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# Self-pumping of gas in pulsed-periodic energy supply

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Self-pumping of gas in a closed loop by pulsed-periodic energy supply was realized in experiment. Some questions involved in the investigation of the possibilities of self-pumping in periodic-action pulsed lasers are considered.

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The feasibility of self-pumping of a gas mixture in a closed loop without the use of special pumping devices, and its use in periodic-action pulsed lasers (PAPL), was first indicated by Gubarev, Drobyazko and Yakushev.[1] The interest in this problem is due to the fact that by dispensing with the compressor it would be possible to increase the efficiency of the PAPL, as well as to ensure good hermetic sealing of the loop when the laser operates in a closed cycle.

The energy released in a pulsed discharge leads to rapid increase of a pressure in the discharge region and to the onset of shock waves propagating away from the discharge zone in the gas channel. The thermodynamic cycle that characterizes the operation of the gas in such a process is the Lenoir cycle[1,2] which includes: 1) isochoric energy input; 2) adiabatic expansion described by the Poisson formula; 3) isobaric cooling of the gas. The thermal efficiency of this cycle, when the pressure is doubled at the instant of the discharge, is ~10% for air. From the calulation of the cycle it follows that to increase its efficiency the energy supply must be made rapid and as large as possible. The estimated energy of a self-pumping system is optimistic. The necessary pumping rate can be calculated by specifying the gas temperature at the input, using the condition that the average power input to the discharge is carried away by the gas stream.

The dominant factor in our case was the thermal resistance, and the power loss necessary to surmount it is easy to calculate. In this case the ratio of the power needed to ensure the gas flow to the average power input into the discharge turns out to be $6\times10^{-5}$. Assuming a thermodynamic-cycle efficiency $10^{-1}$, it can be concluded that the only problem is the conversion of the work of the waves into the work necessary to pump the gas mixture.

In our experiments, self-pumping of the gas was realized by using a system with an aerodynamic valve (Fig. 1). The electrode system consisted of a solid aluminum anode 1 and a sectionalized cathode 2 located near the closed end of a quarter-wave acoustic resonator 20 cm long. The length of the input channel was 12 cm. The inductive decouplings of the cathode sections and their small geometrical dimensions ensured low sensitivity of the electrode system to the gas dynamic inhomogeneities. The discharge volume was 3.2 cm$^3$ at an interelectrode distance 1.5 cm. The energy input to the discharge in one pulse was 0.55 J.

The choice of the construction of the input channel 4 is governed by the desire to effectively absorb and scatter the waves that enter the input channel from the acoustic resonator. The ratio of the cross section areas of the acoustic resonator and of the exit valve was chosen equal to three. The stream velocity in the acoustic resonator was determined from the deflection of a test body secured with the aid of a cathetometer. The chamber was placed in a Mach-Zahnder interferometer; the displacement of the interference fringes at a chosen point of the channel was registered with a photomultiplier. The signal from the photomultiplier was used to monitor the resonant excitation of the natural frequencies of the quarter-wave resonator.

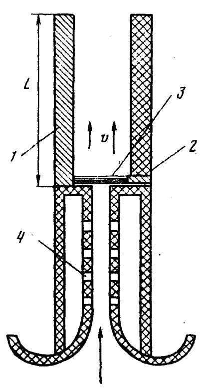


FIG. 1. Diagram of discharge chamber. 1—Anode, 2—cathode, 3—discharge region, 4—input channel.

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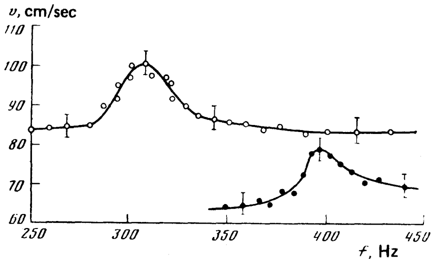


FIG. 2. Dependences of the self-pumping velocity on the pulse-repetition frequency (○—$CO_2$, $P$=100 Torr, ●—air, $P$=200 Torr).

Figure 2 shows the measured gas stream velocities at various discharge pulse-repetition frequencies at a pressure $P$=200 Torr in air and at $P$=100 Torr in $CO_2$. The plots reveal the presence of a sufficiently broad maximum near 310 Hz for $CO_2$ and 400 Hz for air. These values agree with the corresponding natural frequencies of the quarter-wave acoustic resonator $\nu_1 = C/4L$, where $C$ is the speed of sound in air and $CO_2$ and $L$ is the resonator length.

The electric-discharge chamber was so located that the gas flow $v$ was directed upward. In this case the convective thermal motion of the gas from the heated region of the discharge 3 makes its own contribution to the directional gas stream through the channel. However, on the one hand this motion is weakened by the cooling of the gas by heat conduction to the metallic wall of the channel, and on the other hand the resonant character of the dependence of the stream velocity on the pulse repetition frequency points to a decisive role of the wave processes in the pumping.

The resonant character of the variation of the gas stream velocity with the pulse repetition frequency depended on the length of the input channel. This is evidence that the waves are not effectively enough absorbed in the input channel and that it is necessary to examine the resonant properties of the entire system treated as a complex acoustic resonator.

Thus, as follows from Fig. 2, the maximum gas self-pumping velocity was reached in $CO_2$ at a pulse repetition frequency 310 Hz and amounted to 1 m/sec. The width of the discharge region along the stream was 2.5 mm. It should be noted that a resonant increase of the self-pumping velocity was also observed at a pulse repetition frequency $f$ equal to $\nu_1/2$, but weaker than at $f = \nu_1$.

The importance of realizing self-pumping in pulsed-periodic $CO_2$ lasers is directly connected with the progressin the development of electrode systems that are not sensitive to the gas dynamic inhomogeneities of the medium and that ensure large energy input into the discharge. The use of mechanical valves in place of aerodynamic valves would also increase the effectiveness of the process, but these operate only at low discharge-pulse repetition frequencies.

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