oA9

OPTICAL RADIATION IN THE VISIBLE RANGE IN CO_2:N_2:He ACOUSTOPLASMA

Aleksan S. ABRAHAMYAN, Suren A. CHILINGARYAN and Karen V. HAKOBYAN
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: karenvhak@gmail.com

ABSTRACT: Experimentally in CO_2 acoustoplasma laser, oscillograms of the integral optical radiation and the spectral components, which represented by Fourier spectra, have been obtained. Experimentally it is shown, that under certain discharge conditions (pressure, depth and frequency of the discharge current modulation) the intensity of optical radiation in the tube can change abruptly, when the discharge current varies smoothly.

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

In CO_2 laser, papers usually focused on radiation with a 10.6 microns wavelength. However, other emission lines are being excited in laser mixtures, including those in the visible wavelength range. The spectrum and intensity of these lines in the near UV (ultraviolet), IR (infrared) and visible spectral regions may provide useful information to describe acoustoplasma discharge. As opposed to the vibrational-rotational lines of molecules (working in the area of 10.6 microns), electronic spectra is already work in 0,35-1,7 microns. Research of the CO_2 laser radiation spectra in the visible range is necessary for several reasons. Firstly, up to today in the theory of electrons spectra there are more clarity than in the theory of molecular spectra. Secondly, joint study of the emission spectra in the areas of 10.6 microns and visible range will distinguish which of the acoustoplasma effects is associated with the molecules vibrations and which with the kinetics of the electrons formed in a fields of acoustoplasma.

Experiment scheme and setup are similar to those described in [1]. The differences were as follows. We used a discharge tube with flat glass windows at the ends. Discharge length was 25cm. Radiation, had withdrawn from the end of the tube, was connected to the input of the spectrometer with a quartz light guide ("Ocean Optics Inc. PC2000' computer-based spectrograph) and to a photodiode. The photodiode detected changes in time (during one period of modulation of the discharge current) of the integral optical signal in the 0,35-1,7µm wavelength range. Simultaneously, we detected the discharge current changes in time (for the period of modulation). The discharge voltage and other parameters of the experiment also were recorded. In Figure 1 are shown the discharge current's (I) (Figure 1a) and the integral optical signal's (S) changes in time (Figure 1b) for a period of discharge current modulation. Pressure of the gas mixture (CO_2:N_2:He=1:1:8) in the tube was Po=21torr, the modulation frequency f=280Hz, the modulation depth $M \approx 1$ (ratio of the RMS value of the discharge current variable component to the constant component). The measurement error in the experiment is up to the thickness of the lines in graphics, therefore, the error is not specified.

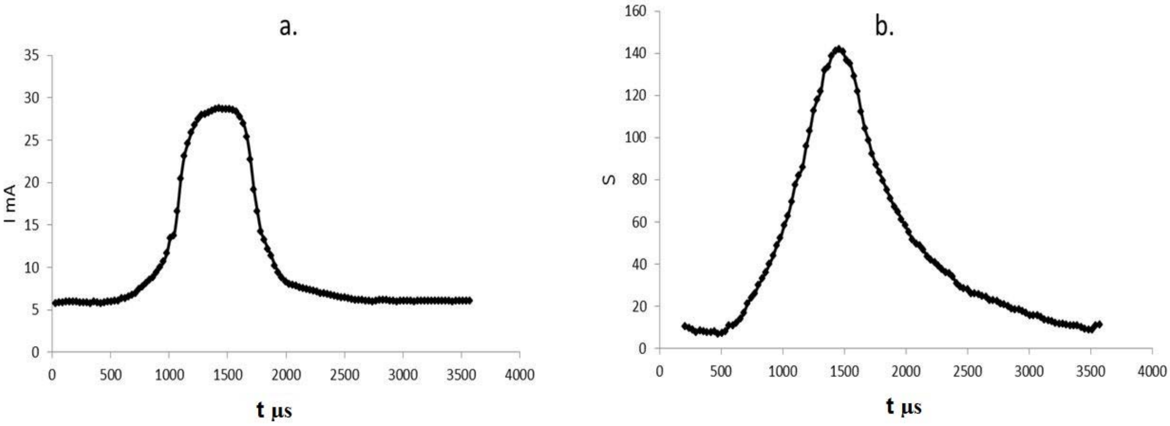

Figure 1: The acoustoplasma discharge characteristics changes in time for the period of modulation; a. discharge current (I), b. integrated intensity of the light beam (S) (in the range of 0,35-1,7 μm)

Abscissa is the time in microseconds, ordinate, respectively, is the instantaneous value of discharge current (mA) and light beam intensity (in relative units.).

