OOO “Center of ultrasonic technologies”

Ultrasound. Formation and application.

www.u-sonic.ru

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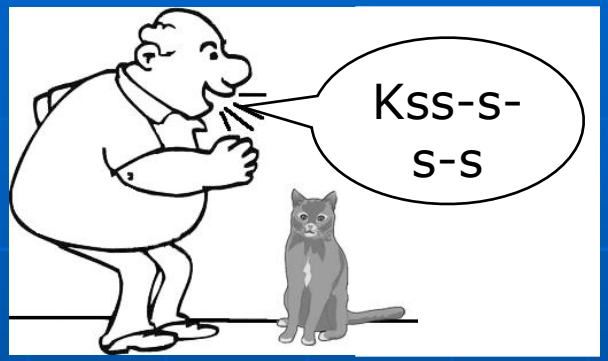
What is the ultrasonic?

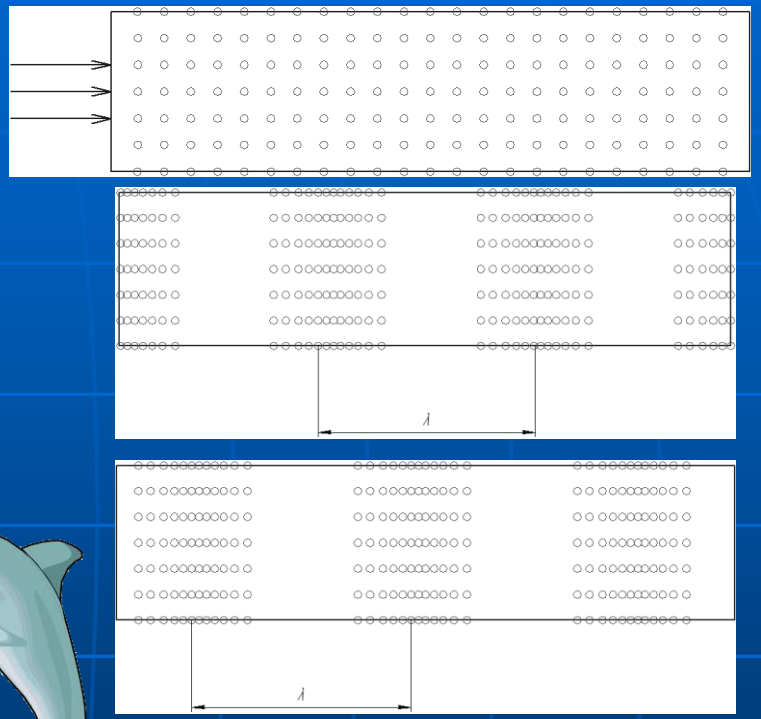
A human and ultrasonic



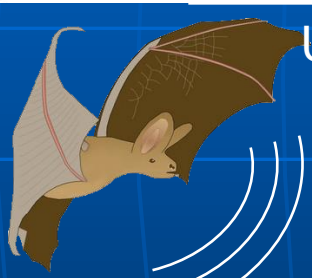
$$\lambda = \frac{c}{f}$$

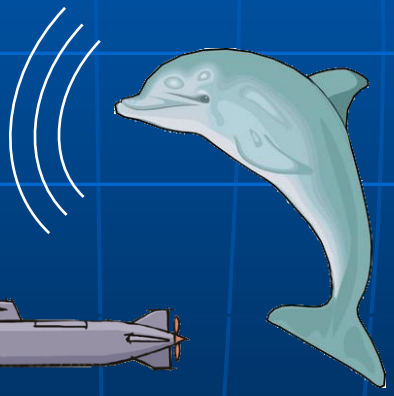
$$T = \frac{1}{f}$$

Physical meaning



Ultrasonic in the nature





Elastic vibrations in material mediums

Ultrasonic frequency band

16…20 kHz
Boundary of human audibility

25…100 MHz
Intermolecular distance in crystals

Ultrasonic and sound. Differences

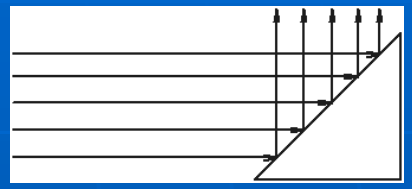
f_{sound}~1,5-16 kHz f_{us}~25-150 kHz

Water c=1500 m/s

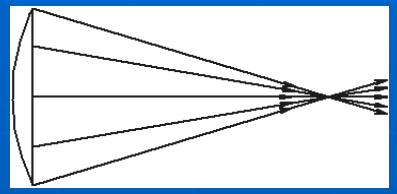
$$\lambda_{sound} = \frac{c}{f} = \frac{1500}{1500} = 1m$$

