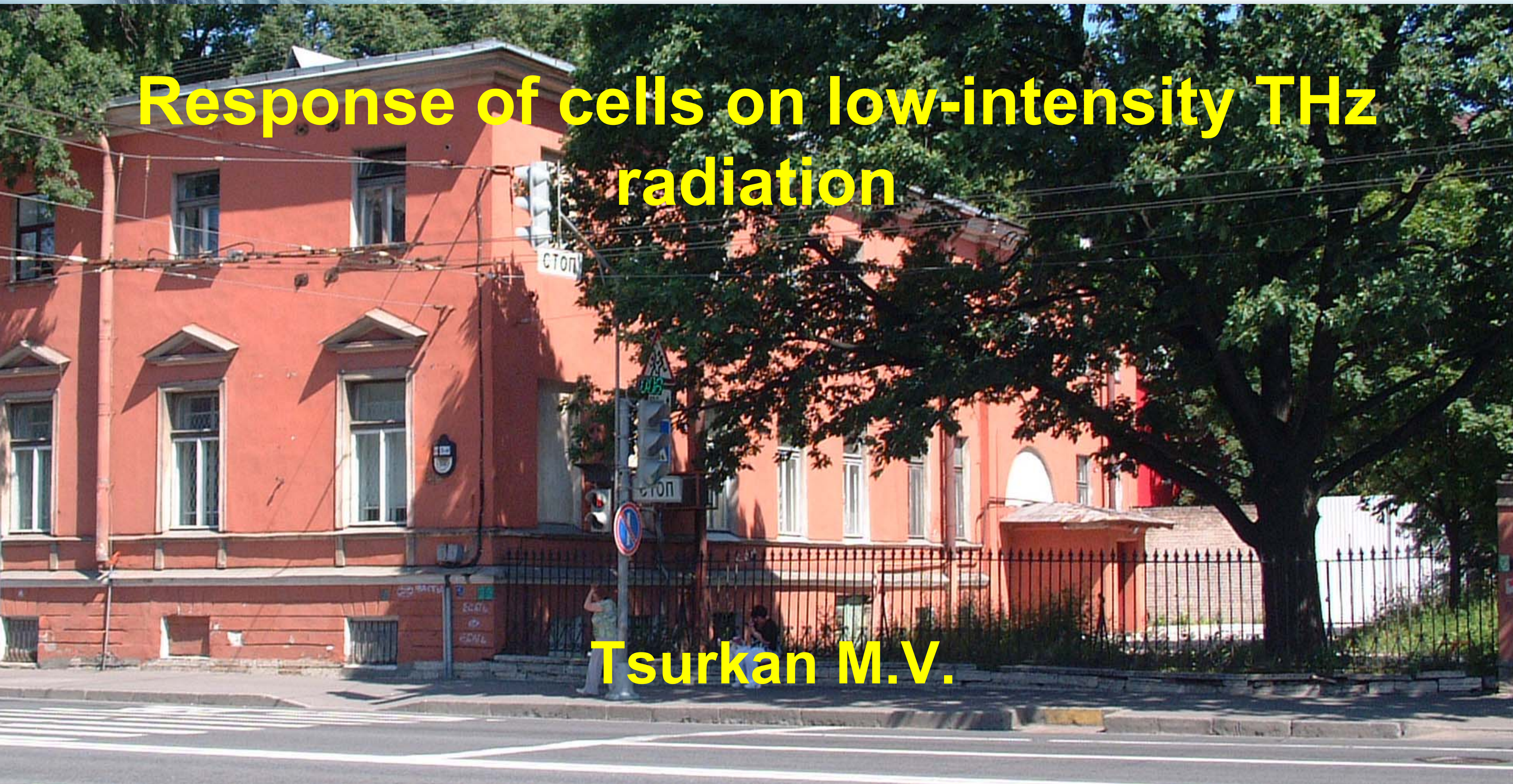
National Research University of IT, Mechanics and Optics

Research-Educational Center for Femtosecond Optics and Femtotechnologies

Response of cells on low-intensity THz radiation

Tsurkan M.V.



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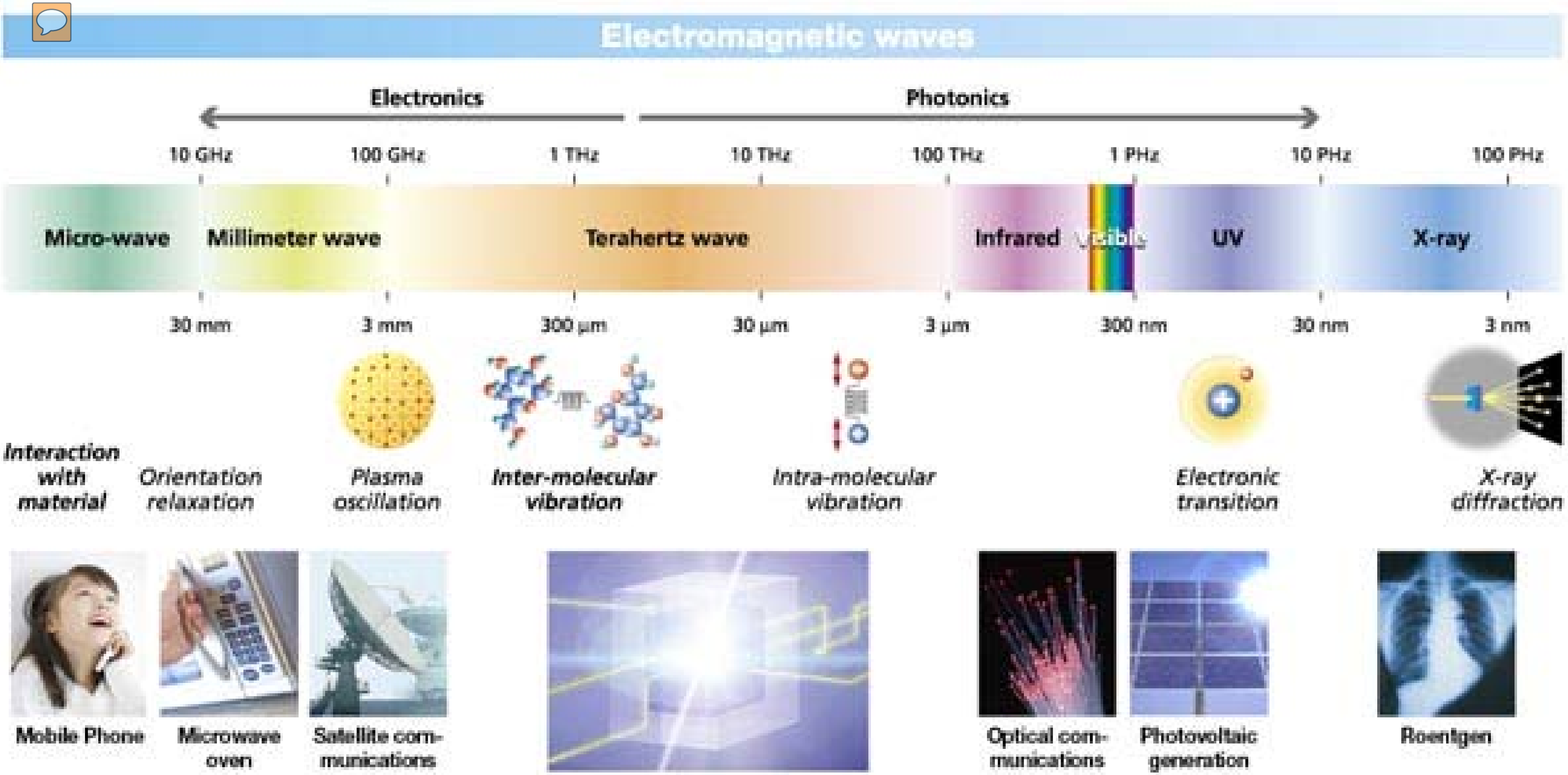


