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IMPROVING MEASUREMENT ACCURACY AND CONTROL RELIABILITY OF OPTOELECTRONIC DEVICES

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Abstract: *When developing single-wave optoelectronic non-destructive testing devices for various purposes and their metrological support, one of the most urgent tasks is to create stable two-color LEDs. The relevance of mid-infrared (IR) LEDs for solving problems in such areas as gas analysis, environmental monitoring, moisture measurement, medical diagnostics and communication systems is revealed.*

Key words: *LED, parameters, radiation flux, stabilization, temperature, measurement, block diagram, feedback.*

INTRODUCTION

The Ioffe Institute of Physics and Technology of the Russian Academy of Sciences (Ioffe Institute of Physics and Technology) has developed an LED with a built-in thermal cooler for the mid-IR region of the spectrum, which is characterized by compactness and unity of design. The developed design ensures stability and the same operating conditions of two LED channels in the temperature range from -40 to +60 ° C with an accuracy of 0.8-1 ° C. However, this design does not provide for ensuring the equality of the initial measurement and reference radiation fluxes of a two-color LED, and therefore the development of technical solutions to ensure the equality of the initial measurement and reference radiation fluxes of a two-wave LED used in optoelectronic devices is one of the urgent tasks. The authors of this article propose a solution to this problem.

The main task of optoelectronic automatic control devices is to ensure the stability of LED radiation fluxes, which determine the measurement accuracy. To solve this problem, a schematic diagram is proposed that ensures the stability of parameters during 50 thousand hours of operation. Over the past decades, technological progress in the development and manufacture of mid-IR LEDs has been proceeding at an intensive rate [1]. Creating a Map Item.The use of heterojunctions resulting from the contact of two semiconductors with different bandgap widths allowed us to take a new approach to the design of semiconductor devices: lasers, light-emitting diodes, photodetectors, and solar cells. a number of optoelectronic sensors were developed: a paper moisture, carbon dioxide and methane analyzer, an oil water content analyzer, and a new type of hydrogen sensor based on the photoelectric recording method [2]. When developing optoelectronic nondestructive testing devices for various purposes and their metrological support, the most urgent task is to create stable radiation sources. One of the main characteristics of LEDs is their time and temperature stability of the main parameters [3].

Methods and materials

It is advisable to use semiconductor materials with a band gap of 0.6-0.25 eV to create LEDs operating in the wavelength range of 1.94-2.20 microns. Multicomponent solid solutions should be used to create devices in a wide range of wavelengths.

Four-component solid solutions A^3B^5 allowют to independently control the band gap and the parameteramand the lattice. Four-component solid solutions make it possible to cover the entire wavelength range of 1.8-2.2 microns and ensure high perfection of the heterogeneous boundary on a GaSb and InAs substrate [3-4].

Hotspot materials.

The following solid solutions can be used for the active area of the devices.

Wavelength range:

GaInAsSb – 1.8-2.2 microns.

InAsSbP is 1.5 - 3.9 microns.

In this study, we used a standard open-type liquid-phase epitaxy unit. Epitaxial layers were grown in a horizontal reactor made of optical quartz in a stream of hydrogen purified by diffusion through heated palladium filters in an industrial installation UOV - 1.

The heating part of the unit was a SDO-125/4 furnace. Using a heat pipe (operating temperature range 500-900 °° C), the installation made it possible to obtain a constant temperature zone (± 0.1 K) at a distance of 30 cm in the furnace. Temperature modes were set using the temperature controller control units. A gearbox with a motor was attached to the setpoint unit responsible for controlling the temperature in the working area of the heater, with the help of which it was possible to obtain a smooth decrease or increase in temperature at a rate **of 0.1**-2 deg/min. Thermocouples were used to control the mode and control the temperature. Containers for epitaxial cultivation were made of MPG-7 graphite.

Single-crystal gallium antimonide plates oriented in the crystallographic planes (III) A, (III) B , and (100) C were used as substratesGaSb ; p-type unalloyed GaSb with a hole concentration of about 2 $*^{10-17}$ cm^{-3} and GaSb *n*-type GaSb doped with tellurium with a concentration of $7 \cdot 10^{17-1} \cdot 10^{18}$ see^{-3}.

