

UDC 621.315.592
EDN: PIREAA

PACS: 81.

Possibilities of a planetary machining scheme for group grinding and polishing of InSb wafers and matrix modules

V. A. Ul'karov^{1*}, A. A. Trofimov^{1,2}, N. A. Sarkisov¹, V. O. Kuzin¹, K. Yu. Arbuzov¹,
I. D. Razmahnin¹, A. N. Kobysh², R. Yu. Kozlov^{3,4}, and M. S. Nestyurkin^{3,4}

¹ RD&P Center ORION, JSC, Moscow, 111538 Russia

*E-mail: ulkarov@yandex.ru

² MIREA – Russian Technological University, Moscow, 119454 Russia

³ Giredmet, JSC, Moscow, 111524 Russia

⁴ University of Science and Technology MISIS, Moscow, 119049 Russia

Received 5.03.2026; revised 20.03.2026; accepted 27.04.2026

During serial production, one of the key aspects, along with increasing productivity while maintaining product quality and reproducibility, is the desire to reduce costs and labor intensity. Single-sided lapping and polishing operations typically use an orbital machining system with individual loading. Switching to a planetary system potentially offers the optimal solution; however, it requires high precision and a significant upgrade in equipment design.

This paper proposes a planetary scheme of lapping and polishing, develops design and technological solutions, and conducts a series of processes on InSb wafers and matrix modules. Measurement results demonstrate the potential for increased labor productivity and yield while simultaneously reducing material costs.

Keywords: planetary lapping and polishing, photodetector array, lapping and polishing, InSb.

DOI: 10.51368/2949-561X-2026-2-50-55

For citation: Ul'karov V. A., Trofimov A. A., Sarkisov N. A., Kuzin V. O., Arbuzov K. Yu., Razmahnin I. D., Kobysh A. N., Kozlov R. Yu., and Nestyurkin M. S., Applied Physics, No. 2, 50–55 (2026).

The photosensitive indium antimonide (InSb) material is one of the main materials in the industrially oriented production of matrix photodetectors for the mid-wave IR range and the photoreceiving devices based on them, which are mass-produced by various domestic enterprises [1].

The manufacturing technology for such devices is well-established; however, during mass production, one of the key factors, along with increasing productivity while preserving the quality of products and the reproducibility of results, is the desire to reduce costs and labor intensity, which motivates the search for new solutions and the modernization of individual processes within the manufacturing workflow. For one-sided grinding and polishing operations, as a rule, an orbital machining pattern with

single-piece loading is used. Switching to a planetary pattern is potentially the best solution; however, it requires high accuracy and the structural modernization of the equipment. In this paper, we investigated separate operations at the stage of material processing to establish the possibility of their optimization to increase productivity.

The processing of bulk InSb wafers is conducted piece by piece using a loose abrasive and includes sequential grinding on both sides using abrasive suspensions with different grain sizes [2, 3]. The wafers are polished on each side after grinding. The schematic processing procedure is shown in Fig. 1.

Productivity gains while reducing the costs of the consumables used are provided by group processing methods [4]. To implement the group

processing shown in the scheme in Fig. 1, it is proposed to use a disk carrier with the maximum possible diameter (112 mm) for the bonding of wafers, which allows the existing equipment and tooling for grinding and polishing to work with it.

Knowing the current diameter of the processed wafers (50.8 mm) and applying the solution to the two-dimensional packing problem (“packing circles in a circle”) obtained in 2014 by E. Specht [5] and reviewed by domestic authors [6], it was found that a 112 mm carrier disk accommodates 3 InSb wafers with a diameter of 50.8 mm (Fig. 2).

To assess the viability of the proposed solution, the group processing of the wafers was conducted by grinding using standard tooling. An

Al_2O_3 abrasive with a grain size of 3 μm diluted in deionized water was used. The total load on the samples was 1.35 kg (23 g/cm²), the rotation speed of the grinding plate was set at 15 rpm, and the processing time was 10 min. The profile of the grinding plate surface (diameter of 300 mm) is shaped as a convex surface (+3 μm) to compensate for the difference in material removal in the central part of the disk carrier and at the edges due to the difference in angular velocities during grinding, since in this processing model using three wafers on one disk carrier, the InSb wafers are located close to each other. The measurement of the wafers’ thickness was performed on a Logitech NCG-2 (Scotland) non-contact gauge as shown in Fig. 3.