$$\lambda_{US} = \frac{1500}{1{,}5 \cdot 10^3} = 1cm$$

Advantages of ultrasonic



Possibility: to direct



to focus

Solids – fluids – gases

- Metals
- Polymers
- Conductors
- Dielectrics
- Transparent
- Opaque

$P \sim f^2$

0,000001 W/cm²

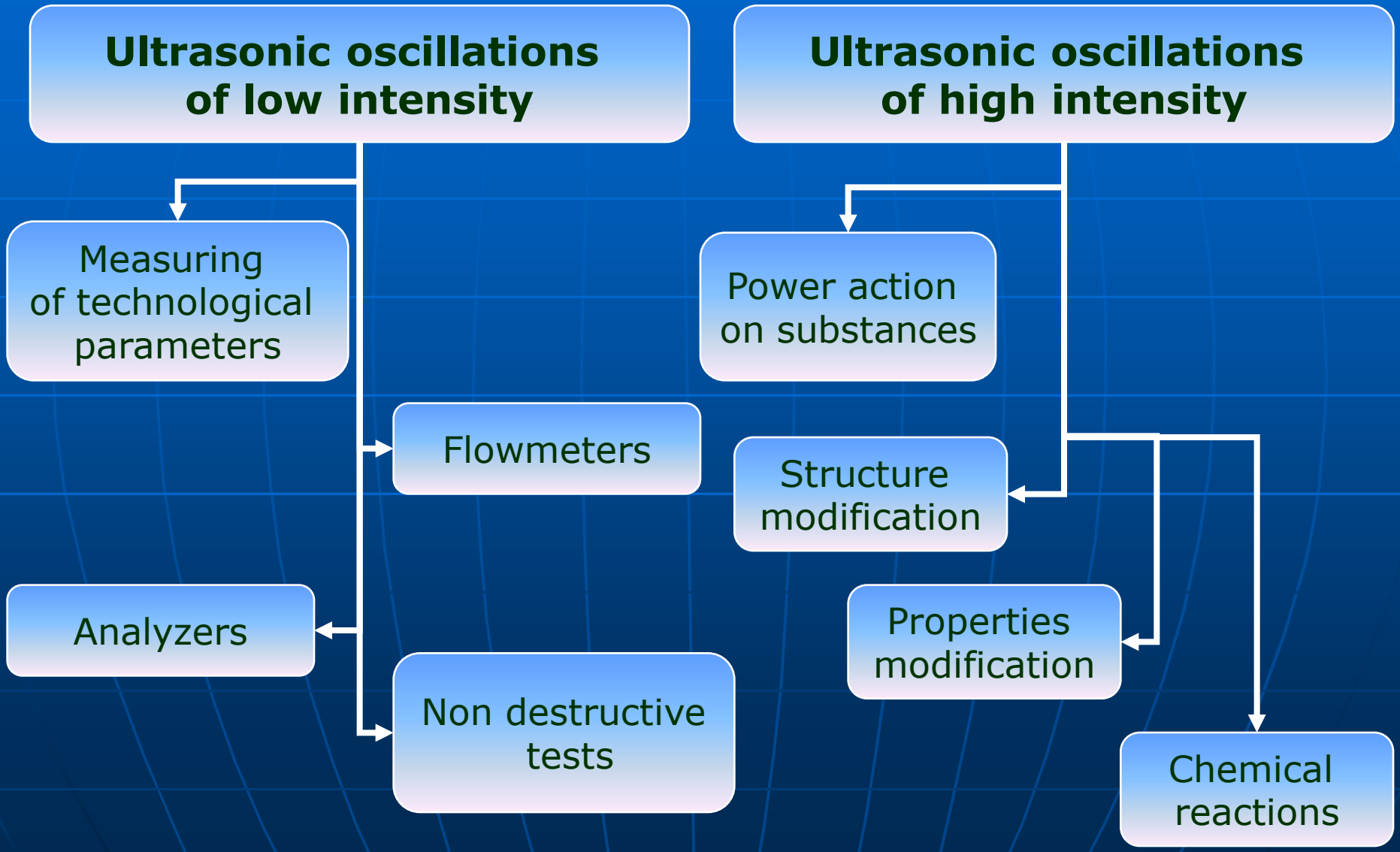
0,01 W/cm²

100 W/cm²

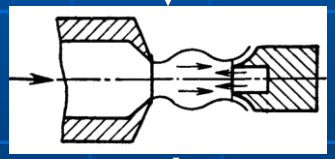
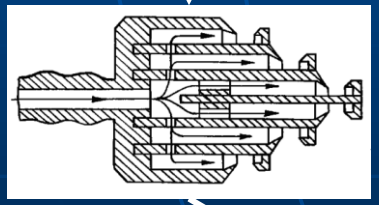
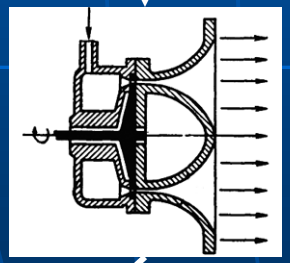
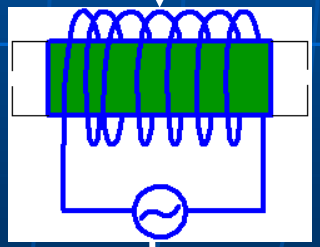
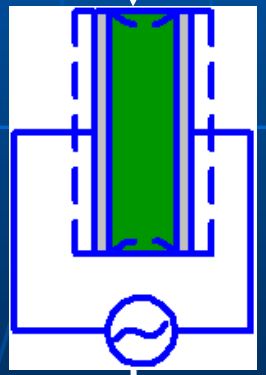
P=0,5-5 MPa

f=20000 Hz

Industrial application



Sources of high intensity ultrasonic oscillations

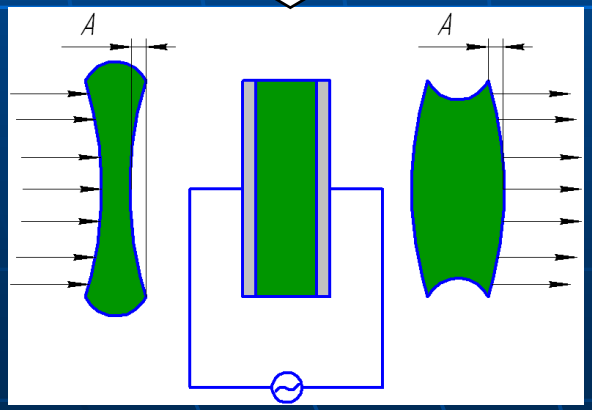
- Aerodynamic
  - Static sirens. Gas-jet radiators
    - 
    - 
  - Dynamic sirens
    - 
  - → f≤20 kHz Low efficiency<25%
- Hydrodynamic
  - Shibber
    - 
  - → f≤10 kHz Low efficiency<10%
- Electromechanical
  - Magnetostric-tive
    - 
    - → f≤100 kHz Water cooling efc.<40%
  - Piezoelectric
    - 
    - → f≤25 MHz T_{Curie}~300K efc.≥50% Without inertia

