Generation of microwave self-channeling undamped temperature waves and their use for stimulation of nuclear fusion in remote and behind-screen targets

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The problem of energy transfer without loss over long distances and the problem of efficient use of this energy for various applications (including for controlled nuclear fusion) are among the **most important problems of modern physics**.
Usually, special electromagnetic waves (in particular, ultrashort laser pulses) or intense beams of fast particles are used for this purpose, the generation of which requires very great effort and expense. The motion of charged particles in unstructured media is limited by scattering and deceleration

One of the possible mechanism of long distant energy transfer may be connected with generation and propagation of thermal waves.
On one hand the solutions of the "standard" equations of thermodynamics lead only to thermal waves with very fast damping .
On the other hand it is easy to verify that the “standard” classical equations of thermodynamics were obtained with rather incorrect assumptions..

In the report are discussed:

the **problem of nondissipative distant energy transfer of undamped thermal waves (similar to quasichanneling)**;

the **method of generation of these waves during water jet cavitation;**

distant action of these waves (including X-Ray generation);

effective stimulation of low energy nuclear reactions in distant targets

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The basic concepts of classical thermodynamics

The traditional concept of the laws of thermodynamics is based on assumption that the propagation of thermal excitations is of a purely diffusive (incoherent and irreversible) process. ***The standard description of the heat transfer process is based on two hypotheses (principles).***

*The first of them makes it possible **to pass from the equation of energy conservation in the integral form to that in the differential (local) form**, while the second one assumes (without adequate grounds) that the **non-equilibrium** system under study can be presented as **many small locally-balanced subsystems.***

Mathematical description of these processes is based on the joint usage of two basic equations: **the Fourier law for a nonstationary heat flow *q(r, t)***

$$\vec{q}(\vec{r},t) = -\lambda \cdot grad(T(\vec{r},t))$$

and the equation of continuity

$$\rho c_v \frac{\partial T(\vec{r},t)}{\partial t} = div\vec{q}(\vec{r},t)$$

λ, ρ and c_v - coefficients of heat transfer, density and specific heat.

From these two equations, the classical parabolic differential equation for a spatial-temporal variation in the temperature field follows

$$\rho c_v \frac{\partial T(\vec{r},t)}{\partial t} = div\{\lambda grad[T(\vec{r},t)]\}$$

This equation has "standard" solution – two colliding plane waves

$$T(\omega,x,t) = A_\omega \mathrm{e}^{-\kappa x} e^{i(\omega t-\kappa x)} + B_\omega \mathrm{e}^{\kappa x} \mathrm{e}^{i(\omega t+\kappa x)},$$

with very great damping coefficient

$$\delta \equiv \kappa = \sqrt{\omega / 2G}, G = \lambda / \rho c_v$$

G, λ, ρ and c_v - coefficients of thermal diffusivity, heat transfer, density and specific heat.

It can be seen that the "standard" heat wave attenuates over an interval equal to the wavelength! In air at $\omega = 80\, MHz$ $we\, have$ $\delta \approx 10^4\ cm^{-1}$ and

$very\ \ small\ \ attunuation\ length\ \delta^{-1} \approx 1\ mkm!$

These basic equations are based on the approximate assumption that the energy flow q(r,t) and temperature T(r,t) change synchronously. This assumption is valid only for a slow change in temperature

The simplest (but rather effective) way of this relaxation accounting is to modify the continuity equation with the time shift and taking into account **which part of this equation is the result of thermal action**:

a **change in a temperature over time in the considered microvolume when additional energy enters this microvolume**

$$div\vec{q}(\vec{r},t) \Rightarrow -\rho c_v \frac{\partial T(\vec{r},t+\tau)}{\partial t}$$

or a **change in the flow of thermal energy in space as the result of change in a temperature**

$$\rho c_v \frac{\partial T(\vec{r},t)}{\partial t} \Rightarrow -div\vec{q}(\vec{r},t+\tau)$$

In the process of propagation of a heat wave, these processes are always connected and for this reason it is necessary to take into account both variants of this equation. As a result, a joint analysis of these equations (together with **Fourier law for a nonstationary heat flow *q(r, t)*)** leads to a modified equation of thermal conductivity

$$\frac{\partial T(\vec{r},t\pm\tau)}{\partial t} = G\nabla^2 T(\vec{r},t)$$

which takes into account the time delay (for thermal relaxation) between the local thermal energy flux and the change in the local temperature.

The solution of this equation in 1D case is superposition of colliding thermal waves

$$T(\omega,x,t)=A_\omega\,\mathrm{e}^{-\delta x}\,\mathrm{e}^{i(\omega t-k'x)}+B_\omega\,\mathrm{e}^{\delta x}\,\mathrm{e}^{i(\omega t+kx)}\equiv$$

$$A_\omega\exp\left(-\kappa\left|\cos\frac{\omega\tau}{2}\pm\sin\frac{\omega\tau}{2}\right|x\right)\exp\left\{i\left(\omega t-\kappa\left|\cos\frac{\omega\tau}{2}\mp\sin\frac{\omega\tau}{2}\right|x\right)\right\}+$$

$$B_\omega\exp\left(\kappa\left|\cos\frac{\omega\tau}{2}\pm\sin\frac{\omega\tau}{2}\right|x\right)\exp\left\{i\left(\omega t+\kappa\left|\cos\frac{\omega\tau}{2}\mp\sin\frac{\omega\tau}{2}\right|x\right)\right\},$$

(8a)

fundamentally different from the solution of "standard" heat equation without this delay.

From these equations follow expressions for the actual wave number and damping coefficient of the temperature wave

$$k=\kappa\,|\cos(\omega\tau/2)\pm\sin(\omega\tau/2)|,$$

$$\delta=\kappa\,|\cos(\omega\tau/2)\mp\sin(\omega\tau/2)|,\kappa=\sqrt{\omega/2G}$$

Waves with frequencies $\omega_{opt(n)} = (n+1/2)\pi/\tau, \;\; n = 0,1,2,...$

correspond to the existence of undamped temperature (thermal) waves with a damping coefficient $\delta \equiv 0$!

In this case, the general solution of thermal equation has the form of the **superposition of the forward and backward undamped temperature waves**:

$$T(\omega_{opt}, x, t) = A_{\omega_{opt}} \exp\left\{ i\left(\omega_{opt} t - \kappa\sqrt{2}x\right)\right\} + B_{\omega_{opt}} \exp\left\{ i\left(\omega_{opt} t + \kappa\sqrt{2}x\right)\right\}$$

In air $\omega_{opt(n)} \approx 70...90(2n+1)\,MHz, \;\; n = 0,1,2,...$

In water $\omega_{opt(n)} \approx 100(2n+1)GHz$

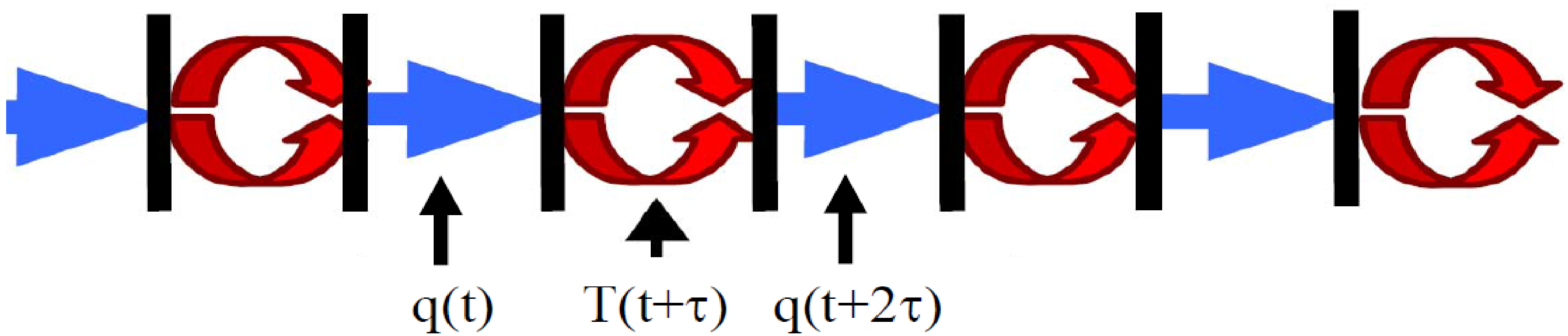
In metals $\omega_{opt(n)} \approx 10...50(2n+1)THz$

The velocity of this waves in air at normal conditions is

$$v_p = \sqrt{2G\omega} = 50...60m/\sec$$

For comparison, it can be noted. what for acoustic waves (hypersound) with the frequency about 80 MHz propagation in air at room temperature corresponds to a very large damping coefficient $\delta \approx 10000$ cm^{-1}. Path lenght of such wave in the air is **less than 1 micron**, which is in 10000 times less than the experimental results.