We measured the static and dynamic characteristics. Characteristic called static, when the time between successive measurements (or counts) is greater than the longest relaxation time, which characterizes the process (i.e. when all processes in the discharge can be considered as steady-state). If that time is less than relaxation time, we have dynamic characteristics, which can be obtained by considering with together I(t) and S(t) parametric equations (t is the time, I-discharge current, S-light intensity of discharge in the direction of the fiber).

Figure 2 shows the light-current dynamic characteristic. Here abscissa is the discharge current (mA) and the ordinate the light intensity (in relative units).

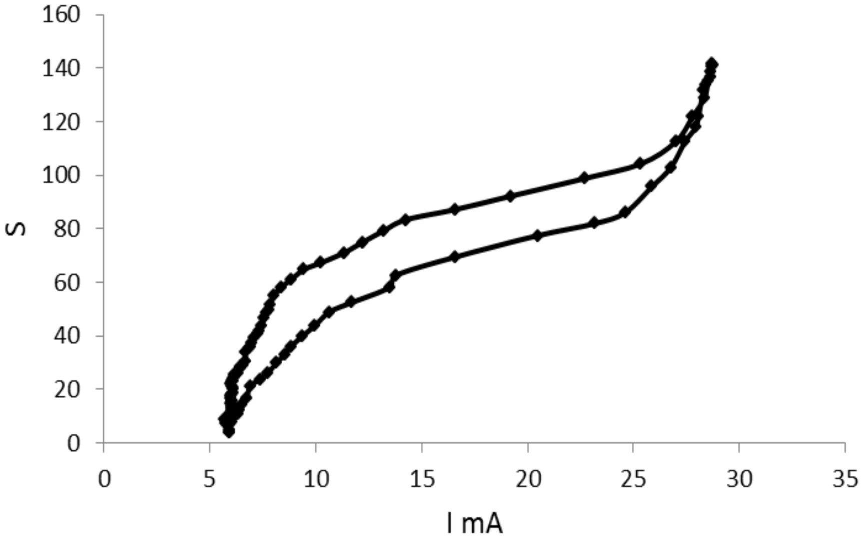

Figure 2: Light-current dynamic characteristic

In our case, when modulation frequency is 280Hz, part of the relaxation processes have time to complete, and some do not. Therefore, the dynamic characteristic takes the form shown in Figure 2. Here, the part of the recombination processes had time to finish [2], but the decay processes of acoustoplasma had not been occurred yet [3]. Relaxation of the nitrogen molecules long-lived levels (υ=1) was also not complete. These arguments apply only to the discharge current variable component. The constant component presents throughout the period of modulation.

In Figure 1 and 2 shown, that the light-current dynamic characteristic is nonlinear and there is a hysteretic. This hysteresis can be described as a “cusp” catastrophe [4]. That is, the optical radiation intensity changes abruptly.

Figure 3 shows the Fourier spectra of the discharge current and optical signal of Figure 1.

