Effect of Maximum Interaction of Circularly Polarized Electromagnetic Waves with the Molecule of DNA

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Abstract:

Investigation of polarizing properties of DNA is chosen as one of primary importance due to mirror asymmetry of the shape of DNA. Preliminary theoretical calculation has shown that the form of DNA is optimum for radiation of a circular electromagnetic wave under the resonance condition (~10 nm). This conclusion has been proved for the metal DNA-like helices in a microwave range in accordance with the principle of scaling. In the given work it is experimentally confirmed the presence of the effect of polarization selectivity in double reflection of microwave waves from DNA-like helical elements depending on their sign (the right-handed and left-handed helices).

It is shown that the circular polarization of waves plays an important role in case of interaction of microwaves reflected from the artificial DNA-like structures. Probably, the identical effect takes place in some processes that involve DNA in biological organisms' cells, but in the range of far ultraviolet radiation and the "soft" X-ray range.

These results are also interesting in connection with an opportunity of creation of artificial 2D and 3D structures on the basis of branches of a molecule of DNA. Such structures can be into a basis of new type metamaterials.

Keywords: *DNA, helix, polarization selectivity.*

1. Introduction

Research the phenomenon of interaction of electromagnetic waves with biological helical objects and first of all with DNA in connection with its universal form for all organisms and huge biological importance represents for us the big scientific interest.

As the first approximation it is important to us to carry out research on models of DNA-like helical structures for example in a microwave range by a principle of electrodynamic similarity (scaling). And further to approach to experiment with molecules of DNA, being based on results of the obtained conclusions and analogies. Such idea is realized in the given work.

In the work [1] it is established that molecules of amino acids interact variously with the light waves, which are circularly polarized to the right or to the left. However selectivity of such interaction is insignificant and the relative distinction of influence of the light waves achieves a few percent.

It is shown in [2] that the molecule of DNA can display the maximal (absolute) selectivity of interaction with circularly polarized waves in a "soft" X-ray range. It means that in the wavelength range λ ~7-8 nm the molecule of DNA can "feel" only the left-handed wave and remains "transparent" for the right-handed wave.

The criterion of the strongest display of the effect of polarization selectivity for a long helical molecule in relation to circularly polarized electromagnetic radiation is obtained: an optimum pitch angle of helix should be near to 24.5°, the helix must be double and the main frequency resonance should be realized.

2. Using a scaling factor at investigation of polarization properties of DNA

An electromagnetic wave of a microwave range reflected from 2D array, consisting of helical conductors, is investigated in [3], [4]. Each helical metallic element is geometrically similar to the helix of DNA. The lattices composed of copper helices and fixed on the radio transparent material have been manufactured. In Fig. 1 it is shown one of these lattices, that are composed of 7 half-turn double right-handed helices.

The helices in the experiment were activated by plain incident waves, so each helix was in the uniform field which was shielded from external fields by the anechoic chamber. The reflected by sample (with the angle of reflection equals 45°) electromagnetic wave is investigated depending on frequency nearby the main resonance. Both the ellipticity and the wave intensity of the reflected wave are investigated depending on the frequency.

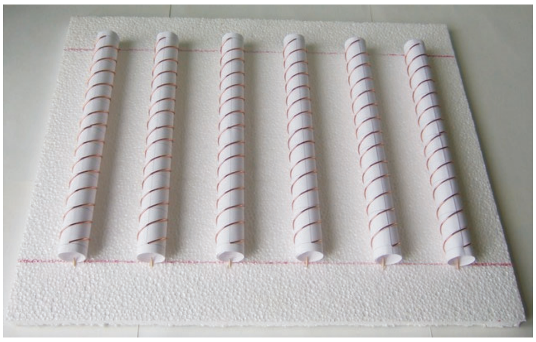

Fig. 1. Photo of the experimental sample of 2D array composed of the double right-handed DNA-like helices.

Ellipticity-frequency diagram that characterizes the reflected waves can be seen in Fig. 2 for the case when the electric vector of the incident linearly polarized wave oscillates along helix's axis. As it can be seen on the indicated figure, the ellipticity of the wave is high on the whole investigated wave range. Case when the electric vector has been directed perpendicular to the helix's axis was experimentally investigated also. Ellipticity-frequency diagrams for these cases have been similar with specified on Fig. 2.

In the work [5] the effect of polarization selectivity at interaction of right-handed double helices with the electromagnetic radiation of left-circularly polarized waves is experimentally confirmed. The linearly polarized waves reflected from the flat sample, consisting of the right-handed double helices and transformed into the left-circular polarization waves. Then they fall onto the identical sample. Thus, the double reflection of waves from the identical samples of helices was investigated. In this case the effect of polarization selectivity was observed. When the second sample with right-handed helices has been replaced on the sample with left-handed helices the effect of polarization selectivity was not observed. Moreover, the intensity of the reflected wave in the second case has been much lower than in the first case.

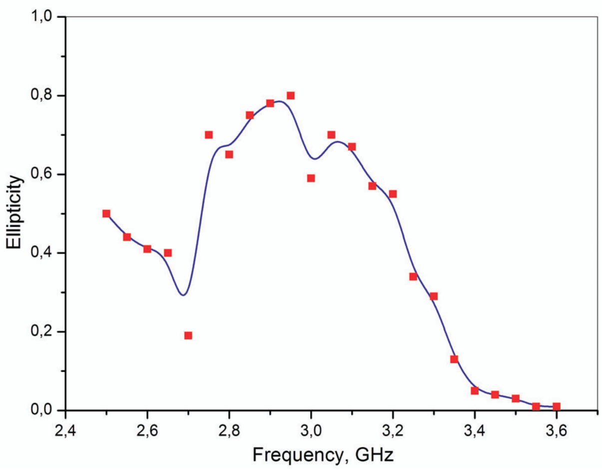

Fig. 2. Dependence of the ellipticity of the reflected wave on the frequency when the electric vector of the incident linearly polarized wave oscillates along helix's axis.

