



STUDY OF THE PROCESS OF INTERACTION OF RADIATION WITH A CONTROLLED SILKWORM COCOON

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ABSTRACT

The article investigates the effect of radiation from semiconductor LEDs with controlled silkworm cocoons. To study the passage of rays of different wavelengths through the shell of the cocoon, an experimental setup was developed and its design scheme was considered. The passage of rays with different wavelengths through the obstructed and non-obstructed by the pupa of the parts of the shell of the cocoon was investigated. The results of the scientific research showed a high closeness of the comparative analysis of experimental studies with theoretical ones. Based on the results of scientific research experiments, the possibility of designing highly sensitive optoelectronic converters that control silkworm cocoons or similar complex objects has been created.

KEY WORDS: COCOON; doll; semiconductor feed; photodiode; optoelectronic converter; radiation spectrum; equivalent resistance; constructive drawing; informative fraction of radiation; sensitive surface of the photodiode.

DISCUSSION

Silkworm cocoons, from which natural raw silk is produced, depending on breeds and hybrids, vary in density. Therefore, in preparation for unwinding, it is required to group cocoons with the same technological characteristics as possible, which are called a production batch [1], requiring the same cooking mode, finding the ends of the thread and making it possible to produce raw silk from them with a given linear density, purity and defectiveness.

To build a density sensor and correctly select its design parameters, you must:

1. To study the interaction of radiation with different wavelengths with the shell of the cocoon;
2. Investigate the distribution of radiation after interaction with the cocoon.

An experimental setup has been developed to study the interaction of radiation of different wavelengths with the cocoon shell. Figure 1 shows a block diagram of the setup, which consists of a radiation and photo detector parts.

The radiative part of the installation consists of a direct current power supply (DCPS) and a pulse

power supply (PPS), a switch (S), a commutator (C) and a set of semiconductor emitters of the types AL336V, AL102A, AL307VM., AL307AM, AL106D, AL108A.

The photo receiving part consists of a photo detector (SF2-9 or FD24K) of the measuring M and the devices registering the DR.

A stabilized source with parametric stabilization and a double emitter follower on KT315B transistors is used as a constant current source.

The pulse power supply is made on the integrated circuits K284PU1, K155LAZ and transistors KT315, KT814-815. The source provides for the possibility of smooth regulation of the pulse repetition rate and duty cycle. To ensure the simultaneous examination of various emitting diodes, all emitters are mounted on a movable cassette with a clear fixation. Figure 2 shows a structural drawing.

A feature of the setup is that the setup allows time-based research of the radiation interaction process under various operating modes.

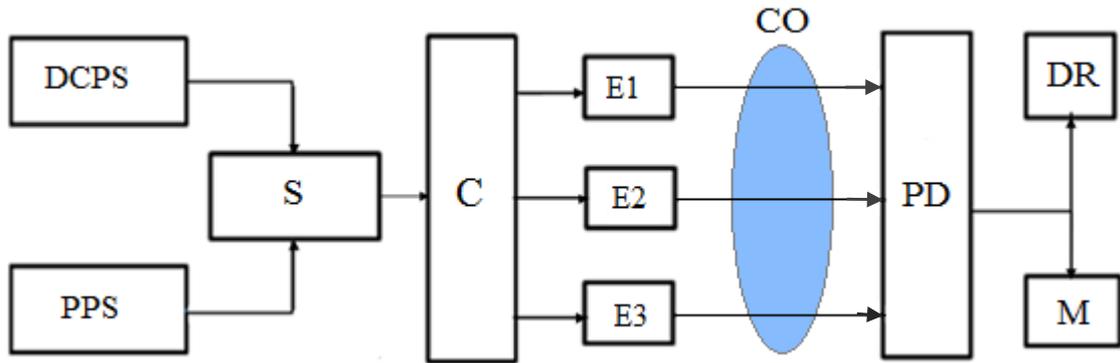


Fig. 1 Block diagram of the experimental setup.

