

UDC 621.56, 621.383.4
EDN: AVMBCF

PACS: 07.20.Mc, 85.60.Gz

Determining of the longitudinal and transverse displacements of a coldfinger in a cryocooler manufactured

E. P. Lobachev, G. I. Nekrasov^{*}, D. D. Babenko, N. A. Semenchenko,
A. V. Polesskii, M. V. Bannikov, and M. S. Sorokin

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

^{}E-mail: gleb.nekrasov.18@mail.ru*

Received 9.06.2026; revised 24.06.2026; accepted 06.08.2026

The results of a study examining the impact of an integrated cryogenic system on cooled IR photodetectors are presented. It is shown that longitudinal displacements are below the measurement accuracy threshold, while transverse displacements depend on the rotor speed and range from 4.3 to 11.9 μm . This must be taken into account when developing algorithms for compensating for image shift during operation of the photodetector.

Keywords: gas cryogenic machine, cryocooler, Stirling's cycle, microcryogenic machine, cold tip temperature.

DOI: 10.51368/2949-561X-2026-4-87-91

For citation: Lobachev E. P., Nekrasov G. I., Babenko D. D., Semenchenko N. A., Polesskii A. V., Bannikov M. V., and Sorokin M. S., Applied Physics, No. 4, 87–91 (2026).

Introduction

It is important during the operation of cooled array photodetectors to minimize the influence of longitudinal and transverse displacements of the cooling system on the image. However, no values directly regulating this parameter are established in the regulatory documents of the current standards of the Russian Federation and CIS countries [1].

Western standards also do not prescribe specific linear displacement values, but rather test the device under conditions simulating real operation. The functionality of an array photodetector is confirmed by measuring its primary photoelectric parameters (noise equivalent temperature difference, voltage sensitivity, defect rate), among which there is no control of matrix displacement [2].

There are scientific papers that determine the linear displacement of the photosensor array during the operation of cryosystems, specifically

in [3, 4]. Methods are described for measuring the orientation of the photosensor array of array photodetectors, controlling the longitudinal and transverse displacements of the cooled finger of the microcryogenic system (hereinafter referred to as MCS), and the tilt angle of the MCS cooled finger.

Research Method

The schematic diagram of the experimental setup for measuring linear displacements of the reticle plane is shown in Figure 1.

The setup is arranged as follows: the investigated vacuum cryostated housing (6) integrated with an MCS of the Kryo 2000 model is placed in front of the microscope objective (2). The objective used has a numerical aperture of $A = 0.64$ and a working distance of 8 mm. Prior research [3] mentions the interest towards the tests using an input window made of leucosapphire to enhance measurement accuracy.

To study linear displacements, a vacuum cryostated housing with a leucosapphire input window was fabricated. The distance between the outer end face of the input window and the plane where the array photosensitive elements are installed is equal to 3 mm on the reticle (see

Figure 2). Linear displacements were recorded along gold paths deposited on the reticle. As a reference on the reticle for determining the maximum displacement amplitude of the plane where the photosensor array was installed, a corner of the gold path was chosen.

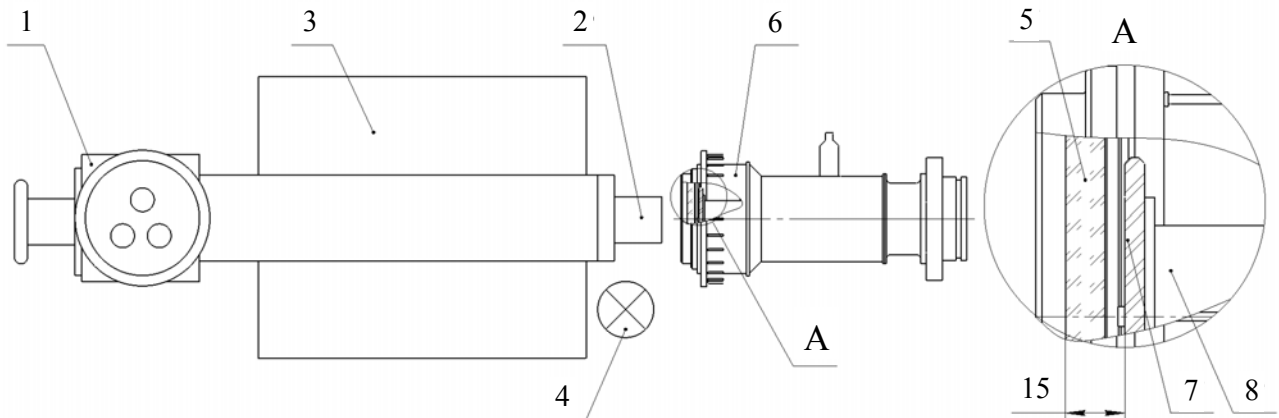


Fig. 1. Setup for monitoring displacements of a photosensor using a microscope: 1 – eyepiece, 2 – microscope objective, 3 – microscope rider, 4 – light source, 5 – input window, 6 – vacuum cryostated housing, 7 – reticle, 8 – cooled finger of the MCS

