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Photo Converter for Research of Characteristics Laser IR Radiation

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ABSTRACT: An experimental study was made the recording of the pulsed IR laser radiation with the use of ionization-type semiconductor photographic system. Semi-insulating gallium arsenide was used as a photodetector since it possessed photoconductance in the wavelength range of 0,8-1,7 μ. The gas discharge gap thickness was ~60μ; the air pressure in the gap was ~100 mm.Hg. A laser with the radiation pulse length of ~60μs and λ=1,315 μ was used in the experiments.

KEYWORDS: Photoconverter, optoelectronic converter, semiconducting electrode, ionization chamber, luminescent screen, semi-insulating gallium arsenide.

1. INTRODUCTION

In connection with the development of IR lasers, the problem of measuring the spatial distribution of energy over the beam cross section is currently an acute problem. In the near IR region (λ <1.3 μm), registration issues were mainly resolved based on the use of IR films or electron-optical converters (EOCs). These methods give good results in both integrated and frame-by-frame registration modes. In the latter case, the information is naturally more complete, since it becomes possible to trace the kinetics of changes in laser parameters during a radiation pulse.

Further advancement of the sensitivity of silver halide photomaterials towards longer waves encounters fundamental difficulties [1], since such photographic materials are significantly affected by thermal radiation from the environment. The scope of the image intensifier tube is limited by the red border of the external effect with λ = 1,2-1,5 μm [2].

Non-selective radiation detectors, such as heat-sensitive phosphors [3] and magnetic films [4-6], have a relatively low sensitivity (~10^3 cm^2/J) and a small dynamic range (~15 and ~ 30, respectively), which narrows, and in some cases and completely excludes the possibility of their application.

Matrix systems using pyroelectric or thermoelectric [7.8] infrared detectors in principle solve the problem under consideration. However, for a satisfactory description of the parameters of the laser beam, a large number (≥104) of measuring channels is necessary, which is very difficult to practically implement.

Thus, existing registration methods, either due to physical limitations, cannot work at λ≥1.5 μm, or do not possess the totality of technical characteristics necessary to determine the spatial distribution of energy over the laser beam cross section. Of particular note is the issue of measuring the energy distribution in single-shot mode. If for λ≤ 1.3 μm such registrars are developed on the basis of image intensifier tubes, then for large wavelengths all known image receivers do not have the ability to change their sensitivity, which is necessary for the single-frame shooting mode.

II. SCHEMATIC DIAGRAM OF THE SYSTEM. THE EXPERIMENTAL TECHNIQUE.

The operation of the device is based on controlling the discharge current in a thin gas-filled gap by means of a photosensitive semiconductor layer distributed over the discharge cross section. Figure 1 shows a schematic diagram of a device used in the studies described below. The system consists of a semiconductor photosensitive plate (1) equipped with a translucent electrode (2). The inner surface of the plate is separated from the surface of the recording layer (4) by a gas gap (3). The recording layer (4) is located on a transparent conductive counter electrode (5) made, for example, of a glass plate coated with a conductive film. When a voltage is connected to the system, a gas discharge breakdown occurs, characterized in that the distributed cell contains a distributed semiconductor resistance, which contributes to the damping of current instabilities. The resistance of a semiconductor fully determines the magnitude of the current density over the cross-sectional area and when illuminating the semiconductor, it can control the magnitude and distribution of the current in the gas gap.

Photographic registration can be carried out due to the direct effect of the glow of the discharge region gas on the photosensitive material (the first method). In addition, excitation by energetic particles of the discharge gap (as well as UV glow) of a luminescent layer deposited on the inner surface of the transparent electrode 5 can be used. In this case, the image on the photosensitive material is formed due to the glow of the phosphor (second method).

It should be emphasized that the photographic sensitivity of the system appears only when a sufficiently high voltageis applied to its electrodes. Thus, the devices of this type satisfy the principle of controlled sensitivity, according to which a high photographic sensitivity in the IR region can be achieved if the sensitivity is communicated to the system only for the duration of the useful exposure.

III. EXPERIMENTAL RESULTS

In these studies, photographic registration was mainly carried out by the first method. Electrode 5 (Fig. 1) was made in the form of a thin fine-structured metal grid, to the outer side of which a film was pressed (emulsion to the grid). In the second method, a luminescent layer (K-60 light composition) was deposited on the surface of a transparent conductive electrode facing the discharge ($Sn0_2$ layer on glass). In both recording modes, RF-3 film was used.

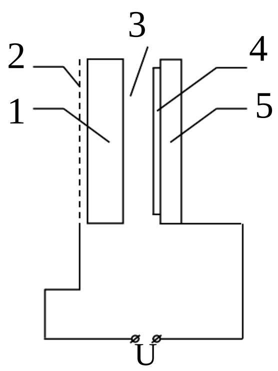

Fig.1. Schematic diagram of the device.