Key features:

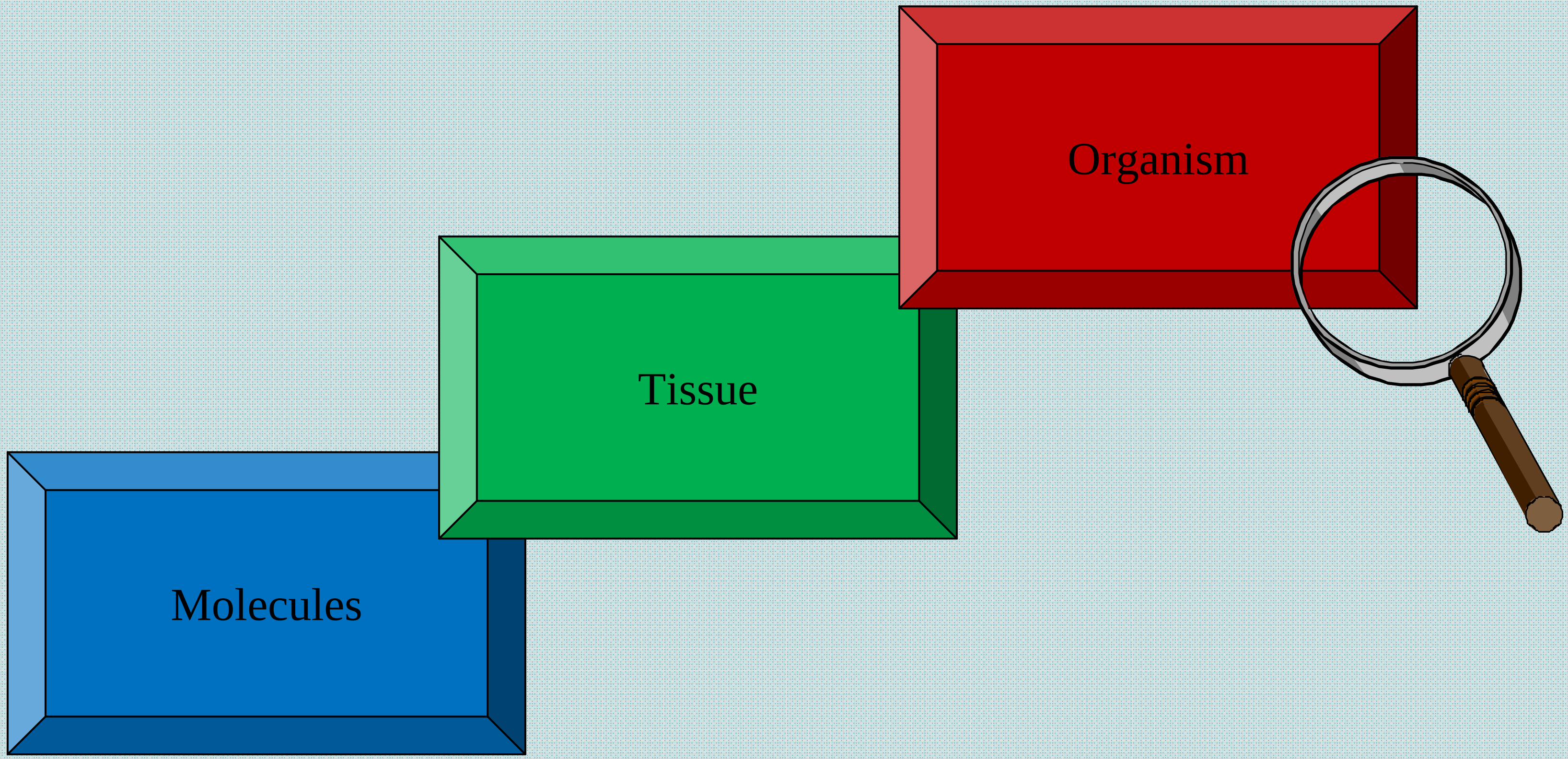
- non-ionizing
- absorption spectrum is different for healthy and diseased tissues
- frequencies of hydrogen bonds and intermolecular interaction
- many biological molecules have vibration and rotational modes in the THz range

http://technodaily.ru/?p=440

Can be dangerous?

THz radiation has a major impact on biological objects. But good or bad?

Timeliness



The use of sources of terahertz (THz) radiation in various fields, including biology and medicine is increasing every year. At the same time the need for better understanding of the mechanisms of the interactions and their potential is increasing as well.

Under the influence of radiation both stimulating and depressing effects were observed in the nerve fibers

THz-induced changes

- Cell viability
- Cell morphology
- Action potential
- Membrane permeability

Experimental results of other laboratories

Changes in cell growth

Escherichia coli

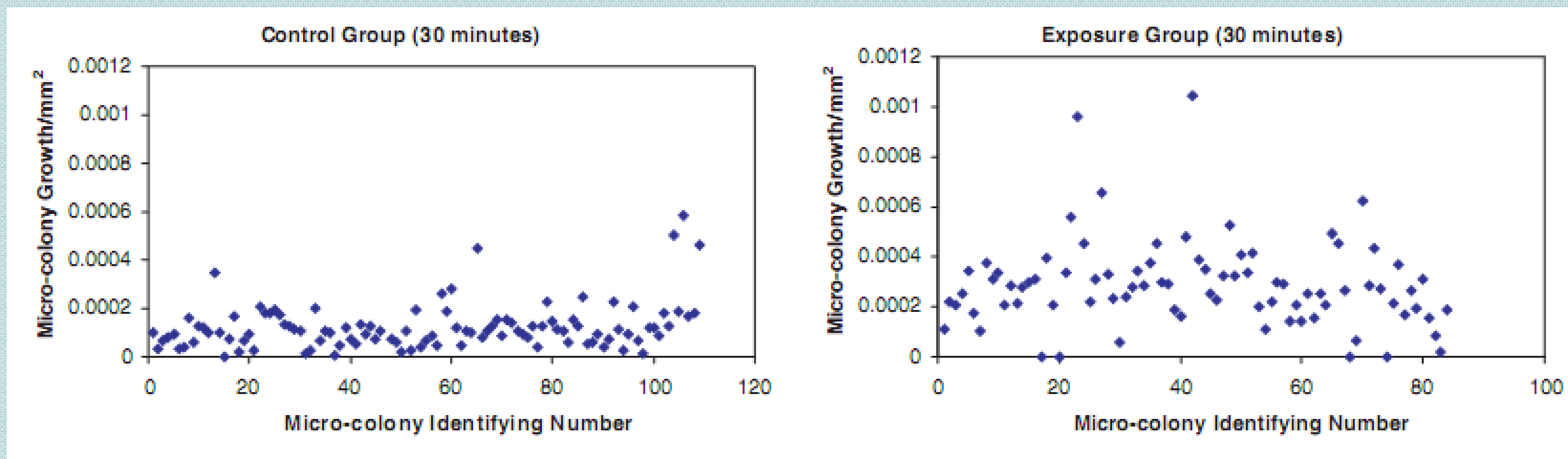
Treatment	Incubation time (min)								
	0	30	60	90	120	150	180	210	240
Irradiated (lag phase)	125*	121	142	136	124	135	123	134	129
Control (lag phase)	131	136	129	138	204	263	412	506	810
Irradiated (log phase)	142	163	211	251	284	286	283	281	288
Control (log phase)	126	184	241	341	462	673	998	1,340	1.960
Temperature (°C)	25·2	25·2	25·4	25·6	25·8	25·7	25·8	25·9	25·8