When applied to monitoring the displacement of the position of the photosensor array plane on the reticle, the measurement accuracy is determined by the sensitivity of transverse and longitudinal focusing. Specifically, the transverse focusing sensitivity governs the measurement accuracy in the direction transverse to the optical axis, whereas the longitudinal focusing determines it along the optical axis [4].

The transverse focusing sensitivity is determined by the formula:

$$T = \frac{1}{6} \cdot \varepsilon_p, \mu\text{m}$$

$$\varepsilon_p = \frac{\lambda}{2A}$$

where ε_p is the linear resolution limit of the instrument, λ is the wavelength, and A is the numerical aperture.

The longitudinal focusing sensitivity is determined by the following expression:

$$\Delta z = \frac{0.2}{A^2}, \mu\text{m}.$$

When monitoring in the visible range, the ultimate measurement accuracy achieved with the selected microscope objective is $0.06 \mu\text{m}$ for measurements in the direction perpendicular to the optical axis and $0.39 \mu\text{m}$ for measurements along the optical axis. Any displacement induced by various reasons will be visually imperceptible if it falls below these values.

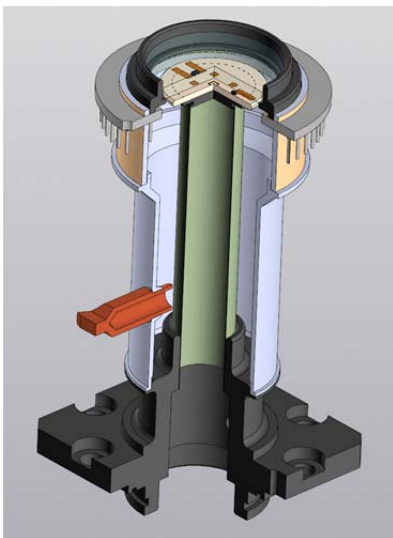


Fig. 2. Three-dimensional model of the vacuum cryostated housing

Measurement Results

Figure 3 shows a gold path with a width of $350\text{ }\mu\text{m}$ in the steady state. When the MCS is activated, vibrations of the photosensor array plane are observed; furthermore, the magnitude of displacements varies depending on the MCS rotor speed. Figures 4a and 4b show the extreme positions describing the displacement amplitude.

Figure 5 shows the obtained experimental dependence of transverse displacements of the

photosensor array plane across the entire range of rotation frequencies under the steady-state mode used in array photodetectors of various configurations. The values on the ordinate axis correspond to the root-mean-square deviation of the controlled point in two directions. The minimum displacement amplitude of $4.3\text{ }\mu\text{m}$ was recorded at the rotation speed of 20 Hz, whereas the maximum amplitude of to $11.9\text{ }\mu\text{m}$ was observed at 33.3 Hz.