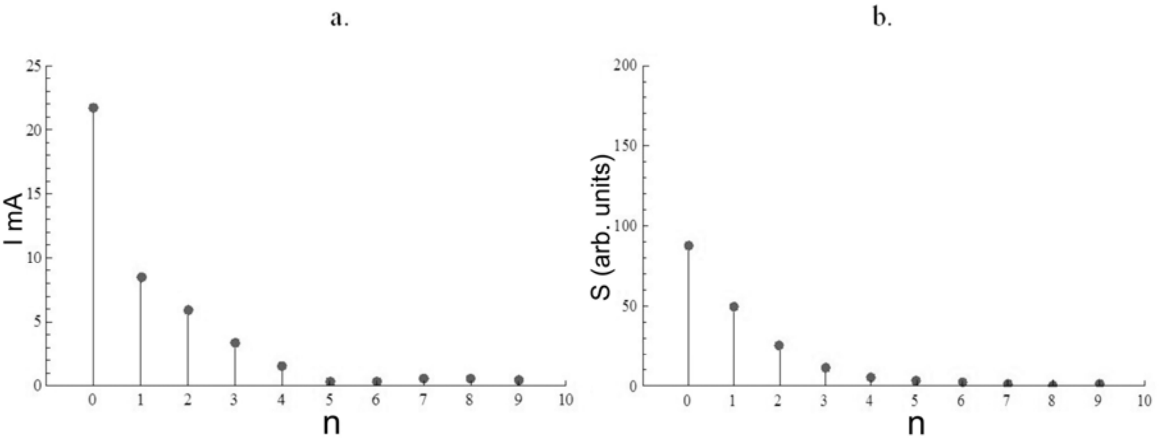

Figure 3: Fourier spectra of the amplitudes of the signals harmonic shown in Figure 1; a. for the discharge current, b. for the optical signal

Coefficient of the harmonic distortion can be determined, having the Fourier spectrum amplitudes.

$$K = \frac{\sqrt{\sum_{i=2}^{n} U_i^2}}{U_1}$$

where K is the coefficient of nonlinear distortion, U_1 the amplitude of the first harmonic, $\sum_{i=2}^{n} U_i^2$ is the sum of the squares of the higher harmonics amplitudes.

For the curves shown in Figure 1-3 the coefficient of nonlinear distortion for a current K(I)= 0,85 and for a light K(S)=0,57.

Figure 4 shows the light and current curves at the other parameters of the discharge. On the section AB, with increasing current, intensity of the light also increases (almost linearly). At the point B it increases abruptly at a constant and maximum current (Figure 4c, section BC). On CD it is constant, although the current decreases from 30 to 10mA. Finally, on DA intensity of light drops abruptly (17 times) by a little decrease of current.

Comparing Figure 2 and 4(c), we see that the hysteresis in Figure 4 is much larger than in Figure 2. In addition, it has more complex character and for its description it is advisable to apply a higher order catastrophe (for ex."swallowtail") [4].