Piezoelectric transducers

Piezoelectric effect

Polarization of a dielectric at squeezing

Inverse piezoelectric effect



Piezoelectric materials

Natural quartz

1000V- 1μm/cm

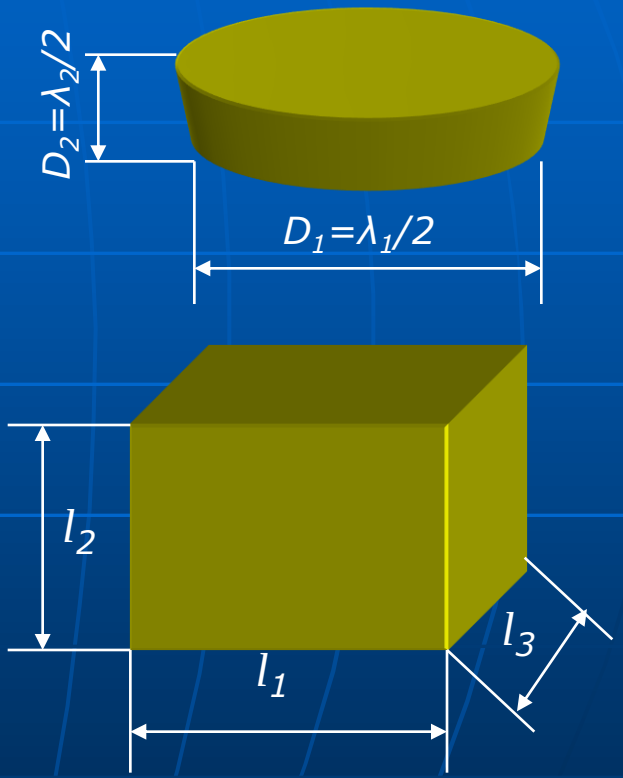
Synthetic piezoelectric materials

1000V-50 μm/cm

Zirconate – titanate of plumbum

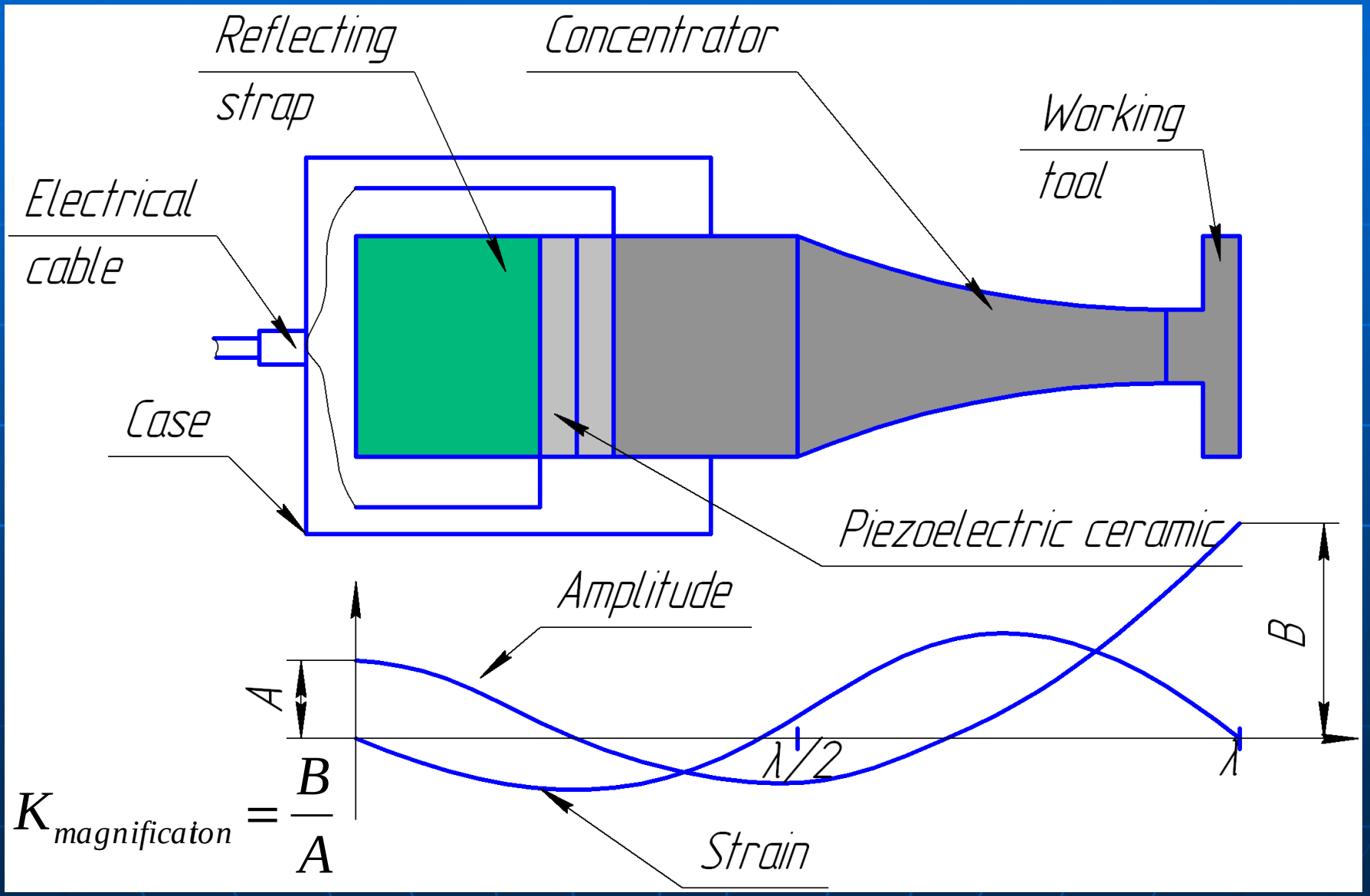
PZT-5, PZT-8 (ZTP-23), APC-841

Piezoelectric elements



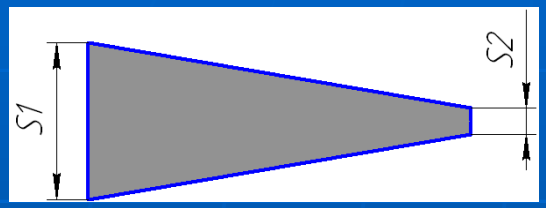
$$f_1=\frac{2c}{l_1},\ f_2=\frac{2c}{l_2},\ f_3=\frac{2c}{l_3}$$

