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Construction of Three-Dimensional Characteristics of Acoustoplasmic Processes

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Abstract: A new method for processing experimental data is presented that is suitable for cyclic processes that depend on three parameters. Two parameters vary smoothly, and the third can vary both smoothly and abruptly. The method is as follows: two-dimensional sections of the three-dimensional process are created - two-dimensional graphs of cyclic processes for each of the fixed values of the third parameter; a parameter that can vary jumps into a two-dimensional section; these two-dimensional graphs of cyclic processes are located along the axis of the third parameter for its corresponding values; all points with the same phases of a cyclic process are connected by straight line segments. It turns out the frame of the three-dimensional process. Any distortion of one of the parameters of the two-dimensional section leads to well-marked deformations of the three-dimensional frame. If necessary, the three-dimensional framework can be represented as a three-dimensional surface. The method can be used in various fields of science and technology.

Keywords: Experimental data processing method, acoustoplasma, phase transition

1. Introduction

The goal of any experiment is either to build a new mathematical expression for any dependencies of the process under study, to make a certain decision, or to estimate the probability of possible assumptions. The basis for a consistent theoretical approach to applied problems currently constitutes the methods of mathematical statistics. They allow producing a fairly good assessment and decision making. Computers allow to quickly perform complex calculations and process large amounts of data. In the future, computers will be able to fully take over the complete processing of experimentally obtained information. But today, the elementary "exploratory" analysis has not yet lost its significance. Such an “exploratory” analysis is well described in monographs [1,2]. And computers will be able to significantly simplify and speed up such an "exploratory" analysis. Most physical processes are multidimensional. For example, due to self-consistency, all processes in the plasma are multiparameter [3].

For the analysis of multidimensional processes, one can use the generalized theory of signals based on the decomposition of processes into various systems of basic orthogonal functions [4]. Instead of the Fourier transform (sinusoids of constant frequency and indefinite duration), at the present time, wavelet transforms (decomposition into pulsed basic functions of finite duration) are often used. As is known [5,6], the wavelet transform is better suited for signals of limited duration with abrupt changes in frequency and amplitude. The combinatorial methods given in [1] can also be used.

One of the methods of this analysis is a graphical representation of the information received. Graphs of unidirectional processes do not cause difficulties and are easily perceived by human thinking. Cyclic processes are harder to represent graphically and harder for human perception.

For such processes, methods of dynamic systems have been developed [7-9]. Periodic fluctuations can also be represented by a cyclic process [10]. To adequately reflect the occurring phenomena, it is advisable to build multi-dimensional graphs. The first step towards an adequate description of multidimensional processes is the transition from two-dimensional sections of multidimensional processes to three-dimensional sections, i.e. construction of three-dimensional graphs. Particularly it is difficult to construct three-dimensional graphics of cyclic processes that contain jumps of parameters. In the transition to three-dimensional processes, you can use the theory of catastrophe [11-14].

In this paper, a technique for processing experimental data is presented, where the two parameters vary smoothly, and the third can vary both smoothly and unevenly. Generally, it is possible that only one parameter can vary smoothly, and the other two have both jumps and ambiguous values. But the graphic representation of such processes is rather similar to the painting of abstract artists, while the scientific perception of such graphic information requires a large share of the artistic imagination and is ambiguous.

2. The method of constructing three-dimensional characteristics

The technique is as follows:

1. On a dual-beam oscilloscope screen, oscillograms of two synchronized time scan of two processes under study are obtained with a fixed value of the third processInstead of a time sweep, you can use a sweep for some other process.Thus, we obtain a set of oscillograms for different values of the third process;
2. Then the oscillograms are digitized with the preservation of their original phasing obtained in the experiment. The quantization step is chosen sufficiently small. For example, in order to fit the first 6 harmonics of the Fourier transform entirely, each period of the cyclic signal is quantized into 120 parts (with the Fast Fourier Transform, if the harmonics do not fit entirely, then large errors may occur during the calculations);
3. Then time is eliminated and two-dimensional graphs of cyclic processes are created for each of the fixed values of the third process;
4. These two-dimensional graphs of cyclic processes are located along the axis of the third process, for its corresponding values;
5. All points with the same phases are connected by straight line segmentsThus we obtain the frame of the three-dimensional process. You can fill the frame with an appropriate surface, for example, using the Wolfram Mathematica software.