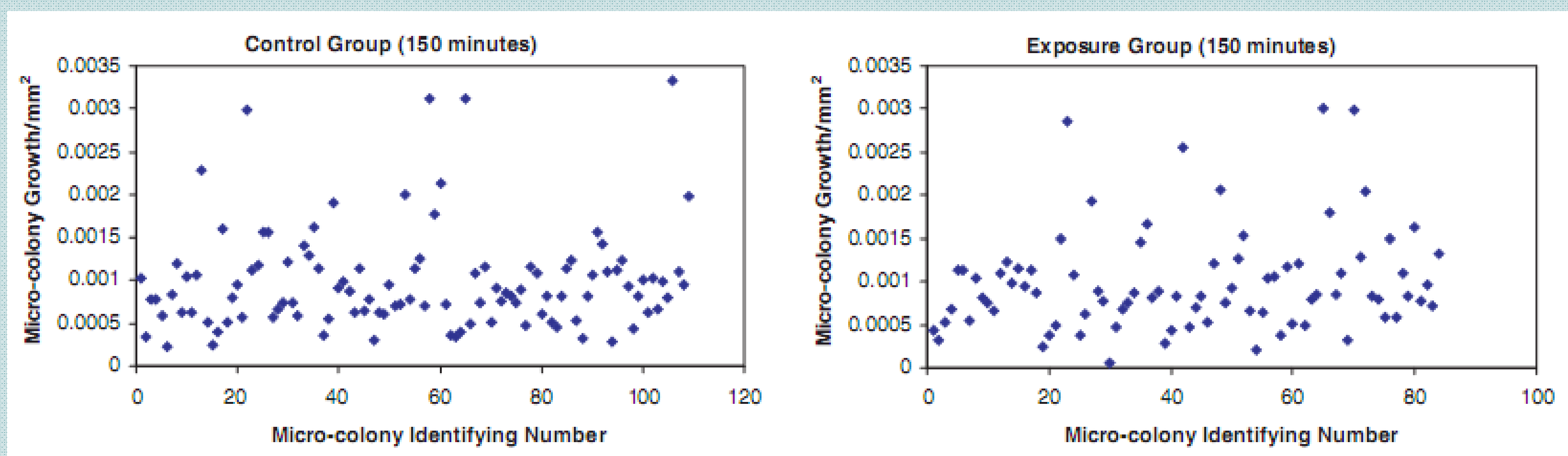
When exposed to the radiation 0.136 THz during first growth phase (lag) and after 90 minutes of incubation (log) the cell growth was inhibited at 2 and 7 times, respectively

2 effects: to slow down cell division and to inhibit specifically metabolic process occurring during the early part of the life span of a cell

Webb, S. J. and Dodds, D. D., “Inhibition of bacterial cell growth by 136 gc microwaves,” Nature 218(5139), 374–375 (1968).

Changes in cell growth





THz radiation with frequency of 0,341 THz and a power density of 5.8 mW/cm^2. The impact of the electromagnetic field was carried out for 2.5 hours. Growth rate was assessed every 30 min.

•adjiloucas, S., Chahal, M. and Bowen, J., “Preliminary results on the non-thermal effects of 200–350 GHz radiation on the growth rate of S. cerevisiae cells in microcolonies,” Phys. in Med. and Biol., 47(21), 3831 (2002).

Changes in cell morphology and membrane permeability

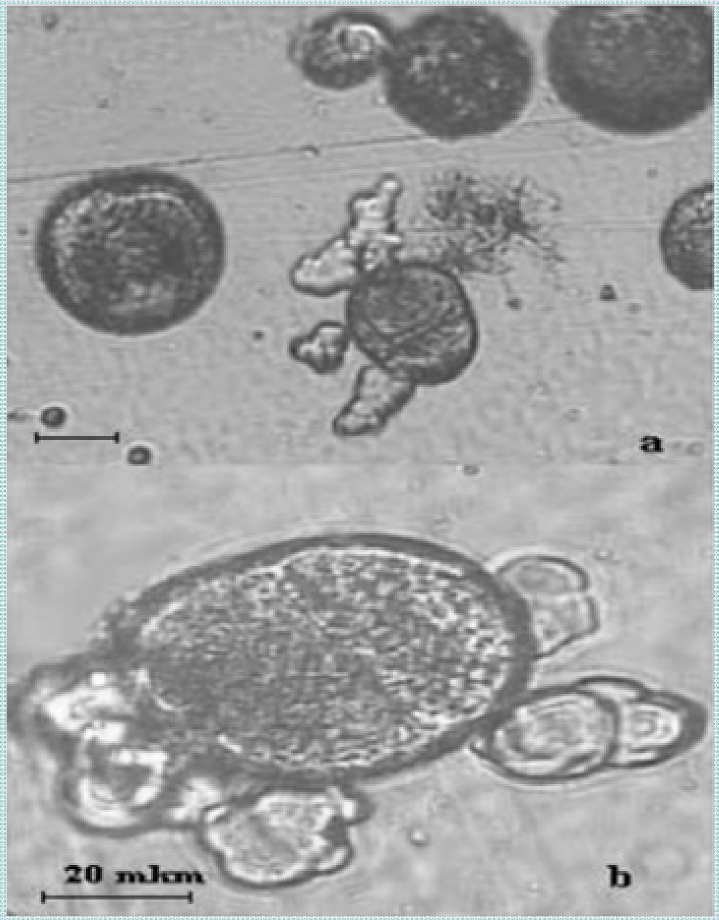


Fig. 1. Isolated neurons after action of radiation. a, b anomalous growth of neuritis at the same stage of neogenesis of neuritis

The effects of THz radiation with frequencies of 2.5 THz and power densities of 0.3-30 mW/cm^2 on the structural and functional properties of isolated Lymnaea stagnalis neurons