The working side of the substrate was processed by chemical-dynamic method, the reverse side was polished by mechanical method. Before loading into the reactor, the substrates were processed in the following order:

a) washed in carbon tetrachloride;

b) were processed in an etchant withRo3_3+H+Hg+H2o$_2$O – 1:1:3 for 30 ÷ 40 seconds;

c) washed in distilled water:

d) washed in hydrochloric acid (HCI);

e) washed in hydrofluoric acid (HF);

f) washed in isopropyl alcohol and dried.

The thickness of the substrates after treatment was 350-380÷microns.

For the preparation of melts, gallium (99.9999), antimony (99.99999), indium (99.999), aluminum grade Al-000, unalloyed изgallium antimonide plates-GSD grades (p = $2\cdot10^{17}$ cm^{-3}), doped with germanium - GSDG grades (p = 1 $\cdot10^{18}$ cm$^{\text{-3) were used.3}}$) and tellurium-doped GSET grades n=(6÷8)·$^{10-17}$ cm^{-3}), as well as plates made of unalloyed indium arsenide (n = 1 *$^{10-16}$ cm^{-3}) and gallium arsenide (n = 1·$^{10-16}$ cm^{-3}). Germanium, respectively introduced from doped gallium antimonide plates, was used as the acceptor impurity or donor impurity.

Graphite cassettes were periodically treated in aqua regia, then repeatedly boiled in distilled water and annealed in a hydrogen atmosphere for several hours at a temperature of 900 $^{\circ\circ}$ C. The quartz reactor was boiled in aqua regia, then several times in distilled water and calcined for several hours in a stream of hydrogen at 900 $^{\circ\circ}$ C.

Semiconductor structure. GaSb was chosen as GaSbthe substrate. Epitaxial GaInAsSb layers that are isoperiodic with GaSb can be grown on, изопериодные с GaSbthe substrate. The donor GaInAsSb layer was chosen as the active layer materialGaInAsSb, since it has a lower probability of nonradiative Auger recombination than the acceptor layer.

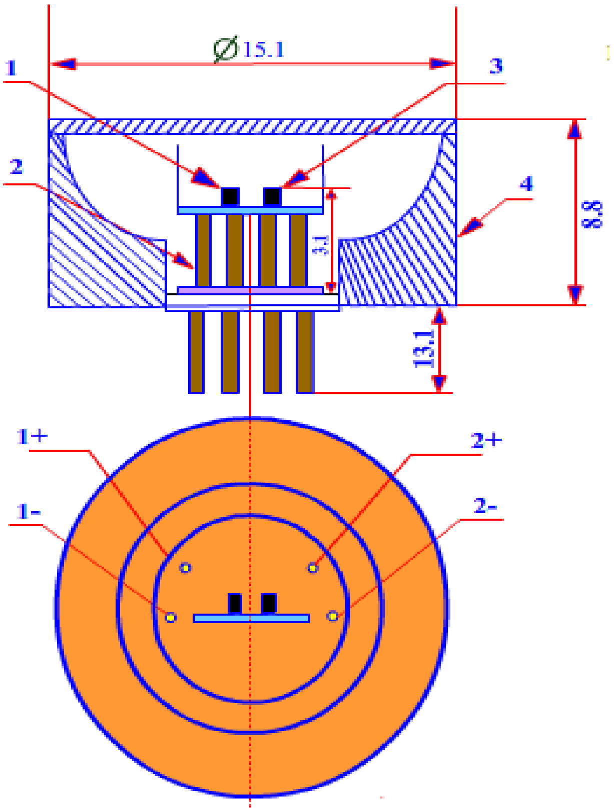
The acceptor AlGaAsSb was chosen as an injector because it has a larger band gap than GaInAsSb.