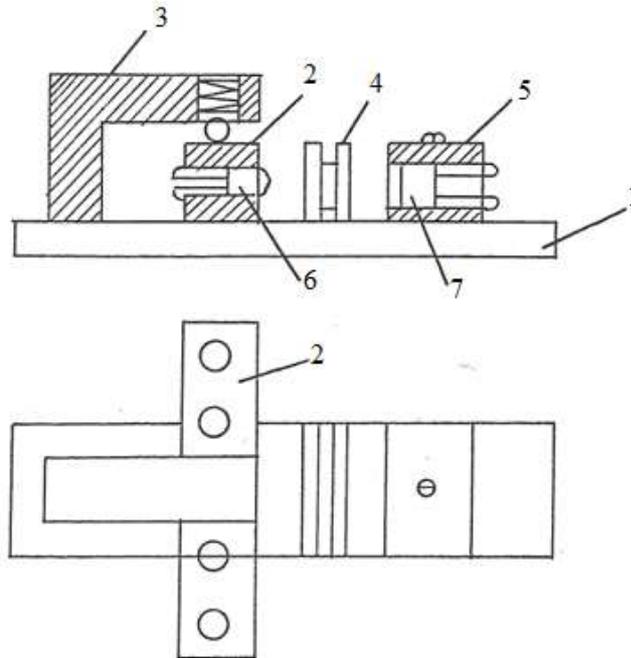


Fig. 2. Construction drawing of the installation.

where: - 1- bed; 2 - cassette; 3 - retainer; 4- cassette for installing the shell of the cocoon; 5- base for installing the photo detector -7; 6- emitting diode.

When using emitting diodes in lensless optical circuits as sources of analyzing radiation, the selected photo detector must satisfy the following basic conditions [2].

- 1- Maximum spectral agreement with the radiation spectrum;
- 2- High speed and sensitivity;
- 3 - Reception by the photo detector of 95% of the informative fraction of radiation. The first condition is provided by the choice of a photo detector, the spectral characteristic of which maximally overlaps the emission spectra of the emitting diodes [3].

The determination of the integral sensitivity of the photo detector for any given radiation spectrum is carried out according to the formula [4]:

$$S = S_{\lambda_{\max}} \int_0^{\infty} (\tau S_{\lambda} / S_{\lambda_{\max}}) \cdot \rho d\lambda, \text{ [mA/BTr]}, \quad (1).$$

where: ρ is the relative density of energy distribution in a given radiation spectrum; $S_{\lambda} / S_{\lambda_{\max}}$ is the relative spectral sensitivity of the photo detector; $S_{\lambda_{\max}}$ is the maximum value of the spectral sensitivity of the photo detector.

To calculate the integral sensitivity of the photodetector to the radiation of a given source, it is necessary to know the power distribution over the radiation spectrum. Usually such a distribution is known from the spectral characteristics of the emitter [5,6].

Knowing the maximum value of the spectral sensitivity, it is possible to determine the spectral sensitivity of the photodetector for the selected wavelength from the relative spectral characteristics and from the obtained values to find the integral sensitivity to the given radiation.

The second condition is reduced to the choice of a photodetector with a constant time



three, four times less than the duration and radiation pulse. The sensitivity and speed of the photodetector largely depend on the correct choice of load resistance [7.8]. When the duration of the radiation pulse is less than the transient process, it becomes necessary in the photodetector circuit to dynamically match the photodetector with the load, which would ensure the maximum output overtook by the end of the pulse.

Recommended in work [3] the following method for choosing or a given pulse duration t_u and equivalent capacitance C:

- 1) computation $R_{eq\ action} = t_u/C \ R_H \rightarrow \infty$;
- 2) determination of the actual value of the equivalent resistance at the end of the pulse action based on the ratio:

$$R_{eq\ action} = (0.9 \div 0.95)R_{eq\ max},$$

which is selected from the conditions for maintaining the photodiode mode by the end of the pulse;

- 3) substituting the value $R_{eq\ action}$ get

$$R_{eq\ action} = R_{n,opt} (1 - e^{-t_n/R_{n,opt}C}), \quad (2)$$

the value of $R_{n,opt}$ can be determined from the ratio:

$$R_{n,opt} = \frac{0.9U_{sup,opt}}{S_\phi} \quad (3)$$

To fulfill the condition, first of all, information about the law of distribution of the emitting diode flux after interacting with the controlled object is required.

If we assume that the emitting diode is a point one, then the luminous flux of the studying diode recorded at a distance x from the symmetry axis with an error of 5% can be approximated by the dependence:

$$\Phi = \frac{\Phi_0 e^{-\frac{K_\lambda m \sqrt{y^2+x^2}}{y}}}{y^2+x^2}, \quad (4)$$

where: y-is the distance between the emitter and the photodetector;

m is the value of the controlled parameter (mass, concentration, density);

K_λ - coefficient depending on the wavelength.