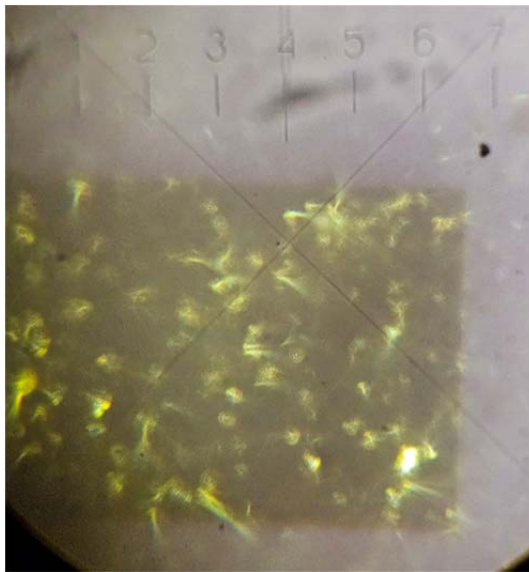
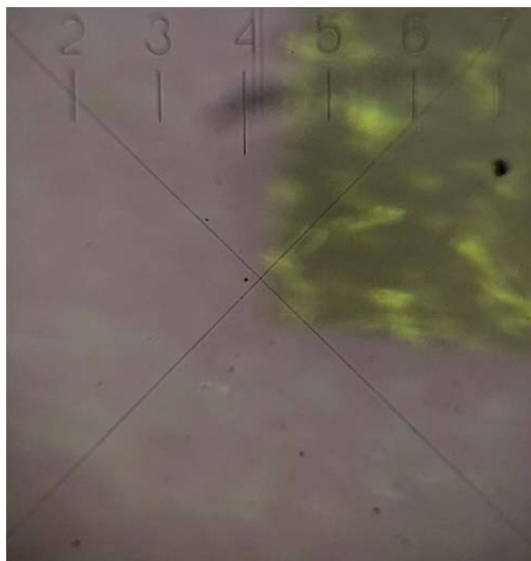
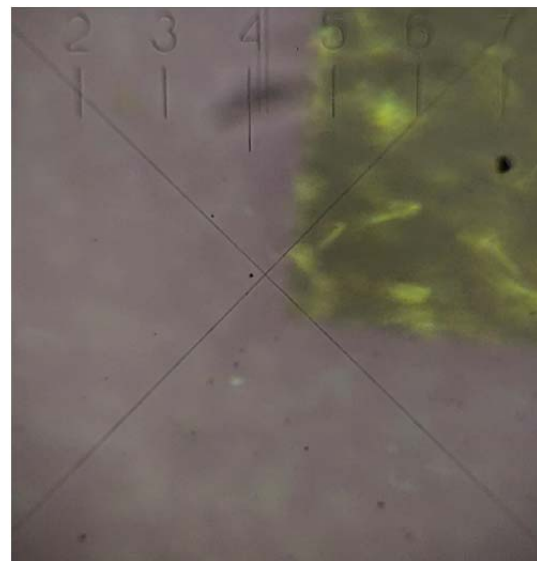


Fig. 3. Gold path on the reticle



a)



b)

**Fig. 4. Displacement of the photosensor array plane of installed on the reticle:
a) – extreme left position, b) – extreme right position**

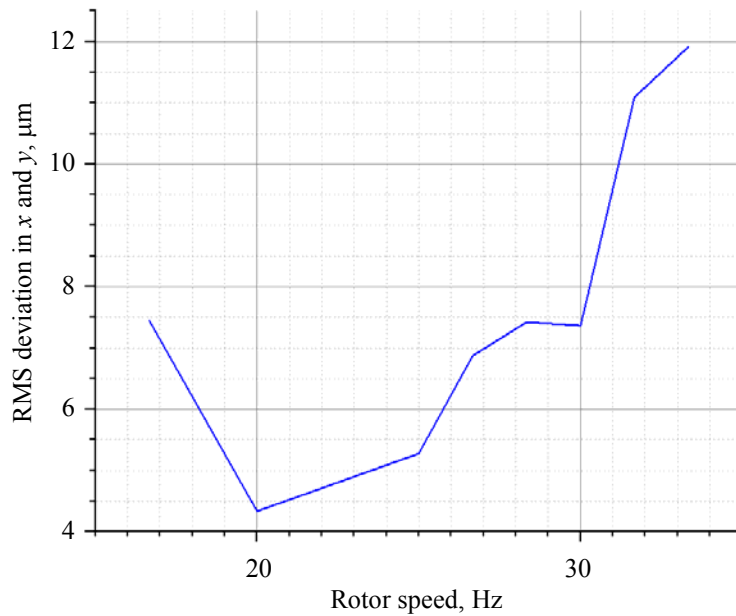


Fig. 5. Displacement of the photosensor array plane at different speeds of the MCS rotor

No displacements along the optical axis were visually observed during the MCS operation, i.e., the maximum amplitude remained below $0.39 \mu\text{m}$.

As can be seen from the cooling capacity graph in Figure 6, the cooling capacity increases as the speed of the MCS rotor speed rises. With

an increase in wear, the efficiency of a single MCS cycle declines; thus, the MCS increases its speed to maintain the cryostating temperature of the array photodetector. Consequently, this implies that as the MCS operating time increases, the displacement magnitude will be higher.