LED structures are made by the LFE method and grown on *GaSb n*-type GaSb substrates, doped *with Te* to an electron concentration of 8 ×$^{10-17}$ cm^{-3}. Emitters for measuring the humidity of raw cotton consisted of an active layer *of n-GaInAsSb* (($_g$Eg = 0.51 eV) with a thickness of 2-3 microns and grown on *n-GaSb substrates* and doped *with Te* to a charge carrier concentration of 9 * 10^{17} cm^{-3}, a wide-band emitter *of p-AlGaAsSb*, doped with germanium to a concentration of 5 * 10^{18} cm^{-3}.

Improved measurement accuracy and control reliability

To increase the optical power of LEDs for automatic control, a design with more efficient heat removalis proposed. The design of a parabolic reflector for light – emitting diodes that focuses IR radiation at an angle of 8-10 degrees is proposed. LED crystals with emission spectra of 1, 94 microns and 2.2 microns are mounted in one housing to ensure high accuracy and sensitivity of optoelectronic devices.

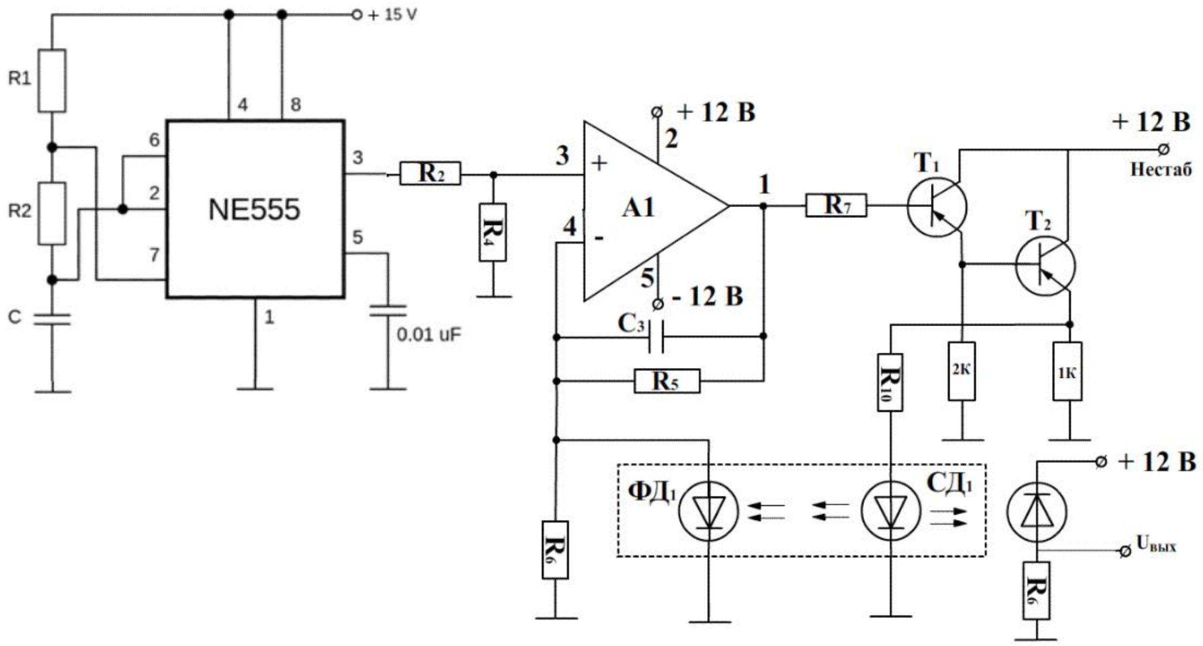
Figure1 shows the design of an LED with a parabolic reflector:
1-LED chip (1.94 microns)
2-thermal cooler
3-LED chip (2.2 microns)
4 – parabolicreflector.



