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INFRARED RADIATION IN CO_2:N_2:He ACOUSTOPLASMA

Aleksan. S. ABRAHAMYAN, Suren. A. CHILINGARYAN, Ruben. Yu. CHILINGARYAN,
Karen. V. HAKOBYAN, Aghasi. S. MIKAYELYAN and Kristine. G. SAHAKYAN
Institute of Applied Problems of Physics, National Academy of Science of the Republic of Armenia,
25 H. Nersisyan St., Yerevan, 375014, Republic of Armenia
E-mail: rubo01@yahoo.com

ABSTRACT: Modulation of the discharge current by a sinusoidal law in a discharge tube excites an acoustic field and plasma transferred to acoustoplasma state.
It is shown, that parameters of the acoustoplasma significantly differ from the parameters of the unperturbed plasma. For the discharge tube of a CO_2 laser, operating in an acoustoplasma state, experimentally have been shown power-current characteristics and the Fourier spectra of laser pulses at 10.6 microns.
The same time, the results of experiment show, that in acoustoplasma all the defining parameters of the plasma strongly depend on the components of a mixture of gases in the discharge, frequency and modulation depth of the discharge current.

KEYWORDS: acoustoplasma, infrared radiation, CO_2 laser, acoustic interaction on plasma

Cold plasma Interactions with acoustic waves are being studied 20 years In the Institute Of Applied Problems Of Physics Of The NAS RA.

If supply discharge tube by modulated current, which contains constant and variable components, the variable component loads to a generation of acoustic waves in a tube [1,2]. These acoustic waves interact with the plasma, through which flows modulated current. Consequently plasma transforms to a new state, which has been called acoustoplasma [1]. Parameters of the acoustoplasma can considerably differ from the parameters of plasma without acoustic interaction (unperterbed plasma).

In Figure1 shown the block diagram of the experimental setup. Source of the DC voltage (1) is connected to the anode (3) of the discharge tube. Discharge current flowing through the tube is modulated by the variable ballast (4), which is connected to the cathode of the tube. High-voltage electron lamp was used as a variable ballast resistance. Schema of the lamp as a current generator provides possibility to obtain a sinusoidally modulated current (with constant and variable components) on the cathode of the tube. Sound generator (6) provides the necessary frequency and amplitude for the modulation current. Nonlinearity of the parameters of the discharge tube leads to a fact, that the current on the anode can be non-sinusoidal. The magnitude of the discharge current was measured by mA-meter (2). KV-meter (5) shows the voltage, which is applied to the anode-cathode interval of the discharge tube. Signals from mA-meter (2) and kV-meter (5) were fed to a digital indicator and dual-beam oscilloscope. Pressure, temperature of the discharge and light were measured also during the experiments. As the state of plasma can change very quickly, even with sudden jumps, experiments with acoustoplasma require a large number of simultaneously measured parameters.

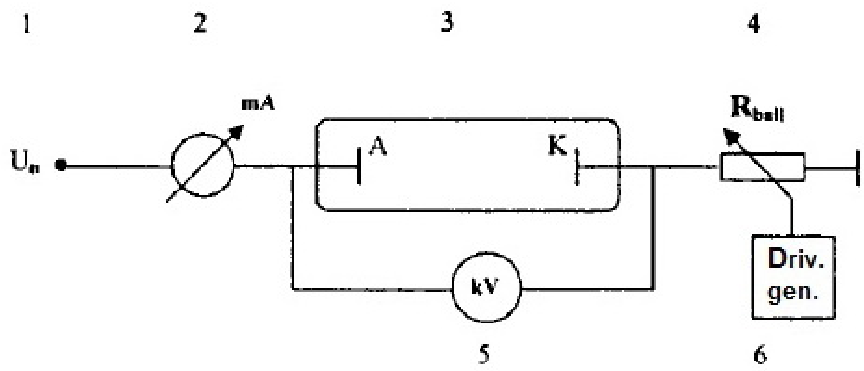

Figure 1: Block diagram of the experimental setup; 1-Source of the regulated high-voltage DC voltage; 2-mA-meter; 3-Discharge tube; 4-ballast resistor; 5-kV-meter; 6-Driving generator

In Figure 2 shown the diagram of the experiment.