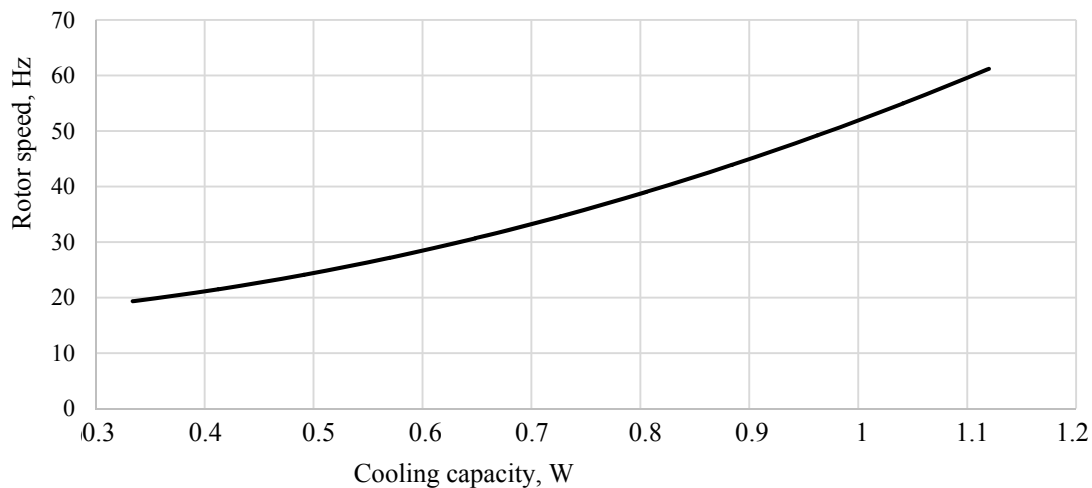


Fig. 6. Graph of the cooling capacity of experimental MCS

Conclusion

The study of the linear displacements of the photosensor array plane during the operation of experimental MCS samples manufactured by AO NPO Orion revealed that the magnitude of longitudinal displacements is less than the measurement accuracy, while the magnitude of

transverse displacements depends on the rotor speed. Depending on the MCS operating mode, the displacement magnitude varies from $4.3 \mu\text{m}$ to $11.9 \mu\text{m}$. Therefore, the increase in displacement amplitude with increasing MCS operating time must be accounted for when developing displacement compensation algorithms for cooled array photodetectors.

REFERENCES

1. GOST R 59606-2021 Optics and photonics. Photodetector devices of second and next-generations. Methods for photoelectric parameters measuring and determination of characteristics
2. MIL-STD-810F
3. Eremchuk A. I., Polessky A. V., Samvelov A. V., Sysojev D. A., and Hamidullin K. A., Usp. Prikl. Fiz. (Advances in Applied Physics) **1** (2), 220–223 (2013) [in Russian].
4. Polesskii A. V., Samvelov A. V., Semenchenko N. A., Smirnova E. A., and Khamidullin K. A., Applied Physics, No. 1, 83–87 (2014) [in Russian].

About authors

Lobachev E. P., Engineer Cat. 2 of the Vacuum Structures and Cryosystems Department RD&P Center ORION, JSC (Moscow, 111538, Russia). E-mail: egorloba@bk.ru

Nekrasov G. I., Candidate of Technical Sciences. senior research scientist of the department of vacuum structures and cryosystems, RD&P Center ORION, JSC (Moscow, 111538, Russia). E-mail: gleb.nekrasov.18@mail.ru SPIN code: 6957-1320, AuthorID: 976504

Babenko D. D., Candidate of Technical Sciences, senior research scientist of the department of vacuum structures and cryosystems, RD&P Center ORION, JSC (Moscow, 111538, Russia). E-mail: rainbowdm1802@gmail.com SPIN code: 9634-1880, AuthorID: 1172254

Semenchenko N. A., head of department, RD&P Center ORION, JSC (Moscow, 111538, Russia). E-mail: nafara@mail.ru SPIN code: 8094-5126, AuthorID: 775858

Polesskii A. V., Doctor of Technical Sciences, Director for Research and Development, RD&P Center ORION, JSC (Moscow, 111538, Russia). E-mail: polesskiyav@orion-ir.ru SPIN code: 3992-4520, AuthorID: 571156

Bannikov M. V., Acting Head of the department of vacuum structures and cryosystems, Deputy Head of the STS MFE, RD&P Center ORION, JSC (Moscow, 111538, Russia). E-mail: maxnutnet@yandex.ru

Sorokin M. S., Technician Cat. 2, RD&P Center ORION, JSC (Moscow, 111538, Russia).