Compact flow-type shipborne fluorimeter

A.Yu. Maior,[1] O.A. Bukin,[1] V.A. Krikun,[1] E.N. Baulo,[2] and I.A. Lastovskaya[1]

[1] *V.I. Il'ichev Pacific Oceanological Institute, Far Eastern Branch of the Russian Academy of Sciences, Vladivostok*
[2] *Far Eastern State Technical Fisheries University, Vladivostok*

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We describe a compact flow-type shipborne fluorimeter, which is intended for measurements of spectral components of laser-induced fluorescence of seawater and allows one to make on-line determination of the chlorophyll "A" concentration as well as estimation of the level of the dissolved organic matter fluorescence. The fluorimeter is a monoblock of $20 \times 20 \times 60$ cm in size comprising a flow-type optical cell, a fluorescence detection system, a laser (Nd:YaG, 532 nm), and a computer. The fluorimeter can be employed from onboard any nonspecialized vessels.

On-line data on the state of seawaters is an important problem in the environmental monitoring. One of the method for obtaining such data is the laser-induced fluorescence technique (LIF) based on analysis of fluorescence spectra of organic matter contained in seawater in various forms. Fluorescence spectra bear information on the concentration of chlorophyll "A"[1] and other phytoplankton pigments,[2] type of seawaters,[3] dissolved organic matter,[4] etc. In studying phytoplankton, we deal with bioplasts and the fluorescence spectra parameters strongly depend on the phytoplankton environment, therefore, the measurements are to be carried out *in situ*. Three types of instruments for studying the fluorescence spectra of aqueous media can be distinguished: lidar devices, incoherent and coherent fluorimeters.

Lidar systems[5–7] allow one to perform remote measurements directly from onboard a ship or aircraft. The wavelength of the chlorophyll "A" fluorescence band is at 675 nm and the radiation within this spectral range is noticeably absorbed by seawater. Thus, it is possible to obtain the data on chlorophyll "A" only from the uppermost level of the sea surface. Besides, the state of the sea surface and weather conditions strongly affect the variance of the fluorescence signal intensity recorded with a lidar.

Coherent and incoherent fluorimeters are free from such drawbacks. They measure the fluorescence of outside water in a flow variant (flow-type fluorimeter)[8] or with an immersible probe.[9]

The problem of development a flow-type fluorimeter suitable for researches from onboard of a ship already arose earlier[8] and was solved with designing a flow-type fluorimeter, the optical analyzer of which was built on the basis of a scanning monochromator, photoelectric multiplier, integrator, and analog-to-digital converter (ADC). The scanning monochromator included a diffraction grating the position of which was changeable with a computer-controlled stepper motor. The obtained data were digitized with an ADC and entered into a computer. The device well proved itself in a number of missions.

Nevertheless, some disadvantages were revealed. First, the spatiotemporal resolution, defined by the scanning time through the entire spectral range at the ship speed of 8 knots, was insufficient and equaled to 250 m due to the scanning type of the monochromator. Second, the device hardware required permanent adjustment.

In view of the above problems, a compact shipborne fluorimeter was designed without any scanning parts (Fig. 1).

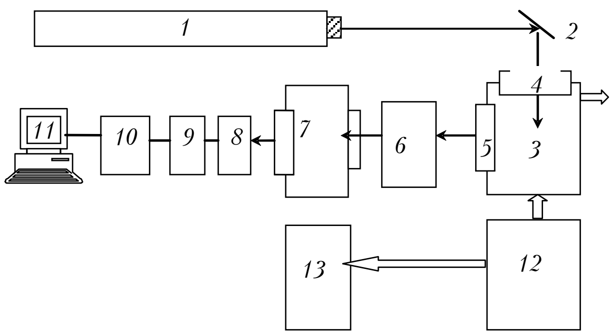

Fig. 1. Block diagram of the fluorimeter.