The motion of a non-absorbed (**undamped)** temperature wave corresponds to the **alternating reversible transformation of the energy flow** $\vec{q}(\vec{r},t)$ **into heat** with temperature $T(\vec{r},t+\tau)$



This process is in a certain sense similar to the channeling of particles in crystals: the mode of particle channeling is associated with **alternating mutual conversion of the transverse both potential V and kinetic energy T of longitudinally moving particles.**

The process of the excitation of undamped thermal waves can be associated with different excitation mechanisms and possible sources. **An ideal case** is the utilization of local periodic heating with optimal frequency that corresponds to one of such waves.

As the sub-sequent experiments show, the frequency of this modulation in air under normal conditions is close to 80 MHz or a multiple of it, which is in accordance with condition

$$\omega_{opt(n)} = (n + 1/2)\pi / \tau$$

Such waves allow recording thermal and "microthermal" processes at a very large distance from the generation site.

An easier method for generating undamped thermal waves is to expose the interface between the condensed media and air to short acoustic pulses, the duration of which Δt should be less than the time τ of relaxation of thermal excitation in air.

In this case, the spectrum of local thermal waves, which are formed in the vicinity of the region of local heating (generated under exposure to these pulses), will include unabsorbable thermal waves with frequencies corresponding to optimal condition.

The reflection coefficient of such temperature waves from the sharp boundary of two media is determined by the formula

$$|R_\omega| = 1 - \frac{\lambda_1}{\lambda_2}\sqrt{\frac{2G_2}{G_1}} = 1 - \sqrt{\frac{2\lambda_1\rho_1 c_{V1}}{\lambda_2\rho_2 c_{V2}}}$$

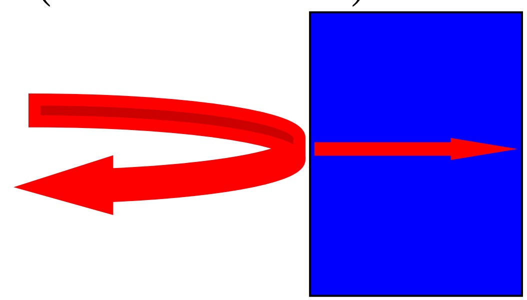
For air with *heat transfer coefficient* $\lambda_1 = 26 \bullet 10^{-5} \text{Watt} / cm\ {}^0K$

and with *thermal diffusivity* $G_1 = 0.22\ \text{cm}^2/\text{sec}\ \ (at\ T = 300K)$

and for steel with $\lambda_2 = 0.8 \bullet 10^{-5} \text{Watt} / cm\ {}^0K$

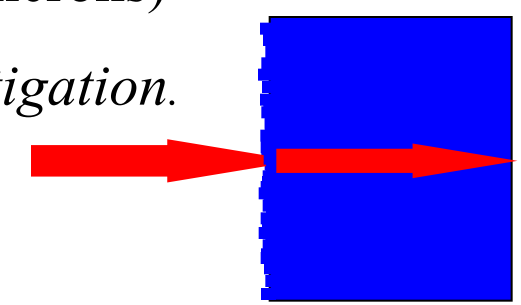
and $G_2 = 0.117\ \text{cm}^2/\text{sec}$

we have $R = 0.9999$

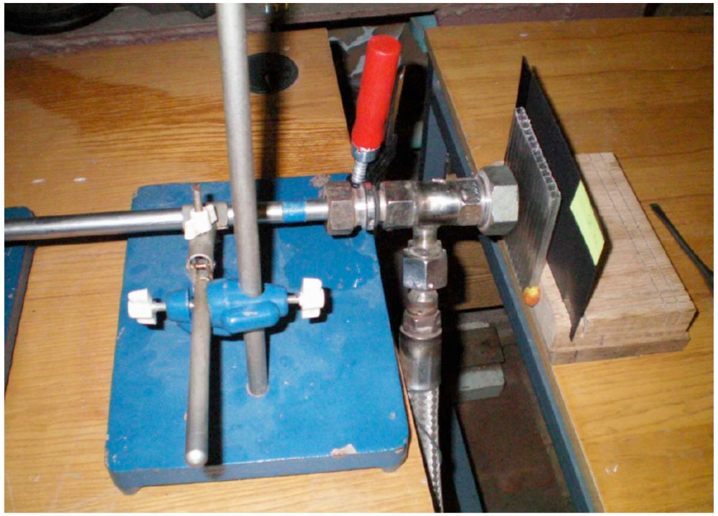


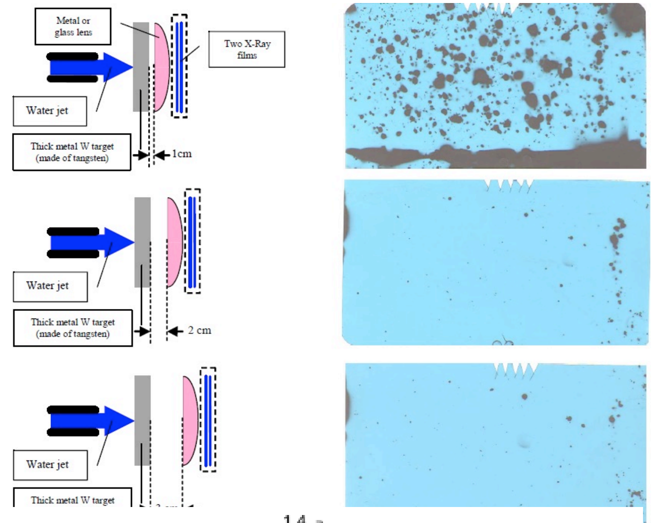
For an **unpolished surface**, the reflection coefficient decreases due to the presence of a transition layer, the thickness of which should be comparable with the length of this heat wave in air (1-2 microns)

[Vysotskii V.I. et al. Journal of Surface Investigation. X-ray, Synchrotron and Neutron Techniques, 2014, Vol. 8, No. 2, pp. 367–373]

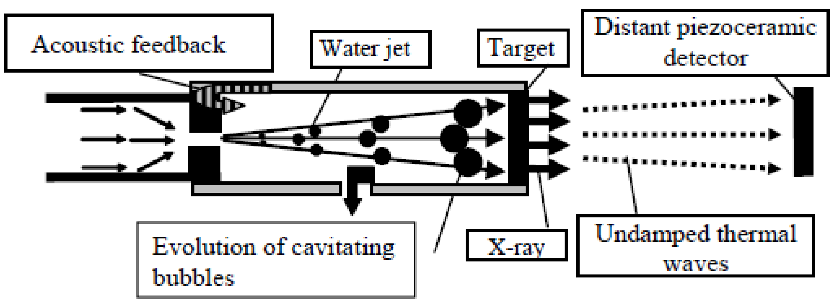


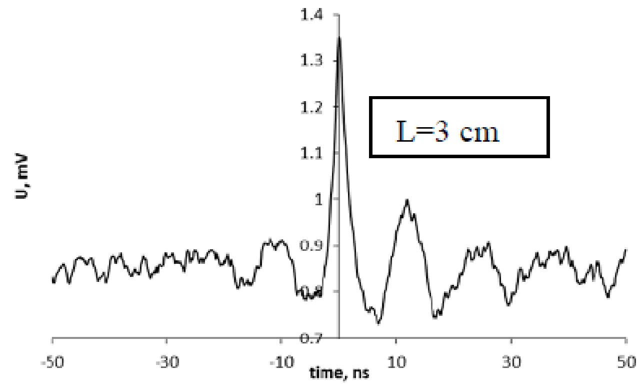
Observation of long-distance thermal waves at water cavitation