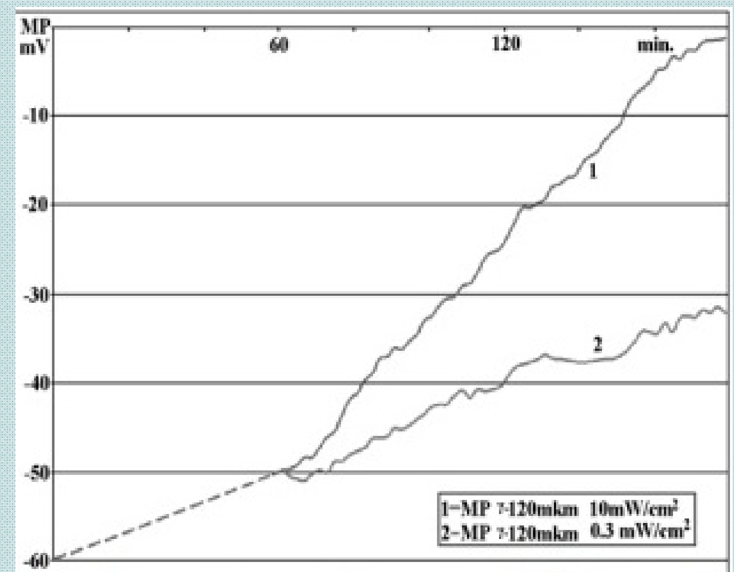
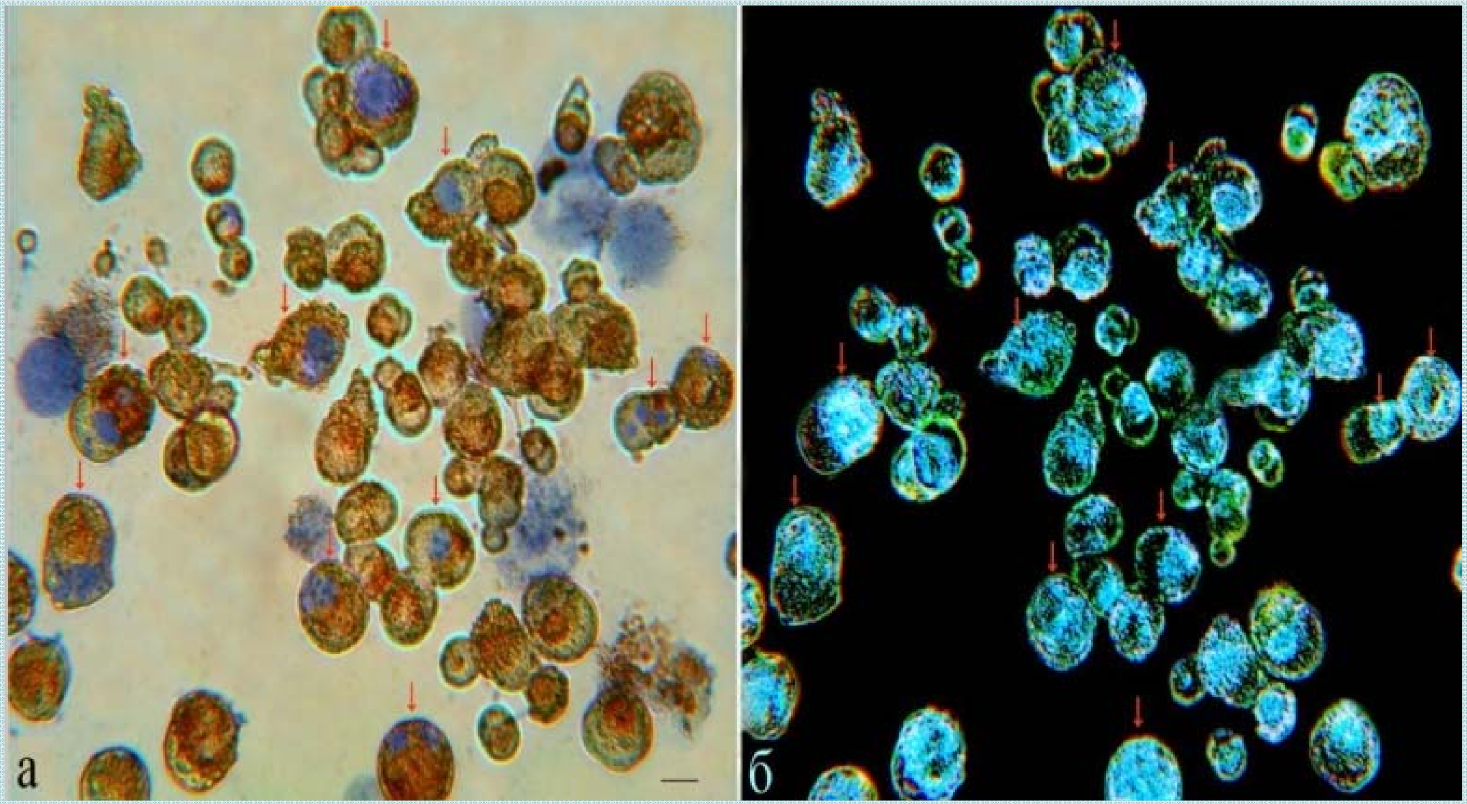


Fig. 2. Changes of neuron membranes potential (MP) after action of radiation

Olshevskaya, J. S., Ratushnyak, A. S., Petrov, A. K., Kozlov, A.S., Zapara, T. A., “Effect of terahertz electromagnetic waves on neurons systems,” Computational Technologies in Electrical and Electronics Engineering, 2008. SIBIRCON 2008. IEEE Region 8 International Conference on, 210–211 (2008)

