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# PROBLEMS OF FORECASTING OF SPREADING AND REMOTE SENSING OF THE UNDER ICE OIL SPILLS

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## ABSTRACT

Features of the oil spreading process and moving of the oil slick under surface are considered. It is stated the main position of the physical model describing transition of spilled under ice oil from spreading to transportation by currents. It is estimated the current speed shearing the oil slick and velocity of its moving along the ice surface under action of the surrounding water medium. The possibilities of optical method for remote sensing of the oil spills under ice are analysed and advantages of fluorescent methods for these purposes are motivated. It is stated the scheme of optical system for oil sensing under ice, on the surface and in water column founded on use of a laser on copper vapour as emitter and multiplex receiver. The recommendations for development of investigations in the examined directions and for the practical application of proposed optical system are formulated.

## 1. INTRODUCTION

Combating with the oil pollution in the ice covered water areas and seas becomes more and more urgent objective in connection with increase volume of oil extracting on shelf and transportation by sea. Its solution is caused by solving of two problems: detection of oil under an ice and snow coverage and forecasting of the spilled oil spreading under ice cover under action of various factors.

The investigations of features of spreading of oil drops and slicks under ice are carried on already long time, and review of its results is contained in report (Liukkonen, 1996). Analysis of these and other published materials shows that it was not created the physical and mathematical models, which adequately described the main features of examined processes. On the other hand experimental researches were carried out in model conditions, and its distribution on the full-scale sea condition is inconvenient in many cases. Therefore further development of studies in the considered directions for creating adequate mathematical models is necessary, because its results will provide development the methods and computer software for forecast of the consequences of oil spills in concrete water areas.

The works on creation of the remote tools for detection of oil pollution under ice cover only start (Goncharov and Lyskov, 1998). The optical characteristics of an ice and snow cover are enough well studied (Sherstiankin, 1975). However to elaboration of the relevant optical systems should precede the calculated determination of its optimum parameters. Creation of the methods of such calculation for a complex multicomponent medium: the snow – ice – oil – water (with various irregularities), is the difficult self-supported task, including the theoretical and the special experimental researches. The outcomes of these researches should provide also the basis for a solution of an inverse task – definition of the oil spill parameters under information contained in a registered signal.

## 2. STATEMENT OF PROBLEM

General problem of detection oil spill under ice cover is divided on some the private tasks, each of which is enough difficult. In the first place, this is problem of behaviour underwater spill and chemical interaction of oil with water and ice. That is definition of state of the crude or various oil products (OP) and its phases (slick, drops, or solution) in surface layer of water and its variability under effect of natural factors (temperature, salinity, and water movements). At last, it is necessary to know the conditions of OP emerging, which are determined by actions of buoyancy, currents and turbulent processes in near ice cover layer of seawater. Under experience of supervision of the emergency oil spills and experimental data of its study (Nelson-Smith, 1970; Goncharov & Lyskov, 1993; Liukkonen, 1996) it is possible to allocate the following main types of state and conditions oil spills under ice:

- OP in form of uniform thin film - slick or thick layer - blot under continuous ice cover, slowly displacing as uniform whole concerning to ice under action of current;
- OP in form of thick films between ice fields, which are moved together with ice floe and change the thickness at change of distance between them;
- OP in form of thin layers in bit ice or between small-sized ice floe in channels, remaining after passes of ships, undergoing such changing of sizes, that and in previous case;
- OP in mix with not formed gel during formation or intensive ice melt;
- OP in form of cloud of separate drops in water medium.

Naturally, that the OP spills in second, third and fourth conditions does not present of difficulties to find out it visual, or with help of systems, using for water area with surface free from ice. For fifth and sixth case the sharp changes of ice or water surface optical properties can serve enough by obvious basis for conclusion about availability oil pollution.

The largest complexity for detection presents first and latest variants, as far as the visual supervision is obviously inefficient. For valuations of parameters of optical instruments requiring for their indication the information, accordingly, about real thickness oil spills and about sizes of drops and density in flow is necessary. The first variant is characteristic of water area, where the oil terminals, and in shelf zone, where oil mining place, and therefore in this paper further it is considers the first variant: the uniform oil spills under continuous ice, though subsequently can be analysed and other variants.

