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Millimeter-Wave Radiation of the Water and Biomedicine

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Abstract. Much of the recent interest in terahertz radiation stems from its ability to penetrate deep into many organic materials, without the damage associated with ionizing radiation such as X-rays and its applications in modern medical therapy and imaging. In this work we report the results of studies related to radiative properties of moving and standing water in the terahertz spectral range. The transmission of such radiation through holes of various sizes (0.2-4mm) was analyzed by detecting it on the photographic film. Emission of millimeter-wave radiation can be explained by the transition of water molecule from the higher rotational states to the lower one. Terahertz emission from different liquids which have strong rotational transitions have been registered.

Keywords: water emission, terahertz radiation, rotational transitions

1. Introduction

It is well known that the main component of the soft living tissue is water molecules (about 70-80 percent), therefore the knowledge of electromagnetic properties of water is important for various applications in modern medical therapy and imaging. Great interest in terahertz radiation is connected with its ability to penetrate deep into organic materials, without its damage in opposite to X-rays ionizing radiation. In this work we report the results of studies related to radiative properties of moving and standing water in the terahertz spectral range.

The emission of electromagnetic radiation from turbulent and laminar stream of water was studied by P. Dobler [1] in the first half of 20th century. He assumed that water jet emit electromagnetic waves due to transformation of the mechanical energy into radiation, however the spectral properties and true origin of this phenomena haven't been cleared up to now. In present times it is well known of water electromagnetic emission properties in infrared spectral range that are connected with vibrational transitions of water molecules. Over one hundred laser lines located in micrometer spectral range up to 10 micrometer have been studied and exploited in collisional pumping scheme [2]. Furthermore due to high quantum yield of emission of water molecules in infrared, the laser systems were successfully constricted which used liquid water as active lasing media [3].

2. Experimental Approaches, Results and Discussions

In the present work we studied the electromagnetic emission properties of standing and moving liquid water in terahertz spectral range that involve studies of transmission of water radiation through holes of various sizes ($0.2-4mm$) by detecting its intensity on the photographic film. We constructed water generator of electromagnetic waves and registered the emission by photographic film (see Figure 1). The liquid water was directed through tapered glass tube with the output diameter of $2\,mm$ that was located in the inner part of glass flask. Water jet exited glass tube and stopped at the wall of glass flask. The area of flask where water jet stops can be considered as a point source of radiation. Since the water speed becomes zero at this area, the magnitude of the negative acceleration reaches its maximum.

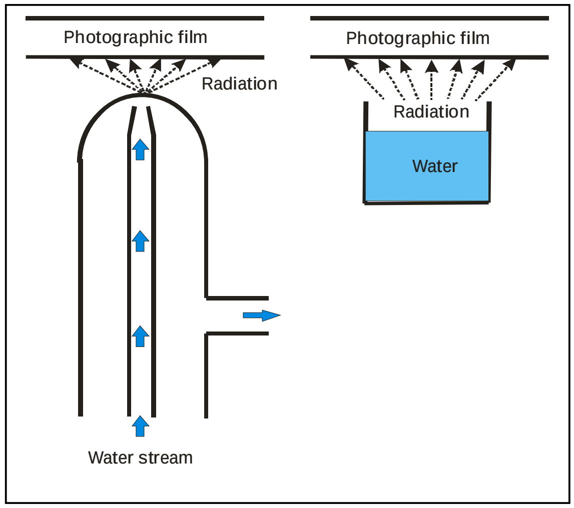
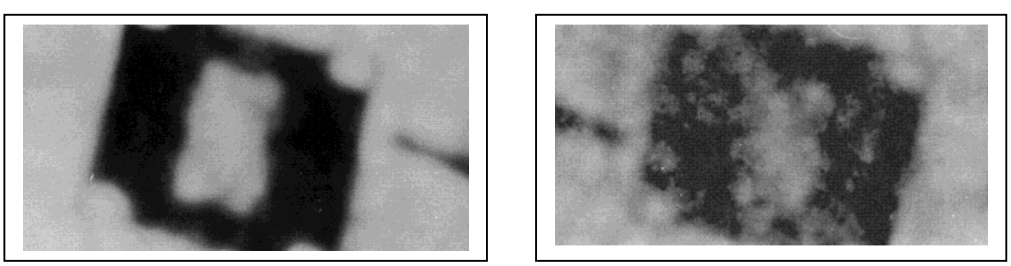


Fig. 1. Schematic representation of experimental setup for photographic registration of the electromagnetic waves with water stream generator and standing water.