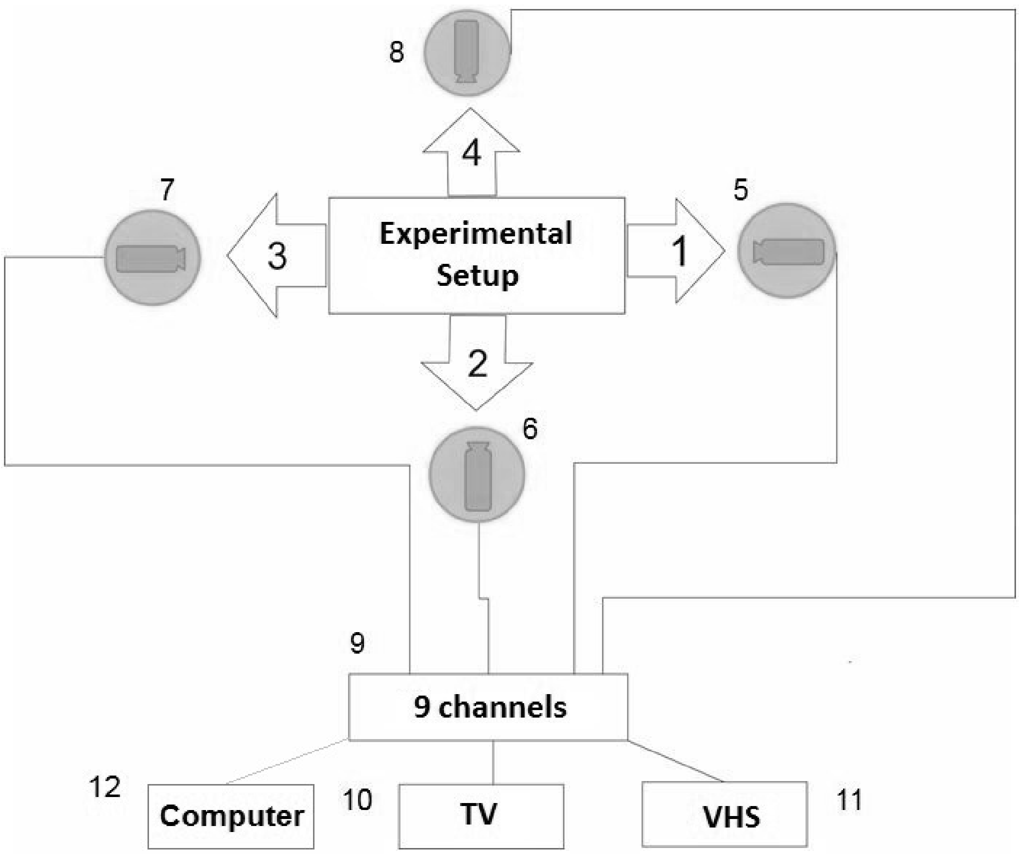

Figure 2: Scheme of the measuring system; 1-4 the information flow from the experimental setup; 5-8 cameras; 9–nine channel video surveillance system; 10-TV monitor; 11-video recorder; 12-computer

Many parameters were simultaneously measured on experimental setup: channel 1 – electric parameters (current, voltage, frequency); channel 2 - optical parameters (brightness, modulation of brightness, spectrum, etc.); channel 3 - thermodynamic parameters (pressure, temperature); channel 4 – geometric and external view of the discharge.

All the data from digital and analog devices and oscillograph were recorded by video cameras (5-8). All the channels were merged to the one standard TV frame by nine channel video surveillance system (9). TV frames were recorded on the video recorder (11) in VHS standard and on computer (12). On one videotape was recorded from 4 to 8 hours of the experiment.

Such kind of system allows to one time conducting an experiment, obtaining great database and then repeatedly reproducing any part of the experiment by video cassette, without repeating the real experiment.