All phase transition points become well visible due to surface deformation.

3. An example and discussion

In the experiments, a sinusoidal modulation of the discharge current was performed (the current contained a constant and a variable component). The voltage on the discharge at the appropriate time was different from the sinusoidal one and could have jumps.

The processing of the oscillograms obtained on the measuring complex in the course of the experiment was as follows. When registering with a web-camera, the oscillogram image was directly recorded to a computer, when it was registered by video cameras it was recorded onto a video cassette recorder (VCR) and then from a VCR - into a computer.

After computer processing, the real time dependences of the current and voltage corresponding to these oscillograms over 3 periods of discharge current modulation are shown in Fig. 1. The abscissa axis shows the time in seconds, and the ordinate axis shows the instantaneous values of the discharge current in mA (Fig. 1a) and the instantaneous values of the voltage on the discharge tube in kV (Fig. 1b).

To enable further computer simulation of experimentally investigated processes, the experimentally obtained current, voltage, and other parameters describing the plasma are approximated by polynomials using appropriate computer software. Our studies have shown that approximation by a polynomial degree 5 is usually sufficient.

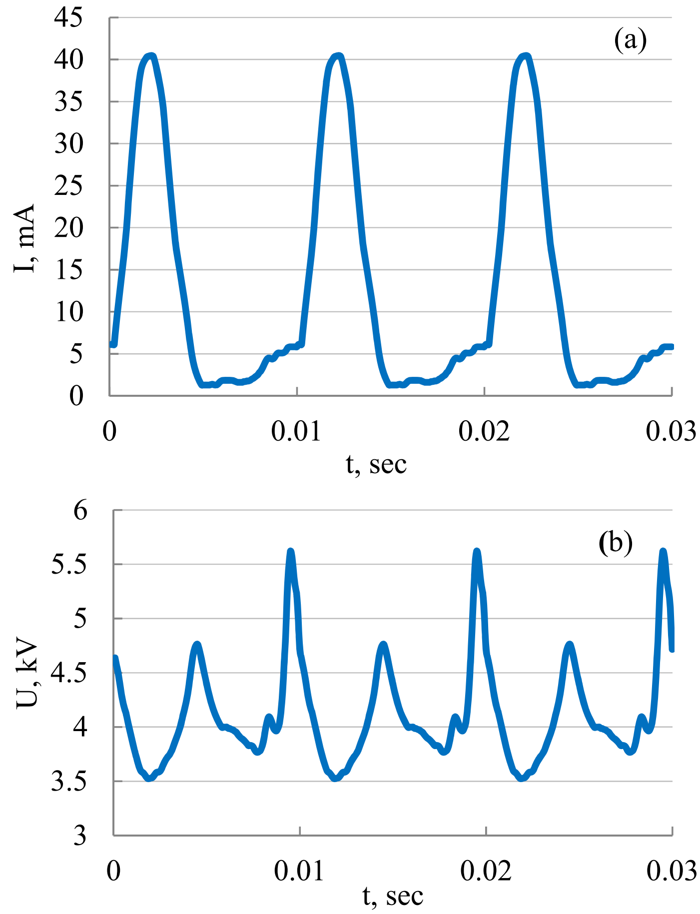

Fig. 1. Time dependencies of current (a) and voltage (b) after computer processing.