It should be noted that the coefficient K_λ can take any values and does not qualitatively affect the nature of radiation propagation after passing through the material.

The same goes for the mass. The distribution of radiation depends on the geometrical parameters and the structure of the material under test. We believe that the material is evenly distributed in the measured area.

For the development of measuring converters, it is necessary to determine what dimensions the photosensitive surface of the photo detector should have so that 95% of the total transmitted light flux falls on its surface. For simplicity, we will assume that

$$K_\lambda = 1.$$

If the light-sensitive surface is a circle (which is true for most photo detectors) with a radius R and it is located on the same axis with a point radiation source, then the perceived luminous flux can be expressed by the integral:

$$\Phi = \int_0^x \frac{2\pi R \Phi_0 e^{-\frac{\sqrt{y^2+x^2}}{y}}}{y^2+x^2} dx, \quad (5)$$

We take $y = 1$ and in these units, we determine the radius of the photosensitive surface of the photodetector:

$$\Phi = 2\pi R \Phi_0 \int_0^x \frac{e^{-\frac{\sqrt{x^2+1}}{x}}}{x^2+1} dx/x, \quad (6)$$

This expression is reduced to the integral logarithm and cannot be calculated directly.

The values of this integral were determined by a numerical method on a computer for $x = 1, 2, 3, 4, \dots$ and are given in table. 1..

Table 1o

x	1	2	3	4
$\int_0^x \frac{e^{-\frac{\sqrt{x^2+1}}{x}}}{x^2+1}$	0,106	0,184	0,21	0,216

The values of the integrals \int_0^3 and \int_0^4 differ by less than 4%. Therefore, the radius of the photosensitive surface of the photo detector should be 3: 4 times greater than the thickness of the translucent material:

$$R = (3 \div 4)y; \quad S = 2\pi(3 \div 4)y^2$$

Thus, if the radius of the photo detector is 3-4 times greater than the thickness of the translucent material, then almost the entire luminous flux that has passed through the controlled material falls on the light-sensitive surface. To study the interaction of radiation with the shell of the cocoon, samples from

controlled cocoon shells were prepared on the experimental setup discussed above. First, the cocoons were selected from the unsorted mixture by hardness using the "VK" device, after which a disc (from the abdominal hemisphere) with a diameter of 5-8 mm was cut from each sample, while ensuring the minimum curvature of the shell. The density of the area (disk) of the shell is determined by the formula:

$$\bar{\delta} = \frac{m_i}{\Delta S l_0}, \quad (7).$$

where: m - mass of the section of the shell crushed in the form of a disk, mg

ΔS - disk area, mm²;

l_0 - is the thickness of the cocoon shell,

mm.

Prepared shell samples (shell sections cut out in the form of a disk) with different densities were placed in special cassettes 4 (see Fig. 2). Then the cassette was installed between the emitting and photo detecting parts of the experimental setup. The emitting diodes (AL336V, AL102A, AL307VM., AL307AM, AL106D, AL108A) were alternately connected to the power supply to irradiate the cocoon shell and measure the current in the FD24K photodiode circuit. The dependence of the output current of the photodiode on the shell density for different emitting diodes is shown in Figures 3 ÷ 8.

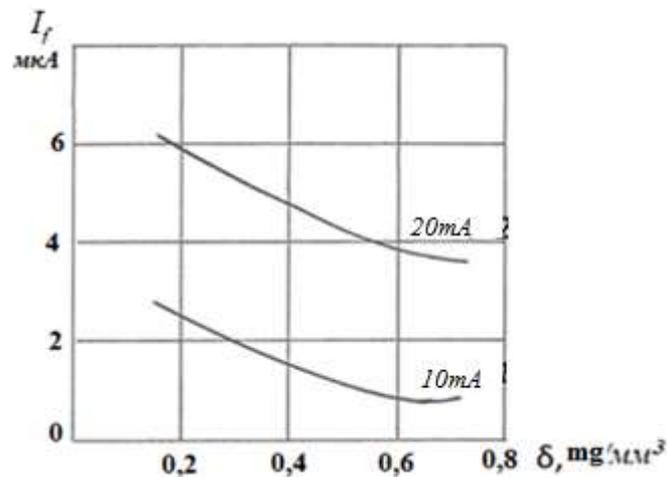


Fig. 3. Dependence of the photodiode current on the density of the cocoon shell at $I_f = f(\delta)$, AL336V