Ultrasonic oscillation system



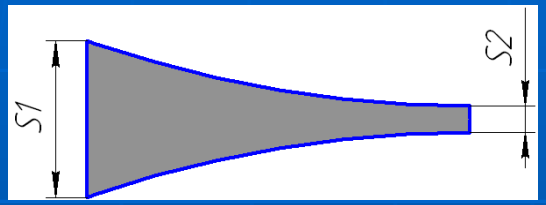
Magnifiers of ultrasonic oscillations

Conical



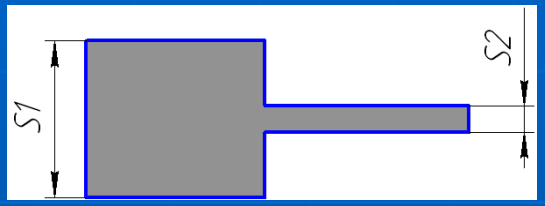
$$K = 0.8\sqrt{\frac{S_1}{S_2}} \quad Q=40$$

Exponential



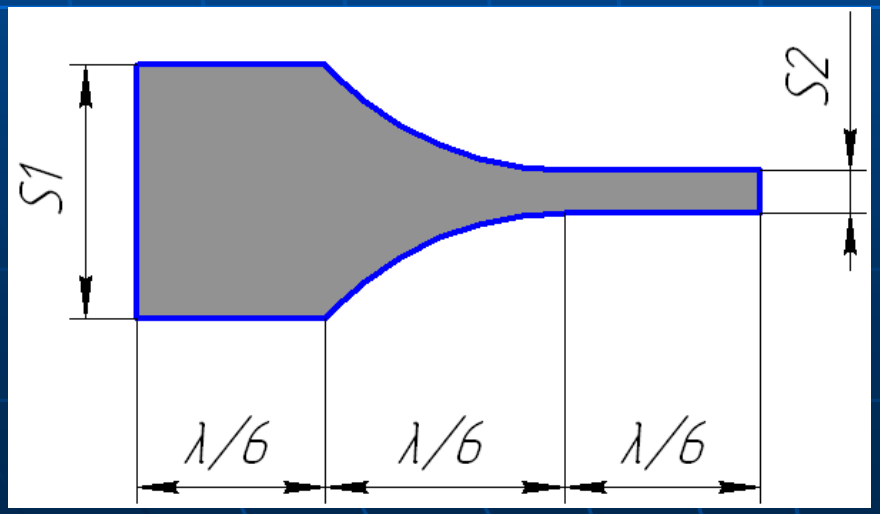
$$K = 1{,}1\sqrt{\frac{S_1}{S_2}} \quad Q=20$$