Obviously, that to design two various systems, one of which is intended for use over the clean marine surface, and other - for use over the surface by covered ice, inexpedient. Really, in continuation one flight it is possible to meet the various conditions of marine surface. This circumstance puts forward the requirement to design the universal system, ensuring detection OP spills in more conditions. It should be the system, working in spectral area transparency of ice and water. Detection property of system in various conditions of supervision will be distinguished. Pursuant to this outline in system of detection OP it is possible to consider two information blocks of signals: reflected and scattered by ice or border of section component on lengths laser waves (elastic scattering), and OP fluorescent light, located on ice bottom or in thicker environment.

In ice conditions the light, reflected by the borders of ice cover, carries the information, mainly, about the ice surface conditions, or about the wind wave characteristics of open sea surface and films of organic substance. This information as more intensive shields information carried by scattered light from the ice and seawater column under surface. The fluorescent light carries the information about processes and state of medium only in depth of ice and water. So fluorescent light is more informative signal for oil spill detection under ice cover and in water column.

## 3. SPREADING AND MOTION OF OIL SPILL UNDER ICE COVER

Processes of the spilled oil spreading and the sleek formation in under ice conditions essentially differ from similar process in the water areas not covered by ice. It is connected to features of interaction of oil with a surface of ice: in air medium the oil wets the ice, but in water medium the oil does not wet an ice surface, and the limiting wetting (or contact) angle lays in a range: $\pi/2 \le \theta_o \le \pi$ (Liukkonen, 1996). On the ice – water interface the capillary force limits of the oil sleek spreading. This process stops with achievement of balance between a capillary tension, oil sleek buoyancy and external hydrostatic pressure. Further in the motionless water environment the oil sleek takes on form of thin oblate body of revolution (blot), which shape is determined by balance of acting on a surface forces and minimum of surface energy of interface. These conditions can be used for estimation of the oil blot form and thickness under ice, and then for estimation of its distortions under action of water flow.

Let the oil blot with total volume $Q$ has contact to ice surface by diameter $d$, then condition of the surface balance in distance $z$ out of ice surface can be presented as equation that is similar to Laplace equation for the liquid droplet on solid surface (Zimon, 1974)

$$4\Delta\gamma_{wo} Q/\pi d^2 + \gamma_o z = \sigma_{ow}\left(R_m^{-1} + R_l^{-1}\right) + \gamma_w z \qquad (1)$$

where $\Delta\gamma_{wo} = \gamma_w - \gamma_o$ is the difference of water $\gamma_w$ and oil $\gamma_o$ densities, $\sigma_{ow}$ is capillary tension of oil in water. First component in left side equation is the pressure on ice surface defined by the buoyancy of oil blot; second component is hydrostatic pressure in oil. Fist component in right side is capillary pressure that characterises in each point of blot surface by two main radiuses of curvature: first radius $-R_m$ situates in the meridian section, and the second $-R_l$ is orthogonal to the first one, and $R_m << R_l$. Last component is hydrostatic pressure in water. It is possible to rearrange (1) to form

$$R_m^{-1} + R_l^{-1} = \Delta\gamma_{wo}\sigma_{ow}^{-1}(4Q/\pi d^2 - z) \qquad (2)$$

This form shows that the bottom border of blot is the point $z = 4Q/\pi d^2 = h_b$, in which both radiuses of curvature should to tend to infinity. That is the bottom surface of oil blot should to represent a flat disk on distance $h_b$ out of ice, which in this case is able to consider as a thickness of the cylindrical blot with equal to a real oil blot volume.

The water flow with velocity $u_0$ acts on the surface of oil blot doubly: the normal hydrodynamic pressure and the tangential stress of friction. First component it is possible to present in next form

$$p_u = 0.5\gamma_w g^{-1} u_0^2 \delta(r,\varphi,z) \qquad (3)$$

Function $\delta(r,\varphi,z)$ features in polar co-ordinates $(r,\varphi,z)$ the distribution of hydrodynamic pressure upon the blot surface. Being based on data of measurements of pressure on surface of the thin symmetric airfoil profiles it is possible to count that in the front stagnant point $\delta = 1$, on the lateral patches of the blot cross section $\delta < 1$ on the upper surface of blot $\delta \approx 0$ and in the rear segment $\delta = 0.4 \div 0.6$. Definition of $\delta(r,\varphi,z)$ is the special laborious task. It is reasonable to simplify the problem and study the static and dynamic balance of the oil blot with enough large volume, that is $h_b/d << 1$. Then it is possible to consider only the rather simple problem for the meridian section form of blot, and for the distribution of the normal hydrodynamic pressure near ice surface to accept the approximate form