In Figure 3 it's shown the temporary characteristics of the discharge current (curve1) and the output optical power of CO_2 laser at a wavelength of 10.6 microns (curve2). Abscissa represents current time, ordinate represents: for discharge current – mA, for output optical power - real power multiplied by 100.

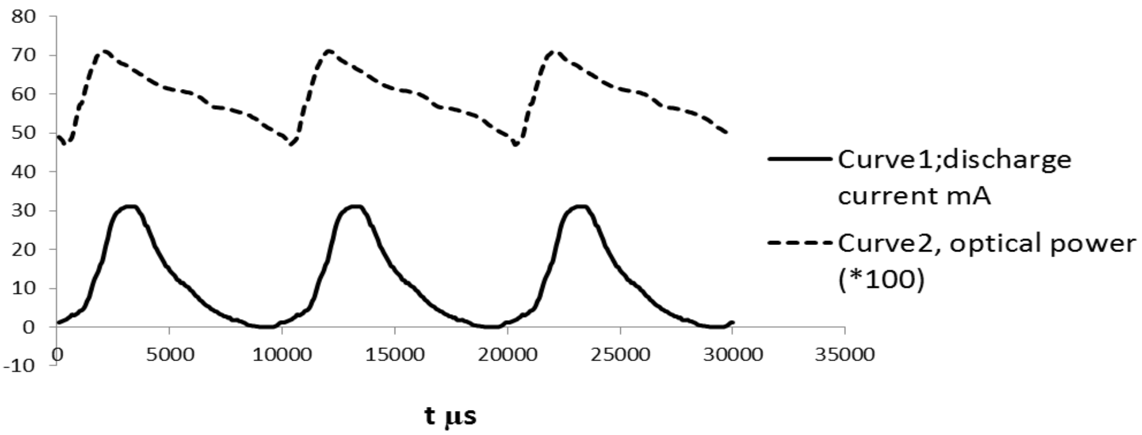

Figure 3: The temporary characteristics of the discharge current (curve1) and output optical power of CO2 laser at a wavelength of 10.6 microns (curve2)

Data from the graph (Figure 3, curve2) should be divided by 100 , in order to get a real optical power of the laser (i.e. optical power varied from 0,5 to 0,75 W).

Without acoustic disturbance at the same pump power for a plasma (under the similar parameters) optical power was less 20-30%. Though, if we compare the maximum power in acoustoplasma mode with the power at constant current, in acoustoplasma mode the benefit is 1,5 times or more.

For plots shown in Figure.3, the depth of the modulation was approximately 1 (modulation depth is the ratio of the RMS value of the variable component of the discharge current to the value of a constant component) and the frequency of modulation was 100 Hz. The value of the constant component of the discharge current is equal to 10 mA. In the laser we used mixture of CO_2:N_2:He= 1:1:8 at a pressure of 10 torr. The measurement error in the experiment is up to the thickness of the lines in graphics, and therefore the error is not specified.

In Figure 4 shown the Fourier components of the amplitudes of the discharge current (4a) and the optical power (4) respectively for the first 10 harmonics of the main frequency of the modulation. The abscissa represents the harmonic number (n). The ordinate represents the current in mA (Logarithmic scale) and the light in relative unit (Logarithmic scale).

