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Hydrophysical laser-interference complex

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Abstract

A new hydrophysical measuring complex has been developed on the basis of a laser instrument for measuring hydrospheric pressure variations. The complex was previously engineered and experimentally verified. This equipment allows to investigate the amplitude-phase variations of hydrospheric vibrations and waves in the low-frequency range. All performance data of the complex was considerably improved by virtue of the operating experience obtained previously. Radically new opportunities of the equipment were provided since the apparatus was rigged with new sensors for accompanying measurements and a container which allowed working independently. The new hydrophysical measuring complex is easier to operate and maintain, ensures higher quality of the data obtained and new spheres of application.

Keywords: Laser meter; Hydrosphere pressure variation; Interferometer; Measurement system; Hydrosphere.

The technical characteristics of the equipment used for solving the problems that arise in studying various processes and phenomena occurring in the geosphere, such as the nature of the emergence and development of crustal deformation variations, are of high importance. Laser deformographs of different modifications [1–3] were created for investigations into the subject. Using methods of laser interferometry for developing other measurement tools allowed to create laser nanobarographs [4] and laser devices for registering hydrospheric pressure variations [5], capable of measuring variations in atmospheric and hydrospheric pressure in the infrasonic or audible ranges with high precision. Simultaneously using a laser nanobarograph and a laser meter measuring hydrospheric pressure variations makes it possible to obtain some fundamentally new results. For example, it was found that pressure wave trains in an aqueous medium with periods lying in the time range from 7 to 13 min are caused by similar wave trains in atmospheric pressure, and not by short-period internal sea waves [6]. Even though the laser device for measuring hydrospheric pressure variations (LMHPV) has already proved successful in studies, it still needs further improvement as it has several substantial disadvantages:

(a) Large dimensions and weight of the device cause instability of the interference pattern (besides, the device is inconvenient to use).

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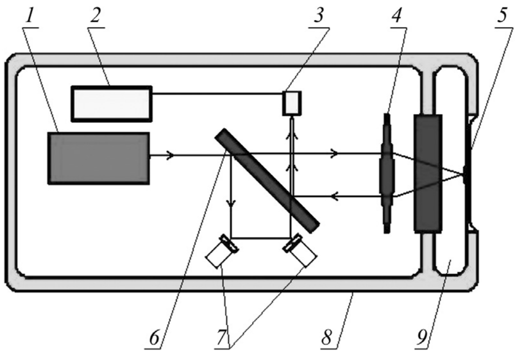

Fig. 1. Optomechanical schematic of the interferometer: radiation source 1 (helium neon laser), registration system 2, photodetector 3, collecting lens 4, membrane with mirror coating 5, parallel-plate beam splitter 6, piezoceramic cylinders for compensation and test signal 7, sealed housing 8, pressure compensation chamber 9.

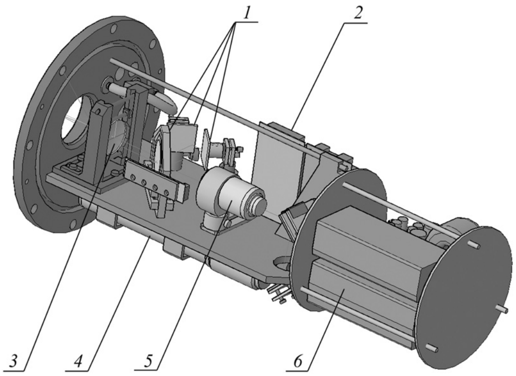

Fig. 2. Three-dimensional model of the arrangement of the measurement system's components: mirrors and beam splitter plate 1, printed circuit boards of the registration system 2, lens focusing the beam to the membrane 3, laser 4, collimator 5, power supply unit 6.

(b) It is impossible to separate the contributions from the variations in the seawater temperature in the device's readings.
(c) The device cannot work as standalone.
(d) It is impossible to connect additional sensors.

Because of these disadvantages, the design of the LMHPV has been changed considerably, which allowed to significantly improve its performance.

The radiation source *1* in the LMHPV is a Melles Griot frequency-stabilized helium neon laser (Fig. 1). The main part of this laser meter is still a modified unequal-arm Michelson interferometer with one reference arm.

A beam propagating along the other arm passes through the mirror mounted on the membrane in the lid of the device (the outer side of the membrane is in contact with water). This beam is thus a measuring one. Converging both beams returning to the beam splitter allows to obtain an interference pattern. The change in the brightness of this pattern is associated with the change in the beam path difference. The change in the brightness is recorded by photodetector *3* of registration system *2* which generates a signal to compensate for the path difference. The same signal is also an output one.

The device uses a system of compensation for hydrostatic pressure. It is necessary for equalizing the pressure on both sides of the membrane to bring it into a neutral position before measurements. Once the system is submerged under water, a signal opens an electromagnetic valve through which air passes from a special container into the chamber. The valve closes upon submersion to the required depth so that measurements can begin. As the system is lifted out of the water, pressure is relieved.

The optical bench (a metal plate bearing all the optical components of the device), which was previously 1144 mm long, was shortened to 400 mm for the new system. This became possible after the component sizes were optimized and the components were arranged more efficiently using three-dimensional simulation software (Fig. 2).

The updated optical bench is made of stainless steel, which, along with stiffening ribs located on both sides and a steel expansion on the upper side, increased the stiffness of this element. The radiation source was transferred from its previous location to under the optical bench, where the beam could be transmitted through a system of mirrors mounted on an original spring suspension compensating for the system's vibrations. Reducing the length of the optical bench allowed to in turn reduce the length of the sealed housing by 543 mm; this significantly lowered the weight of the device, while its new dimensions simplified bringing the device into operation and lifting it from the water.

The thermal sensors based on a DS18B20 digital thermometer were installed one inside (on the optical bench of the interferometer) and one outside (a thin-walled rod probe near the membrane) of the device. Temperature must be measured inside the device because its change introduces a significant error in the performance of an uneven path interferometer. The sensor's temperature resolution in 12-bit mode was 0.0625 °C.

A pressure seal for connecting an ECO FL fluorimeter for determining the biological characteristics