$$\delta(z) = \delta_0 (1 - z / h_b) \tag{4}$$

With using of differential presentation for radiuses of curvature (in orthogonal axes axis with origin in point of contact oil – water – ice) it is obtained the following differential equation

$$d^2 y / dz^2 \cdot \left[1 + (dy/dz)^2\right]^{-3/2} = \left(\Delta\gamma_{wo} h_b^2 \sigma_{ow}^{-1} - 0.5\gamma_w g^{-1} \delta_0 \sigma_{ow}^{-1} h_b u_0^2\right) \cdot \left(1 - z h_b^{-1}\right) \tag{5}$$

with boundary conditions

$$z / h_b = 0 \quad y = 0, \; dy/dz = tg(\theta_o - \pi/2); \qquad z / h_b = 1 \quad dy/dz = -\infty$$

Let input in equation (5) the dimensionless criterions: Bond number – $Bo = \Delta\gamma_{wo} h_b^2 \sigma_{ow}^{-1}$ and Weber number – $We = 0.5\gamma_w g^{-1} \sigma_{ow}^{-1} h_b u_0^2$, then it is possible to simplify an equation (5) form

$$d^2 y / dz^2 \cdot \left[1 + (dy/dz)^2\right]^{-3/2} = (Bo - \delta_0 We) \cdot \left(1 - z h_b^{-1}\right) \tag{5a}$$

The first integration of (5a) permits to obtain

$$\frac{dy}{dz} = -\frac{(Bo - \delta_0 We) \cdot (2z - z^2) + 2 Cos\, \theta_o}{\sqrt{4 - [(Bo - \delta_0 We) \cdot (2z - z^2) + 2 Cos\, \theta_o]^2}} \tag{6}$$

To fulfil the boundary condition at $z / h_b = 1$ it is necessary that

$$Bo - \delta_0 We = 2(1 - \cos\theta_0) \tag{7}$$

From this expression in case, when $u_0 = 0$ and $We = 0$, it is possible to derive the known formula for the oil blot thickness (Liukkonen, 1996)

$$h_b = \left[\sigma_{ow} \Delta\gamma_{wo}^{-1} \left(1 + Cos\,(\pi - \theta_0)\right)\right]^{1/2} \tag{8}$$

which shows that thickness of oil blot depends only from capillary tension, buoyancy of oil in water and the limiting wetting angle. The horizontal size of blot $d$ is determined by volume of spilled oil, the geometrical form of blot and this value $h_b$.

Under action of the water flow pressure for same value $Bo$ the contact angle $\theta_0$ decreases and goes to $\theta_0 = \pi / 2$ under velocity

$$u_w = \left[2g\, h_b \delta_0^{-1} (\Delta\gamma_{wo} / \Delta\gamma_w) \cdot (1 - 2Bo^{-1})\right]^{1/2} \tag{9}$$

The transformation of the forward side of oil blot is presented in figure 1 (as result of numerical solution of equation (5a)). These materials show, that together with decreasing of the contact angle $\theta_0$ there is a relevant thinning-down of a oil blot and increasing of the horizontal size – $d$. Thus under action of water flow a oil blot spreads and thins down originally. Further with growth of velocity the contact angle continues to decrease, and the condition of nonwettabillity of the ice surface by oil in water medium is altered on wettability. From this moment $u_0 \geq u_w$ the rear brow of oil blot assumes the capacity to move under action of friction of water flow. Actually, the existence of the threshold velocity for oil slick