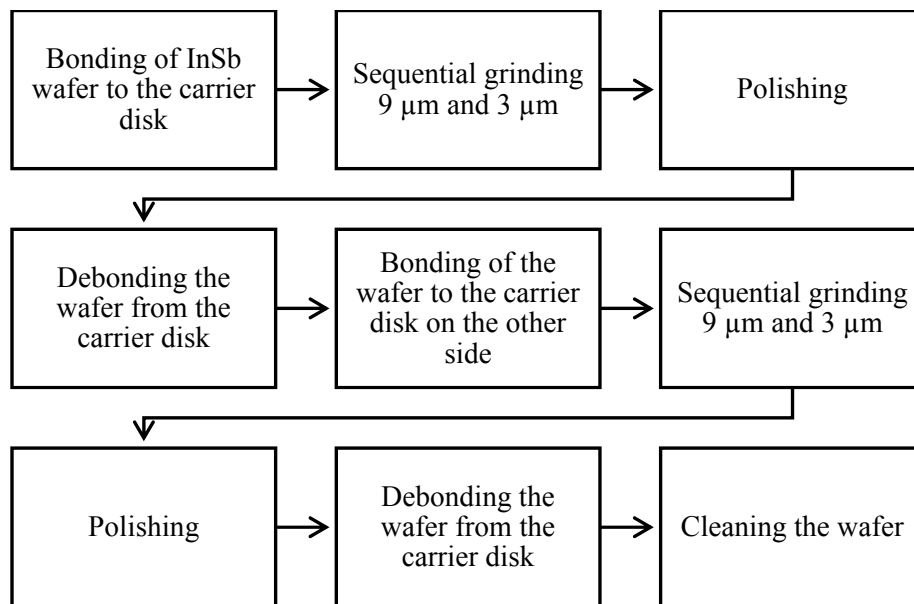
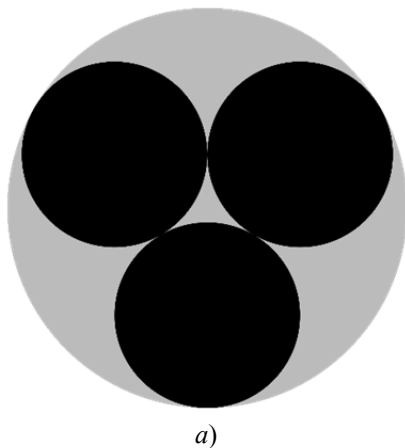
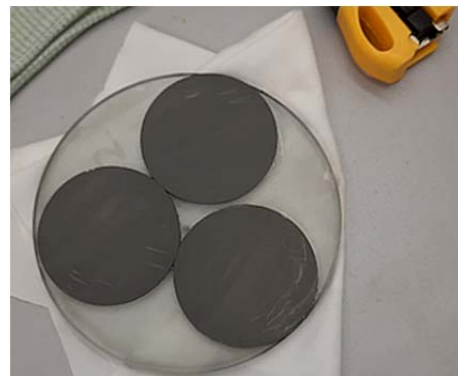


Fig. 1. The scheme of InSb wafers processing during the grinding and polishing stages



a)



b)

Fig. 2. Illustration of the solution of the two-dimensional packing problem for a disk carrier with a diameter of 112 mm and InSb wafers with a diameter of 50.8 mm (a) and a photo of the InSb wafers bonded to the disk carrier (b)

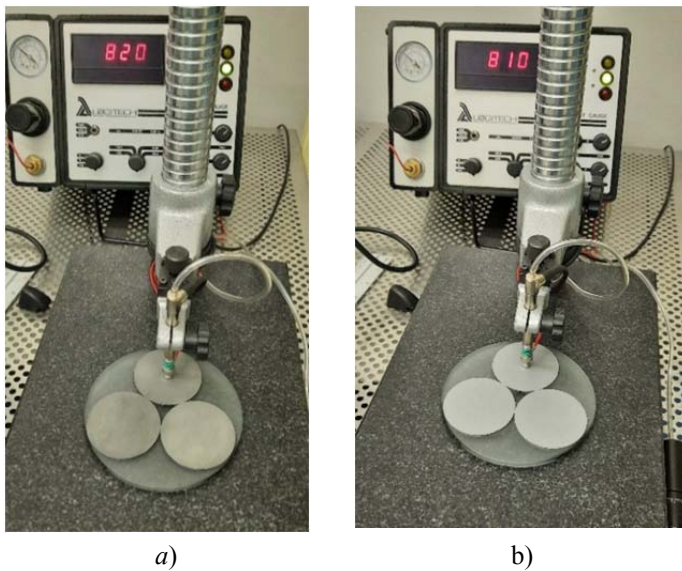


Fig. 3. Simultaneous processing by grinding of three InSb wafers with a diameter of 50.8 mm on a glass disk carrier with a diameter of 112 mm; a) measurement of thickness before processing, b) measurement of thickness after processing

The results of processing and thickness measurements before and after processing, as well as the measurement scheme for several points on each wafer, are shown in Table 1.

