AD-A036 880 NAVAL INTELLIGENCE SUPPORT CENTER WASHINGTON D C TRA--ETC F/G 20/6
EXPERIMENTAL STUDY OF THE DIFFUSION OF THE SHAPE OF A LASER LIG--ETC(U)
FEB 77 I I KALININ, V N PELEVIN, A L SKRELIN
UNCLASSIFIED NISC-TRANS-3887 NL

| OF |
AD
A036880

END
DATE
FILMED
4-77

3 81

DEPARTMENT OF THE NAVY
NAVAL INTELLIGENCE SUPPORT CENTER
TRANSLATION DIVISION
4301 SUITLAND ROAD
WASHINGTON, D.C. 20390

CLASSIFICATION: UNCLASSIFIED

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

6

TITLE: Experimental Study of the Diffusion of the Shape of a Laser Light Pulse During its Propagation in the Sea

(Ekesperimental'noye issledovaniye razmytiya formy svetovogo impul'sa OKG pri ego rasprostranenii v more),

10

AUTHOR(S): I.I. Kalinin, [redacted] V.N. Pelevin, [redacted] A.L. Skrelin [redacted], D.M. Sherbaf [redacted]

PAGES: 5

SOURCE: Optika okeana i atmosfery, Institute of Oceanology of the USSR Academy of Sciences, "Nauka" Publishing House, Leningrad, 1972
Pages 168-173

D D C
RECEIVED
MAR 15 1977
A

ORIGINAL LANGUAGE: Russian

TRANSLATOR: C

14 NISC-TRANS[redacted] - 3887

APPROVED P.T.K.

11 DATE 1 Feb[redacted] 1977

12 6p.

407682

EXPERIMENTAL STUDY OF THE DIFFUSION OF THE SHAPE OF A LASER LIGHT PULSE DURING ITS PROPAGATION IN THE SEA

[Kalinin, I. I., V. N. Pelevin, A. L. Skrelin, and D. M. Sherbaf, Eksperimental'noye issledovaniye razmytiya formy svetovogo impul'sa OKG pri ego rasprostranenii v more, in: Optics of the Ocean and Atmosphere (Optika okeana i atmosfery), Institute of Oceanology of the USSR Academy of Sciences, "Nauka" Publishing House, Leningrad, 1972, pp. 168-173; Russian]

The development of pulse lasers has not only intensified the interest in the nonstationary problem of scattering, but has also provided the researchers with a tool for studying the phenomenon of multiple light scattering itself. It has become possible, by using a laser with a burst duration of the order of several or tenths of nanoseconds and detectors with a high time resolution, to split the light signal propagating between two points of a medium into its component elements, which differ in the photon path length inside the medium or in the number of tested scattering events. /168[*]

References 1 and 2 have indicated the usefulness of representing the matrix of radiation transfer P_{ik}^{12} from point 1 to point 2 of a scattering medium in the form of the sum of matrices $w_{ik}^{12}(\ell)$ corresponding to different photon path lengths from point 1 to point 2:

$$P_{ik}^{12}=\int_0^\infty w_{ik}^{12}(l)\,dl.$$

This approach makes it possible to expand the transfer matrix in powers of quantum survival probability and facilitates the solution of the transfer equation, which is performed by the method of successive consideration of scattering of increasing multiplicity. /16

When suitable polarizers and analyzers are used, the development of the pulse technique along the lines of reduction in the signal duration to a limit beyond which it could be assumed to be a δ pulse may permit one to obtain the components of the transfer matrix $w_{ik}^{12}(\ell)$ experimentally.

In particular, by probing the scattering medium with a short light signal and detecting diffusely reflected light, one can obtain the mean scattering multiplicity of the reflected light as a function of its primary optical characteristics, etc.

However, before using the laser as a tool for the study of a scattering medium, it is necessary to solve several problems of experimental-methodical character. It can be shown that the use of artificial media for the perfection of these methods is difficult. In order to be able to equate the signal to a δ pulse, it is necessary that at least the product of its duration τ and velocity of light in the medium c_n does not exceed the mean free path of the radiation $1/\varepsilon$

$$c_n\tau\varepsilon \leqslant 1.$$

In artificial simulating media, this condition could be fulfilled only by using very short pulses, of the order of fractions of a nanosecond, whose recording is a technicall

---

[*] Numbers in the right margin indicate pagination in the original text.

complex problem. Therefore, the method using lasers to study natural scattering media should be perfected on the investigated objects themselves.

