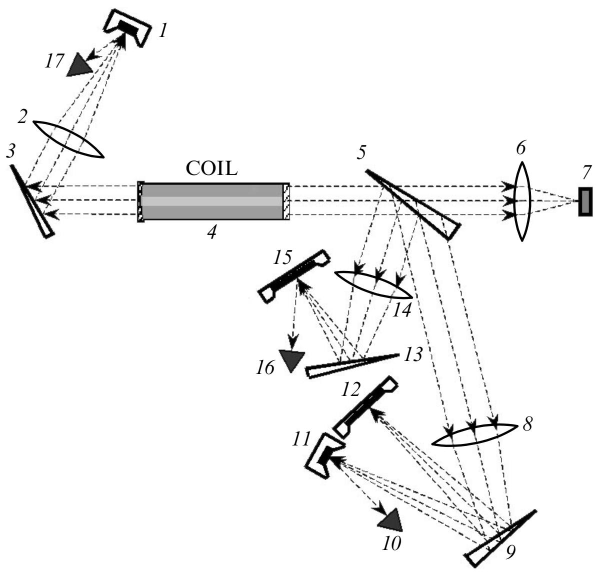


**Figure 2.** Optical scheme for measuring energy parameters of COILs: (*1*, *11*) calorimeters; (*2*, *6*, *8*, *14*) focusing lenses; (*3*, *5*, *9*, *13*) optical wedges; (*4*) COIL model; (*7*) sample; (*10*, *16*, *17*) photodetectors; (*12*, *15*) power meters.

***Acknowledgements.*** The authors thank N.V. Zhidkov, G.A. Kirillov, S.G. Lapin, and E.D. Yakovlev for their constant interest in this work, A.V. Yakovlev and L.S. Proshin for prompt manufacturing of the units and participation in the test-bench assembling, L.M. Vinogradskii and E.A. Kudryashov for useful discussions, Yu.A. Adamenkov, V.A. Bagretsov, M.V. Belukhin, I.A. Bulatkin, L.V. Goryachev, V.I. Efremov, N.A. Konkina, A.I. Krukovskii, V.B. Moiseev, A.V. Seleznev, and A.Yu. Sharov for their participation in start-adjustment works and experiments.

## References

1. Truesdell K.A., Helms C.A., Hager G.D. *Proc. SPIE Int. Soc. Opt. Eng.*, **2502**, 217 (1994).
2. Hallada M.R., Seiffert S.L., Walter R.F., Vetrovec J. *Proc. SPIE Int. Soc. Opt. Eng.*, **3931**, 149 (2000).
3. Fujii H., Atsuta T. *Proc. SPIE Int. Soc. Opt. Eng.*, **3092**, 700 (1996).
4. Adamenkov A.A., Buzoverya V.V., Bulkin Yu.N., Ilyin S.P., Kirillov G.A., Kolobyanin Yu.V., Kudryashov E.A., Savin Yu.V., Vyskubenko B.A. *Proc. Intern. Conf. 'Lasers'96'* (McLean, VA: STS Press, 1997) p. 175.
5. Vyskubenko B.A., Adamenkov A.A., Bakshin V.V., Efremov V.I., Ilyin S.P., Kolobyanin Yu.V., Troshkin M.V. *Proc. Intern. Conf. HPLB'2006* (Inst. Appl. Phys. RAS, Nizhnii Novgorod, 2006) p. 113.
6. Krukovsky I.M., Adamenkov A.A., Vyskubenko B.A., Deryugin Yu.N., Ilyin S.P., Kudryashov E.A. *Proc. SPIE Int. Soc. Opt. Eng.*, **3931**, 99 (2000).
7. Adamenkov A.A., Vyskubenko B.A., Il'in S.P., Krukovskii I.M. *Kvantovaya Elektron.*, **32**, 490 (2002) [*Quantum Electron.*, **32**, 490 (2002)].
8. Emtsov B.T. *Tekhnicheskaya gidromekhanika* (Technical Hydromechanics) (Moscow: Mashinostroenie, 1987).