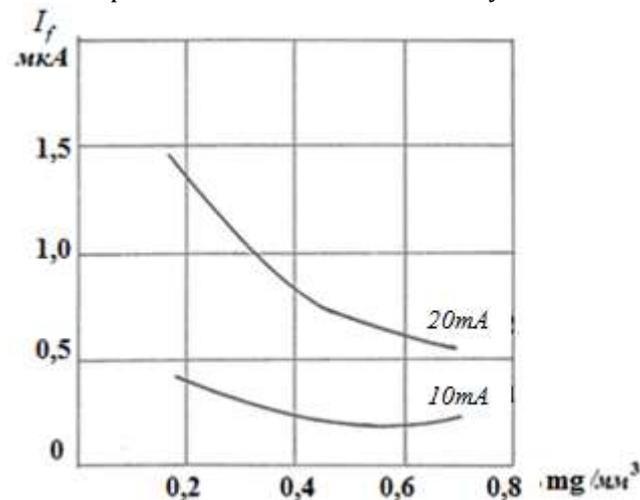


Fig. 4 Dependence of the photodiode current on the density of the cocoon shell at $I_f = f(\delta)$, AL307VM.

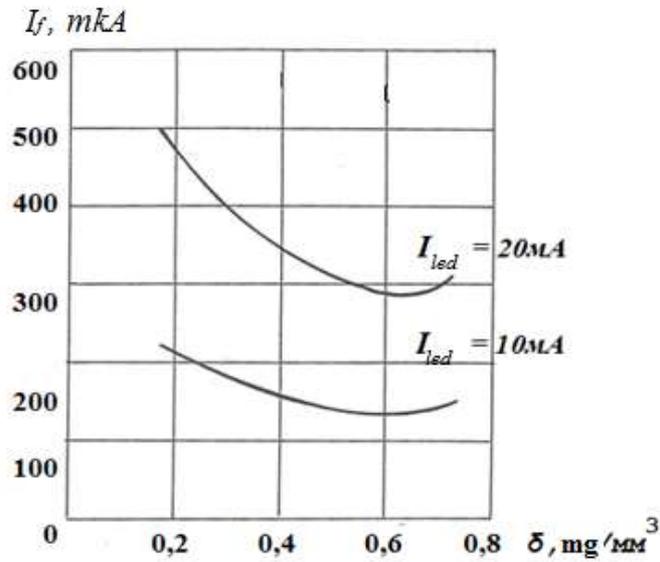


Fig. 5 Dependence of the photodiode current on the density of the cocoon shell at $I_f = f(\delta)$, AL307AM.

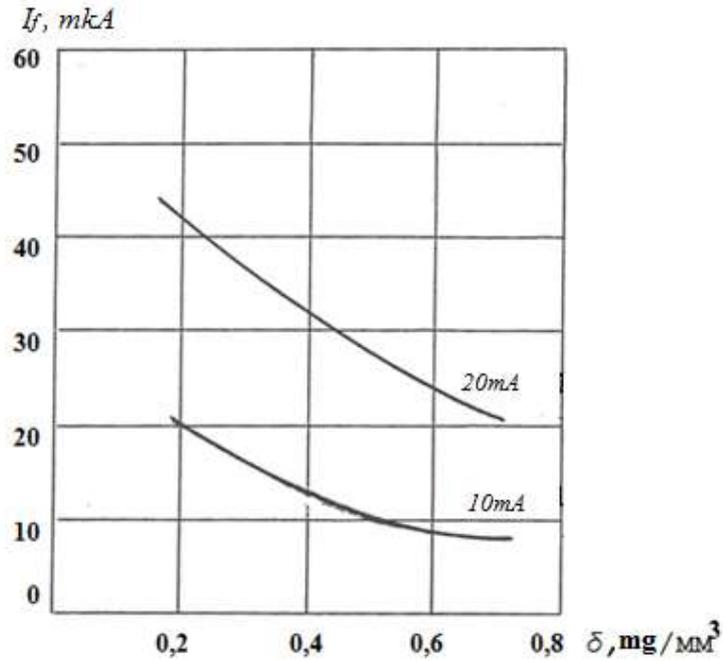


Fig. 6 Dependence of the photodiode current on the density of the cocoon shell at $I_f = f(\delta)$, AL102A.