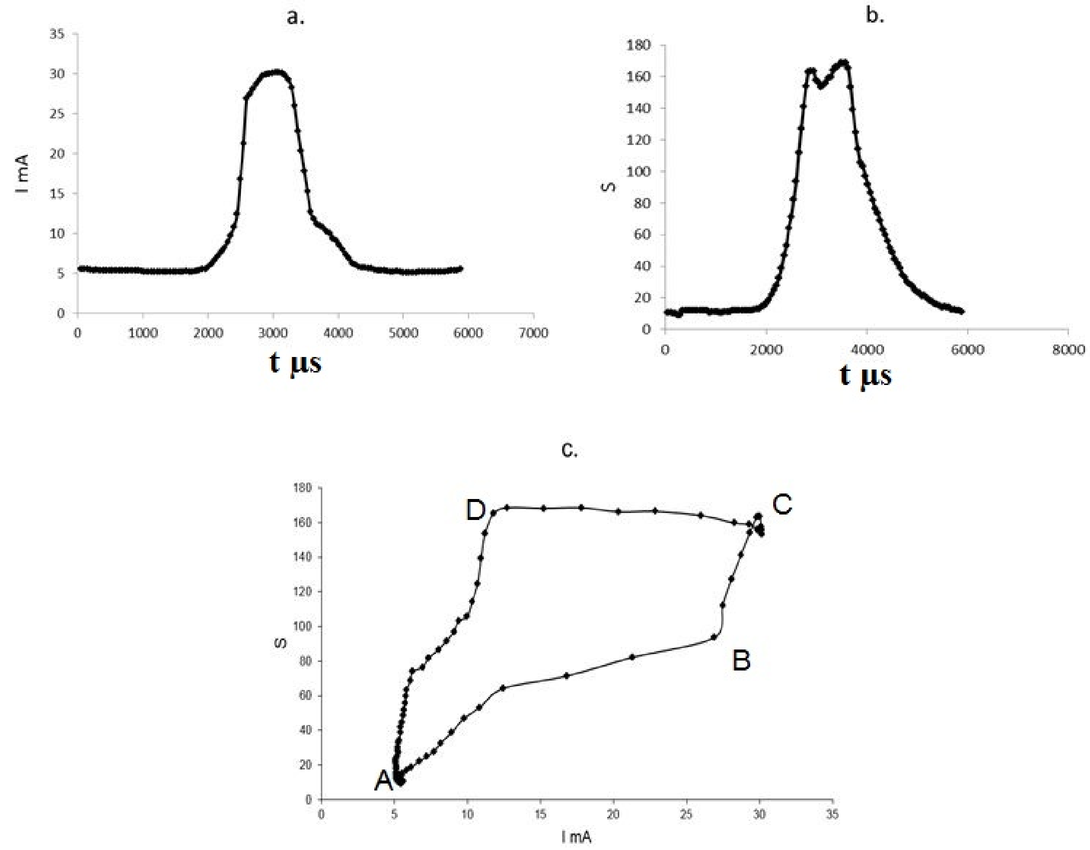

Figure 4: Curves of current, light and dynamic characteristics for Po=15torr, f=170Hz; a. discharge current, b. the integrated light flux, c. dynamic characteristic

The nonlinear distortion coefficients for different discharge parameters are shown in Table 1. The modulation depth M was the same (about 1).

Table 1: The nonlinear distortion coefficients for different discharge parameters

N	Po (torr)	f mod. (Hz)	K(I)	K(S)
1	21	280	0,85	0,57
2	15	170	0,92	0,57
3	9	100	0,92	0,73

We see, that with the discharge current modulation frequency decreasing, the coefficient of light signal distortions is growing faster than the coefficient of current nonlinear distortions. This is due to the fact, that the current's carriers recombination is faster than the relaxation of long-lived excited levels in plasma. In time near 10µs (modulation frequency of 100Hz) the current's carriers recombination have already ended, but we have no excitements yet. Therefore, when the current modulation frequency is below 200Hz, K(I) practically retained to its value, and K(S) increases.

With the pressure decreasing, due to the decrease of collisions, excitation time also increases. When we compare Figure 1 and 4, we see, that the current pulse duration (on half-height) is near 1µs in both cases. But the duration of light pulse is near 1µs, when the pressure is 21torr and modulation frequency 280Hz, and less than 1µs, when the pressure is 15torr and frequency modulation 170Hz.

Figure 5 shows the spectra of CO_2 (CO_2:N_2:He=1:1:8) laser emission in the range of 0,35-1,7µm. It was got by a “Ocean Optics Inc. PC2000” spectrograph. The pressure in gas was Po=10torr, the modulation frequency f=100Hz. Figure 5(a) shows the optical spectrum of the plasma without acoustic disturbance (on constant component of discharge current). Figure 5(b) shows the spectrum of emission in acoustoplasma mode, when the discharge current modulation depth is M=1. In acoustoplasma mode the intensity of spectral lines in the UV and visible spectrums significantly increases.