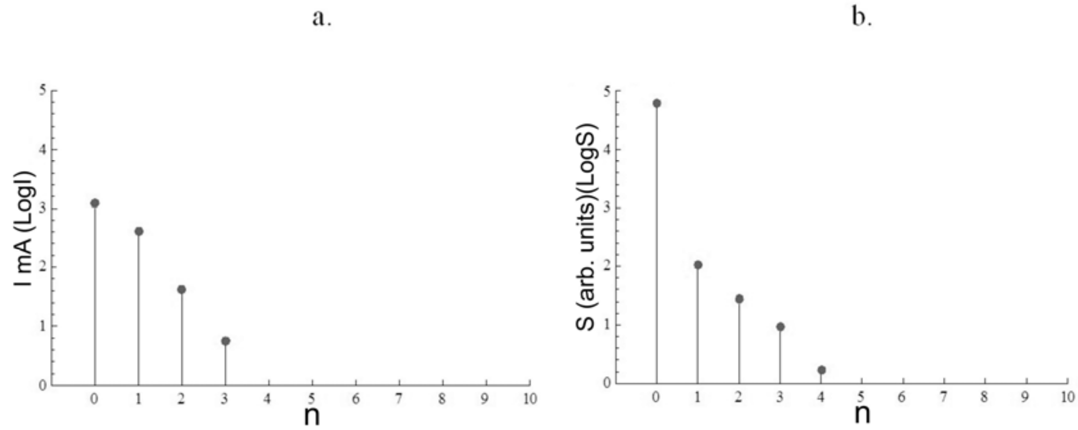

Figure 4: Fourier components of the amplitudes of the discharge current (a) and optical power (b) for the first 10 harmonics of the main modulation frequency (100Hz)

Acoustoplasma interaction strongly depends on the components of the gas mixture. In Figure 5 it is shown the spectra of near UV radiation, visible and near IR regions (0, 35-1, 7 µm) from the discharge of CO_2 laser. We have used the same laser tube. The gas pressure in both cases was 10 torr, the average discharge current 11 mA and the laser power approximately 1 Watt. We used "Ocean Optics Inc. PC2000" spectrometer. Abscissa represents wavelength of radiation from plasma (nm), and ordinate axis the intensity of spectral components in relative units. Figure 5(a,c) corresponds to the standard factory laser mixture containing not only CO_2, N_2, and He, but also small amount of Xe and vapor of H_2O. Xe is used to facilitate the ignition. Water vapor stabilizes the parameters. Figure 5(b,d) corresponds to a laser mixture of CO_2:N_2:He=1:1:8 without any additives. Figure 5(a,b) corresponds to the discharge at a constant component of current and Figure 5(c,d) to the work in acoustoplasma mode with a modulation depth equal to 1.

From Figure 5 we see, that in acoustoplasma mode for a mixture containing water vapor and Xe (Figure 5c) active destruction of acoustoplasma take place, and the emission spectrum is slightly differ from the plasma emission without acoustic disturbance (on constant discharge current, Figure 5a). A sharp increase of intensity of radiation observes in the region of 400 nm in acoustoplasma mode for a mixture do not contain water vapor and Xe (Figure 5d). Investigation of the electrical characteristics and the optical power changes of the acoustoplasma discharge proved that tendency.

From Figure 3 and 4 follows: when the frequency of modulation equal to 100 Hz, it is sufficient to consider the first 4 harmonics of signals. The first longitudinal resonance of the resonator, which was formed by a laser tube, was also in an interval of 300 - 400 Hz. From Figure 4(b) it's evident, that on the first longitudinal acoustic resonance frequency (300-400Hz) the contribution of the harmonics to the total power of radiation is much greater than in the modulation current. For current $W_{3,4}/W_{1-4}$=0,21 and for optical power $W_{3,4}/W_{1-4}$=0,45. Here $W_{3,4}$ is the total capacity of the third and fourth harmonics, W_{1-4} is the total capacity of the first four harmonics of the modulation frequency. The null harmonic (i.e. constant components) does not take into account.