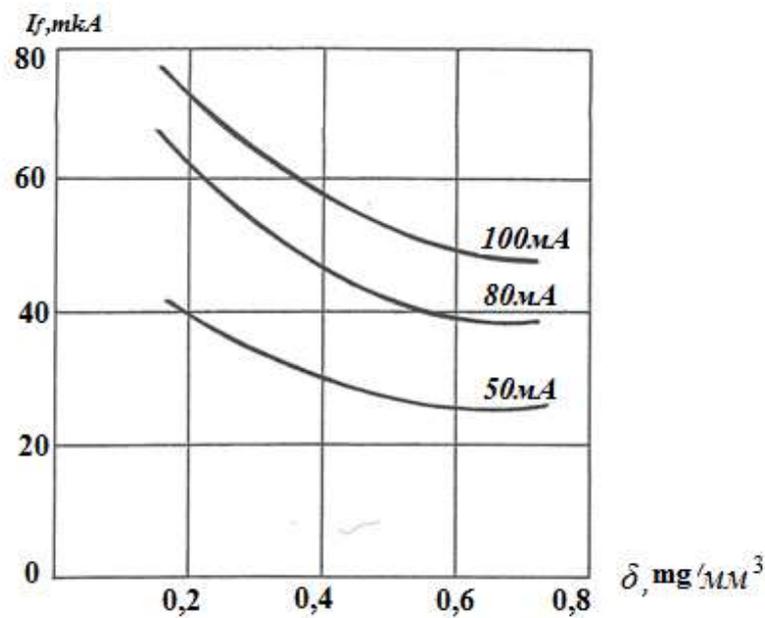


Fig. 7 Dependence of the photodiode current on the density of the cocoon shell at $I_f = f(\delta)$, AL106D.

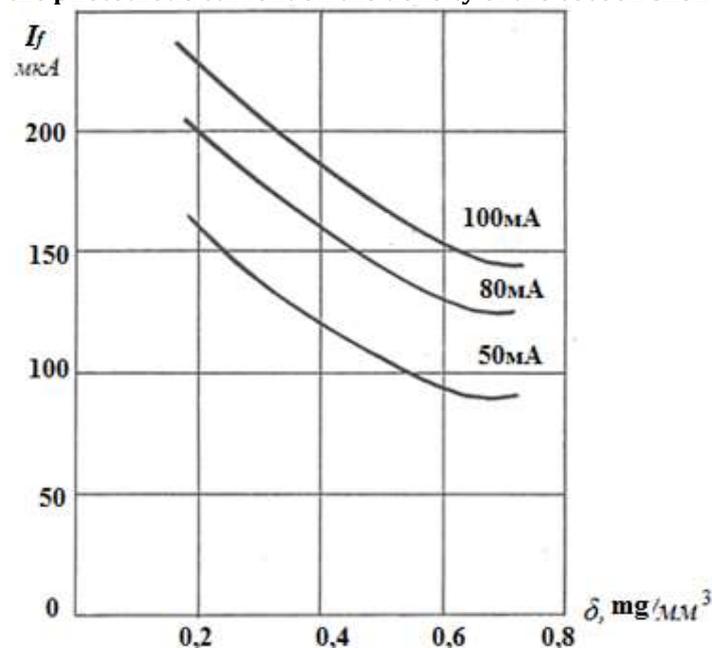


Fig. 8 Dependence of the photodiode current on the density of the cocoon shell at $I_f = f(\delta)$, AL108A.

The results of the study showed that the highest sensitivity of measuring the density of the shell of cocoons is achieved when using an AL108A emitting diode with a wavelength of $0.93 \mu\text{m}$.

Comparative analysis of experimental studies with theoretical ones shows their high convergence.

The resulting model is valid for a single section of the cocoon shell, where we assumed that this section is straightforward.

In real conditions, the shell of a cocoon has a complex shape, and the cocoons are widely scattered in shape and have different geometric dimensions (diameter, distance between side walls, length, distance between poles). The pupa located inside the shell of the

cocoon has a significant effect.