The device operates in the following way. The laser *1* emits a sounding radiation, then radiation passes through the beam folding prism *2*, and then it is directed to the flow-type cell *3* through the optically transparent window *4*. Through the side of the optically transparent window *5*, a fluorescence signal, induced in the cell *3*, come to a polychromator entrance slit *7*, located after the filter *6* aimed to suppress the on-line scattered laser radiation. Just after the polychromator an electron-optical image intensifier (II) *8* is placed that intensifies the fluorescence spectrum image; optical image transfer system *9* transfers the spectrum image from the II output window *8* to the black-and-white digital video camera *10*, digital signal from which is transferred to a computer *11*. The pump *12* flushes the outside water through the flow-type cell *3* and the measurement cell *13*, where the sensors of temperature and seawater salinity are mounted.

A compact BrilliantUltra Nd:YAG laser emitting 8-ns duration pulses of radiation at the second harmonic wavelength of 532 nm, with the maximum pulse energy of 20 mJ is used as a source of laser radiation. The laser optical system allows one to vary the laser radiation power density inside the optical flow-type cell in a wide range.

A polychromator MDP-1, used in the device, provides for recording the spectrum within the range from 530 to 800 nm. The use of corresponding wide-band filters allows us to exclude the overlap of the diffraction orders. The inverse linear dispersion of the polychromator is 10 nm/mm at the image size 5×25 mm allows recording the entire spectral range at a time. The optical image transferring system is a lens, which transfers an image from the II output window to the CCD array of the camera. A black-and-white CCD array of 10^{-3} lux sensitivity was chosen as a recorder. The appearance of the compact flow-type fluorimeter is shown in Fig. 2.

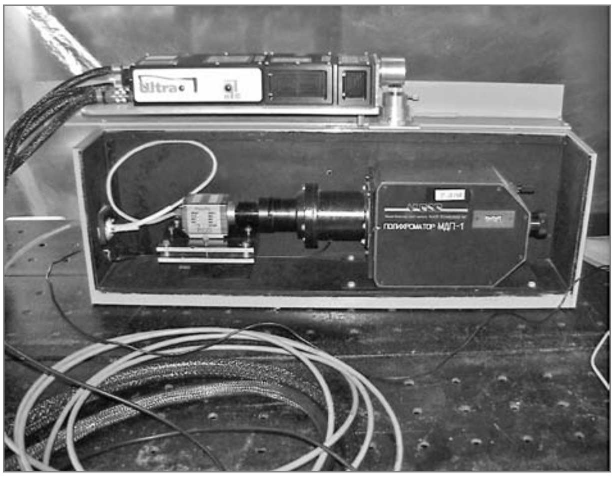

Fig. 2. Compact flow-type fluorimeter.

The versions of the compact laser Brilliant-Ultra and fluorimeter housing allow the fluorimeter to be employed from onboard a nonspecialized vessels. Special pump flushes seawater through the cell via a plastic hose along the ship motion. The fluorimeter is of 20×20×60 cm in size and 10 kg in weight.

Figure 3 shows the LIF-spectrum of seawater recorded in the Peter the Great Bay during the phytoplankton bloom in April, 2006 (averaged over 100 laser shots at the pulse repetition frequency of 10 Hz).

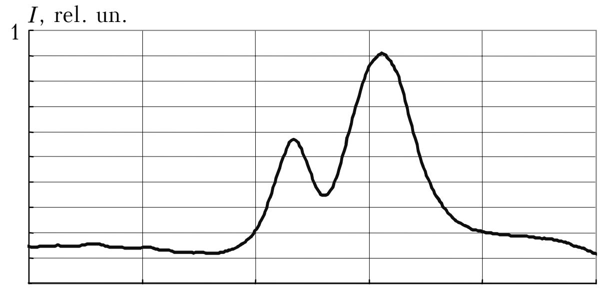

Fig. 3. LIF-spectrum of seawater obtained with the compact laser fluorimeter (*I* is the signal intensity).

The peak at the 650 nm wavelength corresponds to the Raman scattering of seawater while that at 680 nm – to the fluorescence of the chlorophyll "A".

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