If the modulation time is less than the relaxation times, then there are dynamic characteristics. Dynamic characteristic can be obtained either by considering together parametric equations, for example $\{I(t)$ and $U(t)\}$ or by considering the dependence $U(I)$, where time t is excluded, I is the current value (during the modulation period) of the discharge current, U is the corresponding (at the same time) current voltage value on the discharge tube. The same dynamic characteristics can be obtained for other plasma parameters, for example, for the light flux S from the discharge in the direction of the optical fiber.

Figure 2 shows the dynamic current-voltage characteristics of the discharge in the acoustoplasma mode for several modulation frequencies. The abscissa axis is the current in mA, and the ordinate is the voltage in kV.

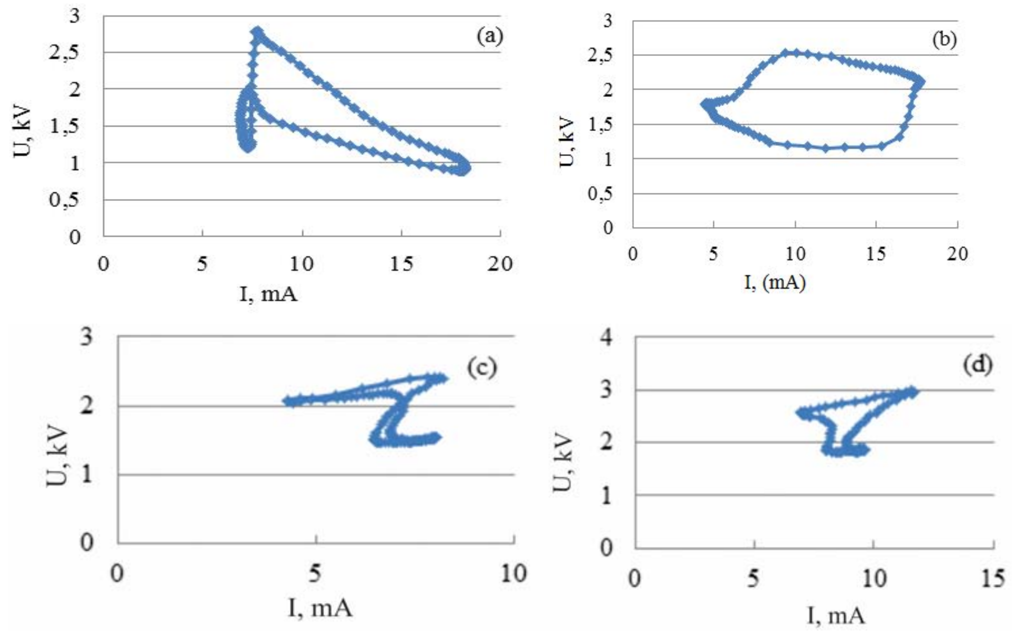

Fig.2. Dynamic current-voltage characteristic for several frequencies of discharge current modulation. A) 0.1 *kHz* b) 1 *kHz*, c) 10 *kHz*, d) 15 *kHz*.

For the usual characteristics, having one direction of change of parameters (either increases or decreases), it is possible to construct three-dimensional surfaces relatively easily, for example, in MS Excel. If one of the two parameters has a changing direction, then each of the values in one coordinate on the graph corresponds to more than one value in the other coordinate, i.e. the schedule becomes ambiguous. For example, for dynamic current-voltage characteristics, which are shown in Fig.2, we obtain closed curves. Each such curve can be represented as a section of a three-dimensional surface with a fixed third parameter (in our case, such a parameter is frequency).