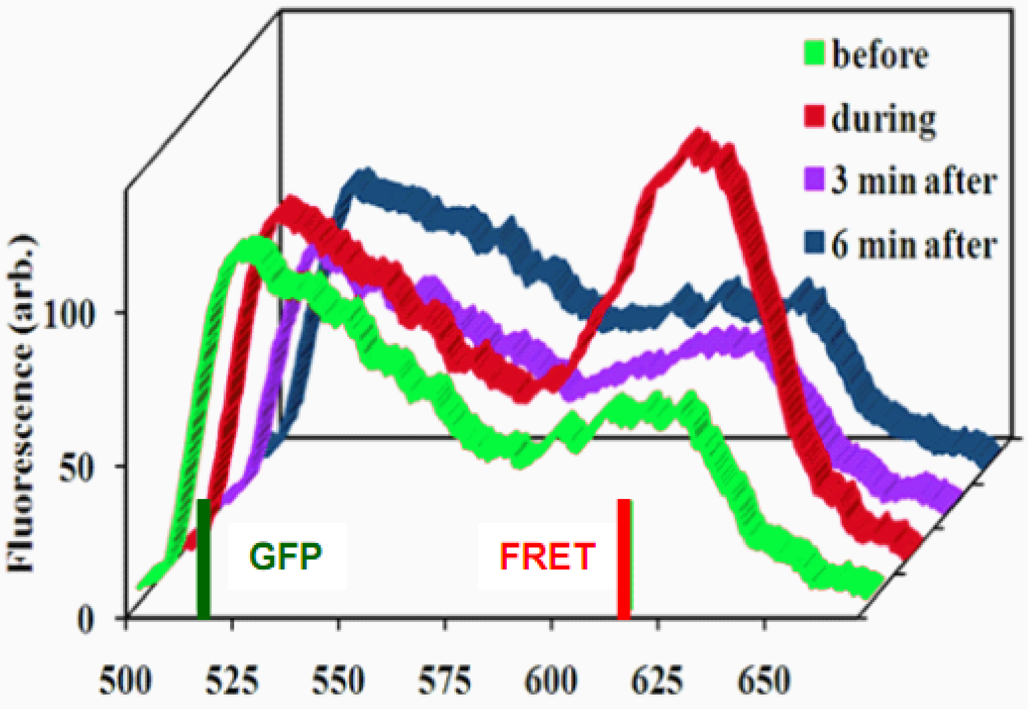
Changes in membrane permeability

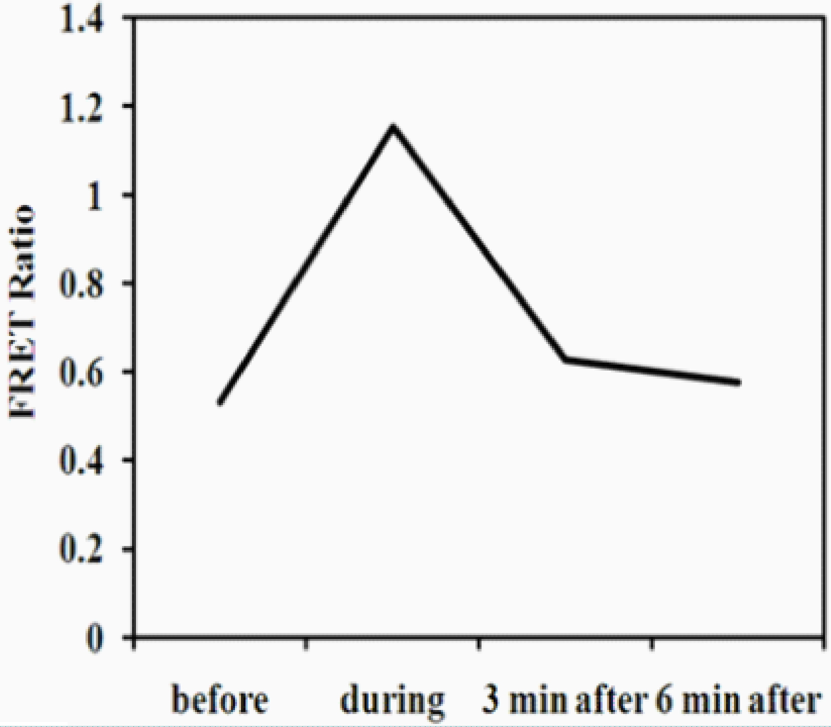


Nerve cells after exposure to laser radiation with a frequency of 2.31 THz and a power of 0.5 mW:
a - light microscopy with the dye Trypan Blue;
b - fluorescence microscopy with the dye BCECF-AM.
Arrows indicate the cells stained Trypan Blue (a) and Trypan Blue + BCECF-AM (b)

Olshevskaya, J. S., Kozlov, A. S., Petrov,A. K., T. A. Zapara, Ratushnyak A. S., "Cell membrane permeability under the influence of terahertz (submillimeter) laser radiation," Vestnik Novosibirsk State University 5(4), 177-181 (2010)

Changes in membrane permeability



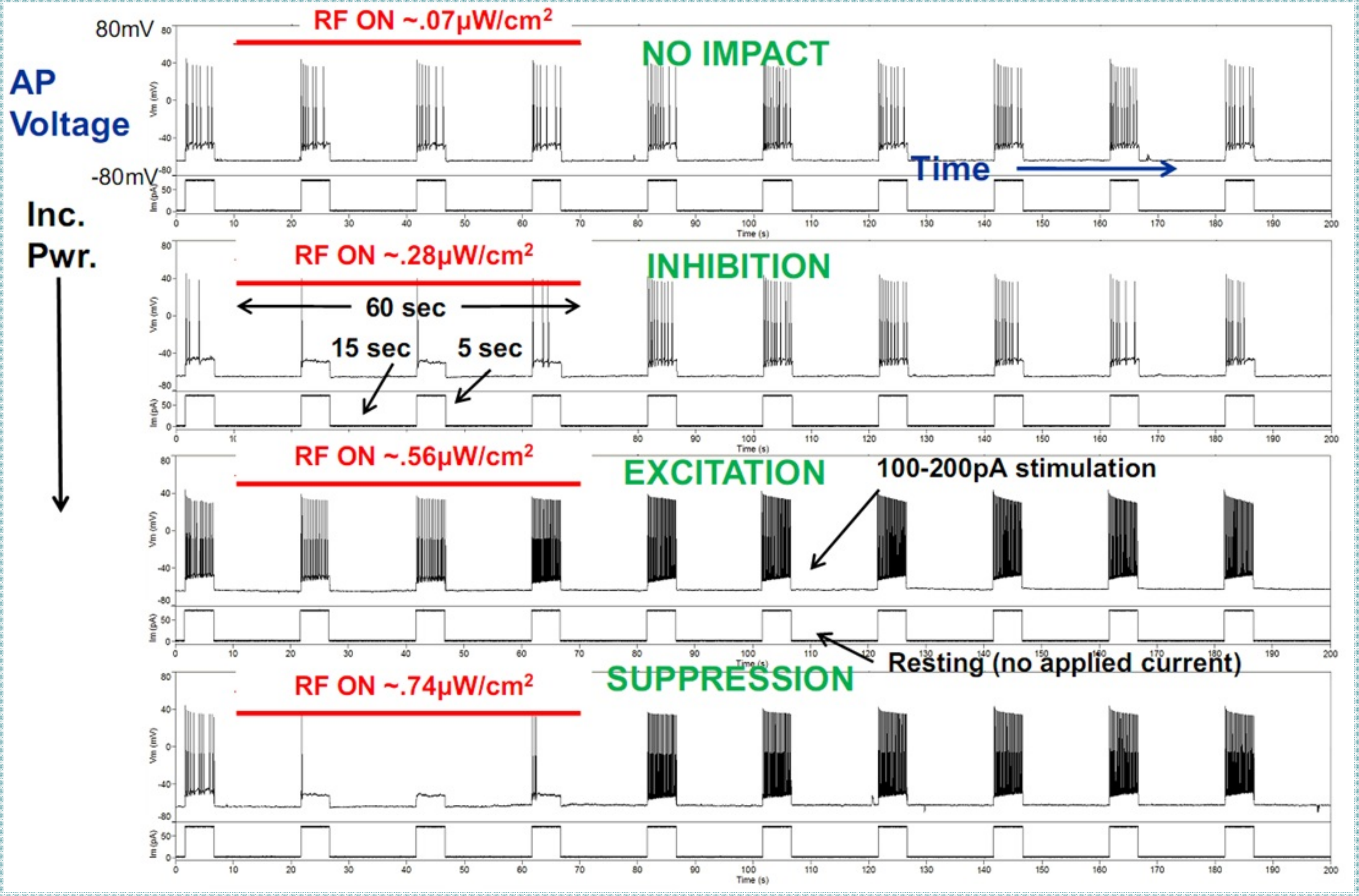


Human lung cancer cell line H1299 spectrum (green GFP & red FRET lines) before during and after exposure to ~15mW/cm^2 RF energy at 0.05 THz for 2 minutes