To study these factors affecting the measurement result, an experimental setup was developed, the electrical diagram of which is shown in Fig. 9, and the design drawing is shown in Fig. 11.

The setup consists of a master oscillator ZG, a point source of infrared radiation, which is an emitting diode of the AL107A type, a radiation receiver, which is a photodiode FD25K, an amplifier A and a measuring device, i.e. micro ammeter. The radiation source is fixed on a vertically, rigidly fixed guide axis, along which the emitter can be moved up and down, and the emitter is placed low to the controlled object.

The radiation receiver is fixed on a movable

vertical axis and can rotate with an angle $\alpha = \pm 90^\circ$ relative to the axis of the investigated cocoon.

The axis of the investigated cocoon is located in the center of the driving control zone by the source and receiver of the radiation. For the origin ("O") the position is taken when the axes of the radiation source of the cocoon and the photo detector lie on the same line.

The radiations were carried out in two areas: I - the lower part of the cocoon, where the pupa is located; II - the upper part, where the latter is missing. The dependence of the photocurrent I_F on the scanning angle α of the photo detector is shown in Fig. 10. Here: graphs 4 (I), 5 (I) and, 6 (I) reflect the dependence I_Φ

$= f(\alpha)$ for the part of the cocoon where the pupa is located, and 1 (II) ÷ 3 (II) - graphs for the upper part of the cocoon. From this it can be seen that in the area of the cocoon containing the pupa, the electrical signal is distorted and depends on the position of the pupa (see Figures 2.4, 5 (I) and 6 (I)). And, on the upper part of the cocoon not shaded by the pupa, the photoelectric signal oscillates (graphs 2 (II) and 3 (II)) due to the random location of the cocoon in the center between the emitter and the photo detector, i.e. depends on the position of the cocoon.

Thus, we need to consider the principles of constructing optoelectronic converters, taking into account the above research results.

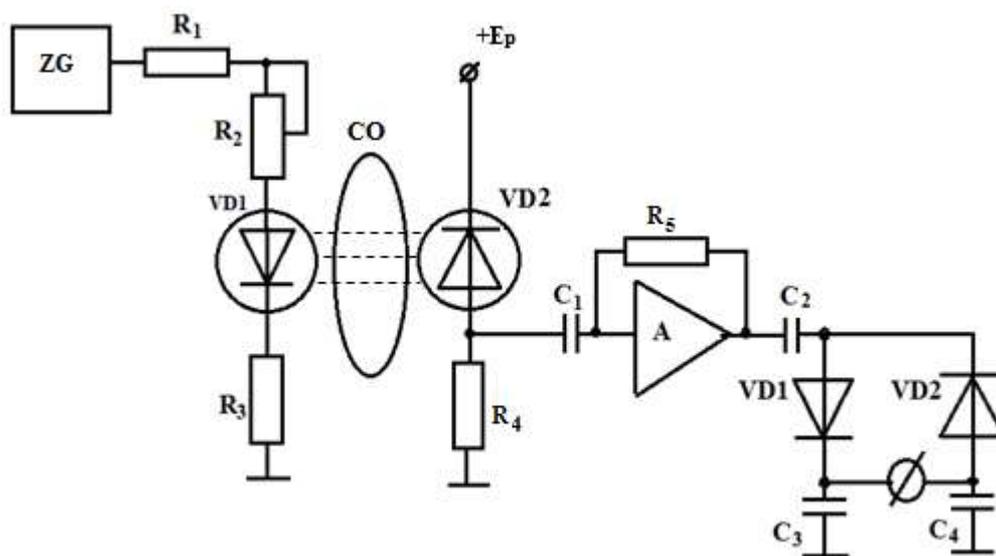


Fig. 9. Schematic diagram of the experimental setup.

