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INVESTIGATION OF A CRYSTAL-OPTICAL TEMPERATURE SENSOR FOR AUTOMATION SYSTEMS

Abstract. The study of the crystal-optical method of temperature measurement is given and a code mask is obtained, by means of which a scale is constructed to determine the initial temperature of the measurements.

Key words: crystal-optical method, temperature measurement, temperature scale.

Introduction. In modern technology, measuring transducers or sensors, which are necessary elements of automatic systems, systems of data collection and processing, monitoring, play an important role. In addition, high-precision transducers are needed for such industries as electronics, medicine, energy, cryogenics, for systems monitoring technological processes, scientific research, etc.

At present, a new direction in thermometry with the use of crystallo-optical temperature sensor (COTS) arose, the special feature of which is that for the transmission of a measuring signal from a sensitive element (SE) COTS, which is in the zone of measurement of temperature to the secondary device, a monochromatic light beam is used, and a sensitive The element is a bifurcation crystal [1].

The purpose of the work. The research of SE COTS for increasing the accuracy and expanding the possibility of measuring the temperature and the probability of their probability in the conditions of the action of electromagnetic fields under high electric potential.

The intensification of the light I (t) recorded by the photodetector [2] can be represented as:

If a birefringent crystal places an environment in which it is necessary to measure the temperature, then its change will cause a change in refractive index and, accordingly, a change in the path difference between ordinary and unusual rays. The intensity of the monochromatic polarized light passing through the crystal has a periodic dependence on the temperature of the crystal t:

$$I = I_o \cdot \sin^2 \frac{p \cdot d \cdot \Delta n(t)}{l}, \tag{1}$$

where I_o – the intensity of the incident light flux; d – the thickness of the crystal along the beam; $\Delta n(t) = \Delta n'(t) - \Delta n''(t)$; $\Delta n'(t), \Delta n''(t)$ – indexes of refraction of a crystal in the crystalline-physical directions lying in a plane perpendicular to the direction of radiation propagation; l – wavelength of radiation.

Then, according to (1), the measured temperature can be given:

$$t = t_0 + m\, t_T + \Delta t, \tag{2}$$

where t_0 – is the known initial temperature, when $t_0 = 0$ i $m = 0$; m – number of minima of the photocurrent recorded with a change in temperature from the initial t_0 to the measured t; $\Delta t < tT$ – temperature of the incomplete temperature interval tT. It is seen that a certain value of the photocurrent corresponds to a set of temperatures $(m \cdot t_T + \Delta t)$, where m = 0, + 1, + 2, ..., t_T is the temperature interval characteristic of the given SE COTS.

However, there is a problem of determining the temperature t_0 and Δt, although this method has a high repeatability of the metrological characteristics of the SE COTS, which makes it promising.

To measure the temperature with the crystal-optical method and to solve the problem of determination of t_0, a primary COTS based on birefringing crystals can be used [2].

In order to extend the temperature range and improve the accuracy of the COTS temperature measurement with the ability to determine the initial temperature, we proposed the COTS shown in Fig. 1

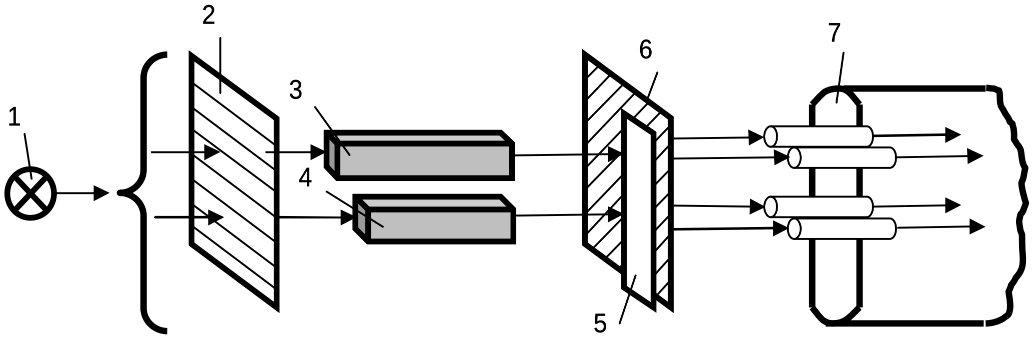

Fig. 1. Laser ЛГН-207Б (1); polarizer (2); crystals ЧЕ (3–4); quarter wave plate (5); analyzer (6); fiber optic (photodetector) (7)

In this COTS, the thickness of the crystals SE 3, SE 4, respectively, d3, d4 are as d3: d4 = 9.7, then the temperature intervals tT4: tT3 = 9.7.

For the possibility of measuring the polarizer 2 and the analyzer 6 are in the crossed position, the crystals SE 3, SE 4 in the diagonal. The rays passing through SE 3, SE 4 receive a phase shift between the ordinary and extraordinary rays depending on the temperature. A portion of the radiation from each channel passes through a quarter of the wave plate 5 and receives an additional phase shift – $\pi / 2$ and gets through the fiber to the photodetector. At the output of the photodetectors we get the electrical signals $U_{ф3\text{-}1}$, $U_{ф3\text{-}2}$, $U_{ф4\text{-}1}$, $U_{ф4\text{-}2}$, determined by the square of the amplitude of the corresponding optical signals at the input, their sensitivity (steepness of the transformation) $S_{3\text{-}1}$, $S_{3\text{-}2}$, $S_{4\text{-}1}$, $S_{4\text{-}2}$, i.e.

$$U_{\phi 3-1} = S_{3-1} I_0 \sin^2 \tfrac{p \cdot k}{l} t \, , \qquad (3)$$

$$U_{\phi 3-2} = S_{3-2} I_0 \sin^2 \tfrac{p \cdot k}{l} (t - \tfrac{T_3}{4}) \, , \qquad (4)$$

$$U_{\phi 4-1} = S_{4-1} I_0 \sin^2 \tfrac{p \cdot k}{l} t \, , \qquad (5)$$

$$U_{\phi 4-2} = S_{4-2} I_0 \sin^2 \tfrac{p \cdot k}{l} (t - \tfrac{T_4}{4}) \, , \qquad (6)$$

where I_0 – intensity of light at the output of the thermosensitive element of a birefringent crystal – SE 3, 4; λ = 632.8 nm – wavelength of source 1 of monochromatic polarized light; k – can be a function of temperature t; t_{T3}, t_{T4} is the characteristic temperature interval for a thermosensitive crystal SE 3, SE 4, corresponding to a phase multiplied to 2π.

The results of the research and the use of two SEs for COTS from lithium niobate allow obtaining high-stability metrological characteristics, which provides the possibility of remote measurement of temperature in magnetic fields at objects under high electric potential, practically without heat transfer in the range 175 … 380 ° C.

Conclusion. The development of scientific researches of crystallo-optic methods and the search for new materials for SE COTS indicates their promising, given the significant expansion of the ability to measure temperature and increase their accuracy [2].

Література

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