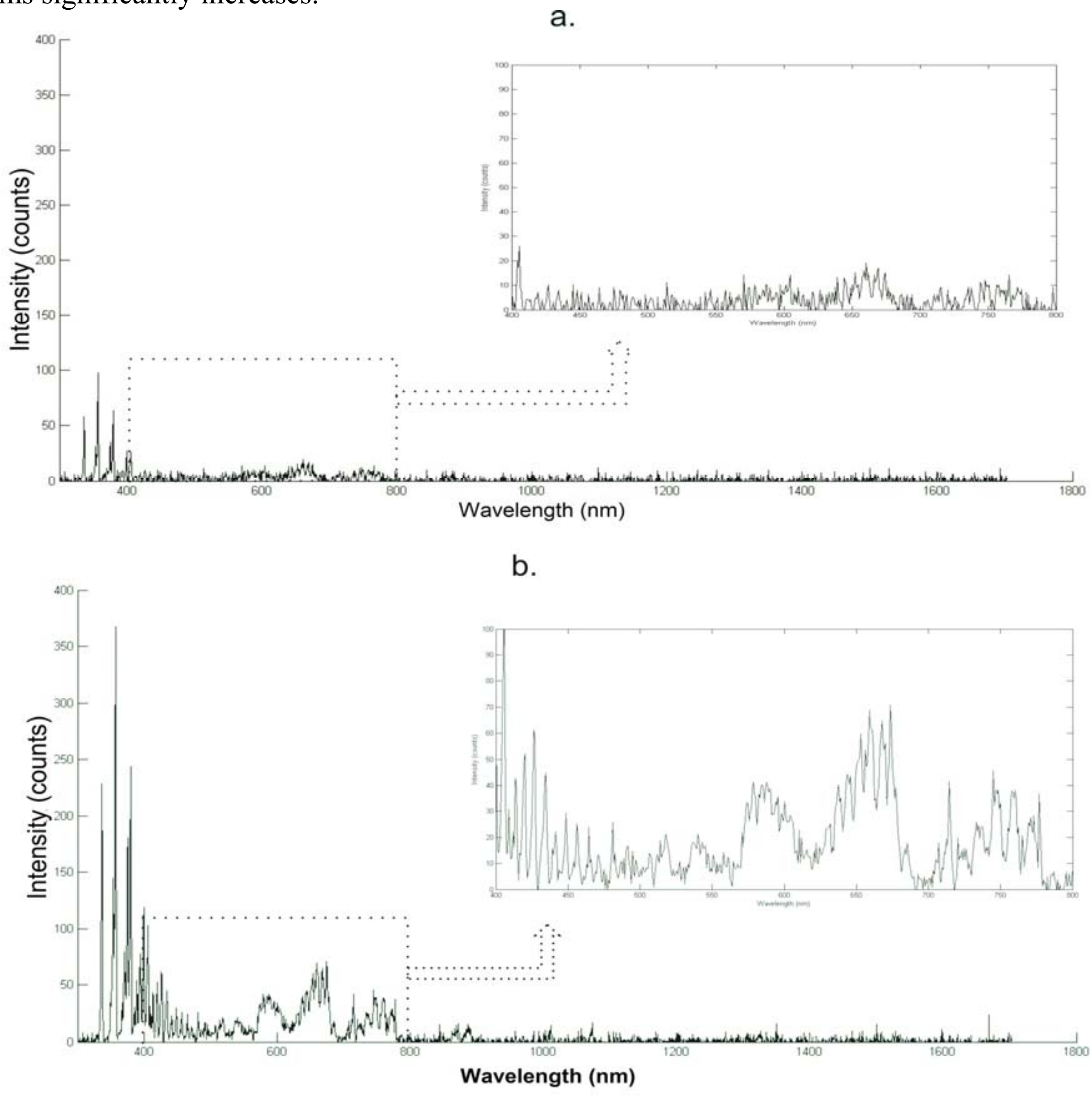

Figure 5: Plasma radiation spectra of the CO_2 laser, the pressure is 10torr, modulation frequency 100Hz; a. spectrum without acoustic disturbance, b. spectrum in acoustoplasma with M=1 modulation depth

Thus, creating an acoustoplasma regime in the plasma of CO_2 laser allows to change the radiation spectral components in the ultraviolet and visible regions. Also abruptly changes the intensity of optical radiation, while the discharge current changes smoothly. Acoustoplasma changes the hysteresis of light-current dynamic characteristic. According to the experimental data various parameters of the discharge can be evaluated.

References

[1] Abrahamyan A.S., Chilingaryan S.A., Chilingaryan R.Yu., Hakobyan K.V., Milayelyan A.S., Sahakyan Q.G.; Infrared radiation in CO_2:N_2:He Acoustoplasma; (in this Proceeding)

[2] Райзер Ю.П.; Физика газового разряда; Изд.2, М., Наука, 536с.; (1992)

[3] Мкртчян К.С., Абраамян А.С.; Время релаксации плазмы возмущенной акустической волной; Изв.НАН РА, Физика; т.40, N3, с.220-222; (2005)

[4] Poston T., Steward I.; Catastrophe Theory and its applications; London-Melbourne, Pitman, 607pg; (1978)