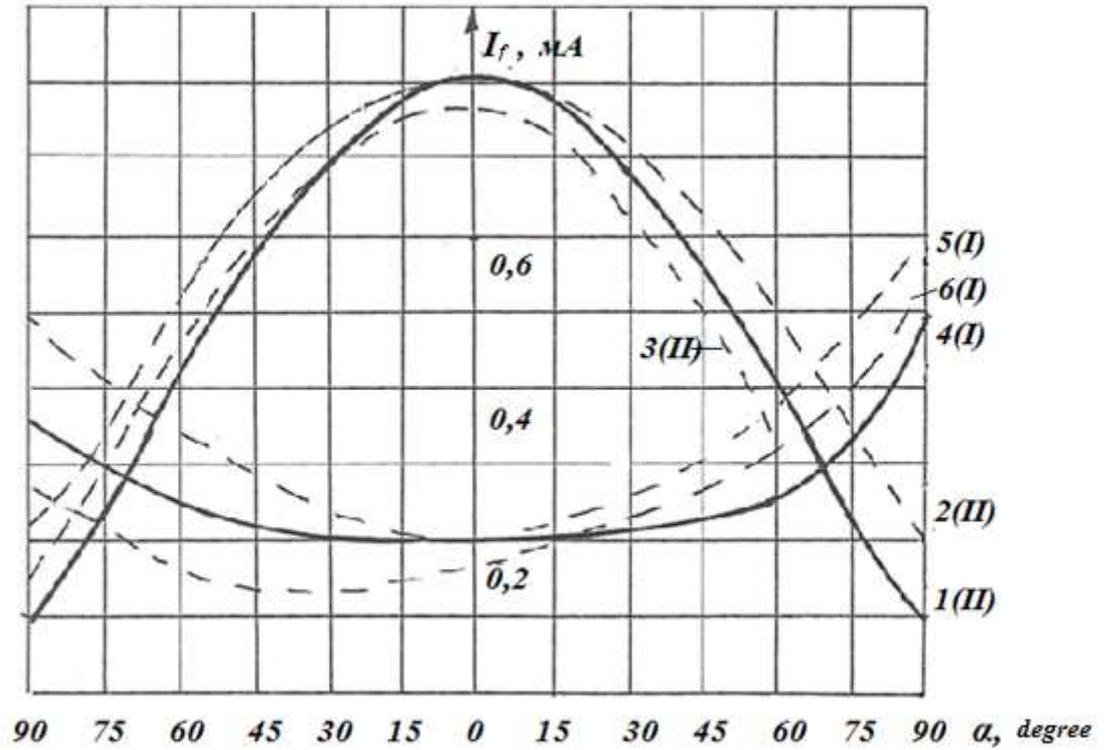


Fig.10 Dependence of the photocurrent I_f on the scanning angle α .

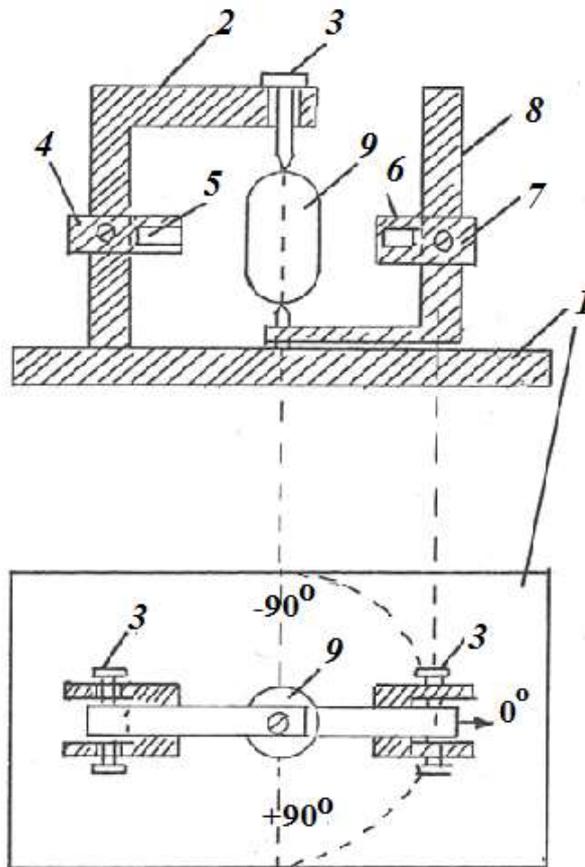


Fig. 11 Construction drawing



1 - bed; 2 - fixed rack; 3 - retainer; 4 - cassette for emitting diode; 5 - emitting diode; 6 - photodetector; 7 - cassette for FP; 8 - movable rack; 9 - cocoon.

For research purposes, the controlled cocoon is placed vertically between the source and the receiver of radiation. Translucent the shell with infrared radiation and, scanning the surface of the cocoon with a photodetector, the transmitted radiation flux is recorded.

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