Semi-insulating gallium arsenide having photoconductivity in the wavelength range λ ~ 0.8-1.7 μm was used as a photodetector (Fig. 2). The gap thickness was 60 μm, and the gas pressure in it (air was used) was about 100 mm Hg. Art. The frame size corresponded to the area of a circle with a diameter of 17 mm. To exclude the illumination of the film by the background light, the camera entrance window is made of optically polished silicon. The photocurrent values (curve 1) when illuminated by intrinsically absorbing light are large when the negative pole of the source is connected to a translucent electrode. With opposite polarity, the voltage short-wave sensitivity is practically absent (curve 2)

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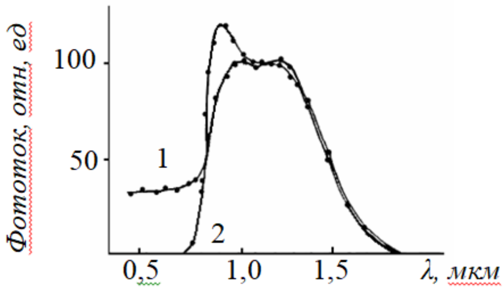

Fig.2. Spectral response characteristic of the photodetector.

The length of the discharge gap has a significant effect on the breakdown formation time. With decreasing d, the delay time decreases (Fig. 3). The fact that we observed a decrease in the breakdown formation time with decreasing d is consistent with the results of [9]

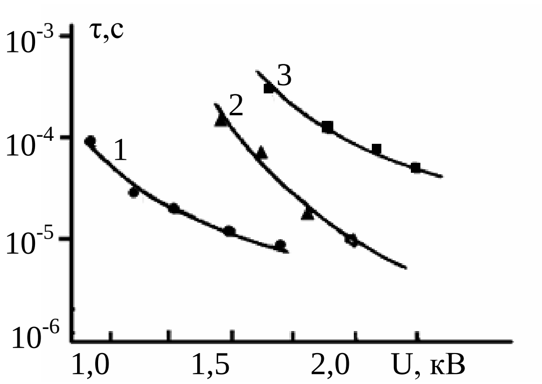

Fig. 3. Dependence of the breakdown formation time on the supply voltage at various thicknesses of the gas-discharge gap. P = 76 mmHg d, microns. 1-30, 2-60, 3-100 microns

Thus, the results obtained show that in order to increase the system speed it is necessary to reduce the thickness of the gas-discharge gap and increase the supply voltage.

The test design is shown in Fig. 4. The radiation pulse of laser 1 (λ = 1.315 μm, duration ~ 60 μs) illuminates a slit-type aperture 4, the image of which is projected by a lens 5 onto the photodetector of camera 9. A part of the diaphragm was covered with a neutral filter. As a result of multiple reflection in the mirror wedge 6 in the plane of the semiconductor, a set of images of the gap with a different energy density is obtained. Calorimeters 2, 7 using translucent mirrors 12 and 14 control the total laser energy and the energy supplied to the photodetector. The interference filter 8 protects the photodetector from background illumination, passing only the laser radiation. The triggering circuit of the high voltage pulse train 10 is produced by a | synchronization pulse coming from the laser. The oscilloscope 11 controls the relative position in time of the high voltage pulse on the camera (its duration is 100 μs) and the radiation pulse, the shape of which is detected by the photodiode 3 using a translucent mirror 13.

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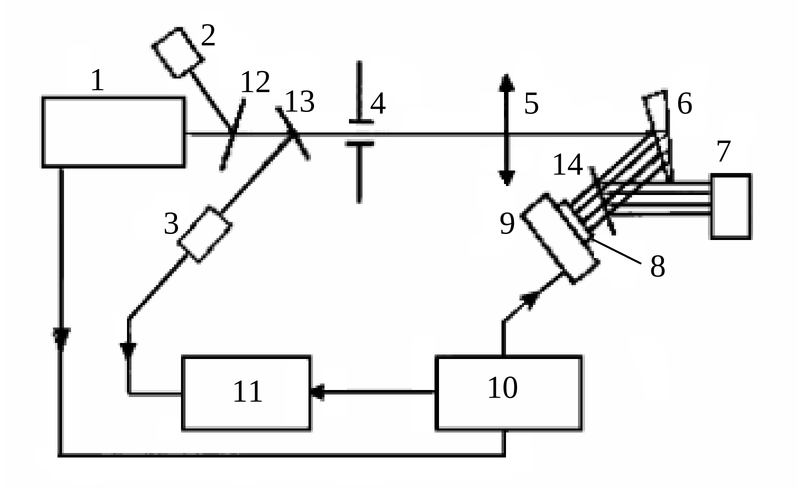

Fig. 4. Measurement scheme of photodetector characteristics

The wide dynamic range of the system, as shown by experiments [10], is due to the fact that in a large range of current density the differential resistance of the gas-discharge gap practically vanishes. Therefore, a change in the resistance of the photodetector during its illumination does not cause a redistribution of voltage between the photodetector and the converting element (gas discharge gap).
The high photographic sensitivity of ionization systems in the IR region of the spectrum is ensured by the efficient process of converting the IR radiation flux causing photoconductivity in the semiconductor photodetector to the energy released in the gas-discharge gap when current flows in it.

IV. CONCLUSION

The test results confirmed the possibility of using semiconductor photographic systems of the ionization type for registration of laser radiation. The camera has substantially better technical characteristics in terms of dynamic range and sensitivity with respect to magnetic films and heat-sensitive screens.
It must be emphasized that the possibility of using ionization systems is not limited to the spectral sensitivity range of photo detectors considered in this paper. The long-wavelength limit of sensitivity can be expanded by using cooled photo detectors with lower photo ionization energies of impurity centers.
An attractive feature of the devices is the ability to electrically control sensitivity (the presence of an “electric” shutter).High sensitivity, large dynamic range, low inertia of the processes in the gas gap open up prospects for single-frame shooting of the studied section of the laser beam.

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