The flatness of the treated surfaces of the InSb wafers was measured by a contact method on a Bruker DektakXT (Germany) profilometer with a scan length of 49 mm (Fig. 4).

Analyzing the measurement results, it is noticeable that deviations from flatness do not exceed $0.5\ \mu\text{m}$. One can notice a slight edge roll-off of $0.25\ \mu\text{m}$, probably due to an insufficient convexity of the grinding plate profile selected for the processing during tooling preparation. Nevertheless, the results are in the permissible range of deviations that is currently applied to the piece-by-piece processing of wafers (up to $3\ \mu\text{m}$).

Thus, the proposed solution for the group processing of InSb wafers in the mass production of matrix photodetectors for the mid-wave IR range shows the possibility of its application for process optimization.

After grinding and polishing, the InSb wafers are subjected to the following operations in the manufacturing workflow aimed at the formation of matrix photosensitive elements and their docking with a silicon LSI. The fabricated matrix photosensitive modules are supplied for thinning, which is a complex technological process necessary to improve the spatial resolution and increase the quantum efficiency of the photodetector device.

Table 1

Measurement results of wafers' thickness before and after grinding (μm)

Number of sample	Point measurements	A	V	C	D	E	Location of measurement points on each sample
9	before	817	819	822	821	820	
	after	809	809	810	809	810	
10	before	816	817	821	818	818	
	after	808	808	810	810	809	
11	before	817	816	819	819	818	
	after	808	808	810	808	809	