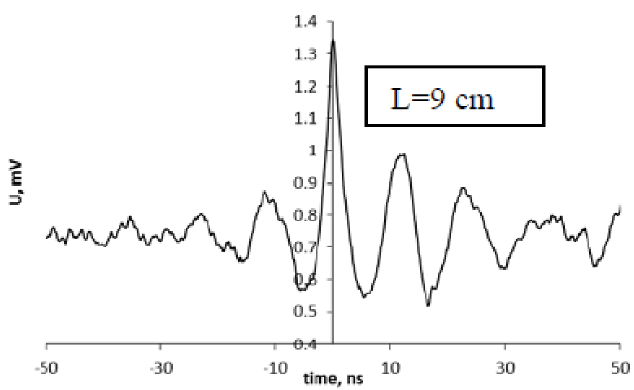




V.I.Vysotskii, A.A.Kornilova, A.O.Vasilenko. Observation and investigation of X-ray and thermal effects at cavitation. Current Science, 2015, v.108, No.4, p. 114-119







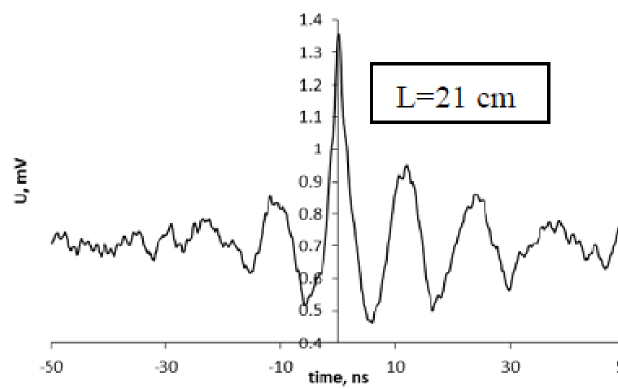
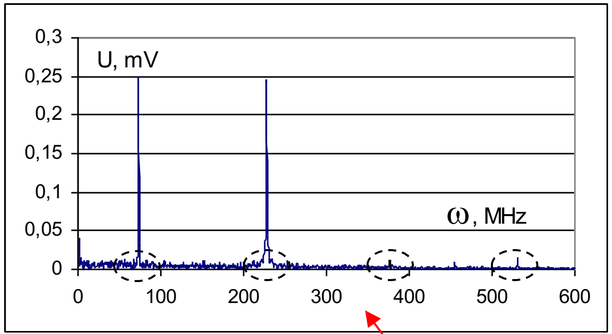
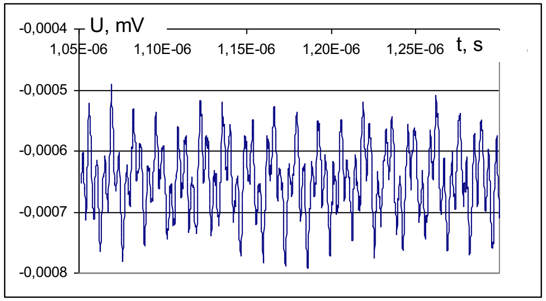
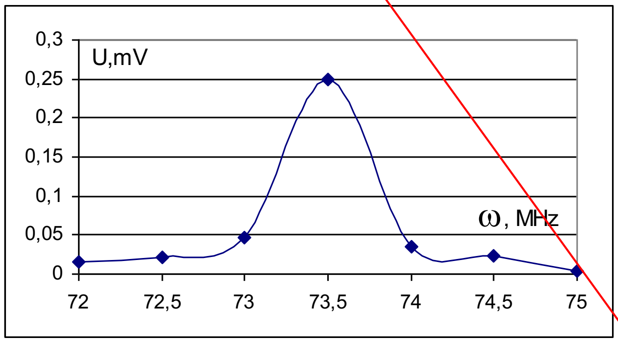


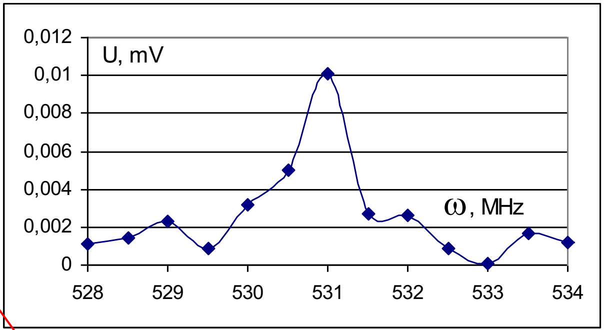
Fig.6. Experimental setup for study of X-ray and undamped thermal waves at cavitation of fast water jet and high-frequency signals registered in air at different distances L.

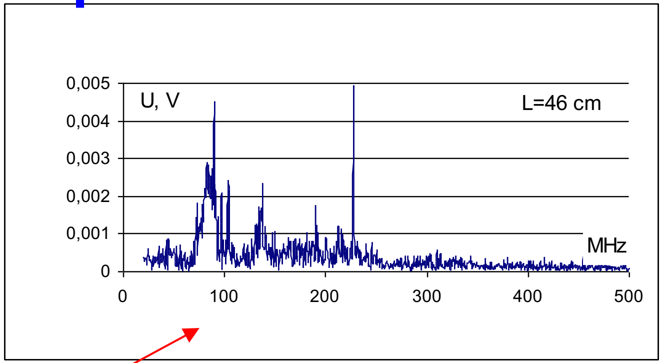
Observation of long-distance thermal waves at the same cavitation experiments

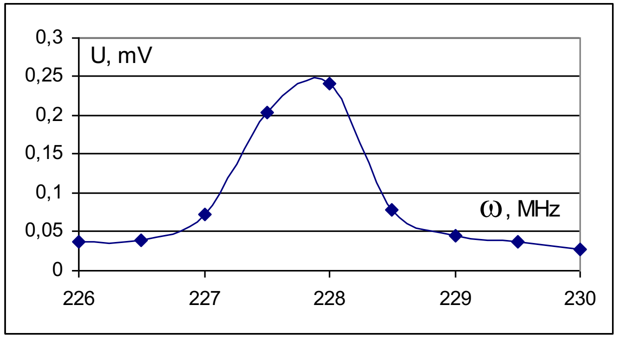


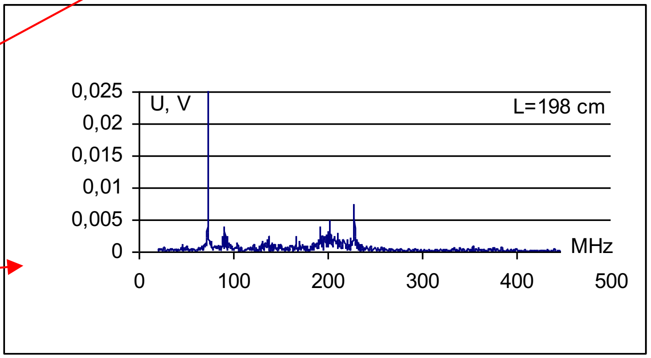


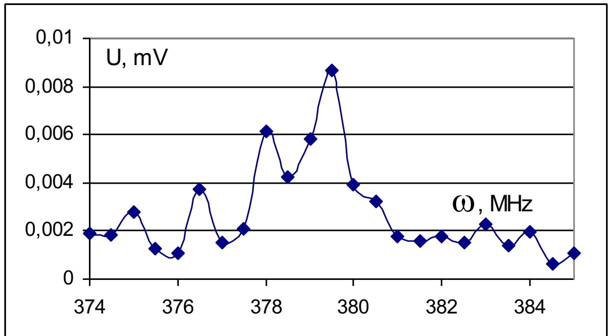












Spectrum of temperatures waves, recorded at distances of (a) L = 18.5 cm; (b) 46 cm; (c) 198 cm from the outer surface of the screen. The maximum distance (198 cm) was limited only by the size of the laboratory

The mechanism of atom excitation by action of shock wave

Excitation of atom (e.g. transition $1s_0 \to 2p_0$) takes place at its sudden acceleration during reflexion of shock wave front from the border between chamber wall and air. The width of front of shocking wave in dense medium is tens of angstroms.