Siegel, P. H.; Pikov, V., "Impact of low intensity millimeter-waves on cell membrane permeability," Infrared, Millimeter, and Terahertz Waves, (2009), IRMMW-THz (2009), 34th International Conference on 1(1), 21-25 (2009)

Changes in action potential firing rates

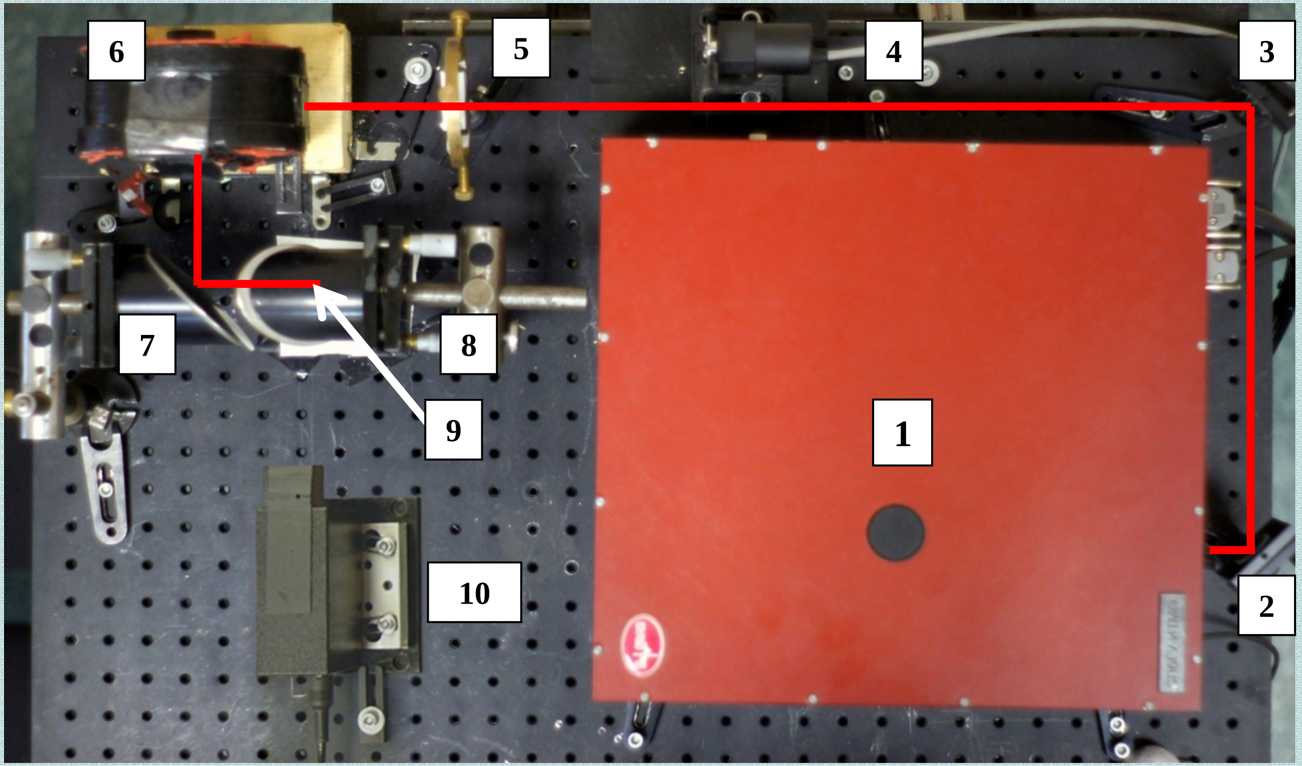
at 0.06 THz CW. Power levels below 1mW/cm². 1 min.



Siegel, P. H. Pikov, V., "Can neurons sense millimeter waves?," SPIE Photonics West, BiOS, 7562-17 (2010)

Experimental results of our laboratories

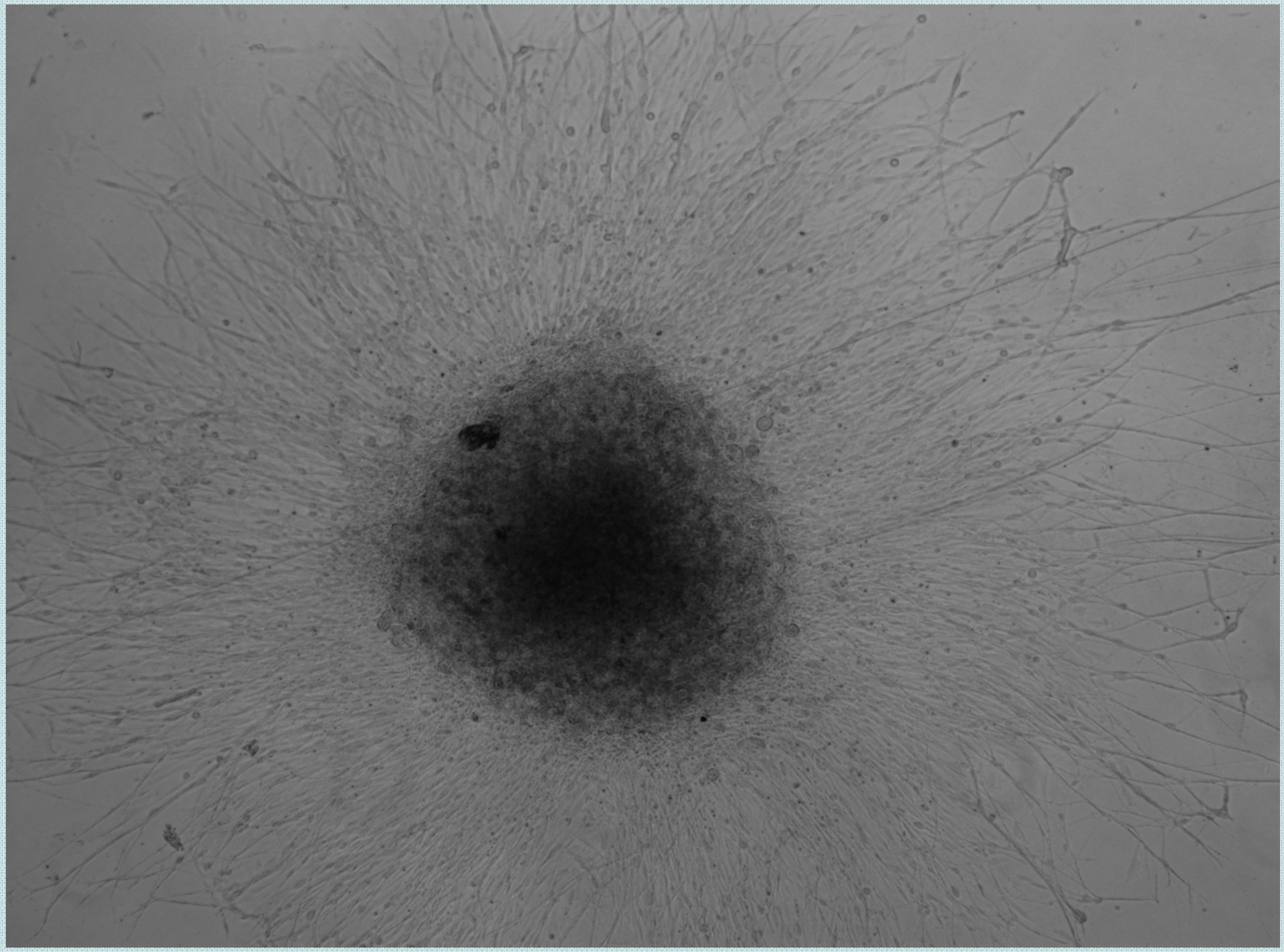
Experimental setup



1 – femtosecond fiber laser (50 MHz, λ = 1560 nm, 125 fs, 120 mW) , 2, 3 – system of mirrors, 4 – mechanical modulator (13 Hz), 5 – lens, 6 – InAs crystal in a strong magnetic field, 7, 8 – off-axis parabolic mirrors, 9 – object,10 - optical-acoustic detector.