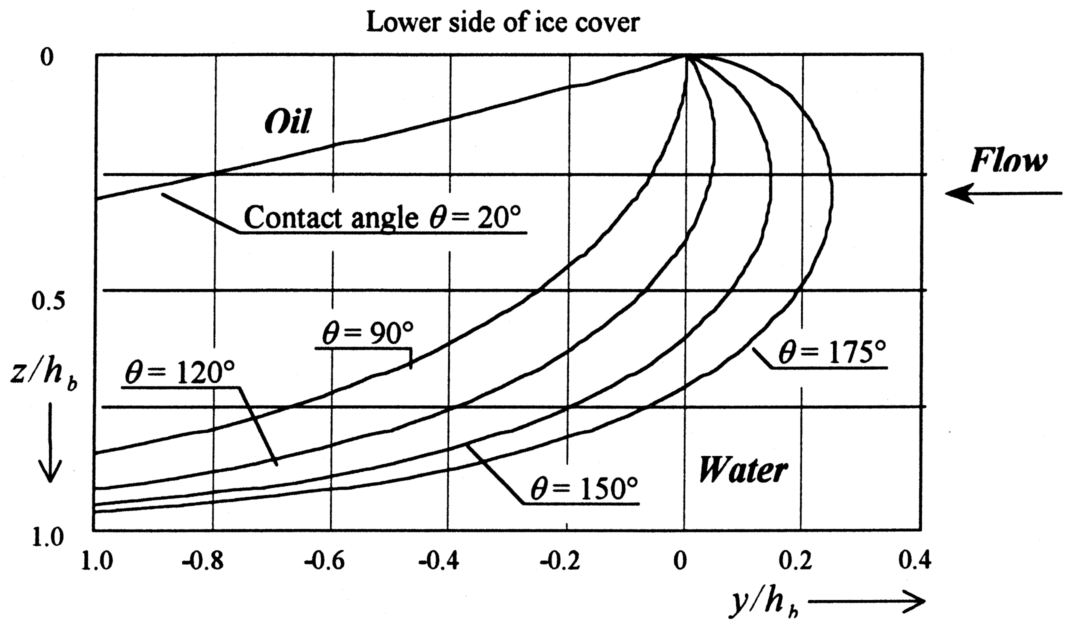


Figure 1. Transformation of the oil blot border under action of water flow.

movement under ice was registered in the experimental studies, and its value varies from 4 cm/s up to 15 cm/s (Liukkonen, 1996). The evaluation under formula (9) for the characteristics of the oils from (Liukkonen, Rytkonen & all, 1997; Liukkonen & Alhimenko, 1997), for coefficient $\delta_0 = 0.6$ and in view of a oil blot thinning gives the magnitude $u_w$ of the order 6 – 15 cm/s, that is closely to above-stated values. It is necessary to notice that in real conditions the oil blot is able to start motion under smaller than calculated values of velocity through the turbulent pulsation of pressure in flow on and behind the rear brow of blot. So it is possible to consider as adequate the above-stated mechanism of the implication of the oil blot (or slick) in motion by under ice current.

In the further conversion to the movement of the oil blot occurs under action of the water flow friction on its surface. The velocity of its own movement $v_b$ can be determined by comparing of the external current action with internal resistance to motion on ice surface. The regime of current under ice cover is to be consider as the turbulent boundary layer on the flat plate, and the coefficient of friction is defined by known expression (Loitziansky, 1987)

$$\zeta_{f0} = 0.0307 \,\mathrm{Re}_{uv}^{-1/7} \tag{10}$$

where $\nu_w$ is the kinematic viscosity of water and Reynolds number $\mathrm{Re}_{uv} = (u_0 - v_b)\, d / \nu_w$, calculated on the relative current velocity. Inside blot the oil moves similarly to the caterpillar tread, as it was proved by the special investigations of the drop motion (Dussan & Devis, 1974). Therefore the distribution of the oil flow velocity on the blot thickness is linear: from $v = 0$ on the ice surface up to $v = v_b$ on the bottom side of the oil blot. It allows to apply to an evaluation of the internal resistance in the oil blot the model of the laminar Couette flow between the fixed and moving plates, for which the friction strain is defined by formula (Landau & Lifshitz, 1988)

$$\tau_b = \mu_o v_b / g h_b \tag{11}$$

where $\mu_o$ is the viscosity of oil. Using (10) and (11) it is possible to obtain following equations for estimation of the velocity of the oil blot movement

$$v_b / u_0 = 1 + \Psi - \sqrt{\Psi^2 + 2\Psi} \quad (12)$$

$$\Psi = 32.6(\mu_o / \mu_w)(d / h_b)\,\mathrm{Re}_{uv}^{1/7}\,\mathrm{Re}_u^{-1} \quad (13)$$

and Reynolds number $\mathrm{Re}_u = u_0 d / \nu_w$, calculated on the current velocity. Because Reynolds number $\mathrm{Re}_{uv}$ (relative current velocity) has the small exponent it is admissible to exchange it on $\mathrm{Re}_u$ (full current velocity). Even at double difference of the current velocity and the velocity of oil blot movement an error of calculation will be within the limit of 10%.