In 1966, a group of scientists at the Physics Institute of the Belorussian Academy of Sciences made an attempt at a direct study of nonstationary light scattering in the waters of Lake Naroch'.[3]

In 1967, the Hydrooptics Laboratory of the Oceanology Institute of the USSR Academy of Sciences and Laboratory of Scattering Media of the Physics Institute of the Belorussian Academy of Sciences organized studies in the open sea aboard the research ship KAPITAN CHUMAKOV. The present article describes some results of these experimental studies.

The chief objectives of the experiment were: (a) to perfect a method of using a laser and detecting instruments with a high time resolution for studying light scattering processes in the sea; (b) to obtain a picture of the temporal diffusion of a light pulse in seawater as a function of the distance between the radiator and the detector - up to distances of the order of 100 m - for different relative orientations of the two instruments.

The following equipment was used for measurements in the sea. /170

The light source used was a neodymium glass laser with Q-switching and frequency doubling, with a laser wavelength of 530 nm. The half-width light pulse duration ranged from 10 to 25 nsec, at an average power of about 100 kW. The light beam diameter did not exceed 12 mm, and the divergence, 3'-5'. The laser was placed in a sealed housing, which contained a set of neutral light filters changing the attenuation order from 0 to 15 at one-order intervals. The change of the neutral filters and monitoring of the number of the inserted filter were performed by remote control.

The light pulse detector used was a specially selected photomultiplier of type FEU-36 with good time characteristics, enclosed in a sealed housing. The PM photocathode was placed in the focal plane of a mirror 400 mm in diameter, producing a high luminosity of the detector at the selected detection angles of 6° and 20°. The photomultiplier was supplied at such a rate that the time constant did not exceed 4 nsec.

The photomultiplier signal was fed by a cable 180 m long to the input of an S1-11 oscillograph; the entire measuring transmission line had a time constant no greater than 5 nsec.

To check the length of the light pulse beamed at water, part of the green radiation of the laser was deflected by a plane-parallel glass plate to an FEU-36 reference photomultiplier located in the housing of the radiation source. The signal from this detector was sent through an attenuator to the same input of the S1-11 oscillograph as the main signal.

The oscillograph sweep was triggered by the signal from the photomultiplier located in the housing of the light source. Thus, signals sent into water and detected in water could be photographed simultaneously on the oscillograph screen by recording both the time lag of the second pulse and the shapes of both pulses.

To immerse the source and detector in water from the ship's side, and also to measure the change in the distance between them in water and their relative orientation, a cable photometric bench was used. The radiation detector was placed on the lower carriage of the bench, whose immersion depth determined the distance between the light source and the detector; the radiator with the laser was located on the upper carriage, immersed to a depth of 1.5-2 m under the surface in order to eliminate the effect of the air-water interface on the formation of a nonstationary light field in the seawater mass. The source and detector could rotate through the required angle in the vertical plane perpendicular to the ship's side.

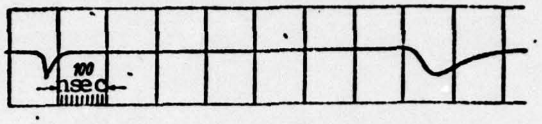

Fig. 1. Typical shape of emitted and detected pulses (from an oscillograph screen). /171

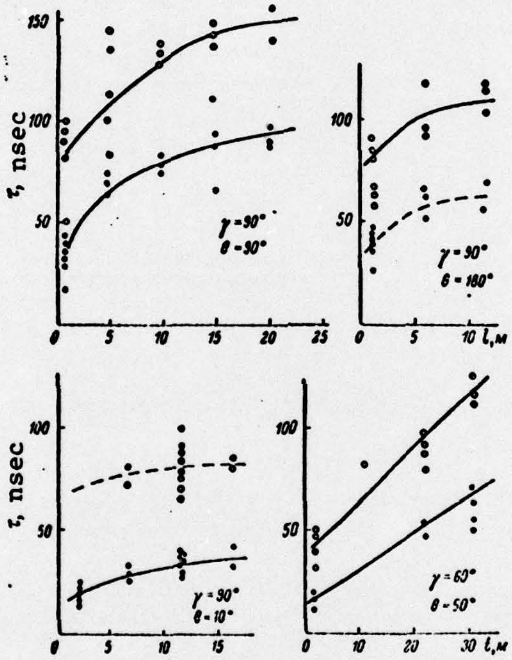

Fig. 2. Difference of durations of detected and emitted pulses $\tau = t_1 - t_2$ at different orientations of the source and detector as a function of the distance between them.

