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THE PRIMORYE–SAKHALIN LASER-INTERFERENCE SYSTEM

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A system of spatially separated devices that form a measurement complex based on laser-interference strain meters is developed and launched in a continuous measurement regime.
Keywords: *laser strain meter, interferometer, measurement system, Earth's crust, monitoring of geodynamic processes.*

A laser-interference system intended for monitoring planet-wide geodynamic processes and phenomena that exhibit a strain response has been created in the Primorye–Sakhalin three-dimensional baseline with the use of devices developed at the Ilichev Pacific Oceanological Institute. The system consists of two spatially separated (1053 km apart) laser strain meters installed at Primorsky Krai (Primorye) and on the island of Sakhalin. The system is synchronized relative to a unit time satellite clock equipped with hardware-software service complexes created from a common design and intended for managing the operation of the laser strain meters and primary processing and storage of the experimental data.

A pericentric–type laser strain meter assembled according to a modified design of a Michaelson interferometer operates at Primorye in a regime of continuous measurements of the variations in microstrains of the Earth's crust. The device is mounted in fixed position in an underground structure at a depth of 3–5 m. The basic characteristics of the device are presented in Table 1 [1]. The total multi-month error due to variations in the temperature, pressure, and humidity in the air spaces of the interferometer, air-filled optical cable, and constant-temperature chambers is equal to $\pm 1.1 \cdot 10^{-9}$ m [1]. The error of the measurement is one-tenth less when studying oscillations and waves with periods of several days and less. Moreover, the meteorological parameters recorded by means of an automatic weather station are taken into account when processing the experimental data of the laser strain meter.

A second pericentric-type laser strain meter is installed in an underground structure at a depth of 2 m south of the island of Sakhalin and its basic technical characteristics are also presented in Table 1.

A digital recording system developed by the present authors [2] is used in the strain meters. The system belongs to the class of extremal regulation systems and controls the operation of interferometers, maintaining the intensity of the interference pattern at a maximum by means of piezoceramic elements in a feedback loop. Once the edge of the dynamic range is reached due to a cyclic shift at the extrema of the interference pattern, the recording system generates a reset pulse, which establishes the zero voltage in the piezoceramic elements. Thus, the dynamic range of the device extends to values that substantially exceed that possible in Nature. The voltage fed to the piezoceramic elements and the number of reset pulses at a particular moment of time correspond to the variation in the optical difference of the path in the arms of the interferometer, which is linearly related to the shift in the Earth's crust. This information is fed to the computer in digital form after traveling through a communication line, where it is written to the hard disk at a specified sampling rate.

The principle used in the measurement of the path on the basis of laser strain meters is the same as in the case of strain meters with similar or higher sensitivity [3–5]. Because of the stability of the temperature, pressure, and humidity, and taking account of their variations in the measurement results and the low range of voltages fed to the piezoceramic elements

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TABLE 1. Basic Technical Characteristics of Laser Strain Meters

Characteristic	Location of strain meter	
	Primorye	Sakhalin
Depth of unit, m	3–5	2
Length of measurement arm, m	52.5	10.5
Precision of measurements of variations in the micro-shifts in a segment of the Earth's crust, nm	0.1	0.3
Working range of frequencies, Hz	0^*–1000	0^*–1000

* Provisional value.

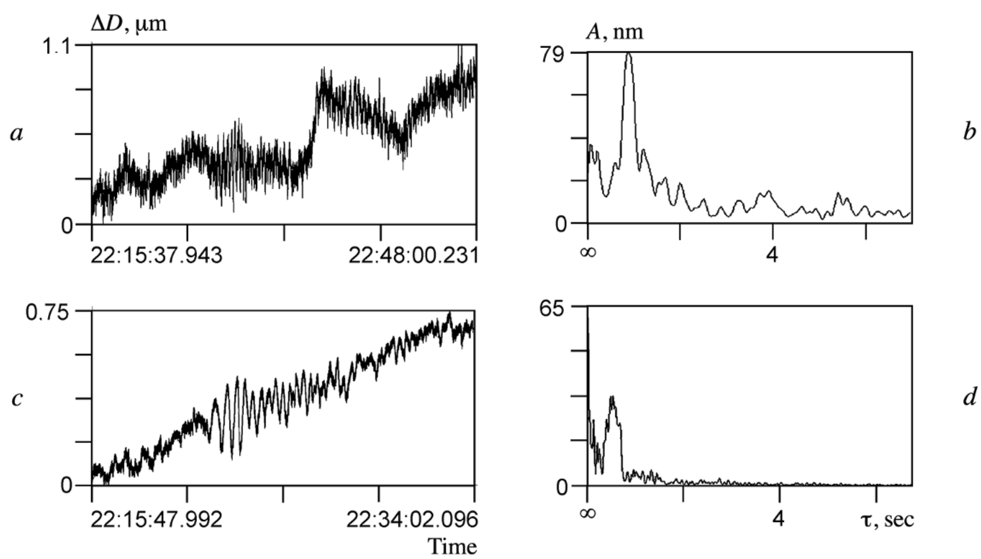

Fig. 1. Fragments of a record (*a*, *c*) and corresponding amplitude spectra (*b*, *d*) of laser strain meters: *a*, *b*) Sakhalin; *c*, *d*) Primorye.

(up to 198 V), such parasitic phenomena as creep and hysteresis in the piezoceramic elements when working with strain meters at frequencies from 0 (provisionally) to 1000 Hz in the linear range may be avoided. The Melles Griot He–Ne lasers used in the units possess a long-term frequency stability of 10^{-10}.

The system of strain meters that has been considered here is intended for studying amplitude-phase variations of oscillations and Earth waves in the subsonic range, including the natural oscillations of the Earth and of the Earth's crust and slow planet-wide waves associated with the mechanism underlying the appearance and development of earthquakes. The experimental data that were obtained were entered into a unified data bank and were then subjected to spectral-time analysis. The present system of devices may also be used in experimental studies for the purpose of identification and direction finding and to determine the parameters of geodynamic events. An example of a record of an earthquake that occurred along the eastern shore of the island of Honshu in Japan is presented in Fig. 1. The earthquake was of magnitude 6.1 and was recorded on October 1, 2012 by the geophysical service of the Russian Academy of Sciences at a depth of 20 km. The figure depicts fragments of a record created by the laser-interference system and the corresponding amplitude spectra, according to which the period of oscillations during the earthquake amounted to 17 sec (from the record made on Sakhalin) and 16.6 sec (from the record made at Primorye).

The newly developed system of spatially separated laser-interference strain meters in the Primorye – Sakhalin field base demonstrated a high degree of efficiency in recording planet-wide geodynamic activity and in determining the parameters of the recorded processes.

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