Leonid Gavrilov

Pioneer Award

Major discoveries that are emerging into clinical applications right now

19th International Symposium of ISTU | 5th European Symposium of EUFUS – Barcelona 13-15 June 2019
Feasibility of US focusing through the skull

Frequencies 0.5 and 1.0 MHz

Fresh bone, normal incidence

No

Skull bone

Prof. P.P. Lele,
Ultrasonics, 1967

Bulletin of Experimental Biology
and Medicine, 1971, 1973

Skull bone images confirmed that ultrasound can penetrate through human skull

Patent USSR, 1970
HIFU lesioning through intact skull
Acoustics Institute, Central Designing Bureau and Brain Institute of the USSR Academy of Medical Sciences

Animals, 1973

Fig. 1. The use of focused ultrasound in a stereotactic apparatus: 1) generator; 2) rubber bag filled with distilled water; 3) stereotactic apparatus; 4) rabbit.

Fig. 2. Pase of destruction in hypophyseal region of a rabbit’s brain (ezev). Wood, 10 x.

1 MHz, 1500 W/cm²
5 pulses x 1 s

Human cadavers, 1977

High-power mosaic transducer
Acoustics Institute

\[ f = 1 \text{ MHz} \]
\[ D = 160 \text{ mm} \]
\[ F = 106 \text{ mm} \]
\[ S = 250 \text{ cm}^2 \]
\[ W = 0.6 \text{ – } 1.5 \text{ kW} \]

In situ
20 kW/cm² (!)
8 - 20 pulses 0.5-1 s repetition 0.5 Hz

Classic work referred to as the first in this field: Fry F.J., Goss S.A. UMB 1980; 6: 33–38

Acoustics Institute and Institute of Brain of the USSR Academy of Medical Sciences

Threshold ultrasonic dosages for structural changes in mammalian brain. Fry F. *et al.* JASA, 1970

Measurements of cavitation thresholds


Physical mechanism of the lesion of biological tissues by focused ultrasound

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(Submitted October 25, 1973)


\( f = 1.72 \text{ MHz} \)

\( f = 0.94 \text{ MHz} \)
Stimulation of sensation effects by focused ultrasound

1972-1973 and further

Acoustics Institute and Institute of Evolutionary Physiology

Frequency from 0.5 to 3 MHz; single pulses from 0.5 to 100 ms; intensity from units to hundreds of W/cm²

It was shown that pulsed focused ultrasound can induce different somatic sensations (tactile, warmth, cold, pain) in humans

Proposed mechanism – acoustic radiation pressure
Stimulation of hearing effects by focused ultrasound

1972-1973 and further

Acoustics Institute and Institute of Evolutionary Physiology

It was shown that US modulated by sound signals (tone, speech, music) induce hearing sensations determined by the character of modulation. Thresholds of HIFU-induced sensations can be measured and used to diagnose neurological, skin and hearing diseases

Proposed mechanism – acoustic radiation pressure
Designing ultrasound generators and transducers


- 7-element system, $f = 1$ MHz with varying focal length
- Portable generator 0.5-3 MHz 300W
- Rotary transducer ablations of annular geometry $f = 1 - 2$ MHz
- Various depths in tissue
- Set of transducers
- $f = 0.5 - 3$ MHz
  D = 6-8 cm, F = 5-7 cm
High-power multi-element 2D random phased arrays

Not only randomization is important, but the directivity of elements, $D \leq 5\lambda$

Imperial College (2009), 1 MHz, 256 elements
diameter 7 mm (4.7 $\lambda$)

Université Paris, 0.9 MHz, 200 elements
diameter 8 mm (4.8 $\lambda$)

Sonalleve V1 MR-HIFU system (Philips/Profound)
1.2 MHz, 256 elements, diameter 6.6 mm (5.3 $\lambda$)

Gavrilov L. R., Hand J. W. IEEE Trans. UFFC, 2000, 47, № 1, 125-139 - strong effect of randomization
Goss S.A. et al. IEEE Trans. UFFC, 1996 2.1 MHz, 108 elements diameter 8 mm (11.2 $\lambda$) – weak effect
Congratulations to Leonid!