Thus, on the basis of the principle of electrodynamic similarity (scaling) the results, obtained earlier theoretically, are experimentally proved.

3. Polarization selectivity of DNA in visible wave range

At present we realize the transition to the experimental verification of the effect of polarization selectivity directly with the molecule of DNA in visible and ultra-violet ranges. The first stage is research the transmission coefficient of the visible light of the He-Ne laser (wavelength is λ=631 nm) through the thin film of DNA in a polymer shell.

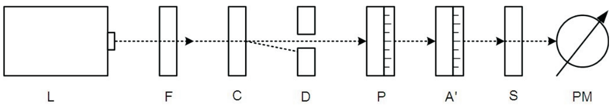

Fig. 3. Scheme of the experiment for investigation of the transmission coefficient of the light passing through DNA depending on the type of the polarization.

In the Fig. 3 the scheme of the experiment is represented. Here L is the He-Ne laser, F is the filter which is used to decrease intensity of the laser beam, C is the crystal of Iceland spar for double refraction, D is diaphragm that lets the linearly polarized light through, P is quarter-wave plate, A' is analyzer to check the obtained circularly polarized light, S is the sample of DNA, PM is sensitive power meter.

In the given experiment the purpose is to analyze the dependence of transmission coefficient of the laser radiation by the sample of DNA of the birch (Fig. 4), depending on the type of polarization of radiation.

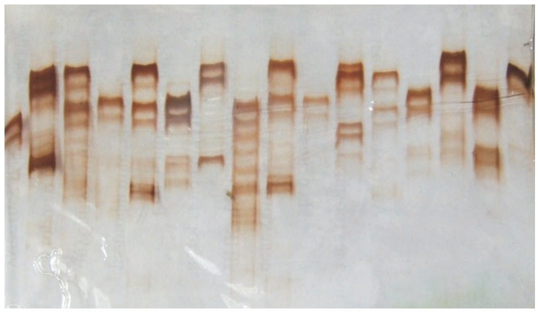

Fig. 4. Sample of DNA of birch tree in polymer shell.

As a result of experiment, it was found out that absorption of the beam of the laser by samples of DNA did not vary depending on the kind of circular polarization of radiation (Fig. 5) but it changes very poorly (on ~4%) if we compare the absorption of the linearly polarized light with the circularly polarized light. By means of a quarter wave plate the polarization smoothly varied from linearly to circularly polarized and back, thus the transmission coefficient of light remained almost constant. From the analysis of the last figure we can conclude that circularly polarized waves with λ=631 nm interact with sample of DNA more efficiently then linearly polarized wave.

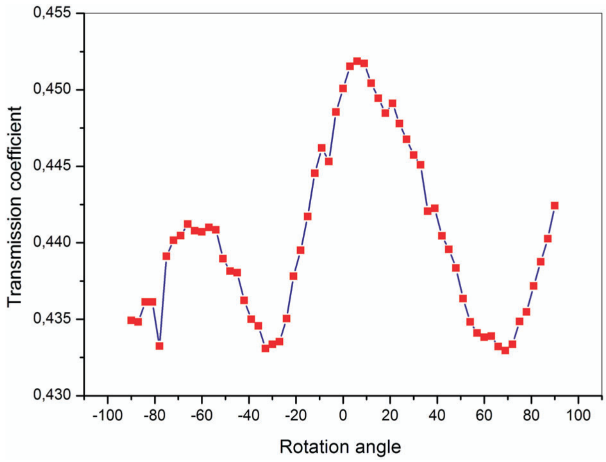

Fig. 5. Dependence of the transmission coefficient of the light passing through DNA on the rotation angle of quarter-wave plate.

The given result corresponds with predictions of the theory since the effect of maximal polarizing selectivity for DNA can be shown at length of a wave λ ~7-8 nm. The length of wave of the He-Ne laser approximately at 90-80 times more the given values, therefore absorption of DNA of a linear and circular wave occurs equally.

4. Conclusion

According to the principle of electrodynamic similarity (scaling), the effect of polarization selectivity, observed in the microwave wave range for DNA-like helices, can take place for the molecule of DNA in a nanometre range.

This effect has a determining role for DNA (probably for other helical objects also) and it is directly connected with infringement of mirror symmetry in natural structures and phenomena. The polarization selectivity of electromagnetic interaction can be important at genetic preservation of distinctions between right-handed and left-handed forms of objects of animate nature.

Last years an interest in creation of artificial 2D and 3D structures directly from molecules of DNA has considerably increased. In work [6] the opportunity to create these nanostructures from DNA branches in the form of lattices, cubes, octahedrons, etc., is shown. It allows us to talk about discovering of a new field of nanotechnology which is design of artificial DNA-like crystals. Probably such crystals will display very interesting electromagnetic properties including the property of polarization selectivity. We think that the effect of polarization selectivity is very important for all living beings in nature because it is directly connected with infringement of mirror symmetry in natural structures and phenomenon. These features can be used at creation of DNA-like metamaterials with selective polarizing properties.

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