solid lines - at 0.5 level
dashed lines - at 0.1 level

A large number of photographs of the oscillograph screen were obtained (Fig. 1) /172 with a recording of the shape of the transmitted and detected pulses. To estimate the parameters of the pulse transfer function of the process, the following quantities were measured (on the photographs):

t_1 - duration of pulse detected at the 0.5 level; t_1' - same, at the 0.1 level; t_2 - duration of reference signal, characterizing the laser luminescence time, at the 0.5 level; t_2' - same, at the 0.1 level; t_3 - time of transmission of the signal through water from the source to the detector, i.e., distance from the start of the reference signal to the start of the detected signal, minus the lag constant in the cable.

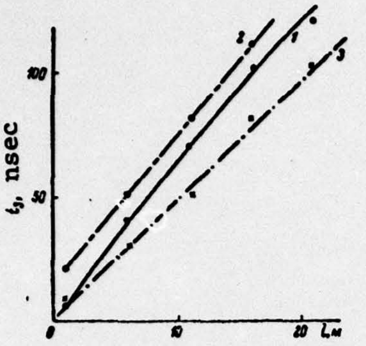

Fig. 3. Time of transmission t_3 of the signal through water for different orientations of the source and detector as a function of distance ($\gamma = 90°$).
θ: 1 - 90°, 2 - 180°, 3 - 10°.

Simultaneously with the photography of the signals, the following quantities were recorded:

ℓ - distance from the source to the detector in water; γ - angle of rotation of the laser beam from the vertical (for $\gamma = 0$, the laser gives light at the nadir); θ - angle of deviation of the detection direction of the detector from the vertical (for $\theta = 0$, the detector points at the zenith).

The primary hydrooptical characteristics were also recorded.

The results of the measurements are presented in the figures.

Since the duration t_2 of the emitted pulse is comparable to the durations of the detected signals t_1 (and varied in the range of 10-25 nsec), it is convenient as a first approximation to take the difference between the two times $\tau = t_1 - t_2$ as the parameter of pulse shape diffusion. Figure 2 shows the values of τ and τ' obtained for $\gamma = 90°$ (i.e., with the laser beam in the horizontal direction under the surface of the sea at a depth of 1.5 m) and different θ and ℓ. The open circles denote values of $\tau' = t_1' - t_2'$, and the closed circles, values of τ. /17

The values of τ and τ' for angles $\gamma = 60°$ and $\theta = 60°$ pertain to the case in which the source and detector were turned in the same plane away from the ship's side, so that their optical axes intersected at a 60° angle.

A certain scatter of the points was in all probability due to instrumental errors. The results may be used for estimating the order of magnitude of the effect observed.

Figure 3 shows values of t_3 for different orientations of the source and detector.

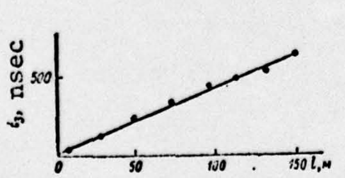

Fig. 4. Time of transmission t_3 of the signal through water for coaxial positions of the source and detector ($\gamma = \theta = 0°$), as a function of distance ℓ.

Figure 4 shows values of t_3 for the case $\gamma = 0$, $\theta = 0$. The mean propagation velocity of the diffuse light signal in water, calculated from this dependence, is practically the same as that for directed light.

The following conclusions may be drawn from these studies.

1. The development of the instruments for studying light scattering in the sea may be considered tentatively completed.

2. Quantitative characteristics have been obtained which make it possible to make the first estimates of the parameters of the pulse transfer function of the process.

3. It was found necessary to increase the time resolution of the detector even more and decrease the duration of the sounding pulse.

4. Continuation of experimental studies in ocean waters of high transparency would make it possible to improve the quality of measurements using existing equipment with the already achieved time resolution.

REFERENCES

1. Van de Hulst, H. C. and W. M. Irvine, Scattering in model planetary atmospheres. Mem. Soc. Roy. Sci. Liege, Vol. 5, 7, No. 1, 1963.

2. Rozenberg, G. V., Physical principles of spectroscopy of light-scattering substances. UFN, Vol. 91, No. 4, 1967, p. 569.

3. Ivanov, A. P., I. I. Kalinin, V. D. Kozlov, A. A. Skrelin, and I. D. Shcherbakh, Propagation of short light signals in water. FAO, Vol. 5, No. 2, 1969, p. 212.