Stepping



$$K = \frac{S_1}{S_2} \quad Q=150$$

Stepping-exponential concentrator



$$K = (0.8-0.9)\frac{S_1}{S_2} \quad K=10\ldots15$$

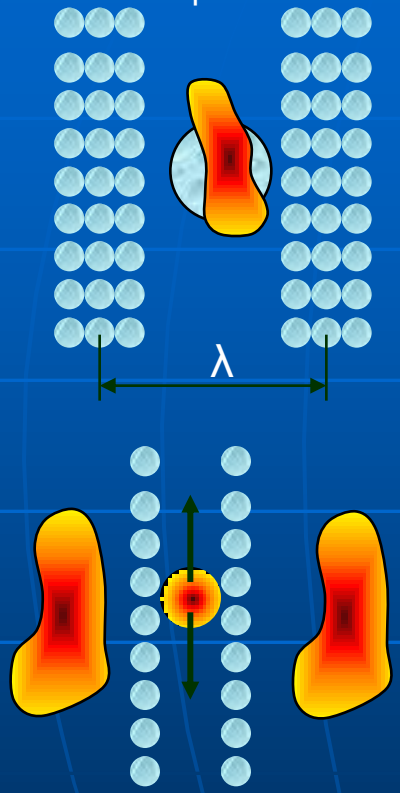
$\rho c_{piezoelectric\ ceramic} =$

$= \rho c_{medium(water)}$

Cavitation

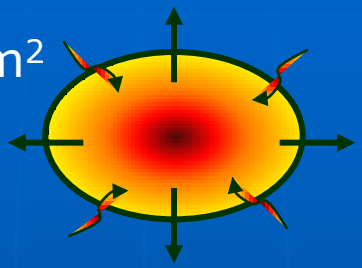
Initiation

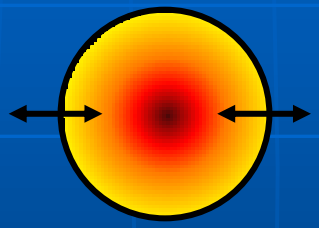
$P<P_{критическое}$



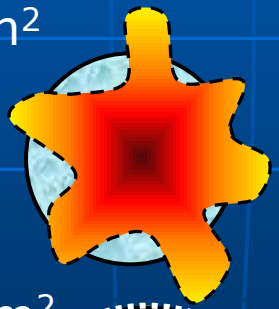
Stages of progress

$I \sim 1\ W/cm^2$





$I > 1{,}5\ W/cm^2$



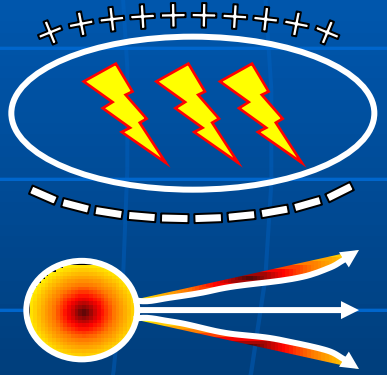
$I > 2{,}5\ W/cm^2$

Active forces

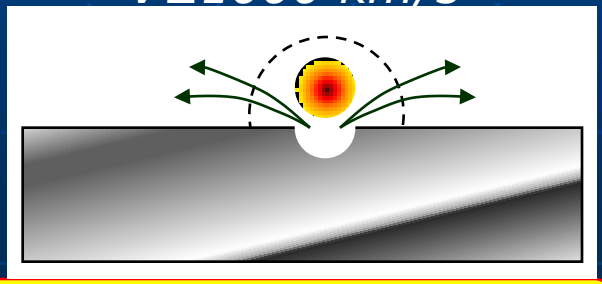
P≥500 MPa

T≥10 000 K

U>1 000 000 V



V≥1000 km/s

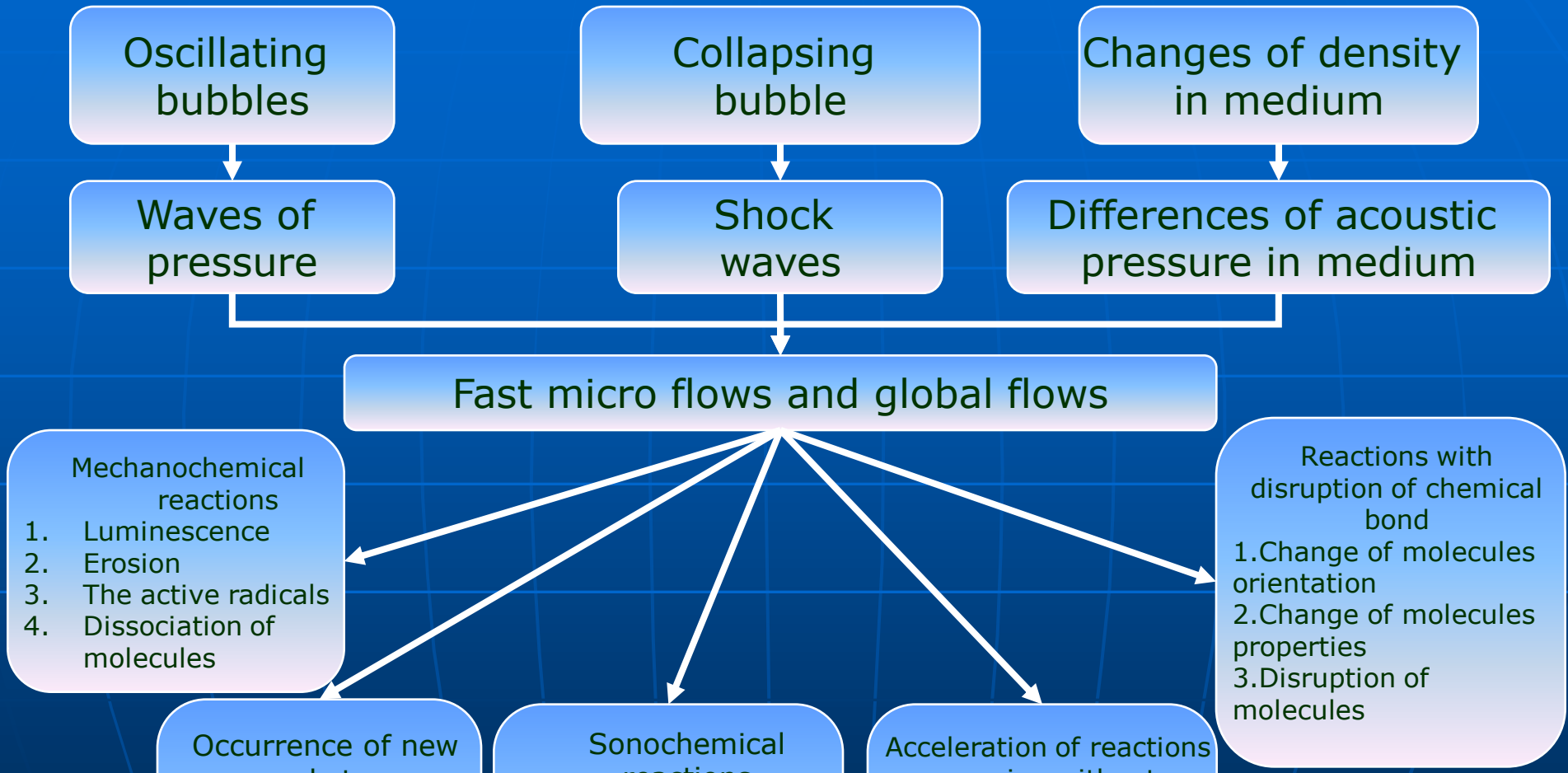


$P_{critical}$=150 MPa

Domains of a cavitation (microscopic gas bubbles)

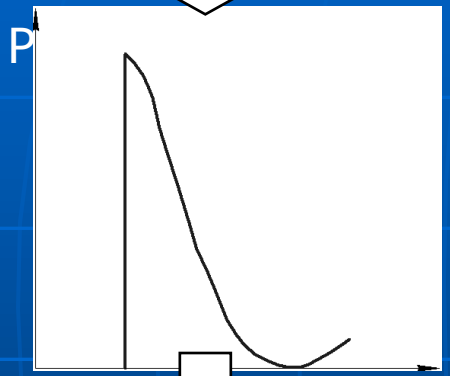
Conditions for thermonuclear reactions realization are provided

Cavitation effects



Cavitation in action

Fracture (solids, surfaces)



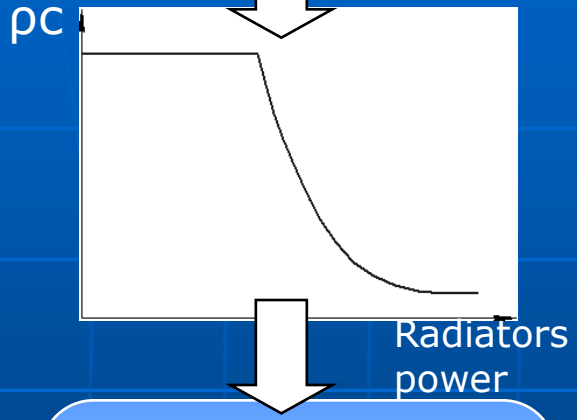
Growth of frequency reduces fracture, but intensifies the flows