Pic.1. *LED design with parabolic reflector*

To avoid temperature and time instabilities, we stabilize the operating mode by introducing feedback on the temperature-dependent parameter of the radiation source. Optoelectronic methods of non-destructive testing are used to solve many applied problems методы неразрушающего контроля [5-6]. As for the LEDa with a built-in thermal cooler for the mid-IR region of the spectrum, it is characterized by compactness and unity of design. In the nine-millimeter space there are two different (measuring and reference) LED emitters, a thermal cooler and a thermal sensor. The known process of slow power degradation of semiconductor LEDs occurs in the same way for two chips of the same type of chip structure, which ensures the stability of the differential signal for eight to ten years. The design allows you to select a common temperature for two emitters in the range of 10-20 °C and maintain it constantly with minimal electrical power consumption. The small size and high efficiency of the thermal cooler allow maintaining a temperature close to room temperature at a constant current of about 10 mA. Светодиоды Mid-IR light-emitting diodesmeet all the requirements for ensuring the measurement accuracy and reliability of optoelectronic nondestructive testing devices.

For improve the measurement accuracy and reliability of single – wave optoelectronic automatic controldevices, a method for stabilizing the main parameters of mid-IR LEDswith optical feedback is developed. Figure 2 shows a schematic diagram.

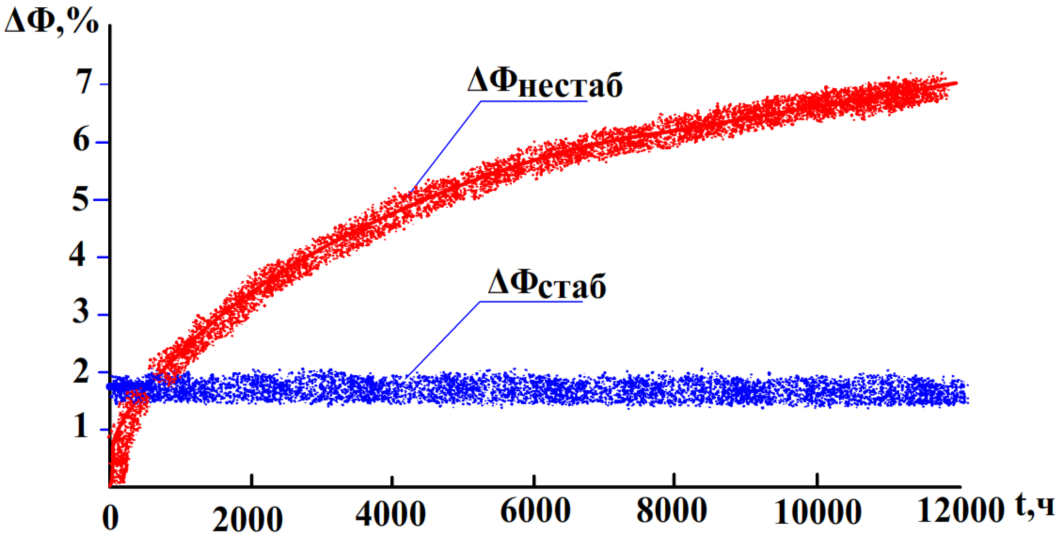


Pic.2. Schematic diagram for stabilization of the LED radiation flux.

The principle of operation of this circuit is based on the stabilization of the forward voltage at *the* $p – n$ junction of the LED. Therefore, controlling the forward voltage *of the* $p – n$ junction temperature is one of the waysto stabilize the LED parameters. Accordingtothe studies carried out according to this schemee, it is established, that by controlling the voltage *of the* $p – n$ junctionof the LED, it is possible to ensure its temperature stabilization.

Figure3 shows the results ofstabilization of the mid-IR LED parameters.

Theазработанный developed method for stabilizing the parameters of mid-IR LEDs with optical feedback to improve the measurement accuracy and reliability of single-wave optoelectronic automatic control devices made it possible to reduce the instabilitya of the radiation flux of mid-IR LEDs to 3...5 %.



Pic. 3. Results of stabilization of the average LED parameters IR areas.

Conclusion

Thus, a schematic diagram was developed for stabilizing the radiation flux of LEDs with optical negative feedback to improve the measurement accuracy and reliability of optoelectronic automatic control devices. ДТо stabilize the LED radiation fluxa, an additionale elementsconsistingй of an optical feedback photodetector is introduced into the electrical circuit.

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