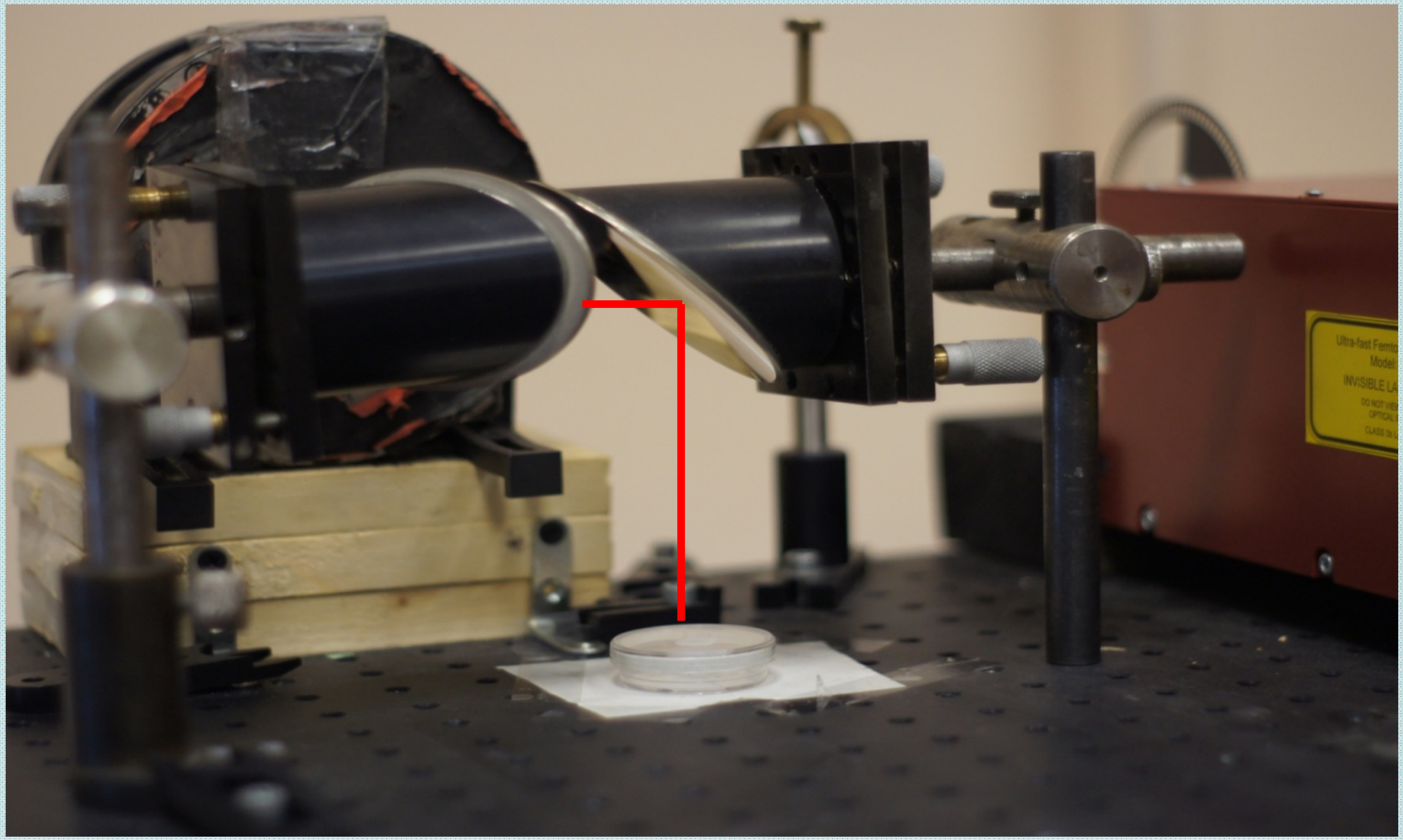
The generated THz radiation had a frequency band from 0.05 to 2 THz. THz radiation power was varied by using different filters and was 11.1 and 1.07 mW, respectively. The pulse duration was 2.5 ps, the irradiation area 0.2 cm^2 and the exposure time 3 min.

Object



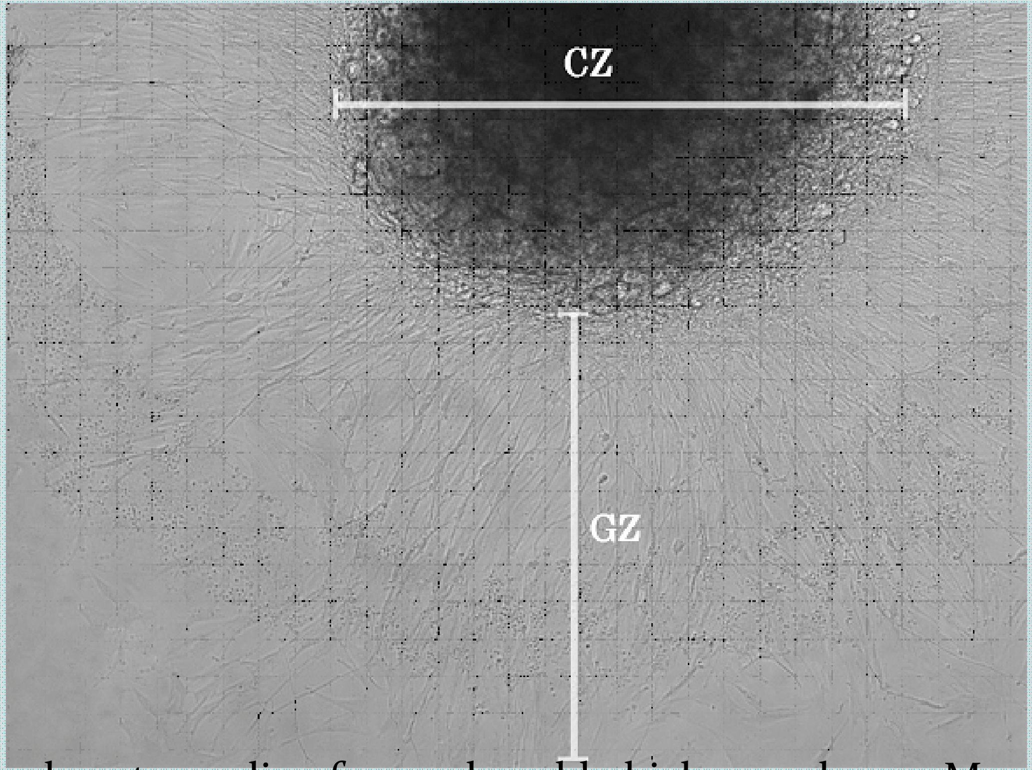
Photomicrograph of the sensory ganglia of 10-day chicken embryos (control). Magnification, x50.