Local heating

Desaturation of gas with atomic and ionized component

Growth of static pressure provides growth of the cavity bubbles number

Reducing the acoustic impedance of medium



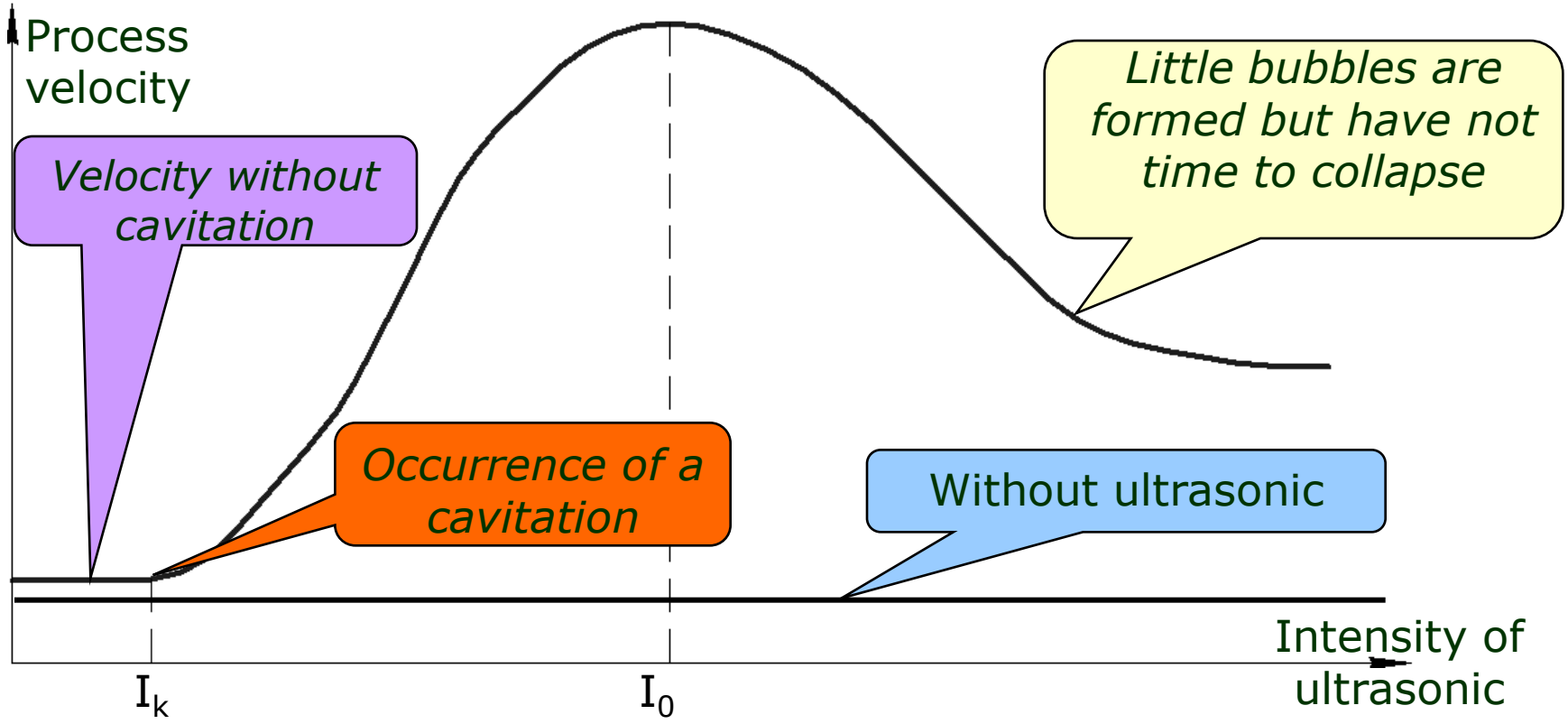
Growth of radiator power restricts the intensity of radiant in medium

Frequency of ultrasonic oscillations

Providing the conditions for increasing the quantity of the cavity bubbles

Optimization of ultrasonic action by means of radiant intensity

Dependence of processes velocity from cavitation parameters



I_k=1 W/cm² – Water

I_k=4 W/cm² - Oil

$I_k \sim f(\omega)$

$I_0 = f(P, \rho c, \eta)$

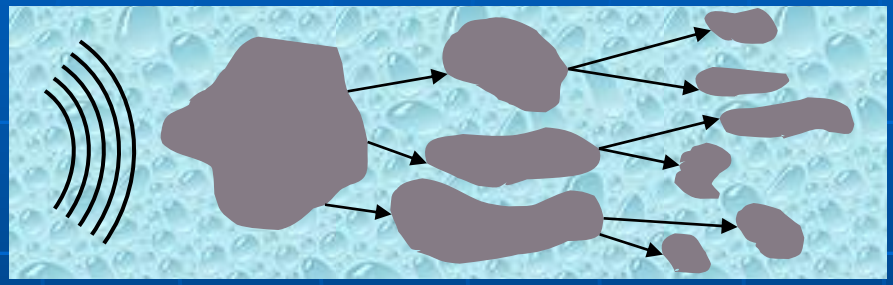
Process velocity = *Generation rate of radicals*