In the bottom part of flask it is constructed a second glass tube with wide diameter of 10 mm to provide output of the water from the flask. In vicinity of the area where water jet stops the special constructed container with the photographic film (color Kodak film ISO 400) is located. The container was constructed from a plastic material which is non- transparent in the visible and infrared spectral range, but transparent in terahertz spectral range. Figure 2 shows the images of nonmagnetic metal (stainless steel) net obtained by photo exposition of emission of water jet. The water velocity was 25 milliliters per second, the jet width was about $2\,mm$ and photoexposition time was 60-130 minutes. As can be seen in the photo image, the small grain of metal lattice with average sizes of $0.2mm$ is not visible, but four relatively large (about $1\times 3mm$) holes located at corners are clearly observed. This result indicates that the radiation with wavelength smaller than $0.2mm$ is not registered on the film.



(a) **(b)**

Fig. 2. Photographic images of a nonmagnetic stainless steel net sample obtained by irradiation of water stream with exposition: a) 130 min, b) 60 min.

For more correct estimation of wavelength of water radiation, metal mask representing a non-magnetic metal plate with thickness of $0.5\,mm$ was used. The set of the holes of various sizes, from $0.2mm$ to $4mm$ as well as an aperture in the form of a wedge (see Fig. 3) were machined in metal mask.

The transmission coefficient of radiation trough the hole can be represented by the following expression [4]:

$$\tau = \frac{64}{27\pi^2}\kappa^4\alpha^4 \ ,$$

where κ is the wave vector of the radiation, a is the radius of hole.

Detection of the transmitted light intensity, after passing the holes of different diameters $(4\,;3\,;2.5\,;1.5\,;1.25\,;1.0\,;0.8\,;0.6$ and $0.4\,mm)$, allows to estimate the value of the wavelength of radiation. Figure 3 shows the image, obtained on the photographic film, when water radiation transmitted through different sizes holes in the metal mask. In the case when we used photographic container we observed only six holes from total amount of nine. Holes with diameters of 0.8, 0.6 and $0.4\,mm$ are not visible on the photographic image. For this reason we have used photographic camera without objective and with optical entrance which was closed to surface of photographic film. In this case, metal mask and photographic film are located at the minimal distance. As one can see from the obtained picture (Fig. 3.), images of all nine holes with diameters in the range of 0.4 to $4\,mm$ are observed. However, the image of the smallest hole with the diameter of $0.4\,mm$ is weak.

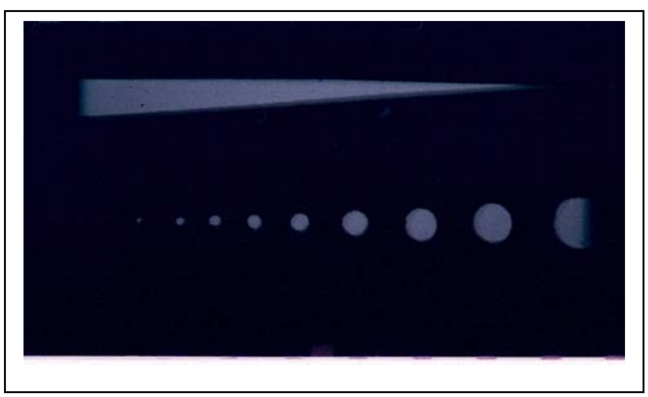
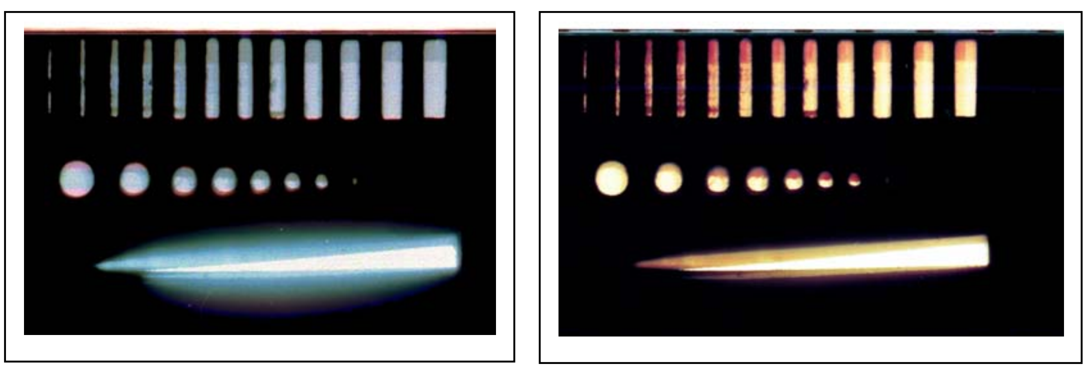


Fig. 3. Photographic image of the holes in metal mask obtained with water jet emission and modified photographic camera. Exposition time is 60 min.