Selection of methodology



The irradiation was performed in a closed sterile plastic Petri dish without the full use of the medium. The radiation loss was measured and was around 16%. An irradiation in such a setup also allows to minimize the impact of the environment, which is important for experiments in tissue culture.

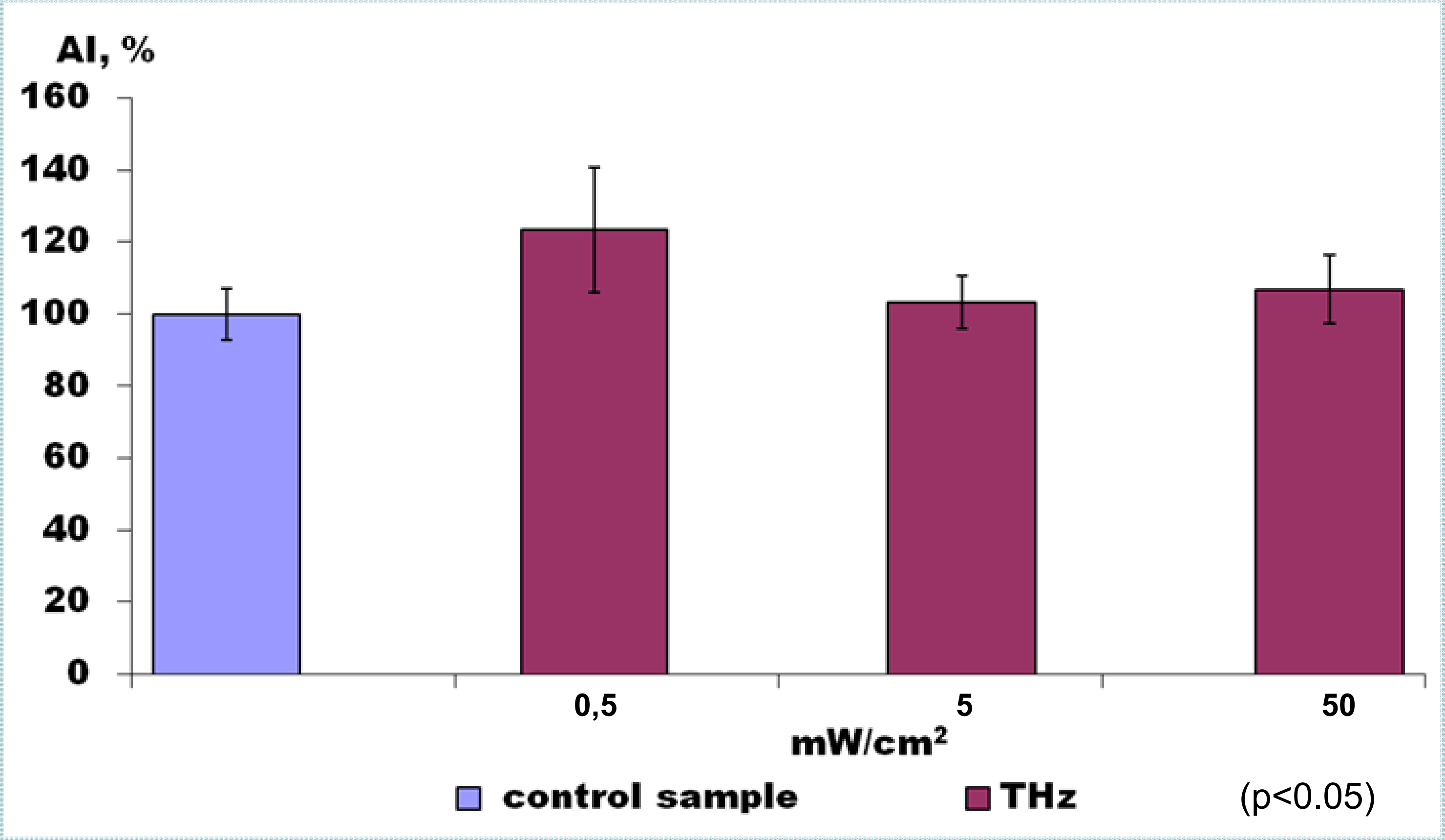
Methodology



Micrograph of the dorsal root ganglia of 10-12 day old chicken embryos. Magnification: x100. CZ is the central zone area (the initial area of the ganglion body) and GZ is the peripheral growth zone.

The explant neurites growth intensity is evaluated by the area index (AI).The area index (AI) was used to estimate the neurite outgrowth, which was calculated as the ratio of the area of the ganglion body with peripheral zone of growth, to the central zone area. For each value of the power density of THz radiation 10 experimental explants were analyzed.

Results



Power density, μW/cm²	0,5	5	50
Area Index(AI) change, %	123,54	103,27	106,95
Evaluation of the effect	Stimulation	Control level	Control level

Conclusions

We can assume a stimulation of the growth of nerve fibers through non-thermal mechanisms, which was achieved using extremely low power density (0.5 μW/cm^2) and a relatively short exposure duration (3 min).

Pulsed broadband radiation (0.05-2 THz) was used in our experiment to cover a larger range of frequencies, which made effects in biological systems more likely to occur under its influence. However, this fact also complicates the search for possible mechanisms of these effects.

Acknowlegments

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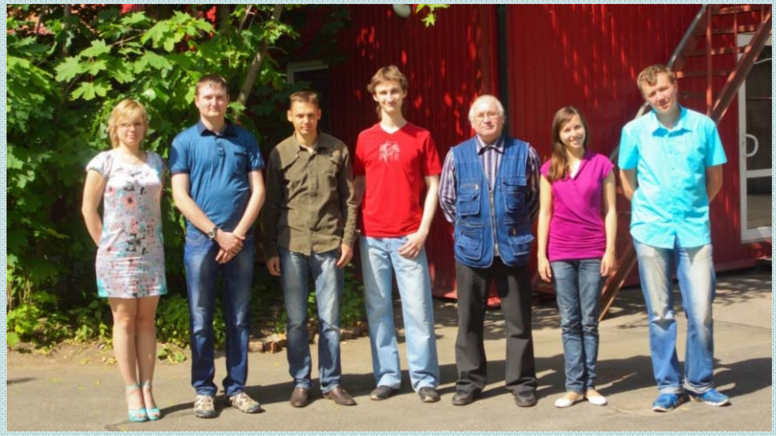

REC “Femtosecond optics and femtotehnology”
(Kozlov S.A., Bespalov V.G.):

- laboratory of pulsed THz optics and spectroscopy;
- laboratory of physics and techniques of continuously THz radiation;
- laboratory of biomedical investigation;
- laboratory of wave process;
- teach laboratory of femtosecond optics and femtotehnology.