$$\Psi = 32.6(\mu_o / \mu_w)(d / h_b)\,\mathrm{Re}_u^{-6/7} \quad (14)$$

It is possible to carry out the estimation of the velocity of the oil blot movement under the formula (12). Such estimation was carried out for the current velocity $u_0 = 30$ cm/s, the diameter of blot $d = 1$m and for the same oil characteristics as above - for the form (9). Its result is $v_b = 9.2$ cm/s, and this magnitude is close to values in report (Liukkonen, 1996). It acknowledges the adequacy of created model of the oil blot movement, and the form (12) certainly requires the experimental verification and improvement.

## 4. FLUORESCENT METHOD FOR REMOTE SENSING OF OIL SPILLS IN WATER

Systems of remote sensing based on principles of marine surface distinction albedo are rather well known. It is reasonable to consider the features of application of multi-frequent laser systems of visible ranges for oil pollution detection. Such systems are analogous to multi-spectral systems, used during ecological monitoring and detection eutrophic water area on "index of colour". The contrast of surface OP slick on background of clean water will be determined by distinction of the optical properties of substances. At appropriate choosing of spectral zone it corresponds to visual contrasts, which are observed by conventional methods. Opportunities of supervision underwater oil spills and its detection arise, if two conditions are executed. In first, level of signal exceeds the threshold significance of sensitivity of a system under given conditions of supervision (height of flight, condition of optical properties of environments). In second, contrast of object exceeds the threshold significance, which is determined by background conditions of marine environment (availability of substances, optical characteristic of which are close to characteristics OP).

Design of device and optimisation of technique of supervision can supply the feasibility of first condition. For completion second it is necessary to be developed special methods and algorithms of processing of information. The reliability of detection OP on background of natural substances can be achieved at use of multi-frequent laser. The method multi-spectral laser photometry assumes the application of detection OP algorithm, based on distinction optical property fluorescence substances, forming environment backgrounds. For completion justified estimation of such system the detailed study of system with considering of the OP optical characteristics, their conditions, concentration, technique and monitoring conditions and their general properties is necessary. This algorithm is similar to "index of colour", used for valuation of concentration chlorophyll pigments in near surface layer of sea. At some consolidate assumption is possible to be accepted that

$$P^{imp}(\lambda_1) / P^{imp}(\lambda_2) \cong P_0(\lambda_1) / P_0(\lambda_2) \exp\left[(\chi_2 - \chi_1) z\right] \times \Omega \quad (15)$$

where coefficient $\Omega$ is photometer hardware function. Values $\chi_1$ and $\chi_2$ are contained in (Karabashev, 1987). The lengths of waves of laser are chosen with inventory of condition optimisation of supervision and properties of found out substances. More the difficult algorithms assume the availability of information about thin spectral structure accepted light.

The marine environment fluorimetry was developed with the purpose of research of biological processes in oceans. The informative properties of fluorimetric method are defined by two conditions: power-generating level of signal surpasses the own noise of instruments or background processes and contrast of object exceeds the threshold contrast of system. The feature consists in conditions of formation of signal. The system of spectral fluorimeter equations, consisting from two channels, one of which measures combinational scattering on molecules of water (CS), and other - organic substances fluorescence (Peiffer & Grassl, 1990) are considered chlorophyll pigments, has the form of CS (Raman signal) as

$$P_c(R_i) = \eta P_0 \frac{c\Delta t}{2} \cdot \frac{S}{(nH + z_i)^2} \cdot \beta_{cs} \tau_{al} \tau_{cs} \tau_{aw}^2 \tau_{wl} \tau_{wcs} \qquad (16)$$

for fluorescence as

$$P_F(R_i) = \eta P_0 \frac{c\Delta t}{2} \cdot \frac{S}{(nH + z_i)^2} \cdot C_F \sigma_F \tau_{al} \tau_{aF} \tau_{aw}^2 \tau_{wl} \tau_{wF} \qquad (17)$$