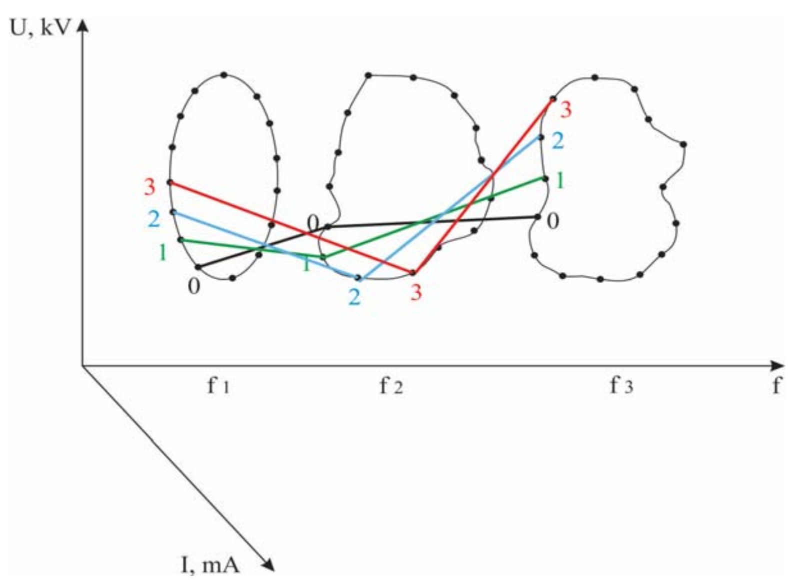

Fig.3. Schematic representation of obtaining three-dimensional framework of the process.

Fig.3 shows three such cross sections of a three-dimensional process.

Fix the initial phase, the same for all sections, in Fig. 3 - this is a black line (in our case it will be, for example, the minimum current). Then, all the values of the corresponding phase of the voltages for the different sections located one behind the other will be connected by straight line segments, as shown in Fig. 3. The black line corresponds to the zero phase. For real experimental data, for example, the minimum current can be chosen as the zero phase. Figure 4 represents one of those broken lines for experimental data.

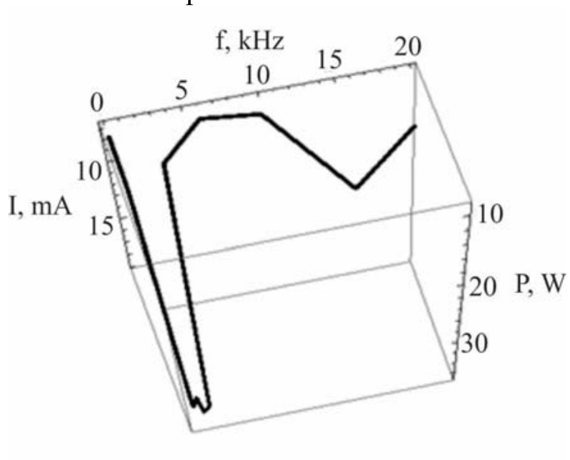

Fig.4. The broken line connects the same phrase in different sections corresponding to different frequencies.

Figure 4 shows the frame obtained from such broken lines. Here each section is a dynamic current-voltage characteristic for the corresponding modulation frequency of the delayed along the third coordinate. The frame is formed by straight lines connecting the same phases during one modulation period.

If necessary, with the help of appropriate programs (for example, Wolfram Matematica), it is possible to put a surface on the resulting frame, as shown in Fig. 6.