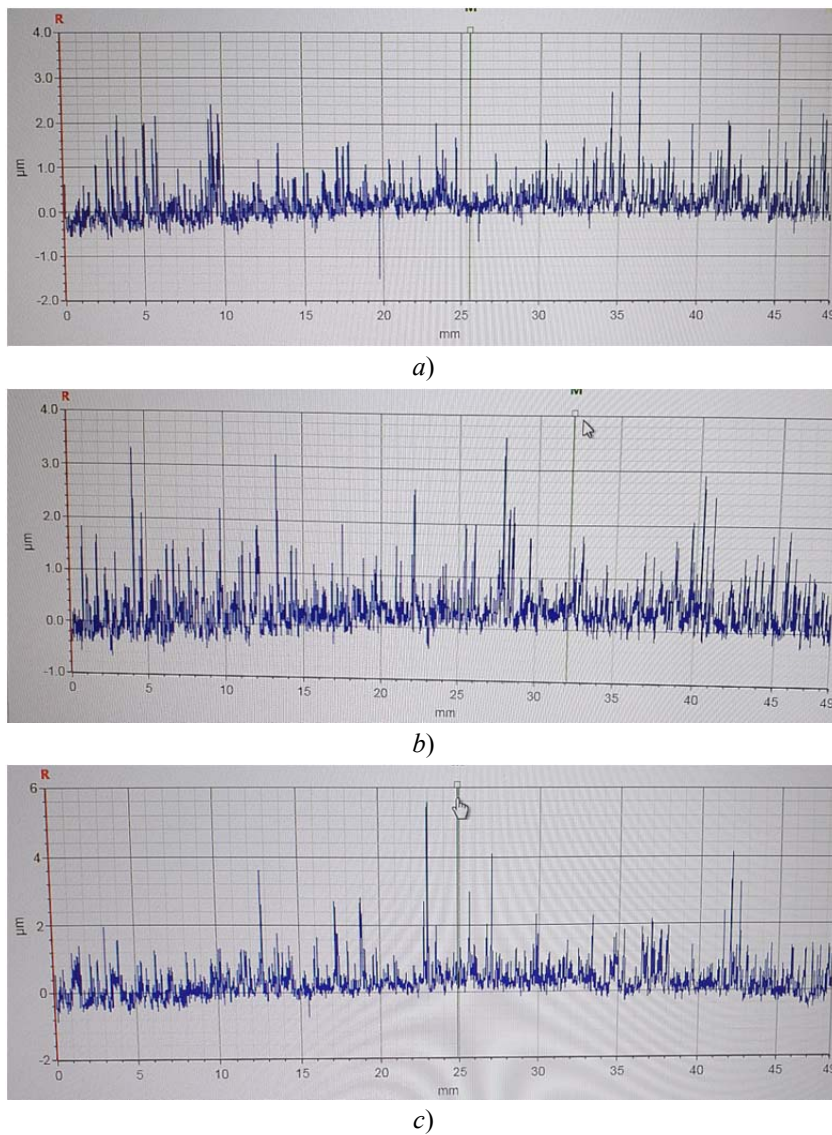


Fig. 4. The results of flatness measurements of the processed InSb wafers surfaces: a) – sample No. 9; b) – sample No. 10; c) – sample No. 11

Currently, at the grinding and polishing stage, the module thinning is conducted piece by piece [7]. To implement the possibility of processing by the group method (3 photosensitive modules simultaneously) a design and

technological solution was developed, a prototype model of a new component was made, and the tooling of the polishing equipment was modified (Fig. 5).

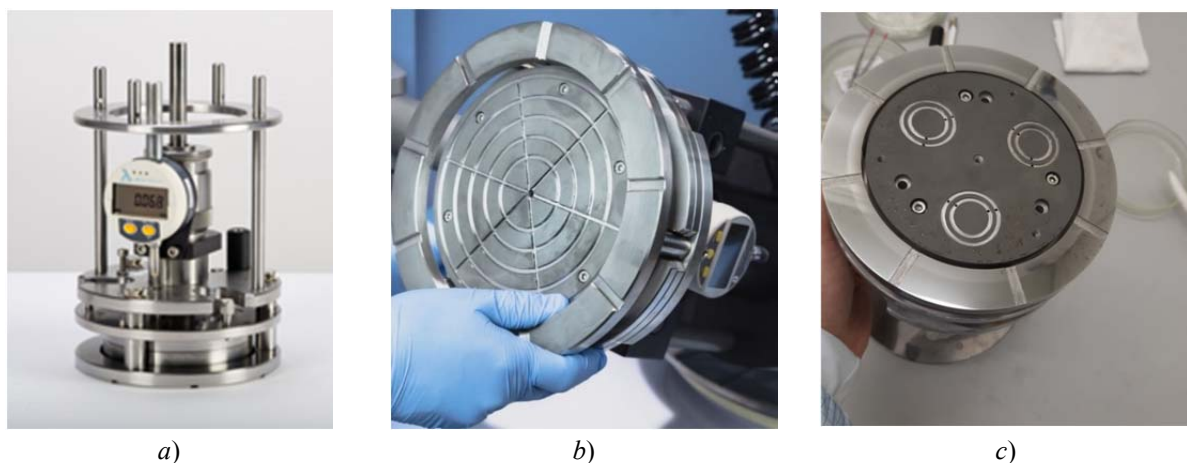


Fig. 5. Tooling for the polishing unit: a) – appearance; b) – standard vacuum chuck of the tooling; c) – tooling modification by adding a prototype model of a new vacuum chuck

The prototype model of a new component is coupled in a certain way with the standard tooling for polishing to ensure maximum surface flatness, which is an important factor for the subsequent group processing of photosensitive modules. The modes and other processing parameters described in paper [7] did not change, except for disabling the reciprocating motion of the tooling along the polishing pad during processing. Such movement during piece-by-piece polishing allows one to achieve the best results in the surface flatness of the processed sample. In the case of group processing, polishing is conducted according to a planetary scheme, which ensures the improvement of the qualitative characteristics of the surface during finishing, high accuracy, and uniform material removal due to the complex spatial movement of each photosensitive module [8, 9].

As a result of the experimental group processing of the photosensitive modules, the thinning was conducted to a thickness of 30–

60 μm . After processing, the measurement results of the flatness of the modules' surfaces, obtained on a Bruker DektakXT (Germany) profilometer, are shown in Fig. 6. The data show that the deviation from flatness at the target distance (highlighted by vertical green and red lines) does not exceed 2–3 μm . The difference in the thicknesses of the processed modules is due to the difference in the thicknesses of the special holders for the modules, which are made of leucosapphire. These holders require their thickness to be adjusted to a uniform size, which ensures the uniform removal of material from all modules in a single process.