Thus, from obtained experimental data we can conclude that the water emission includes the radiation in a millimeter spectral range. It is worth to mention that recently was reported the experimental results, obtained by method of absorption spectroscopy of water vapor in atmosphere and absorption lines of the liquid water connected with the rotational energy levels of water molecules [5,6]. Results of the work [6] indicate that there are two strongest absorption bands in the water that lie in the vicinity of wavelengths $1.64mm$ and $13.48mm$ which are located in submillimeter – centimeter spectral range and connected with the rotational transitions of water molecules.

We also studied radiative properties of standing water in the same photoregistration scheme. In this case, relatively weak radiation from stagnant water has been detected. Emission of motionless liquids is possible due to the fact that at room temperature the energy of light quantum $h\nu$ in terahertz spectral range is lower than thermal energy kT of surrounding media. Therefore, in this case, rotational transitions of the water molecules can be stipulated by the thermal energy of air molecules in the room. In photographic pictures of metal mask obtained with stagnant water radiation the hole with the diameter of $0.4\,mm$ is practically non noticeable. Note that in case of stagnant water the exposition time was increased from 60 min to 270 min to obtain the clear image of metal mask. The difference between images obtained from stagnant water and via water stream generator can be explained by assuming that in case of stream generator the additional mechanical energy is transferred to the water molecules. Such mechanism can explore additional transitions between rotation energy levels which are practically absent in case of motionless water and therefore to widening or shift of the spectral range of emission. This radiation with more short wavelengths will provide transmission trough holes less than $0.4\,mm$ in a diameter.

Based on proposed mechanism of water molecules emission via transitions between rotation energy levels we studied the radiative possibilities of other liquids which have strong rotational transitions.

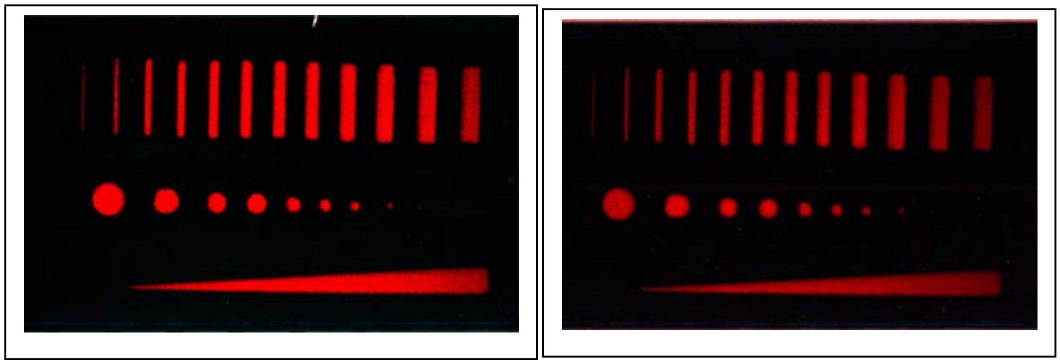


(a) **(b)**

Fig. 4. Photo-registered emission of standing liquids: 4-nitro-benzoylchlorid – (a) and acetone – (b).

As can be seen from Fig. 4, intensive radiation has been detected from these liquids that confirm the origin of millimeter wave radiation by rotational transitions of molecules.

We also studied radiative possibilities distillated water and Ringer’s solution that relative to the human’s body fluids (see Fig. 5.).



(a) (b)

Fig. 5. Photo-registered emission of distilled water – (a) and Ringer' solution – (b).

It can be seen that there are negligible differences in intensities of the distilled water and Ringer' solution.

The influence of temperature on emission of water has been studied. In this case we transformed obtained photographic images to digitization curves that allow to measure level of radiation intensity. The growth of radiation intensity with growth of temperature was registered in temperature range of $35^0 - 65^0 C$. At the water temperature $35^0 C$ the photographic image has poor contrast with ratio of maximal signal to background about of 1.1. Ratio of maximal signal to background reaches 1.55 and the well contrast image was obtained at the temperature of $65^0 C$ that demonstrate growth of intensity on 50% with increase of water temperature.

3. Conclusions

Thus, in the present work we studied the water emission properties in the millimeter range of wavelengths by the method of photo-registration on photographic film. The emission of motionless and moving water was studied and compared. The influence of the water temperature on the emission intensity is revealed.

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