Optoacoustic Effects On Laser Breakdown In A Liquid

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Abstract - The work is devoted to the study of acoustic effects accompanying a laser breakdown in a liquid. The connection between optical breakdown thresholds and acoustic cavitation thresholds has been established. It is shown that the combined optical and ultrasonic effects reduce cavitation thresholds and enhance the intensity of the illuminated spectral lines of chemical elements during laser breakdown in the presence of ultrasound.

Keywords— laser-induced breakdown, ultrasound field, optical cavitation

I. INTRODUCTION

Real liquids always contain gas bubbles and other suspensions. They usually impact both the acoustic and optical characteristics of liquids [1,2]. Of particular importance is the study of fundamental questions about the origin of breakdown nuclei in a liquid exposed to external optical and acoustic effects – regions of a new phase in the liquid [2,3]. The paper presents the results on the determination of cavitation thresholds and characteristic gain coefficients of spectral lines of a number of chemical elements in water.

II. GENERAL RESULTS

Based on experimental data [3] of optical breakdown in real fresh and seawater that have not been subjected to special purification, a model is proposed that allows us to explain and evaluate the features of water rupture by a laser nanosecond pulse in the ultrasound field. It is assumed that at the beginning of cavity formation, heating due to the absorption of focused laser radiation makes it possible to transform the state of water, represented by the point (T_0, P_0) shown in Fig.1, into a point (T_k, P_0) corresponding to the spinodal at $P_0 = Const$. Another way of creating a cavity is due to a sharp decrease in pressure in the water. In this case, the temperature can be considered constant, which corresponds to the transition from point (T_0, P_0) to point (T_0, P_k) on the spinodal in Fig.1. In addition to these transition trajectories, a combined one is possible using an ultrasonic field from a point (T_0, P_0) to a position on the spinodal $(T_k(P_{ac}), P_{ac})$. Thus, it can be concluded that the temperature $T_k(P_{ac})$ required to reach the spinodal is significantly less than the temperature $T_k(P_0)$ corresponding to the pressure P_0. It is shown that in the phase of maximum stretching by ultrasound, the minimum value of critical overheating and the corresponding minimum critical energy in the laser pulse are observed. Simultaneously with an increase in the amplitude of ultrasound, an increase in the intensity of the illuminated spectral lines is observed.

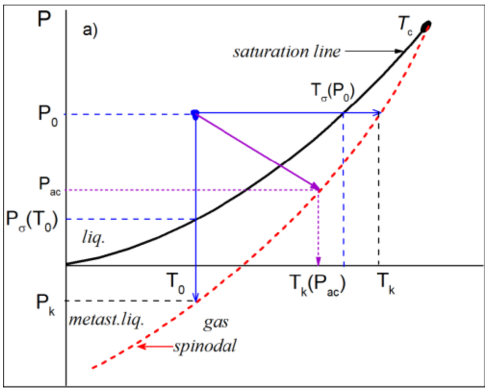

Fig. 1. Ways of liquid breakdown when exposed to a laser without ultrasound and with ultrasound.

III. CONCLUSION

A model is described showing the experimental occurrence of laser breakdown in water at low pulse energy due to the mechanism of heterophase transition caused by the existence of pre-threshold nanoscale nuclei of a new phase in the liquid. The role of ultrasound (amplitude and phase) in reaching critical breakdown thresholds has been clarified. A connection has been established between the thresholds of laser breakdown and acoustic cavitation. In the future, it can be used to independently determine the cavitation thresholds of seawater at great depths in the sea.

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