Thus, as a result of the conducted studies aimed at increasing the efficiency of the industrially oriented production of matrix photodetectors for the mid-wave IR range, solutions for the group processing of InSb wafers and photosensitive modules were proposed and tested. It was established that the quality of the

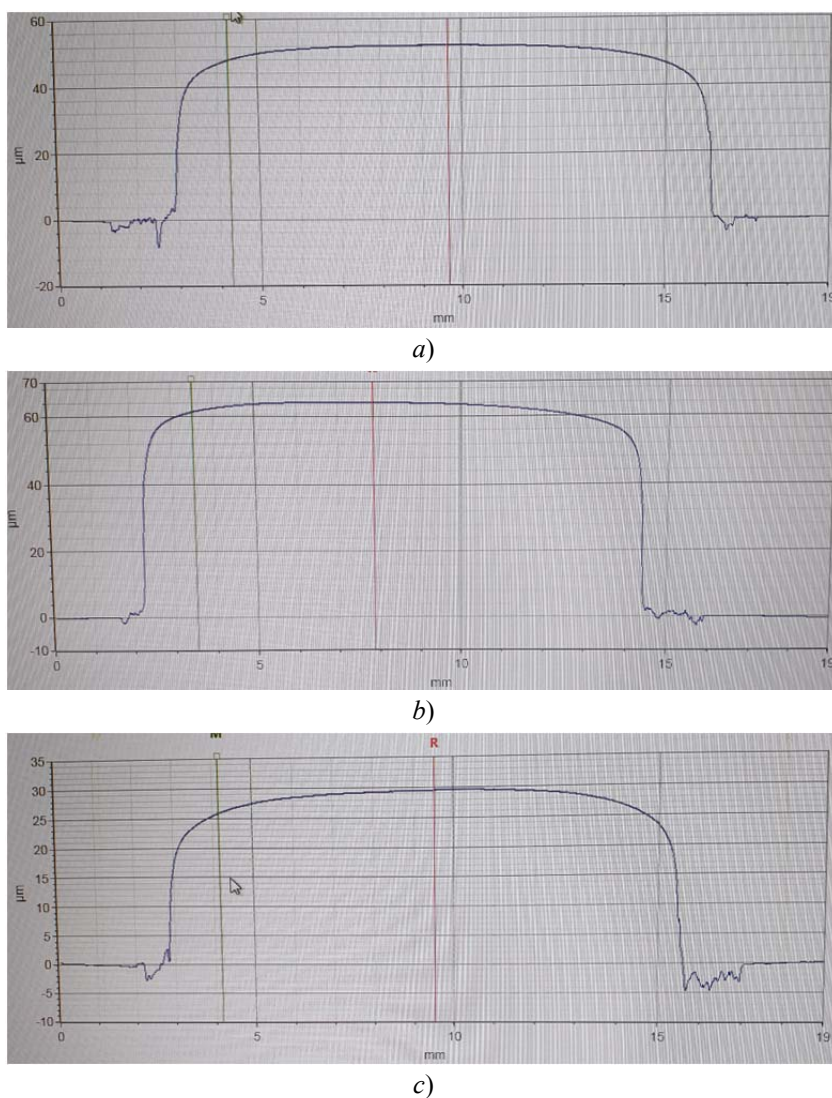


Fig. 6. Measurement results of the surface flatness of InSb photosensitive modules docked with a silicon integrated readout circuit, after group processing:
a) – sample No. 4536; b) – sample No. 4571; c) – sample No. 4573

products obtained during group processing is not inferior in a number of parameters to that obtained during piece-by-piece processing. At the same time, it is possible to increase labor productivity and throughput, while simultaneously reducing the costs of consumables.

However, there are still some unsolved problems within this framework, particularly:

- conducting the full processing of InSb wafers, including material removal from both wafer sides, as well as polishing;
- the preparation of special holders for modules made of leucosapphire and having the same thickness;

– conducting the complete module processing cycle using the new special holders;

– conducting a series of processes for both wafer and module processing to achieve the reproducibility of results;

– the implementation of the obtained and justified solutions into mass production.

Despite a number of unsolved problems, the authors consider it appropriate to continue further studies to achieve positive results in the interests of the industrial production of domestic matrix photoreceiving elements and the photoreceiving devices based on them.