Wave function of the atom on the surface of the chamber in it's initial state is

$$\Psi_{100}(\vec{r},t) = \sqrt{\frac{Z^3}{4\pi a^3}} e^{-Zr/a} \exp(-iE_1 t/\hbar)$$

The wave function of the same (now moving) atom after action of chock wave is

$$\Psi_{210}(\vec{r}',t) = r' \sqrt{\frac{Z^5}{32\pi a^5}} i \cos\theta e^{-Zr'/2a} e^{im_e v z'/\hbar} \exp\{-i[E_2 + m_e v^2/2]t/\hbar\},$$

$$\vec{r}' = \vec{r} + i\vec{e}_z vt$$

Probability of excitation of atom transition $1s_0 \to 2p_0$ is the following

$$W_{100,210} = \left| \int_V \Psi^*_{100}(\vec{r},0)\Psi_{210}(\vec{r},0) e^{imvz/h} dV \right|^2 =$$

$$\left| \frac{iZ^4}{4\pi a^4 \sqrt{2}} \int_0^\infty \int_0^\pi e^{-3Zr/2a} e^{im_e vr\cos\theta/\hbar} r^3 \cos\theta \sin\theta d\theta dr \right|^2 = \frac{9}{32} \frac{\left(v/v_{100}\right)^2}{\left\{\frac{9}{4} + \left(v/v_{100}\right)^2\right\}^6};$$

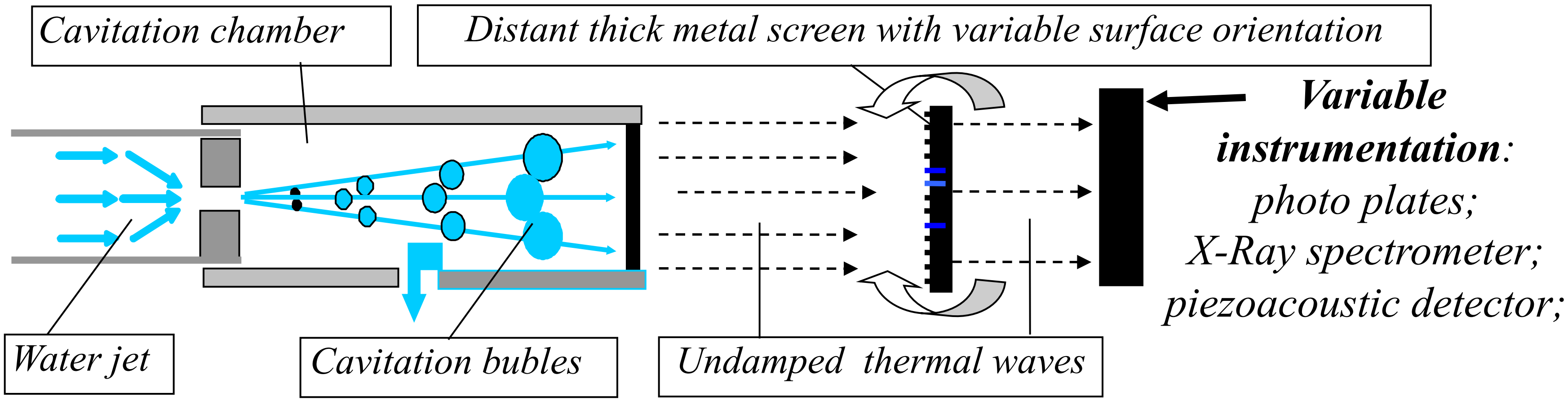
$v_{100} = Ze^2/\hbar \approx 2.3 * 10^8 Z \quad cm/s$ - orbital velocity of atom electron

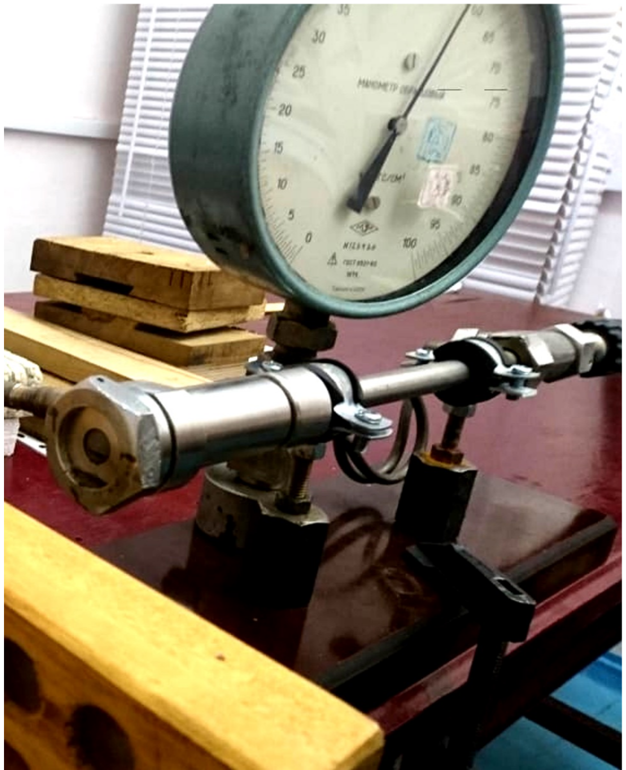
$$\boxed{W_{100,210} \approx 2.2 * 10^{-3} \left(v_{Shock\ wave} / v_{100}\right)^2}$$

