BURKHAN STATIONARY DEEP-WATER METER OF HYDROOPTICAL PARAMETERS

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This paper describes an instrument for deep-water measurement of primary hydrooptical parameters. It is capable of measuring both in sounding and stationary regimes. The spectral range is 350–700 nm. The design, principles of operation and specifications of the instrument have been described. Some experimental data have been presented.

A comprehensive investigation into the primary hydrooptical parameters is carried out in the visible spectral range in the region of neutrino a deep-water telescope on Lake Baikal as part of the program DUMAND. The BURKHAN stationary instrumental-methodical complex developed by us is intended to try out procedures for measuring the light absorption index, scattering index, and scattering phase function in water to depths as great as 2000 m.

The complex consisted of a submersible module and a coast-based computer. A single conductor of a wire cable was used for data exchange between the module and the computer, control of the submersible module, and its power supply. The submersible module had a point isotropic source of light that may reach depths as much as 1–15 m and cosine and collimated detectors. The collimated detector (0.5°) could rotate in the plane passing through the source with a step of 2′. Measurements were carried out at 16 spectral points selected by interference light filters that were automatically changed. The control of the module units and data collection and exchange with the coast-based computer were carried out by a microcomputer built around the K1821VM85 processor. The IBM PC/AT computer was used as a coast-based computer.

The cross-section view, of the submersible module is shown in Fig. 1. The body of the submersible module *1* was formed by a thick-walled tube with lids put hermetically on both ends. Two photodetectors *2* and *3*, the mechanism for changing the light filter *4*, and the voltage transformers *5* were placed inside the body. In addition, the indicators of the light-filter number, hygrometer, two photodiodes for each photodetector to check the linearity of dynamic range, and the collimator *6* with adjusting mechanism were placed inside the body. The attachment with mat glass to measure the absorption index and the mechanism for rotating the mirror *7* to measure the scattering phase function and the scattering index were placed outside the body.

The transmission, i.e., the mechanism for moving the light source driven off the stepping motor *8* was fixed at the bottom of the body. The engine was placed into the body filled with oil. The light source *9* (the KGMN-27 small-size halogen lamp) was placed into a hermetic quartz valve and mounted on a mobile platform. The highest and lowest positions of the source were fixed by end hercones clamped on a transmission base and by magnets lashed to a movable wire rope. Current position of the light source was determined from the number of steps of the stepping motor from the extreme position.

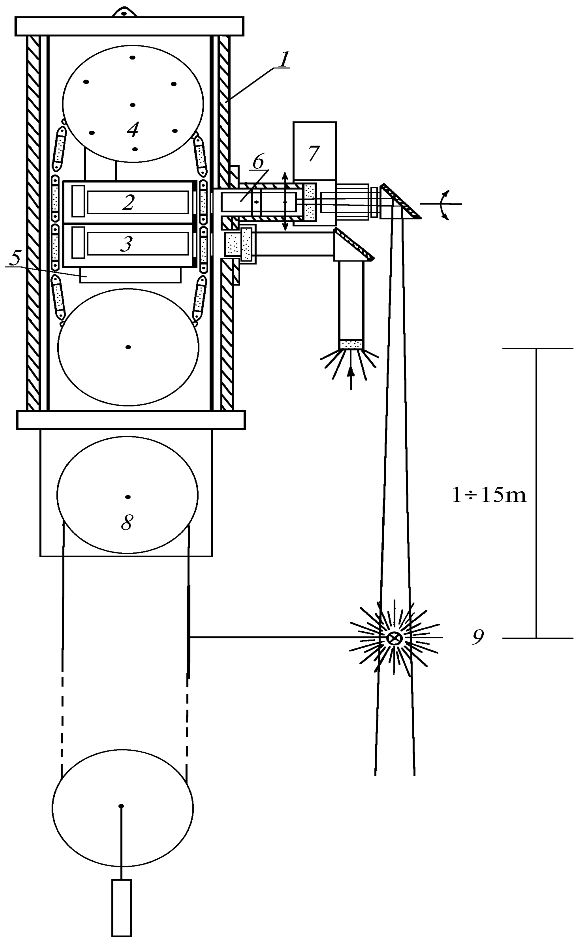

FIG. 1. Cross-section view of the submersible module: 1)body, 2,3) photodetectors, 4) mechanism for changing the light-filters, 5) voltage transformer, 6) collimator, 7) mechanism for rotating the mirror, 8) stepping motor for moving the light source, 9) light source.

