Experimental installation to study the influence of acoustic oscillations on the characteristics of a glow discharge

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Abstract. It is proposed a sketchy scheme of experimental installation to study the influence of acoustic oscillations having longitudinal, tangential, radial and combined forms on the parameters of a glow discharge.

1. Introduction
For half a century the development of laser technology have been created various types of lasers are designed for a variety of scientific and engineering problems. The effective use of laser technology are sufficiently diverse – this material processing, communication, computer science, medicine and many others.

The most significant area of application of lasers is laser processing of materials, which is based, in most cases on the thermal effect of laser radiation. The advantages of laser machining in comparison with other methods is chemical purity, controlled temperature profile, the shape and depth of the zone of thermal effects, small additional machining, contactless operation and ease of automation [1].

Among laser sources used for the treatment of materials, the most widely used high-power gas (CO₂) lasers. Thereby actual task is to develop new ways to increase the power of industrial lasers to produce a significantly higher energy efficiency to make significant progress in the development process of laser treatment.

Our research team carries out studies in the field of vacuum-plasma and plasma-chemical processes production of functional coatings and products. In [2] presents the rationale of effective influence of the transverse acoustic oscillations on constricted electrical discharge that leads to the preservation of the diffuse form of the glow discharge and increase the energy input to the discharge of a CO₂ laser. Objects of research in [3] are coatings and technology of their applying to the piezoelectric elements for ultrasound. Method of plasma coating to restore the defective medical ultrasonic sensors is presented in [4]. In [5] investigated non-independent electrical discharge in the longitudinal flow of dust-electron plasma. In this paper we propose a schematic diagram of the experimental setup to investigate the influence of different forms of acoustic oscillations on the parameters of the glow discharge. Using this experimental setup we can test and debug an acoustic method of preventing instabilities.

2. Methods of prevent the occurrence of instabilities
Uniform diffuse state of the positive column of a glow discharge in the CO₂ laser is often unstable, especially when the discharge is in large volumes at high pressures, high current, and Joule heat release. Random perturbations increase and the plasma goes into a different spatially inhomogeneous
state – contraction. Contraction – compression of the plasma in a brightly glowing cord, and then goes into the arc. Development of the instability of this type in the electric discharge chamber of gas lasers stops lasing laser radiation. Overcoming the contraction of the discharge is the most difficult task in the development of high-power gas lasers.

There are several traditional ways to overcome the instabilities – partitioning the cathode, pumping gas through the discharge gap, the excitation of small-scale turbulence in the gas flow, the use of self-sustaining discharge. Integrated use of these methods can significantly increase the energy input into the diffuse discharge [6, 7].

Increased interest is the acoustic method prevent the occurrence of instabilities glow. Resonance phenomenon of acoustic oscillations in a confined space is widely studied and used in various types of devices: the combustion chambers of rocket and aircraft engines, and other heat power installations. We should also mention vibration combustion, which is accompanied by an acceleration of heat transfer to the walls of the combustion chamber, improving combustion efficiency in comparison with the stable stationary combustion mode [8, 9].

The essence of the method is to prevent the occurrence of instabilities of the glow discharge consists in excited by acoustic oscillations in the discharge chamber of a CO\textsubscript{2} laser. The presence of acoustic oscillations in the discharge gap is accompanied by a modification of a bell-shaped spatial distribution of the electron density along the radius of the tube on the parabolic. Increases the longitudinal electric field decreases the radial temperature gradient, increased diffusion losses of charged particles on the wall [10]. Displaying when the sound is muted a inverted population of the gas in the tube with the subsequent generation of flash super luminescent light, supporting the homogeneous state of the excited gas, due to a series of recombination and relaxation processes in the plasma [11].

3. The apparatus of the experimental installation

As shown in [2, 12] the excitation of the transverse acoustic oscillations in the discharge chamber of CO\textsubscript{2}-lasers could improve the acoustic method for preventing the occurrence of instabilities. But before apply this technology in the development of CO\textsubscript{2}-lasers, it is necessary to conduct comprehensive investigations of the influence of the transverse acoustic oscillations on the glow discharge. For this purpose developed an experimental installation for the studies of the influence of acoustic oscillations on the characteristics of a glow discharge. Schematic diagram of the experimental installation is shown in figure 1.

![Figure 1. Schematic diagram of the experimental installation.](image-url)
Experimental installation includes a set of quartz tubes 1, Copper electrodes 2 (cooled with running water), electroacoustic device 3, LFO 4, a microphone 5 (which can move along the inner wall end), Oscilloscope 6, a high voltage DC source 7, ballast resistance 8 (designed to stabilize and prevent the disruption of a glow discharge in an electric arc), voltmeter 9, ammeter 10, vacuum pump 11 and a pressure gauge 12. To measure the radial temperature gradient in the discharge gap have two thermocouples 13 on the wall and the axis of the chamber. Detachable ends of discharge chamber 14 designed for mounting the optical resonator.

Since we are using the system kilowatt power with large diameter, we have an opportunity install optical resonators of different types – the stable and unstable [13]. In the case of block with an unstable optical cavity installation is provided to output radiation. Block contains intracavity aperture mirror mounted at an angle to the optical axis 45°. Intensity distribution of output radiation in the near field has the shape of a ring. Schematic diagram of the optical unit to output radiation is shown in figure 2.

![Figure 2. Schematic diagram of the optical unit to output radiation.](image)

To achieve low vacuum sufficient mechanical pumping means [6]. In the vacuum system of the experimental installation, the pumping means is a rotary vane pump 11. There is the possibility of organizing a mean flow of gas through the discharge gap. The main parameters of the experimental installation are shown in table 1.

| Parameter                          | Value                  |
|------------------------------------|------------------------|
| Voltage range                      | 0-30 kV                |
| Pressure range                     | 1 до 760 torr          |
| Sound intensities range            | от 80 до 130 Db        |
| Frequency range of the acoustic oscillations | от 50 до 20000 Hz |
| The radius of the discharge chamber | 0,046 m               |

4. Conclusions
The geometrical dimensions of the discharge chamber allow to excite acoustic oscillations of different modes at sound frequencies is perceptible by humans. Longitudinal acoustic oscillations are the most common type of sound in nature. A standing wave of longitudinal acoustic oscillations is characterized by alternating successive maximum and minimum of the pressure and velocity along the axis of the chamber. Particle displacement occurs along the discharge chamber. Transverse acoustic modes of oscillations are of three types – the tangential, radial and combined. For these modes the displacement along the axis of no gas oscillates only in the direction perpendicular to the axis of the discharge.
chamber. Combined modes of transverse oscillations are mixed oscillations that are tangential component and radial component of the vibrational velocity. The frequency of these oscillations is proportional to the order transverse modes. According to the parameters of the experimental installation is given in table 1 in the discharge chamber can excite modes tangential acoustic oscillations of the twelfth order and modes radial acoustic oscillations of the fifth order. Combined modes can be realized when excited tangential and radial oscillations of the third order together.

Visualization of processes occurring in the discharge chamber, measuring the current-voltage characteristics and the temperature gradient between the axis and the wall of the discharge chamber allow an assessment of the thermal conductivity in the radial direction, the energy input into the glow discharge and the volume of plasma formations.

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

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