where $P_{cs}$ $(R_i)$, $P_F(R_i)$ are the power of light flow with distance $R_i$ between scattering volume and optical receiver; $\lambda_{cs}$, $\lambda_F$ are length of wave CS and fluorescence; $P_0$ is power of laser on length of excitation wave; $\eta$ is efficiency of optical system; $S$ is area receiver optics; $H$ is height of flight; $z_i$ is depth fluorescent volume in water; $\beta_{cs}$ is coefficient return scattering CS; $\sigma_F$ is fluorescence effective section; $C_F$ is fluorescent substance concentration; $\tau_{al}$ is penetration of atmosphere on laser wave length; $\tau_{aF}$ is penetration of atmosphere on fluorescence wave length; $\tau_{acs}$ is penetration of atmosphere on combinational scattering wave length; $\tau_{wl}$ is penetration of ocean water on laser wave length; $\tau_{wF}$ is penetration of ocean water on fluorescence wave length; $\tau_{wcs}$ is penetration of ocean water on combinational scattering wave length; $\tau_{aw}$ is penetration of ocean - atmosphere border.

The combinational scattering radiation is determined by interaction of radiation with water molecule. The factor $\beta_{cs}$ for molecules of water is known, therefore the value $P_{cs}$ is "mark" of system. It is known, that at simultaneous measurement of fluorescence and calibrated signals CS their attitudes are accepted the by form

$$n = \frac{n_{‰}}{k_1 k_2} \frac{d\sigma_h}{d\Omega} \frac{4\pi}{\sigma_F} \frac{N_F}{N_{CS}} \qquad (18)$$

where $n_B$ is number of molecules in volume water unit, $n_B$=3,33×10$^{22}$ см$^{-3}$, $d\sigma_{cs}/d\Omega$ is differential (on directions) section CS in water, integrated in spectral band CS, $d\sigma_{cs}/d\Omega$= 0,53×10$^{-29}$ см$^2$× ср$^{-1}$; $k_1$ is coefficient, describing frequent band receiver, $k_2$ is coefficient of fluorescence saturation, $\sigma_F$ is the isotropic fluorescence section, $N_F/N_{cs}$ is attitude of integrated sizes of photon numbers.

## 5. LIDAR FOR REMOTE SENSING OIL SPILL IN ICE COVERED WATER AREAS

The laser methods are indirect methods, enabling to find the oil spill and to measure the concentration with significant error. The executed researches, theoretical, laboratory and experimental data confirm the opportunity of creation of monitoring systems. The most widespread system includes the source: the laser on AIG with doubling frequency (length of wave 532nm) power 2.5 W, and receiver - photomultiplayer, optical aperture - 0,25m, relative aperture 1:1. It was presented results about opportunity determination the suspended organic materials to depth 25m at height of flight 250м. It is necessary to execute valuations expediently only in connection the effects of ice on optical field structure and its power. The most perspective method of detection oil spills in water medium including ice cover is the fluorescent method, which arise at use as radiance source of multi-frequent laser. The optical scheme of such system is presented in figure 2. The results of researches the optical properties

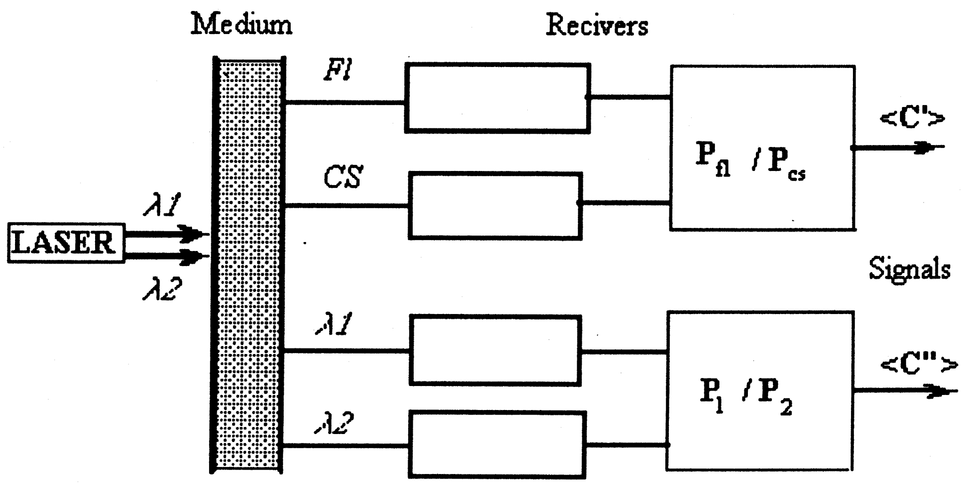


Figure 2. Optical scheme of the fluorescent method for detection oil spill under ice cover