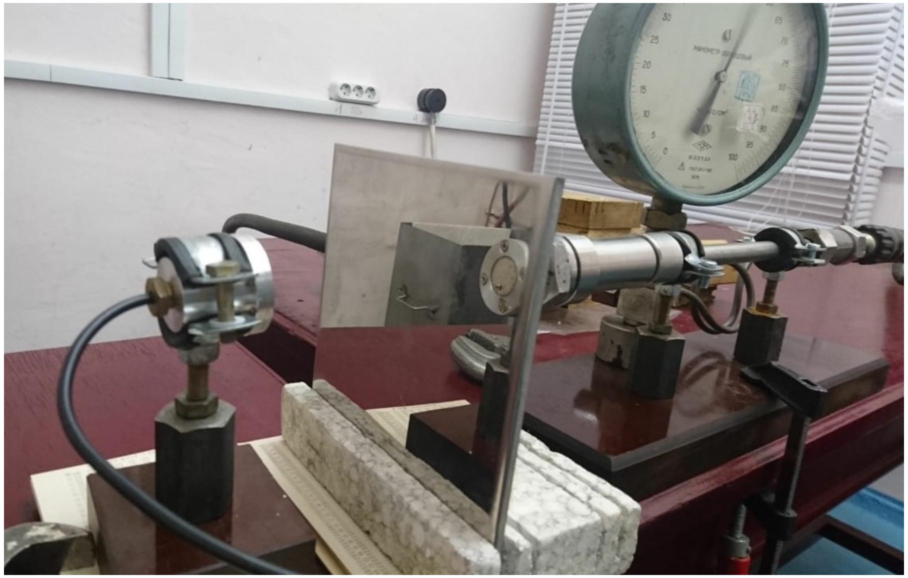
- probability of excitation

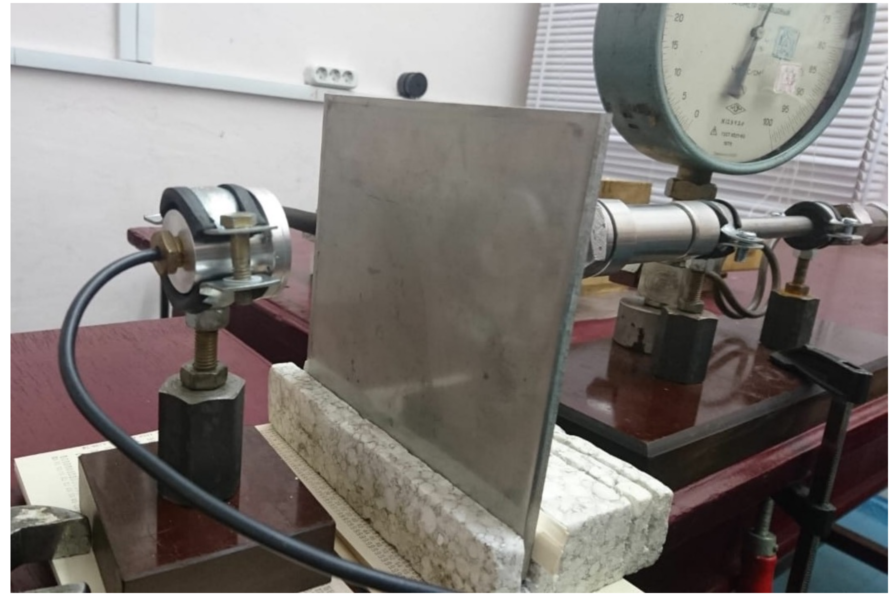
Generation and Registration of temperature waves

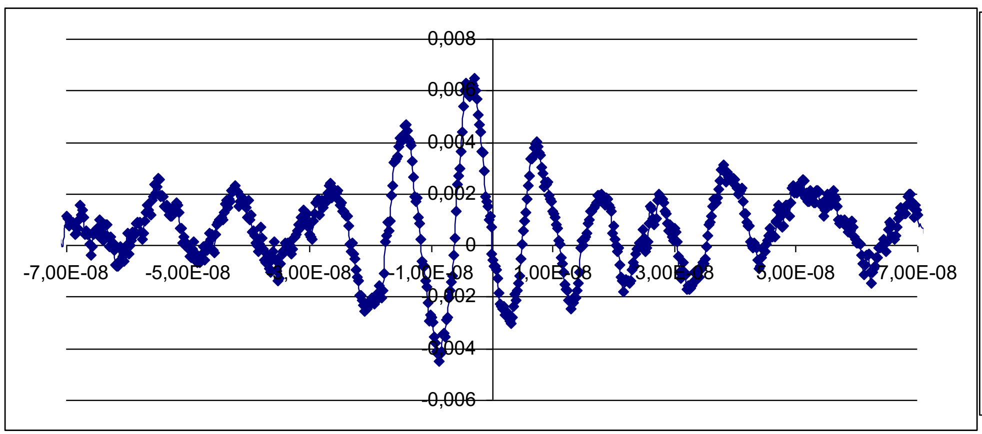
behind a remote steel screen

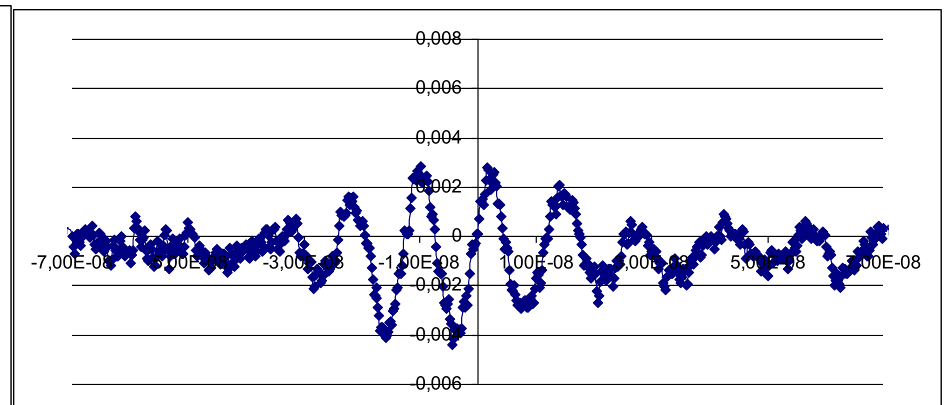








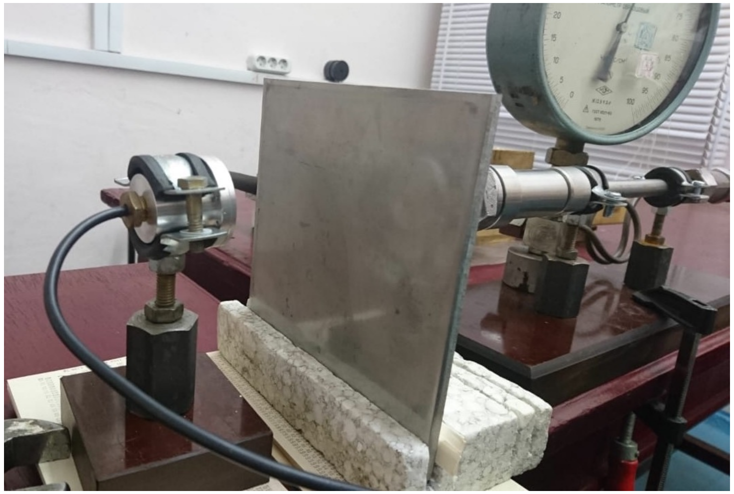


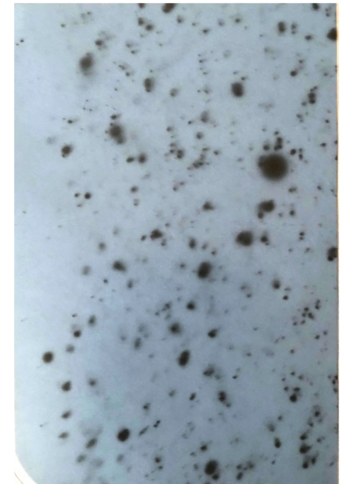


Polished front surface of the steel plate

83 MHz

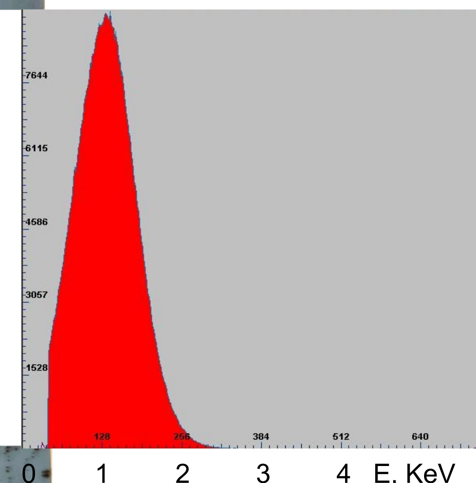
Unpolished front surface of the steel plate



