Dynamics of cluster structures in the near-surface layer of distilled water under laser excitation

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Abstract. We explore changes in the distilled water structure by optical methods in this work. The lack of rigorous ideas about the structure of water and its organization at the molecular level hinders the development of methods not only for quantitative analysis, but also for qualitative assessment of the structure of water. Optical methods of studying changes in the structure of water are used in present work, since it is a disordered fluid whose hydrogen bonds are short-lived. The mechanism for the formation of cluster structures near the surface of a water drop is proposed. It is shown that water has unique properties associated with the presence of order in its various states due to the cooperative effect of structural and dynamic changes in a heterogeneous hydrogen bond network.

1. Introduction

In recent years the interest paid on the structure of water not only from biologists, chemists, or physicians, but also from physicists has been growing. Water as a widespread solvent has unusual properties. Due to intermolecular hydrogen bonds it has different properties from other hydrides and is structurally a very sensitive system with a huge number of metastable states. The question of observation water and aqueous solutions structure has already moved to the plane of studying the effect of changes in the structure of water and aqueous solutions on various technological processes, as well as on the level of human health. The lack of rigorous ideas about the structure of water and its organization at the molecular level hinders the development of methods not only for quantitative analysis, but also for qualitative assessment of water structure.

Unique properties of water structure can be explained by the presence of order in its various states, which is a consequence of the cooperative effect of the structurally changing inhomogeneous network of hydrogen bonds. As a result, the structure of water can be associated with the presence of hydrogen bonds and the formation of hydrated ions that form a complex three-dimensional network. The number of possible ways to connect tetrahedral water molecules with each other and stable configurations based on them is enormous, and therefore non-stationary processes lead to the formation of clusters. Individual molecules connected by hydrogen bonds are combined into associates or clusters, the size of which depends on different conditions, primarily on temperature [1].

One of the important properties of the surface layer of water is a change in the transmission and refraction coefficients of laser radiation due to which it is possible to “see” clusters, determine their size and number [2]. It is believed that the lifetime of stable nanoclusters in the bulk phase of water does not exceed 0.01 nanoseconds [3]. Getting from the bulk phase to the near-surface one short-lived clusters stabilize in it, and their lifetime increases significantly. Stabilization of clusters in the near-surface layer
of water is associated with a high structural ordering of the layer. As the distance from the interface into the liquid increases, the degree of order decreases. And vice versa, at some distance from the surface the order corresponds to the state of the liquid in the bulk phase.

As we mentioned above, water and aqueous solutions are highly sensitive to external influences, especially to the influence of temperature. Therefore, nondestructive research methods are necessary for their adequate study.

The purpose of this work is to explore changes in the structure of water as an unordered liquid by optical methods. Water despite the fact that its hydrogen bonds are short-lived is capable of self-organization due to the formation of new hydrogen bonds and cooperative effects.

2. Experimental part
A rather simple realizable laser interferometry method based on the use of amplitude-phase modulation of an extended laser beam passed through a layer of water droplets, which allows us to study the formation and changes of a non-uniform structure in the surface water layer, is considered in proposed work [4-6].

The scheme of the experimental setup for visualizing the fractal-cluster structure of inhomogeneities of double-distilled water in laser radiation is shown in Fig. 1.

Figure 1. Scheme of experimental setup for visualization of fractal-cluster structure of double distilled water in laser radiation [4].

As a result, for the first time by the amplitude-phase laser interferometric method the water structures were fixed and models of cluster formation in the surface layer of double distilled water were proposed, which are given below:
Figure 2. Structure and models of water clusters (associates) $\text{H}_{11}\text{O}_{5}$.

Figure 3. Structure and models of water clusters (associates) $\text{H}_{21}\text{O}_{10}$.

Figure 4. Structure and models of water clusters (associates) $\text{H}_{29}\text{O}_{14}$.

Figure 5. Structure and croquet mechanism of cluster formation in the surface layer of double distilled water.
Figure 6. Structure and models of $\text{H}_4\text{O}_20$-endo-$\text{H}$-fullerene clusters in the near-surface layer of double distilled water.

Figure 7. Cyclic forms of the structure and hexamer model of double distilled water with two intracyclic hydrogen bonds.

3. Conclusion
The obtained structures of the clusters of double distilled water rather convincingly testify in favor of the fact that stable polymeric states are present in liquid water.

It was confirmed, that water has unique properties that are associated with the presence of order in its various cluster states due to the cooperative effect of structural and dynamic changes in a heterogeneous network of hydrogen bonds. Clusters can have a different number of molecules that form associates of various shapes.

The results of this study can serve as the basis for new, simple to implement laser methods for quickly determining the structure of water.

Acknowledgments
The reported research was funded by RFBR and Council of Ministers of the Republic of Crimea according to the research project № 19-42-910010.

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