THE INVESTIGATION OF NONLINEAR ABSORPTION OF LASER BEAMS IN DIFFERENT OIL SAMPLES

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The appearance and distribution of optoacoustic signal in different oil samples are experimentally investigated. The bond between absorption coefficient and period of acoustic signal is established. The confirmation technique of nonlinear absorption coefficient of laser beams in liquids is suggested.

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INTRODUCTION

The nonlinear optic effects at interaction of light with liquids present the big interest for both the study of their fundamental properties and investigation of possibilities of their practical use in different fields of science and technique. In connection with the fact that experimental and theoretical investigations of non-linear one- and multi-photon absorption and also other nonlinear optical effects in liquids which haven/t been studied yet, the revealing of their coexistence or competition, domination or redistribution of the influence at different excitation conditions present the big scientific interest.

There are two main reasons causing the different character of light field interaction of low and big intensity with the substance. Firstly, the multi-photon processes play the main role at high intensity besides the one-photon processes confirming the interaction on microscopic level at low light intensity. This means that not one but several phonons are absorbed in light interaction elementary act with substance atom. Secondly, the substance initial properties under the light influence propagating in it change at big intensity. The substance characteristics become alternative values depending on incident light intensity, i.e. the medium becomes nonlinear. As a result the dependence of optical phenomenon character on light intensity value appears. Consequently, the interaction has the nonlinear character at big intensity in difference from interaction linear character belonging to low intensity light.

The appearance and distribution of optoacoustic waves in oil and oil products are experimentally investigated in [1,2]. The increase of technological process efficiency with the help of physical field influence has had the important practical use last time. In particular, the treatment by laser beams should lead to increase of transmission capacity of oil products at transportation of oil and oil products. In this connection the investigation necessity of nonlinear interaction of laser beams with oil samples appears.

EXPERIMENTAL INSTALLATION AND INVESTIGATION TECHNIQUE

The laser facility (fig.1) the principle of operation of which is described in [3], is used at carrying out of investigations. TEA CO_2 impulse laser working on wave length 1,06 μm serves as the optical radiation source. The duration and laser impulse energy are 20nsec and 5MJ correspondingly. The unfocused beam of laser radiation by diameter 1,6 cm is vertically directed to cell with investigated liquid. The experiments show that optoacoustic signal front for all investigated oil samples by the form is similar. The heterogeneity of temperature and absorption coefficient confirms the form of optoacoustic signal. In the given case all experiments are carried out at the similar temperature. By this reason the difference of wave front of optoacoustic signals in different oil samples is confirmed by the difference of oil absorption coefficient.

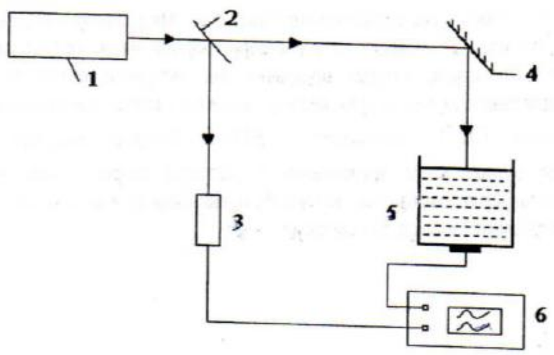

Fig.1. The scheme of experimental installation for investigation of liquid optoacoustic properties (1 is impulse laser CO_2, 2 is semitransparent plate, 3 is photodetector, 4 is mirror, 5 is cell with investigated oil, 6 is oscillograph by C9-8 type).

The optoacoustic signal form for three oil samples is shown on fig. 2.

Carrying out the treatment of experimental data in Matlab medium it is established that these curves of optoacoustic pressure distribution in dependence on time can be described by the formula:

$$P(t) = At^n \exp(-Bt^2) \qquad (1)$$

Here *B* coefficient characterizes the absorption coefficient. It is seen that the optoacoustic pressure shifts to the side of big *t* with increase of absorption coefficient, i.e. both the period and amplitude of oscillations increase with absorption coefficient increase.

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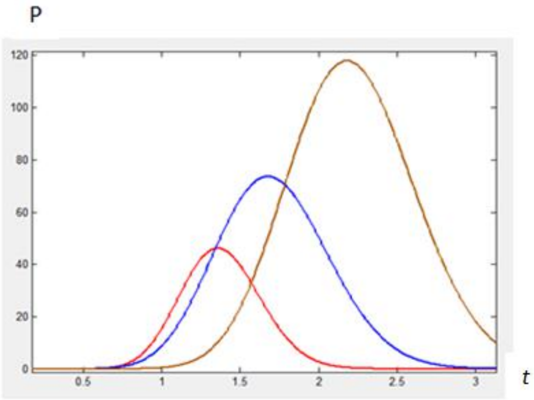

Fig. 2. The graph of *P* optoacoistic pressure dependence on t time. The samples are taken from Shievan, Garadag and Binagadi oilfields.

The connection between oscillation period and absorption coefficient is confirmed by us from the condition of curve maximum:

$$\frac{T^2 B}{n} = 8 \qquad (2)$$

B, *n*, *A* and *t* including in (1) is presented in table:

B	3,86	1,93	1,54
n	14,2	10,87	14,59
A	739,5	61,16	2,02
t_{max}	1,35	1,68	2,78

The wave leading front is the information part of optoacoustic signal. The non-linear factor of second order can be confirmed by signal information part character, i.e. signal front character.