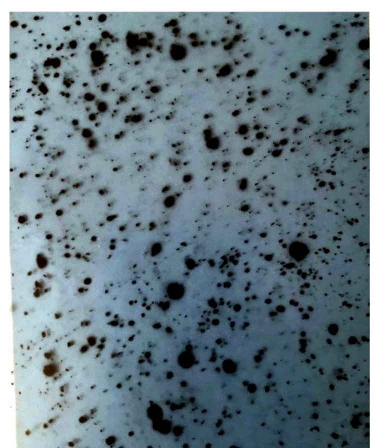


Polished front surface of the steel plate

Spectrum of X-ray radiation of steel surface generated during cavitation

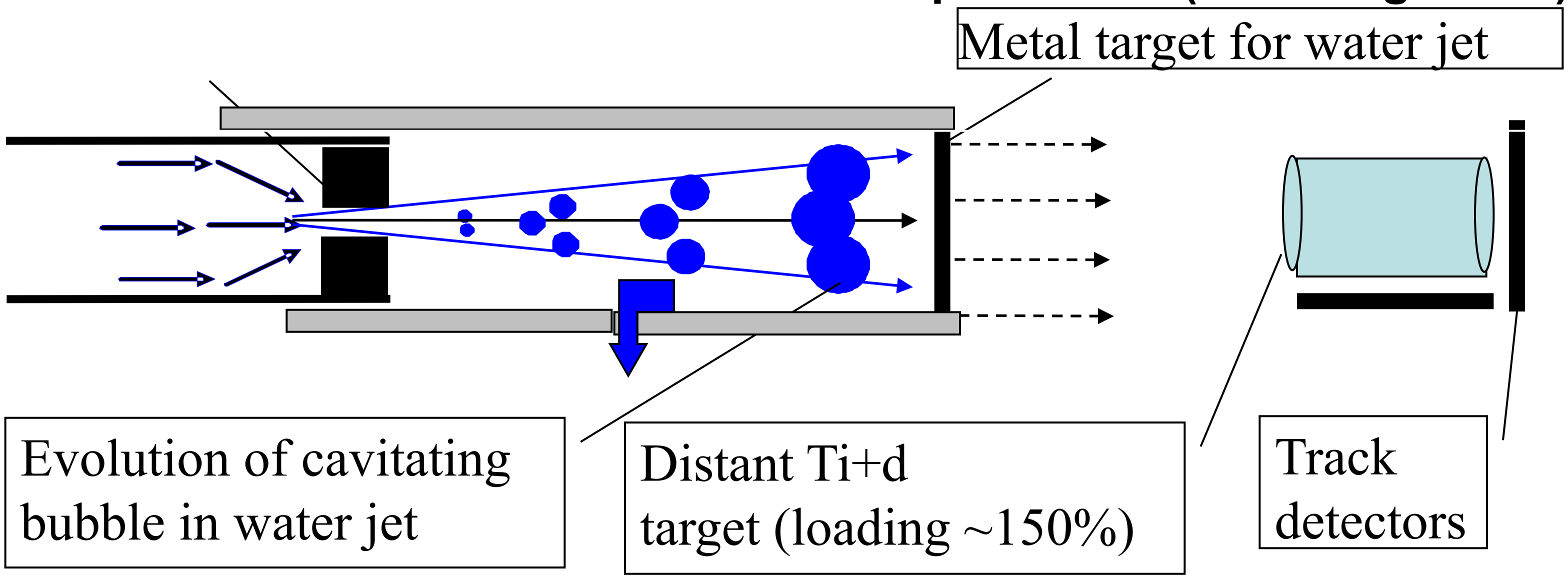


Unpolished front surface of the steel plate

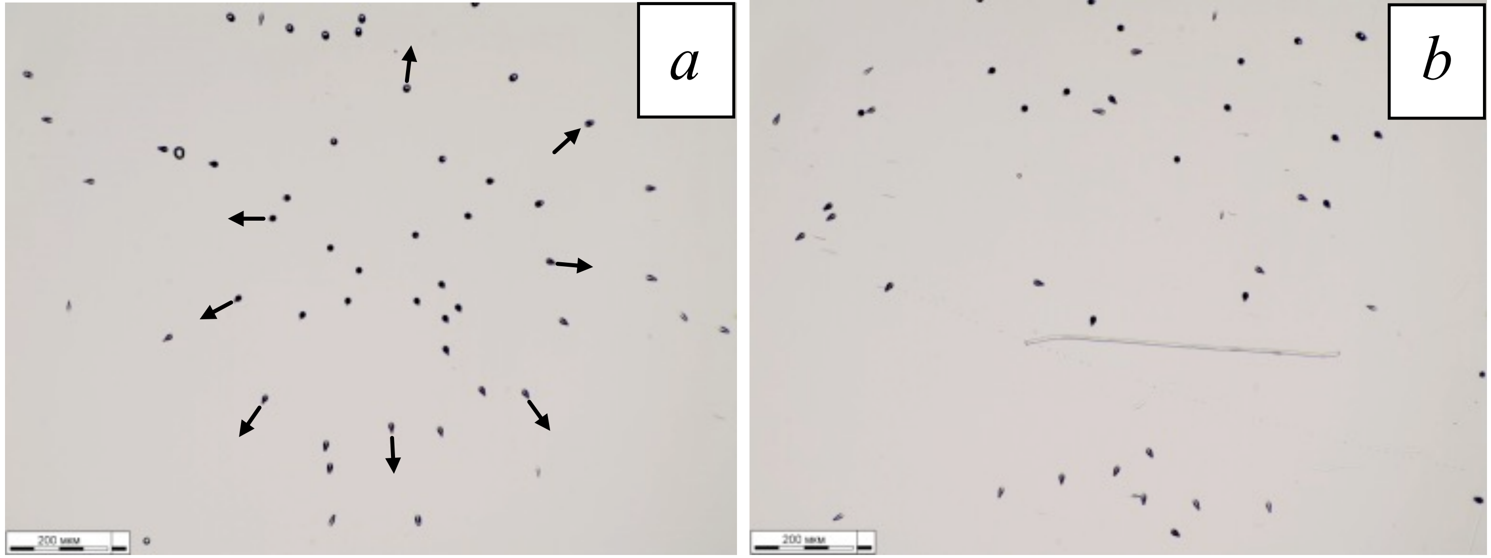


Controlled LENR stimulated by the action of undamped thermal waves in deuterated titanium

One of the possible application of undamped thermal ways is connected with direct distant stimulation of nuclear processes (including LENR).



For carrying out the alpha-track analysis, a plastic detector made of polycarbonate (polyallyl diglycol) of the CR-39 type with a density of 1.3 g / cm^3 was used. The thickness of the "TASTRAK®" detector (Track Analysis Systems Ltd, Bristol, UK) was 1 mm thick. The typical setting of the experiments corresponded to the location of the detector at a distance of 5 mm from the surface of the target, which was affected by the thermal wave for a certain time (for example, 20 and 40 min).



Microscopic track analysis of the spatial distribution of tracks and the direction of motion of alpha particles in samples subjected to the action of a thermal wave for 40 minutes when the track detector is located near the end (Fig. 1a) and lateral (cylindrical) surfaces of the deuterated sample1b.

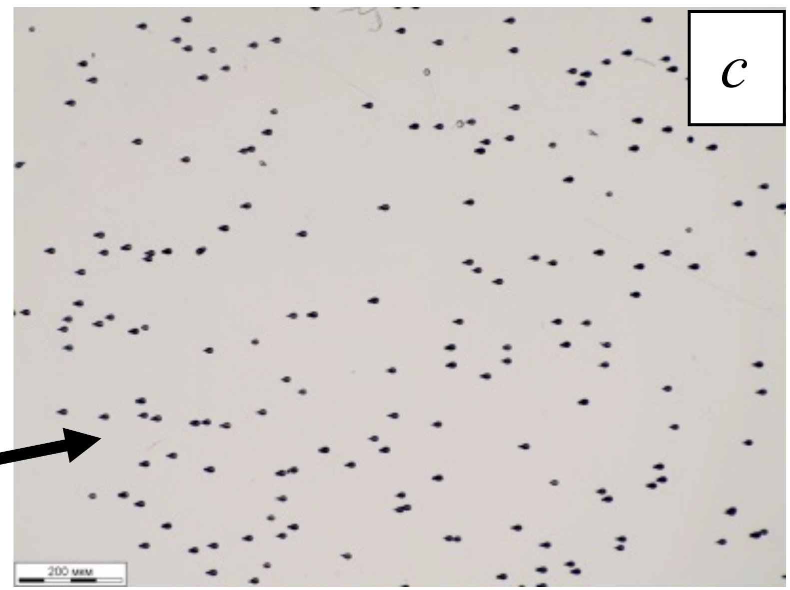


Fig. 1c corresponds to a control measurement using an alpha emitter based on a combination of three radionuclides U^{233}, Pu^{239} and Pu^{238}.

