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Phase difference meter between the alternating current and voltage components for determining the impedance of plasma of glow discharge lasers

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Abstract. In this work meter for the phase difference of the variable components of the discharge current and the voltage drop was developed and tested. The operation of the meter is based on the transformation of harmonic signals into rectangular pulses, and further determination of the time shift between them. The possibility of using this meter for monitoring the dynamic resistance of glow discharge lasers is shown.

Gas-discharge devices are widely used in various fields of science and technology. Among the widest range of such devices, a special place is occupied by instruments with an extended positive column of a glow discharge, to which, in particular, glow discharge lasers belong. Glow discharge lasers is actively used for technological and metrological purposes [1, 2]. However, due to physical and structural features, the laser radiation has a temporary instability caused by the influence of various factors. This, in turn, involves the use of glow discharge lasers in conjunction with systems to stabilize the power of their radiation [3].

Methods of stabilizing the power of laser radiation are divided into passive and active. In practice, active methods are often used, since passive methods do not take into account all the factors that affect the instability of the laser radiation power. Active stabilization methods suggest negative feedback. One of the options for stabilizing the power of laser radiation is to adjust the pump level. In glow discharge lasers, this process reduces to the modulation of the discharge current. Such a system is called a current power stabilization system. Let us assume that at a time t the laser had a power level P_0 at a current I_0, which corresponds to point A (Figure 1). However, due to external influences, the energy characteristic can shift and the power $P_0 + \delta P$ (point B) will correspond to this current. The principle of current stabilization of power consists in forcibly changing the discharge current by such a value δI so that the radiation power level again is equal to P_0 (point C). In this case, the output power level of the laser radiation will be at a stabilized level [4].

The discharge conditions realized in glow discharge lasers correspond to the region of sharp drop in the current-voltage characteristics characteristic of the gas gap, when there is a transition stage from free electron diffusion to ambipolar. Since glow discharge lasers operate on direct current, one can use the method of small perturbations to obtain expressions for the total dynamic resistance. In accordance with this, the current and voltage of the discharge will, respectively, have the form: $U = U_0 + u$, $I = I_0 + i$. In these expressions I_0, U_0 are stationary values of the current and voltage drop at the discharge, i and u are the variable components of the discharge current and voltage, where $u << U_0$, $i << I_0$. Since the glow discharge plasma has reactive properties, there is a phase shift between the values of *u* and *i*. In this case, the dynamic resistance of the discharge will be defined as the total resistance to alternating current [5]:

$$Z_d = \frac{u}{i} e^{j\Delta\varphi} = R + jX,$$

where *R* and *X* are the active and reactive components of the discharge impedance; Δφ is the phase shift between the alternating current and voltage components [2].

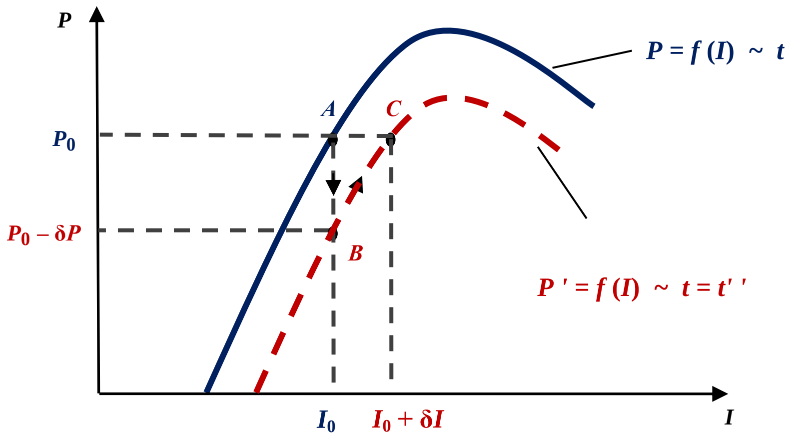

Figure 1. Explanation of the principle of the current stabilization of radiation power.

The basis of the experimental study of the dynamic discharge resistance is the measurement of the values of the alternating current and voltage components at a fixed frequency, as well as the phase shift between them. In the circuit, the discharge burns at a constant current, and is modulated by an external sinusoidal signal fed from a high-voltage oscillator with tunable frequency. Variable components of current and voltage are taken from the measuring resistors and amplified. Next, the phase shift between the signals is determined using a phase difference meter [6].

To register the difference between the phases of the current and the voltage drop of the discharge gaps of lasers, it is necessary to simultaneously measure and compare them with each other. The paper suggests the following version of this task. First, it is necessary to convert the sinusoidal signal into rectangular pulses of the same frequency (figure 2). For this purpose, the chip MAX942EPA + serves, in one case it contains two comparators.