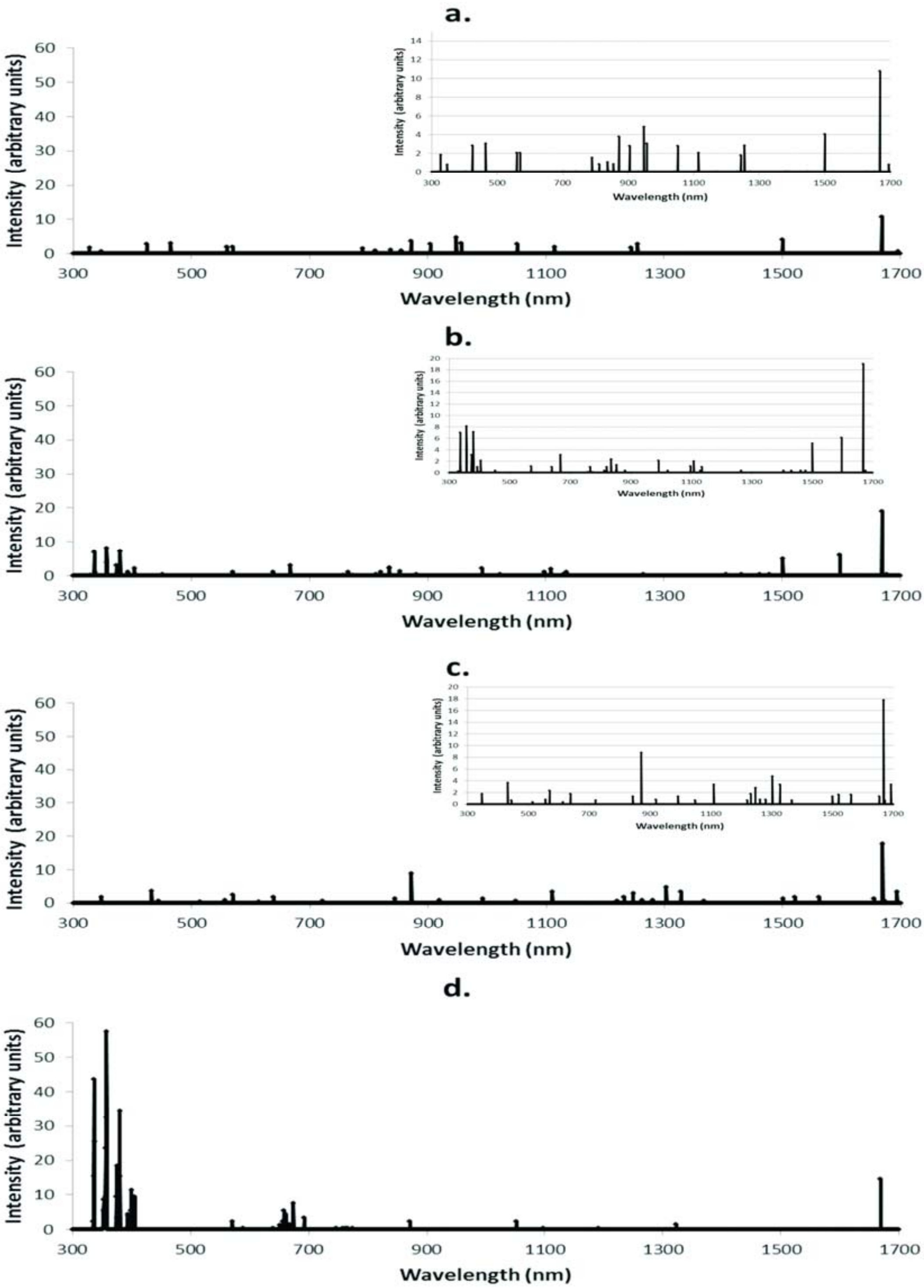

Figure 5: Emission spectrum in the region of 0,35-1,7 µm from the plasma of a CO_2 laser; a. without acoustic disturbance for a mixture containing water vapor and Xe; b. without acoustic disturbance for a mixture do not contain water vapor and Xe c. acoustoplasma mode for a mixture containing water vapor and Xe, d. acoustoplasma mode for a mixture do not contain water vapor and Xe; the inserts are the same spectra by intensity Zoom

Thereby:

1. Acoustic waves interact with the plasma, through which flows modulated current and plasma transforms to a new state, which has been called acoustoplasma.
2. Acoustoplasma strongly depends on the components of a mixture of gases. Water vapor destroys acoustoplasma state.
3. For the same pump power, in acoustoplasma state spectral components in the short-range significantly increase compare with the state working on constant component of the current.
4. Optical emmision of the CO_2 laser in acoustoplasma state is modulated by amplitude. Without acoustic disturbance at the same pump power for a plasma (under the similar parameters) optical power is less 20-30%. Though, if we compare the maximum power in acoustoplasma mode with the power at the constant current, in acoustoplasma mode the benefit is 1,5 times or more.

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