The presumed nuclear reactionы in this system are

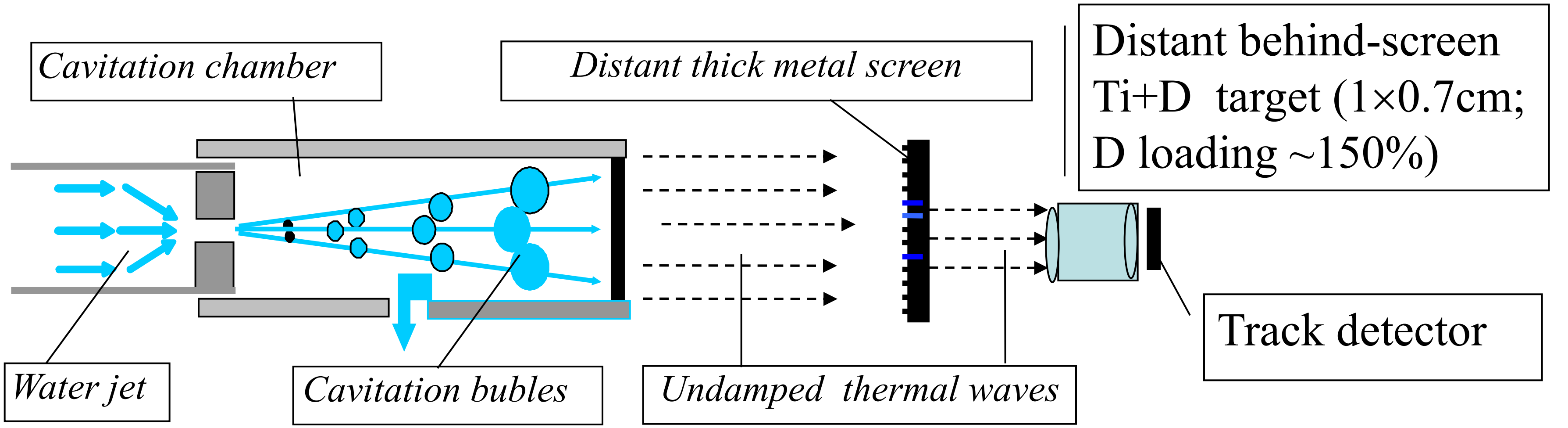
$$d + d = He^{3} + n$$

$$d + d = He^{4}$$

The direction of motion of the alpha particles correlates well with the axial symmetry of the target end

Distant behind-screen LENR under the action of undamped heat waves

[V.I. Vysotskii, A.A. Kornilova, P.L.Hagelstein, T.B. Krit, S.N.Gaydamaka, M.V.Vysotskyy, JCMNS, v.33, 2020].



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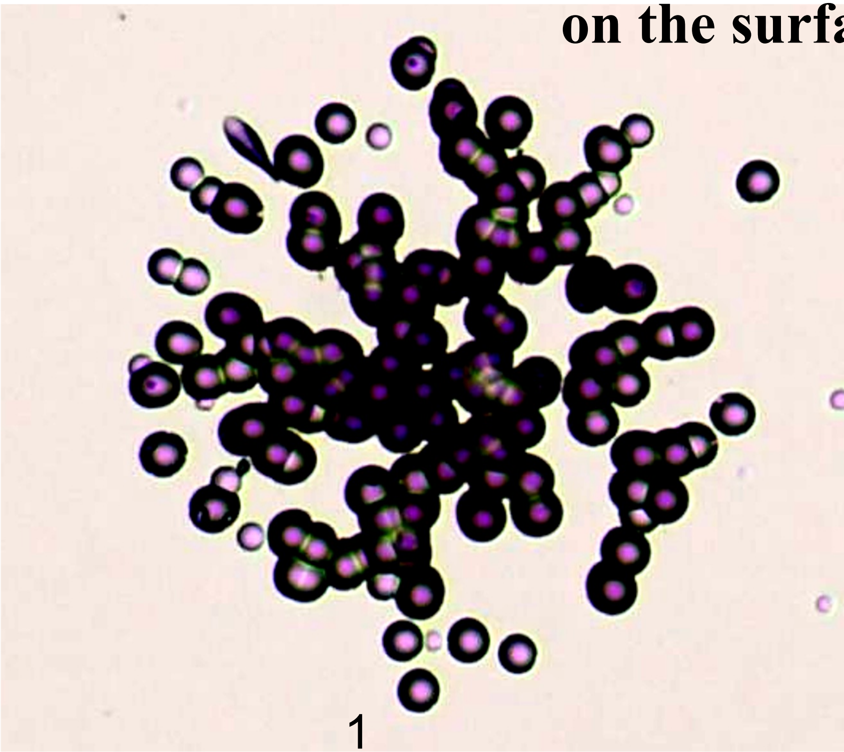
The location of the areas of alpha tracks analysis on the surface of the track detector

$$d + d = He^3 + n$$

$$d + d = He^4$$



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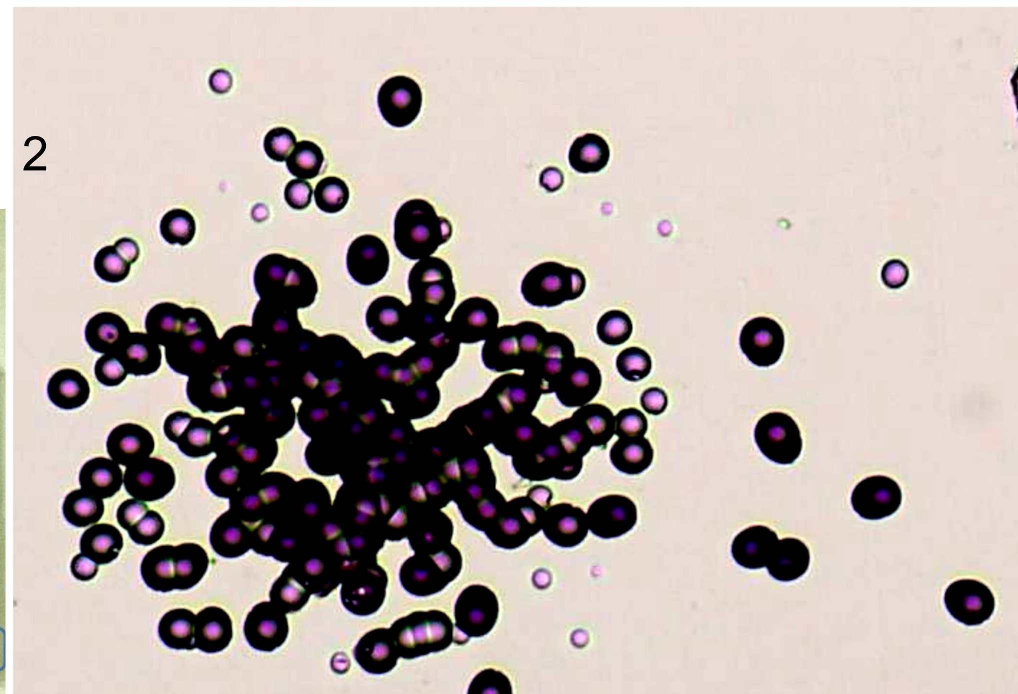