The mechanism of processes acceleration in fluids

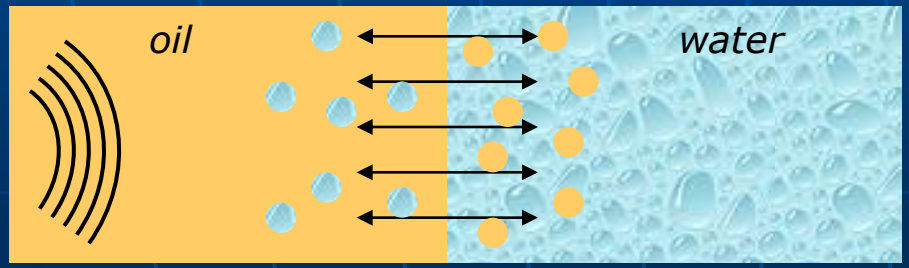
Action on interaction surface

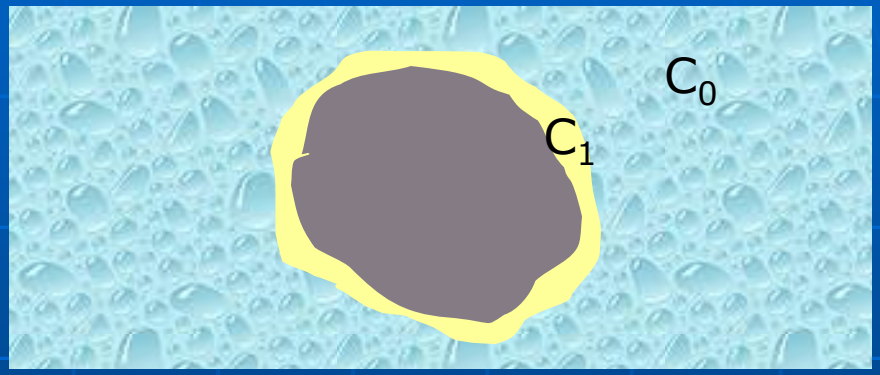
Action on interface layer

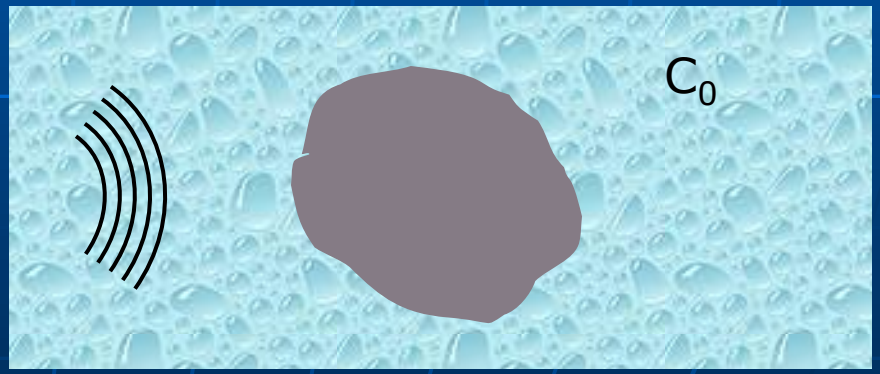
1. Dispersion



2. Emulsification







Dilatation of interface surface of interaction

The cavity flows effect on interface layer (decrease it)

Intensification of processes in fluid mediums

Processes of mass transfer

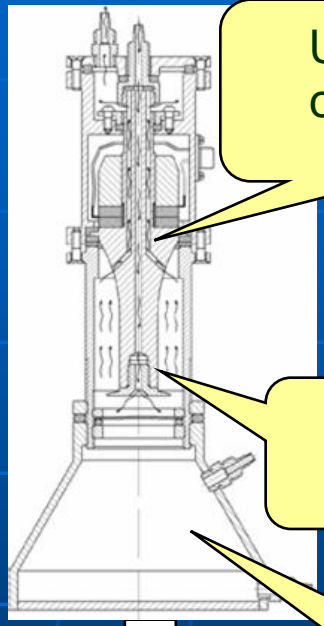
1. Extraction of vegetative raw material f=20 … 300 kHz
   - 100 … 10000 times
   - Increasing of yield
   - Sterilization
2. Partitioning multicomponent systems
3. Demulsification
4. Coagulation of hydrosols
5. Degassing
6. Crystallization
7. Prevention of crystallization

Chemical reactions

Disruption of substances chemical bond in the cavity bubble and on its surface

1. Redox reactions
2. Depolymerization
3. Polymerization

Requirements to the apparatus



Ultrasonic oscillation system

Flowing volume

Volume

120 W

200 W

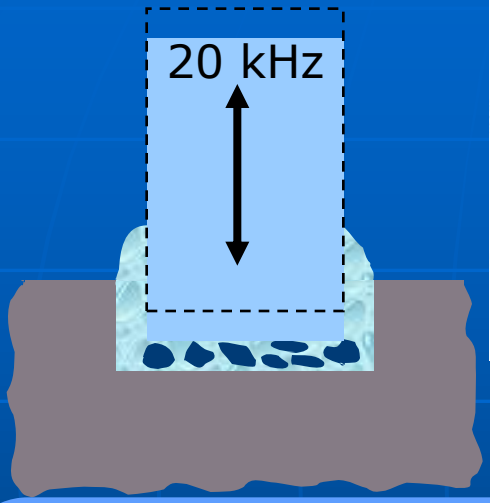
400 W

1000 W

3000 W

Intensification of processes in solids

Processing of hard and brittle materials



«Saphire-2»

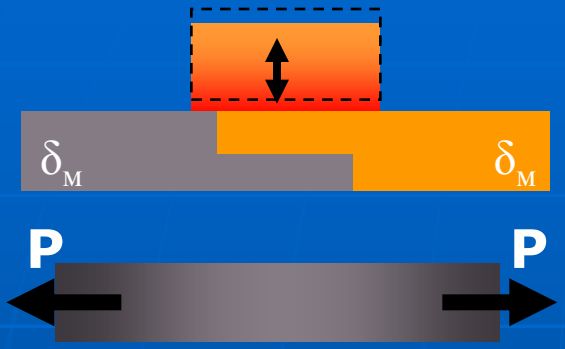
Results

- Power consumption < 10J/sm^3
- Velocity > 10 mm/s
- Absence of flaws
- Diameter from 1 up to 120 mm

1. Shock action of abrasive particles
2. Circulation and changing of abrasive

«Saphire»