THE RESULTS AND DISCUSSION.

Let's consider the non-linear interaction of laser beams with liquid at multi-photon absorption. At non-linear interaction of laser beams with liquid the intensity change with thickness is expressed by the formula:

$$-d\dot{I} = \alpha \dot{I} dx + \delta_n \dot{I}^n dx \qquad (3)$$

Neglecting the linear absorption (one-photon absorption) from (3) we have:

$$\dot{I} = \frac{\dot{I}_0}{\left(1+(n-1)\delta_n \dot{I}_0^{n-1} x\right)^{\frac{1}{n-1}}}, \dot{I}(0) = \dot{I}_0 \qquad (4)$$

Moreover, the optoacoiustic pressure is confirmed by formula:

$$P_n = \frac{1}{2c_p} \frac{c_0^2 \beta \delta_n \dot{I}_0^n}{\left(1+(n-1)\delta_n \dot{I}_0^{n-1} x\right)^{\frac{n}{n-1}}} \qquad (5)$$

The optoacoustic pressure appearing at linear interaction of laser beams with liquid is expressed by formula:

$$P_1 = \frac{\alpha c_0^2 \beta \dot{I}_0}{2c_p} e^{-\alpha x}, \qquad (6)$$

From comparison of (5) and (6) formulae we have:

$$\frac{P_1}{P_n} = \frac{e^{-\xi}}{\sigma_n}\left[1+(n-1)\sigma_n \xi\right]^{\frac{n}{n-1}}, \qquad (7)$$

where $lx=\xi$ and $\sigma_n = \frac{\gamma \dot{I}_0^{n-1}}{\alpha}$. The graph of $\frac{P_1}{P_n}$ dependence on ξ at different σ_n and *n* values is shown on fig.3.

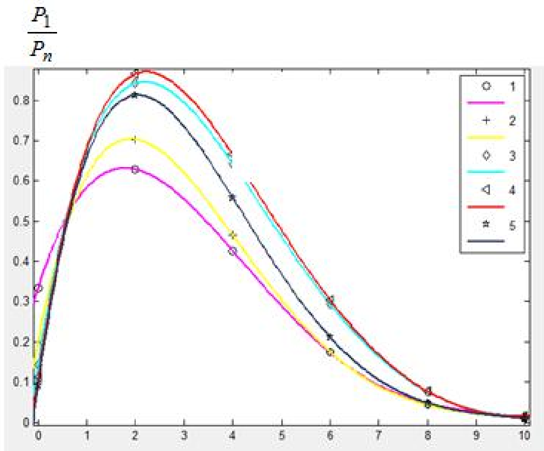

Fig.3. The graph of $\frac{P_1}{P_n}$ dependence on ξ at σ different values.

Formula (7) allows us to confirm the nonlinearity coefficient of *n* order. For this aim let's logarithm the formula (7):

$$\ln\frac{P_1}{P_n} = -\xi - \ln\sigma_n + \frac{n}{n-1}\ln\left[1+(n-1)\sigma_n \xi\right] \qquad (8)$$

From (8) it follows that at ξ=0, $\ln\frac{P_1}{P_n} = -\ln\sigma_n$

From here

$$\frac{P_1}{P_n} = \frac{1}{\sigma_n} = \frac{\alpha}{\delta_n \dot{I}_0^{n-1}} \qquad (9)$$

The non-linearity coefficient of *n* order can be confirmed from (9) on the base of experimental data knowing $\frac{P_1}{P_n}$:

$$\delta_n = \frac{\alpha}{\dot{I}_0^{n-1}} \frac{P_n}{P_1} \qquad (10)$$

Taking into consideration that one- and multi-photon absorption of laser beams in liquids take place simultaneously and applying the superposition principle we have the following expression for resulktant pressure of optoacoustic signal:

$$P_n^* = P_1\left[1+\sigma_n e^{\xi}\left(1+(n-1)\sigma_n\xi\right)^{-\frac{n}{n-1}}\right] \qquad (11)$$

From (11) it follows that at $\xi \to 0$,

$$\ln\left(\frac{P_n^*}{P_1}-1\right) \to \ln\sigma_n \ ,$$

i.e.

$$\frac{P_n^*}{P_1}-1=\frac{\delta_n I_0^{n-1}}{\alpha} \qquad (12)$$

Formula (12) allowws us to find the coefficient of multi-photon absorption of δ_n laser beams in liquids on the base of experimental data at simultaneous one-and multi-photon absorptions.

CONCLUSION

The interaction of laser beams with different oil samples is experimentally and theoretically investigated. The character of optoacoustic pressure change in time is confirmed by experiment results. It is established that the opto-acouastic pressure shifts to the region of big *t* with increase of the absorption coefficient. The character of optoacoustic pressure ratio change at linear and non-linear absorption is theoretically established. The formula allowing the confirmation of multiphoton absorption coefficient of laser beams in oil has been obtained. Matlab programming package is used by authors for investigation of physical phenomena and analysis of experimental data.

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