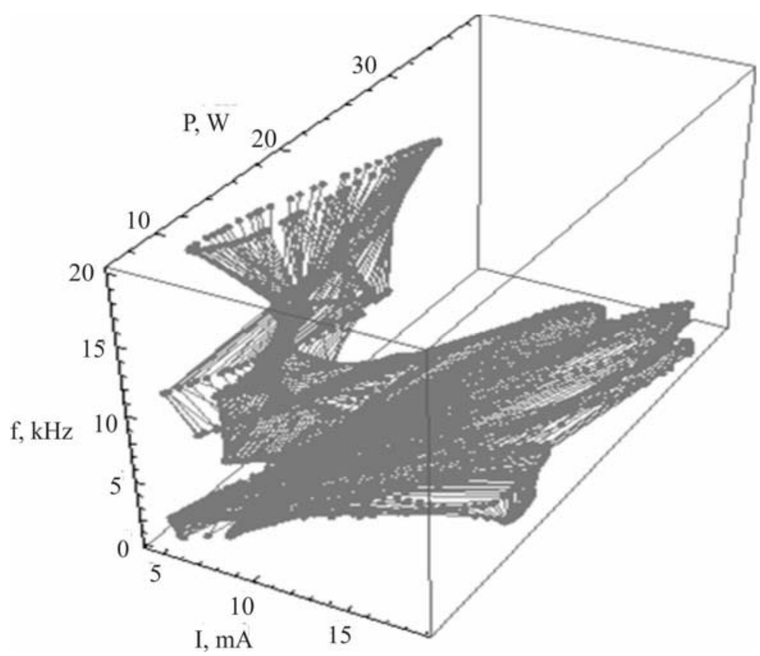

Fig.5. The framework of the three-dimensional process during the modulation period.

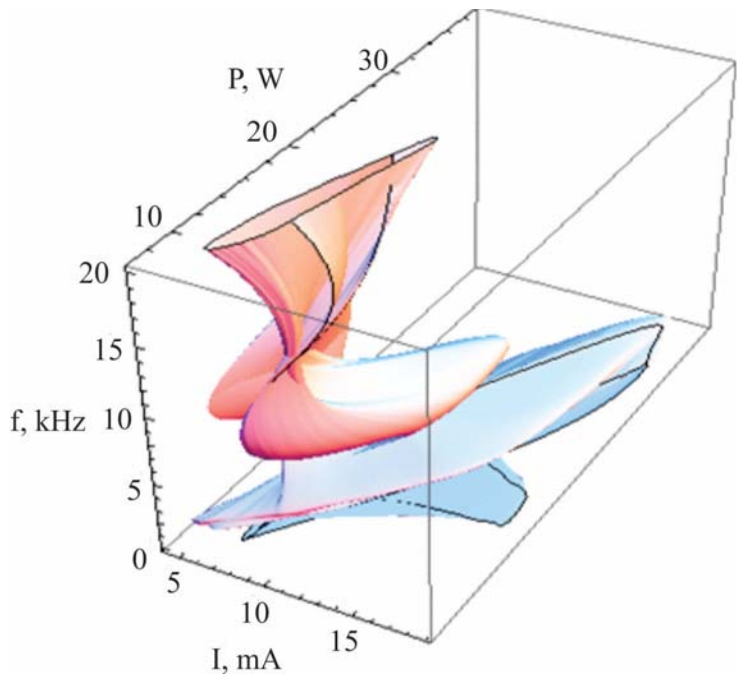

Fig.6. Three-dimensional surface depending on the current-voltage characteristics of the frequency.

If the phases and amplitudes did not change in different sections, then the surfaces of the current-voltage characteristics would be cylindrical surfaces. Changing the parameters leads to deformation of the frame and surfaces. Any physically realizable phase transition leads to jumps in the corresponding parameters. This causes deformation of the frame. Figure 6 clearly shows the points of phase transitions, where the surface is twisted.

4. Conclusion

A method for constructing surfaces of three-dimensional characteristics is proposed, especially suitable for cyclic processes. The parameters on two coordinates change smoothly, and on the third coordinate, the changes can be both smooth and unevenly. For the three-dimensional process, two-dimensional sections are constructed for each of the fixed values of the third parameter (third coordinate). A parameter that can vary in jumps should be in a two-dimensional section. These two-dimensional sections of cyclic processes are located along the axis of the third parameter at the corresponding points of the same cyclic process. All points with the same phases in sections located one behind the other are interconnected by segments of straight lines. So we obtain the frame of three-dimensional process. Phase transitions lead to jumps in the parameters, and jumps in the parameters lead to a three-dimensional frame deformation, which is clearly visible. Thus, all areas of phase transitions, jumps and emergency situations become clearly visible. The technique can be used in various fields of science and technology.

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