Intensification of welding

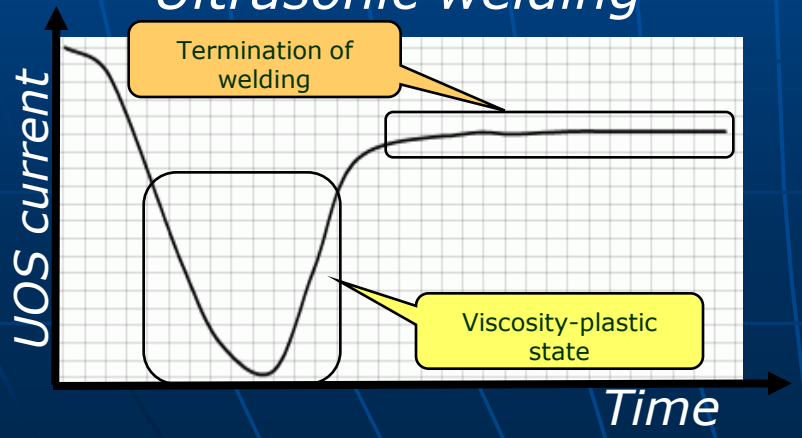


$\delta_{seam} > 70\% \delta_{material}$

Acceleration of diffusion in 1000000 times

$T_{welding} < T_{melting}$

Ultrasonic welding



Medicine

Making of medicinal aerosols

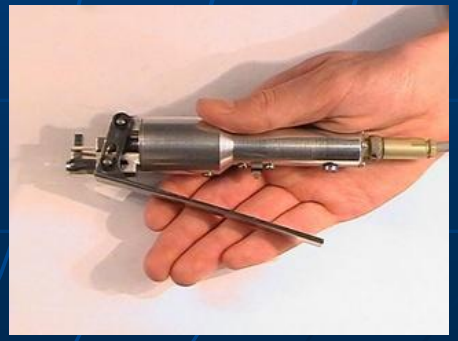
Liposuction

Hermetic sealing of containers with blood components

Aerosols, the size of particles ~50 microns at frequency of 20 kHz

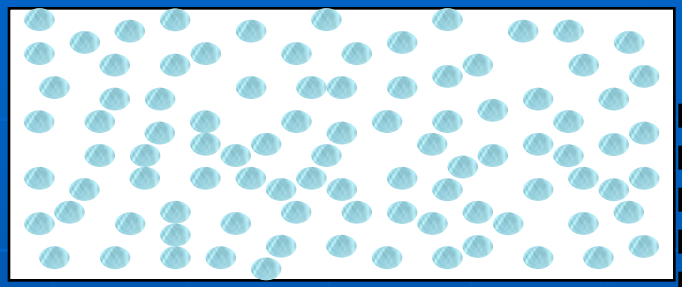
$T<T_{melting}$
Absence of gases
Welding on crude surface

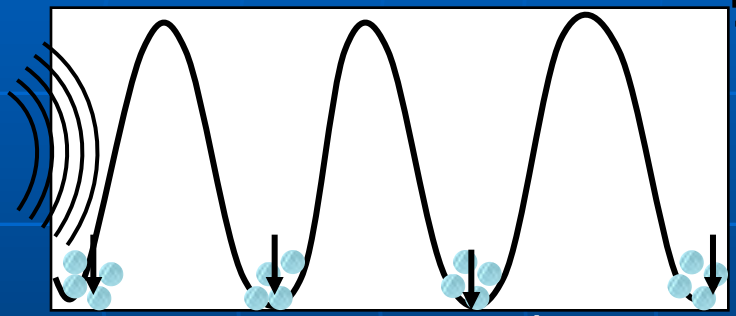
- Speed
- Quality
- Safety



Intensification in gases

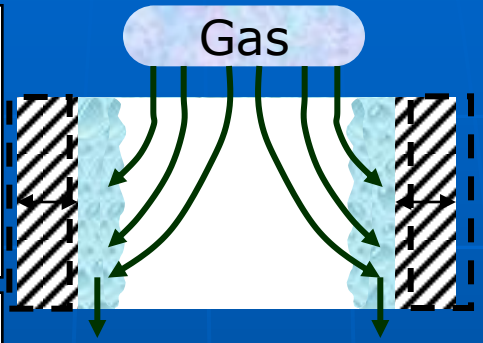
Ultrasonic coagulation





I=140…150 dB

Absorption



I=150…160 dB

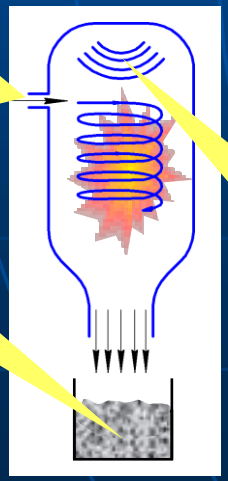
Ultrasonic drying

- Drying without heating of material
- The lower limit of process acceleration (135-140 dB)
- No frequency dependence
- Thin layer (2-3 cm)

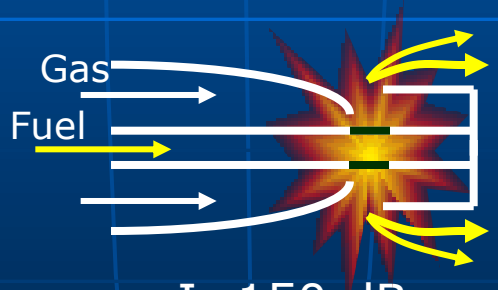
Combustion

Gas 50-60 m³

Soot 90%

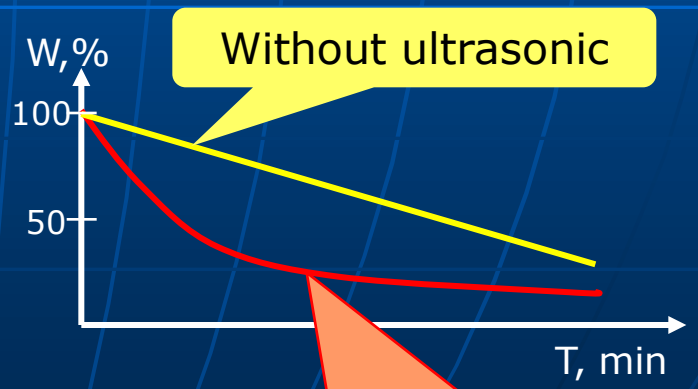


I=10W/sm² (160 dB) *f*=35kHz



I~150 dB

CO< 1%



Without ultrasonic

20 kHz, 156 dB, 20°C

Ultrasound for household

Extraction and intermixing

- Increasing the speed of extraction in 100-10000 times.
- Making of trice emulsion such as "water - oil".
- Increasing the speed of dissolution in hundreds times.

Cutting of products

Producing the minimal portions of provision (dough, cheeses, cakes, sausages) without off-cuts.

Processing of milk

- Sterilization of milk.
- Decrease seaposemination
- Increasing the nutritional value of milk.
- Reducing the size of fatty blobs.

Cooking

1. Producing ketchups, sauces, chocolate.
2. Processing of meat
3. Processing of leaven
4. Salting, smoking.