REFERENCES

1. Burlakov I. D. and Startsev V. V. *Materialy XXVII Mezhdunarodnoj nauchno-tehnicheskoy konferencii po fotoelektronike i priboram nochnogo videniya*. Moscow: RD&P Center ORION, JSC, 2024, pp. 24–27 [in Russian].
2. Trofimov A. A., Kozlov R. Yu., Krivobok V. S., Lopatin V. V., Ul'karov V. A., Molodcova E. V., Pavlov P. V., Pavlova O. S., Kosyakova A. M., Komarovskij N. Yu., Nestyurkin M. S., Klekovkin A. V., Minaev I. I., Eroshenkov V. V., Atrashkov A. S., and Kovin Ya. A., *Applied Physics*, No. 5, 46–56 (2024) [in Russian].
3. Ul'karov V. A., Trofimov A. A., Pavlova O. S., Novikov I. V., Sarkisov N. A., and Kuzin V. O., *Usp. Prikl. Fiz. (Advances in Applied Physics)* **12** (5), 456–464 (2024) [in Russian].
4. Kozlov R. Yu., Trofimov A. A., Molodcova E. V., Abramova E. N., Pavlov P. V., Pavlova O. S., Nestyurkin M. S., and Shchenikov N. V., *Pribory*, No. 12, 32 (2024) [in Russian].
5. Specht E. The best known packings of equal circles in a circle (complete up to $N = 2600$).
6. Kazakov A. L. and Lebedev P. D., *Vychislitel'nye metody i programmirovaniye* **16**, 307–317 (2015) [in Russian].
7. Mirofyanchenko E. V., Mirofyanchenko A. E., and Popov V. S., *Applied Physics*, No. 2, 46–52 (2020) [in Russian].
8. Zverovshchikov V. Z. and Zotov E. V., *Izvestiya MGTU «MAMI»*, No. 2 (8), 209–213 (2009) [in Russian].
9. Artemov I. I., Zverovshchikov A. E., and Martynov A. N., *Izvestiya vysshih uchebnyh zavedenij. Povolzhskij region, Tekhnicheskie nauki. Mashinostroenie i mashinovedenie*, No. 4 (28), 199–211 (2013).
10. Boltar' K. O., Vlasov P. V., Eroshenkov V. V., and Lopuhin A. A., *Applied Physics*, No. 4, 45–50 (2014) [in Russian].
11. Babu S. V. *Advanced in chemical mechanical planarization (CMP)*. Woodhead Publishing, 2016.

About authors

Ul'karov Vadim Airatovich, Candidate of Technical Sciences, Lead Engineer RD&P Center ORION, JSC (111538, Russia, Moscow, Kosinskaya st., 9). E-mail: ulkarov@yandex.ru

Trofimov Aleksandrovich, Candidate of Technical Sciences, Assistant Professor, Head of the department the development Materials RD&P Center ORION, JSC (111538, Russia, Moscow, Kosinskaya st., 9); MIREA – Russian Technological University (119454, Russia, Moscow, Vernadsky Ave., 78). E-mail: aa-trofimov@yandex.ru SPIN code: 3716-5536, AuthorID: 818356

Sarkisov Nikita Andreevich, Engineer Cat. 2, RD&P Center ORION, JSC (111538, Russia, Moscow, Kosinskaya st., 9). E-mail: nsarkisov@mail.ru

Kuzin Vladislav Olegovich, Engineer Cat. 2, RD&P Center ORION, JSC (111538, Russia, Moscow, Kosinskaya st., 9).

Arbuzov Kirill Iurevich, Engineer, RD&P Center ORION, JSC (111538, Russia, Moscow, Kosinskaya st., 9).

Razmahnin Ivan Dmitrievich, Engineer Cat. 2, RD&P Center ORION, JSC (111538, Russia, Moscow, Kosinskaya st., 9).

Kobysh Alina Nikolaevna, Candidate of Technical Sciences, head of the department of optoelectronic devices and systems MIREA – Russian Technological University (119454, Russia, Moscow Vernadsky Ave., 78). E-mail: kobysh@mirea.ru SPIN code: 8836-0683, AuthorID: 514026

Kozlov Roman Yurievich, head of laboratory, Giredmet, JSC (111524, Russia, Moscow, Elektrodnyaya st., 2, bld. 1); University of Science and Technology MISIS (119049, Russia, Moscow, Leninsky Prospekt, 4, bld. 1). E-mail: RYKozlov@rosatom.ru SPIN code: 7324-5403, AuthorID: 1302882

Nestyurkin Mikhail Sergeevich, division manager, Giredmet, JSC (111524, Russia, Moscow, Elektrodnyaya st. 2/1); University of Science and Technology MISIS (119049, Russia, Moscow, Leninsky Prospekt, 4, bld. 1). SPIN code: 1217-6079, AuthorID: 1341074