some OP and natural suspended organic materials in marine water are published (Karabashev, 1987). The fluorescence bands these substances approximately 100nm. One feature of detection OP exists and it is many-valuedness of its data, which is experimentally confirmed (Goncharov & Lyskov, 1994) - detection OP happens on background of natural organic substance, their optical characteristics is close. Therefore at use of considered method the fluorimetric channel signal will present the sum signals

$$P_F = P_F^{(OP)} + P_F^{(DOM)} \tag{19}$$

Problem consists in division of these signals, if quantitative their determinations is required. The area of exciting radiation waves lengths (260 - 350nm) and spectrum fluorescent radiance (400 - 500nm) OP are in area relative ice transparency. In literature present the valuations of distinguish opportunity organic substances and OP with use of phenomenon of distinction of spectra fluorescent beaming these substances from lengths of wave exciting radiance. The application of this method is possible at use of laser on copper vapour (Lovchy, 1995). As attributes of oil it is possible to consider distinction of reflective properties, distinction of fluorescence spectra and distinction of fluorescence kinetics. From these assumptions it is possible to carry out the synthesis of optical outline and valuation of technical opportunities of system (see figure 2). Quantities <C`> and <C``> - significance of concentration, determined by appropriate methods with applications of developed algorithms.

At holding the round-the-clock remote sensing of a near-surface layer of the sea from the air carrier was utilised a multizonal locator with active illumination by a laser emission on pairs of copper (LPC). As well as at development of a laser radiant basing by a determinative of usage LPC was the availability in its radiation of two independent spectral components with wave length $\lambda_1$ = 510,6 nm and $\lambda_2$ = 578,2 nm. That has allowed to expand a range of application of optical methods of monitoring, in particular, to utilise an "index of color" in algorithm of restitution of ecological performances of an aqueous medium. At flying speeds of the air carrier ~ 300 - 400 kph especially in relevant performance LPC appear a high frequency of following of impulses (FFI) of generation (~10 - 20 kHz). In this case, when each of laser impulses will be utilised for self-maintained (independent) measuring, and the recurrence rate defines only distance between points of exploration lengthways traces; LPC allows producing practically continuous irradiance of water surface. In that case, when the good spatial solution is not required high FFI of generation LPC can become a basis of accruing of a series of series impulses for an aftertreatment. Thus the spatial solution, i.e. water area, in which one happens accruing a signal, is defined for a pre-set speed of flying by the ration of number of the accumulated impulses (index of accruing $N$ to a pulse-recurrence frequency of a laser emission *(f)*.

Table 1. Main characteristics of lidar for remote sensing of oil in the ice covered water areas

| | |
|---|---|
| Wave length of generation | $\lambda_1$=510,6 nm, $\lambda_2$=578,2 nm |
| Duty | Pulsewise - periodic, f ~ 10 kHz |
| Mean power of radiation | On $\lambda_1$ =510,6 nm - 4,5 W,<br>On $\lambda_2$ =578,2 nm - 4,5 W |
| Pulse duration of generation | On $\lambda_1$ =510,6 nm ~ 15 ns,<br>On $\lambda_2$ =578,2 nm ~ 20 ns |
| Peak power of radiation | On $\lambda_1$ =510,6 nm - 30 kW,<br>On $\lambda_2$=578,2 nm - 22 kW |
| Dimensions of an emitter LPC | 1600 ×340 ×230 mm |
| Dimensions of a supply unit | 500 ×340 ×270 mm |
| Cool-off | Air |
| Maximal power consumption | No more than 2,7 kW at a feed from the board transformer 115 V, ~400 Hz |

## 6. CONCLUSION

The stated in the paper materials show, that creation of methods for forecasting of the oil pollution spreading under the ice cover and the tools (or devices) for its detection are a real task for the present time. The offered physical and mathematical model require the further improvement and experimental verification. Objectives of these studies are the introduction in computational algorithms of the empirical coefficients, which ensure the compatibility of results of modeling to the observed phenomena in a broad range of a variation of oil properties, characteristics of ice cover and intensity of the under ice currents. It is obviously necessary to create the mockup of a lidar with specified above characteristics and its execution and testing on the special workbench.

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