ANGLE MEASUREMENT DEVICE

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Abstract

Angle measurement means are one of the advanced directions for the application of gas ring lasers. The requirements of ring lasers used in angle measurement devices are different, in many respects, from those used in navigation. A simple ring laser developed for implementation in high-precision angle measurement instruments is described. The main specifications are presented.

Methods of the accelerated tests are imperfect for determining a term of storage; therefore, tests during a real storage term remain the most reliable. Operation of the ring lasers in angle measuring instruments during 20 years has demonstrated their high stability.

Keywords: angle, measuring instruments, ring laser, aviation gravimetric system.

I. Introduction

The basic components of aviation gravimetric system (AGS) for measuring gravity anomalies are proposed in [1]. Those are devices for measuring speed and location coordinates of the aircraft, devices for measuring the height and gravity and airborne digital computer. Gravimeter is a sensitive element of AGS that measures the gravity and the accuracy of which, basically, determines the accuracy of all AGS.

A new types of gravimeters that has greater accuracy from known aircraft gravimeters is proposed in [2, 3].

The accuracy of the previous posting gravimeter sensitivity axis significantly influences on the accuracy of AGS gravimeter. Therefore for precision posting gravimeters axis proposed use laser angle measurement device [4].

II. Formulation of the problem

Studying in high precision angle measurement means, photoelectric angle converters, inductive or capacity converters as well as limbs are used as angle sensors. Manufacturing of the sensitive elements (scales) for such sensors is performed on special equipment such as dividing machines. In this case, an error of the sensors includes an error of manufacturing equipment.

A ring laser comprises an angular scale set by the wavelength of laser radiation. This angular scale is a qualitatively different one in which errors of dividing machine are absent. Use of such a scale improves essentially the parameters of angle measurement means such as accuracy, operating speed and measurement authenticity. Ring lasers can be used in angle measurement devices of different purposes.

A significant attention is paid to the development of goniometers. For example, in [5, 6, and 7] the designs of goniometers as well as test results are described. In [8] a specialized goniometer used in workshop conditions for the measurement of polygons angles is described. In [9] the first commercial automatic angle measurement system (goniometer-spectrometer) GS1L is described. The system is designed for the measurement of plane angles and pyramidality of the prism faces as well as refractive index of optical media. This system is produced in lots and widely used at many plants and metrological center's. On the basis of ring lasers it is also possible to develop automatic devices for the measurement of shaft rotation angles, devices for checking the angle parameters of limbs, modulators, circular optical encoders and other angle structures, as well as devices for determining the angles between marks, stars, geodesic and astronomical devices, laser location devices and

others. The advantages of ring laser implementation in the systems for stabilization of rotation rate [5] are shown experimentally.

The ring lasers designed for navigation were used in the first angle measurement devices. In connection with the specificity of the application of ring lasers for angle measurement systems and because of serial production of angle measurement means on their basis, the ring laser has been specially designed for angle measurement devices.

III. Results

Gravimeter (most gas ring lasers) are used in military and civil navigation systems. The requirements of these ring lasers are high. For example, they must have a minimal lock-in zone, a special frequency separation unit for low angular rate measurements; they also must provide the operation in a wide temperature range, in conditions of shocks, vibrations, radiation exposure, etc. The most important characteristic of the ring laser is scale factor stability during a long period of time. There are rigid weight and dimension restrictions for such devices. Therefore, the ring lasers used in navigation systems are costly.

The requirements of parameters of ring lasers used in industrial angle measurement means are different in many aspects. Generally, such devices operate in a narrow temperature range. They are not exposed to vibrations and shocks during the measurement process. Generally, they don't require a frequency separation unit. The implementation of self-calibration method [11] in angle measurement devices such as goniometers allows decreasing considerably the requirements for a long-term stability of the ring laser scale factor. For most applications, the requirements of minimum dimensions and weight are not the basic ones. Therefore, a design of such lasers is simpler and they are cheaper. Furthermore, their cost falls due to decrease of tests number.

At the same time, additional requirements are imposed to such lasers. For example, in many cases such expensive, high-precision angle measurement devices

operate for several decades. Therefore, the ring lasers implemented must have a service life of the order of 20 - 30 years. An operating life must be from several thousand to tens of thousands of hours. To obtain a high precision the ring laser must have a high angular resolution.

For angle measurement devices of different purposes several types of the ring lasers have to be developed. There are three groups of angle measurement means, which need special ring lasers.

The highest accuracy installations including National standards are concerned with the first group of the angle measurement means. As a rule it is stationary equipment without rigid requirements for dimensions of the ring lasers comprising this equipment.

Workshop's angle measurement means is concerned with the second group. These are portable devices, in which ring lasers weight and dimensions must be limited.

Compact mobile devices are concerned with the third group of angle measurement means. For these devices, there are rigid limitations on dimensions and weight of the subsystems including the ring lasers. Their precision is lower than that of the first and second groups. A ring laser designed for angle measurement instruments of highest accuracy is described here.

A design of the ring laser 3.970.029 is given in [4, 5]. It was developed in the Central Design Bureau (CDB) "Arsenal" (Kyiv, Ukraine) and made in accordance with a classical scheme. The cavity is formed by mirrors and made as an equilateral triangle. The first mirror is mounted on a piezoelectric transducer. With its help, the adjustment of the cavity length is performed. On the second mirror, the mixing optics with the four-section photodetector for information circuit is mounted, on the third one there is a prism with the photodetector of radiation power regulation circuit.

The power supply elements are positioned in such a way that they compensate for Langmuir drift (in the scheme: two anodes, one cathode). There is an iris in the

passive channel of the cavity. Hermetic sealing of working volume is achieved by vacuum-tight joints. The mirrors are mounted using an optical contact. Joints of anodes and cathodes contacts are made by metal soldering.

Using a special adhesive, a mounting surface of the monoblock is fixed to a metal plate made of material with a low linear temperature expansion coefficient. There are three holes in the plate for its mounting in angle measurement devices.

The monoblock has three additional cavities to provide a considerable volume of a working gas mixture.

Basic specifications of the ring laser 3.970.029 are given in Table 1.

Table 1. Basic specifications of the ring laser 3.970.029

1. Monoblock material	Glass ceramic
2. Cavity shape	Equilateral triangle
3. Reflectors type	Multilayer interference dielectric mirrors
4. Length of cavity side, mm	227 "
5. Type of element for perimeter adjustment	Mirror shifting by the piezoelectric transducer
6. Radiation wavelength, micrometers	0,6328
7. Type of polarization	Linear
8. Information output	Two sine signals
9. Phase shift between two information signals, electrical degrees	90 ±5
10. Angle period value of information sine signal, period/arc, sec	1,0
11. DC pumping supply - dc voltage, V, not more than - direct current, mA, not more than	900 3,0
12. Overall dimensions, mm - height - circumscribed circle radius	83 160
13. Weight (with base), kg, not more than	4,3

By using the known frequency multiplication circuit's two phase-shifted information signals allow the angle period value of information signal to be decreased considerably.

IV. Conclusions

Further increase of angle measurement accuracy by using the described ring laser can be achieved first of all due to the improvement of subsystem parameters of

an angle measurement device, and due to application of more perfect electronic circuits for perimeter and radiation power stabilization as well as corresponding information processing with taking into account an estimation of the scale factor drift of the ring laser.

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