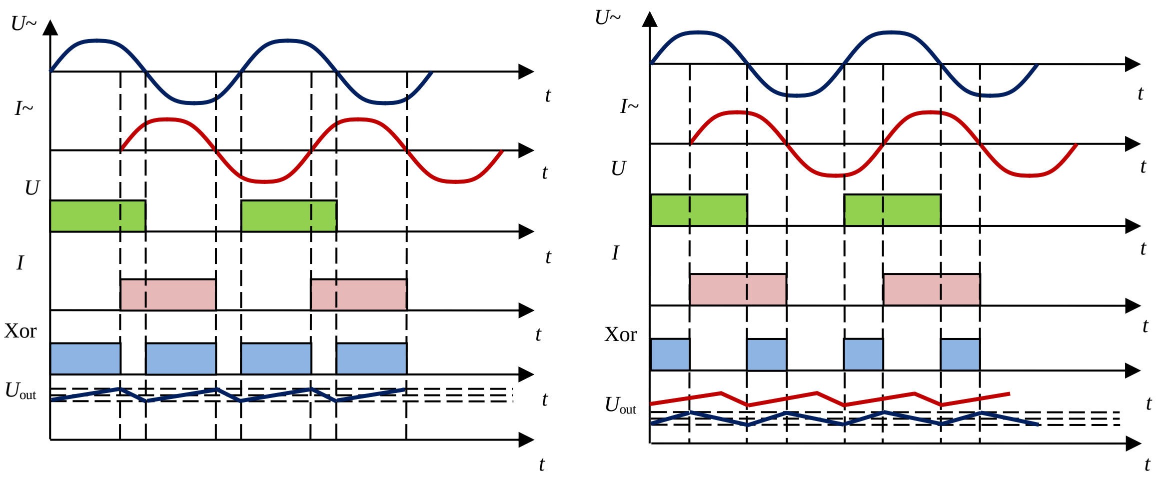

Figure 2. Explanation of the principle of operation of the phase difference meter.

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The input of the comparators is fed with signals proportional to the alternating components of the discharge current and the voltage drop. Then the signals from the comparators go to the logical element "excluding or", at the output of which rectangular pulses are learned. This scheme operates on the principle of pulse width modulation: the greater the phase shift between current and voltage, the lower the duty cycle of the pulses obtained. The output signal from the logic element can be fed to the oscilloscope, or smoothed using an RC filter. The level of the smoothed signal will be proportional to the phase difference between the signals [7].

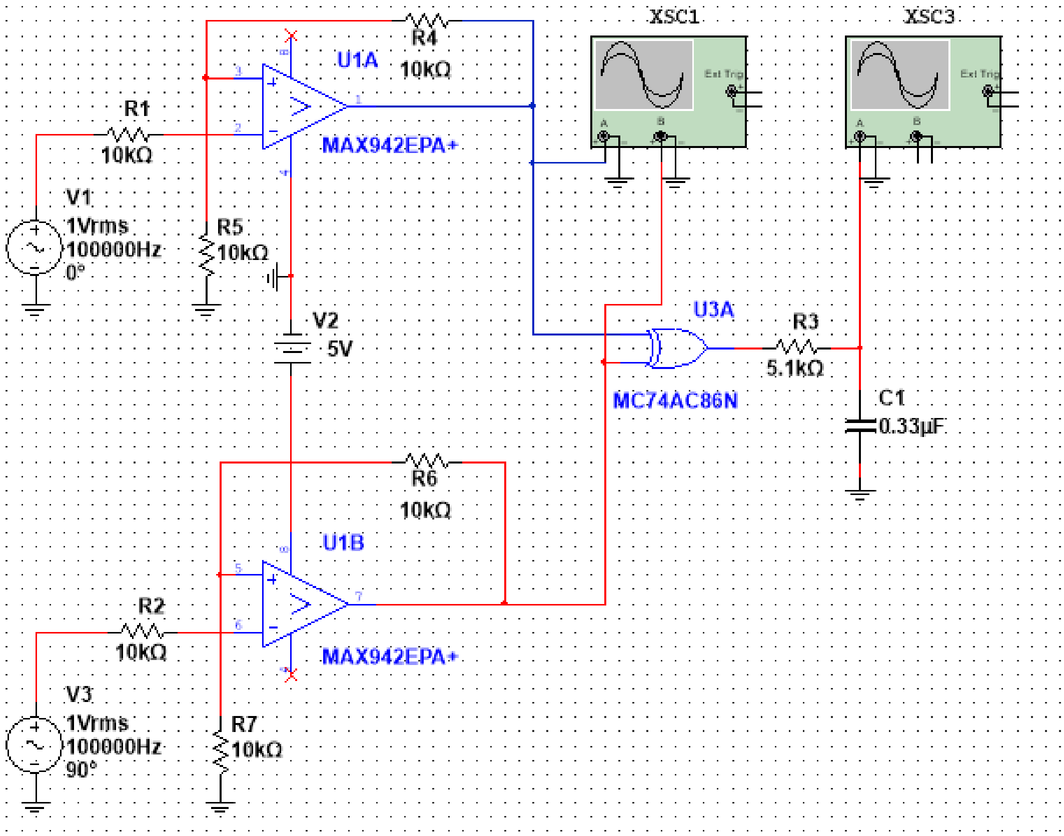

Figure 3. Principal electrical scheme of the phase difference meter.

In the course of this work, a circuit for measuring the difference between the phases of the current and the voltage drop across the discharge gap of the laser was developed and manufactured, and preliminary tests were carried out. The next stage of work is planned to connect a phase difference meter to mock-ups of gas-discharge lasers and to study the phase difference of the current and the voltage drop of the discharge gaps of lasers.

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