To extend the dynamic range of the photometric channel, provision was made for a step change in high voltage on dinodes of both photomultiplyers as well as in the light source brightness. The transformation of the radiation spectrum occurring in the last case did not affect the measurement results because the narrow

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spectral bands of width of about 5 nm were selected by means of the interference light filters.

Instability of a measurement channel in a matter of 10 min (time of measurement at one point of the spectrum) did not exceed 0.1%. The error in determining the light source position was no greater than 1 cm.

All operation regimes of the instrument were controlled by an electronic unit (it is not shown in the figure) placed inside the hermetic body. The block consisted of a controller board, a universal multiscaler, and three boards of controlling peripheral units.

The controller built around the K1821VM85 microprocessor provided a protocol of data exchange with the coast-based computer through a serial communication channel, control of the device, as well as the collection and preliminary processing of the data. The circuit design of controller, universal multiscaler, communications equipment, and protocol support exchange programs were developed in the Laboratory of Physical Electronics of the Scientific-Research Institute of Applied Physics especially for the DUMAND hydrological instrumentation.

The measured dependence of the illumination on the distance is exponential, and the exponent coincides with the absorption index with an error of 1%, according to Ref. 1. The techniques for reconstructing the scattering index and the scattering phase function from the brightness field in the single scattering approximation were described in Ref. 2. Work is now underway on determining systematic error of different techniques used for reconstructing the primary hydrooptical parameters and on finding new techniques considering the multiple scattering.

Specifications of the BURKHAN stationary deep-water complex

Measuring range of absorption and scattering indices, 1/m	> 0.01
Relative error in measuring the absorption	0.01
Relative error in measuring the scattering	0.1
Relative error in measuring the scattering phase function	0.1
Angular range of measurements with the given error, degrees	1.5–90
Wavelength range, nm	350–700
Wavelength resolution, nm	< 10
Time of synchronous measurement of the absorption and scattering indices at one point of spectrum, min	5
Minimum depth when operating in the day-time, m	200

The estimate of measurement error given below is for the techniques for reconstructing described in Ref. 2.

The instrument is unique in design, destination, accuracy of measuring the absorption index. Due to the light source motion, its long-term operation is possible under the conditions of "fouling" of optical surfaces with no loss of measurement accuracy. The technique for measuring the extinction index from the scattered light characteristics allow us to make the instrument adjustment process essentially easier and to lessen its effect on the measurement result.

The instrument was tested in March 1993, from ice-covered surface of Lake Baikal. On April 9, 1993, the instrument was immersed at a depth of 1100 m, at a distance of 5 km from the coast, in southern Baikal trough for long-term operation. The light absorption spectra in the water and the spatial-angular distribution of brightness of the point isotropic source were periodically measured till January 1994. In March 1994, the instrument was raised to the surface, routine maintenance was carried out, broken light source was replaced, and the methodical experiments and measurements of optical parameters at different depths were carried out. In April 1994, the instrument was immersed at a depth of 1000 m.

The optical parameters of the water of Lake Baikal measured near the neutrino telescope in October 1993 and May 1994 are presented in Table I. According to our data, two-year variations of the light spectral absorption index in water did not exceed 20%.

TABLE I. Results of measurements of the optical parameters (λ is the wavelength, in nm; ε, κ, and σ are the indices of extinction, absorption, and scattering, respectively, in m^{-1}).

	October, 1993			May, 1994		
λ	ε	k	σ	ε	k	σ
351		–	– –	–	0.291	–
369		0.330	– –	–	–	–
374		0.280	– –	0.279	0.230	0.049
400	0.190	0.112	0.077	0.214	0.143	0.071
420	0.170	0.084	0.085	0.161	0.099	0.061
460	0.135	0.055	0.08	0.132	0.064	0.068
475	0.122	0.049	0.072	0.124	0.052	0.071
479	–	0.047	–	0.119	0.046	0.073
488	0.120	0.048	0.071	0.122	0.046	0.075
494	0.130	0.044	0.085	–	0.043	–
519		–	– –	0.128	0.058	0.069
550		0.150	– –	0.142	0.074	0.068
651		–	– –	–	0.357	–
691		–	– –	–	0.468	–

It should be noted in conclusion that operation of the instrument showed feasibility of measuring the light absorption and scattering indices in water with relatively short base (up to 2 m). The way to further improvements in the instrument are already directed.

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