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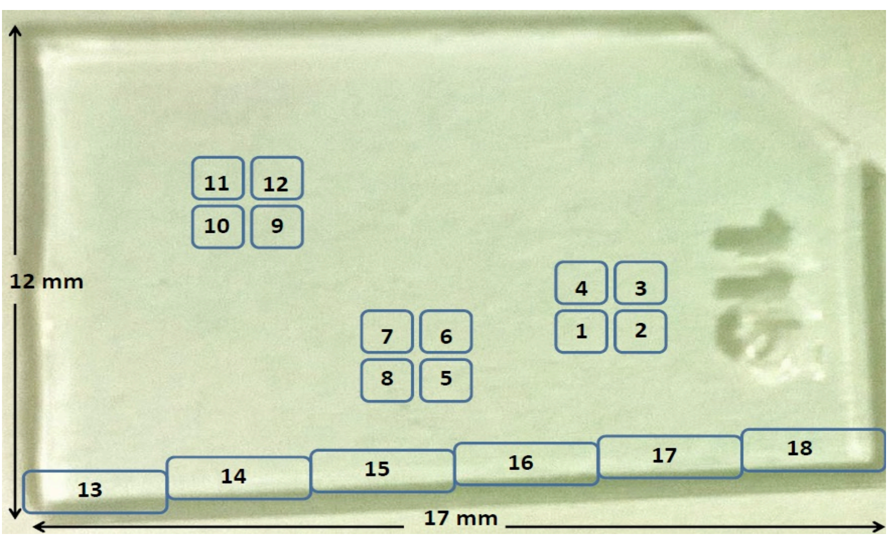


In our opinion, **the course of this reaction is associated with the formation of coherent correlated states of deuterons in nonstationary microcracks (formed during loadind and migration of deuterium in the matrix of titanium) that change (for example, is compressed, and then restored) into a deuterated titanium volume under the action of shock waves stimulated by a thermal wave.**

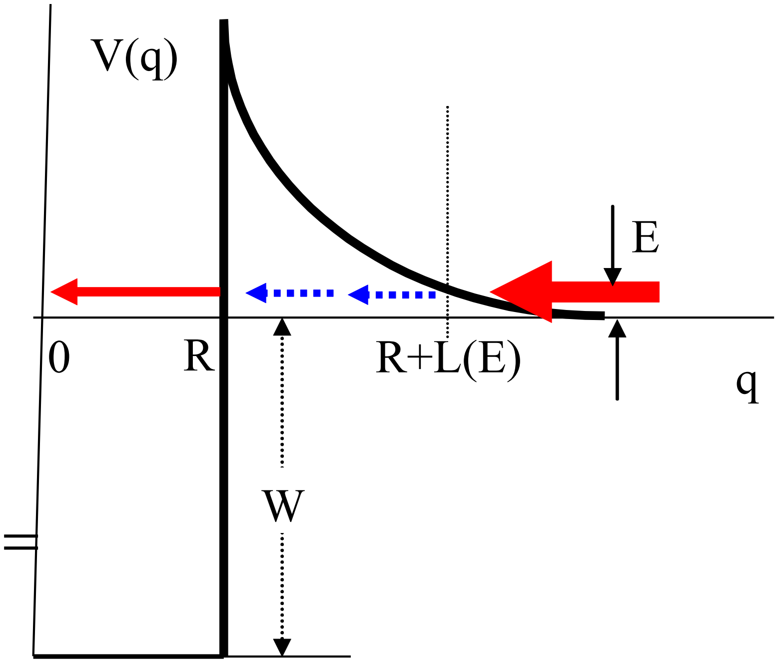
When the deuteron is localized in an interatomic space typical for condensed media with a period a=1.5A, the energy fluctuation in the coherent correlated state exceeds the value $$\delta E^{(\min)} = G^2\hbar^2 / 2M(a)^2 \approx 50-100\,keV$$

that even at this lower threshold is much more that with the temperature planned for tokamaks. It should be noted that the real amplitude of this energy fluctuation can significantly exceed this value.

Here $$G = 1/\sqrt{1-r^2} \approx 10^4$$

is the realistic coefficient of correlation efficiency, r – coefficient of correlation. These investigations will be continued, but even at this stage it is obvious that the **method of such remote stimulation of nuclear fusion opens up new opportunities and prospects for implementing controlled nuclear fusion.**

The problem of “standard” d+d nuclear fusion at low energy



$$D = e^{-W(E)};$$ *Fusion without screening*

$$V_{\max} = Z_1 Z_2 e^2 / R \approx 0.5 - 5.6\, MeV$$

$$W(E) = (2/\hbar) \int_{R}^{R+L(E)} \sqrt{2M[V(q)-E]}\,dq =$$

$$\exp\{-2\pi Z_1 Z_2 e^2 / v\} = \exp\{-2\pi Z_1 Z_2 / 137\beta\},\ \beta = v/c$$

$$d + d : T = 300K,\ \bar{v}/c \approx 3*10^{-6},\ Z_1 = 1,\ Z_2 = 1,\ D \approx 10^{-2500}$$

The traditional approach to the physics of charged particles tunnelling is based on the assumption of mutual independence of the particle states corresponding to each energy level of quantized states. For such systems the tunnelling processes for each state are also mutual independent.

The conceptual basis of the tunneling effect for such states is connected with the wave-particle duality **and Heisenberg -Robertson uncertainty relations (1927-1929)**

$$\sigma_A \sigma_B \geq |< [\hat{A}\hat{B}] >|^2 /4;$$

$$\sigma_p \sigma_q \geq \hbar^2 / 4, \ \delta p \delta q \geq \hbar / 2; \ \sigma_p =< (p - < p >)^2 >,$$

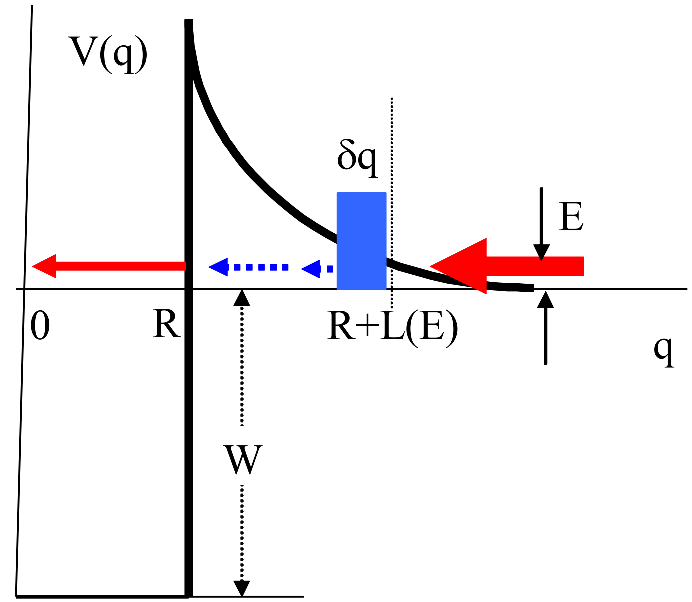
$$\sigma_q =< (q - < q >)^2 >, \delta p = \sqrt{\sigma_p}, \delta q = \sqrt{\sigma_q}$$

which connects the dispersions and mean square errors of the coordinate q and the corresponding component of the momentum of a particle p.

Relation $\delta p \delta q \geq \hbar / 2$ can be used for the estimation of barrier transparency

$$D(E) = \exp(-2 \int_{R}^{R+L(E)} \sqrt{2M[V(q) - E]} dq / \hbar\} = \exp\{-2L\delta p / \hbar\} = \exp\{-L / \delta q\}$$

L(E) – **width of the barrier** *V(q);*



$\delta q \approx \hbar / 2\delta p -$ **quantum-mechanical skin layer;**

$$\delta p \equiv \int_{R}^{R+L(E)} |p(q)| dq / L(E) =$$

$$\sqrt{2M} < \left|\sqrt{V(q) - E}\right| >;$$

$$|p(q)| = \sqrt{2M[V(q) - E]}$$ - mean square

effective radial momentum of a particle with energy $E \leq V(q)$ in the subbarrier region $V(q) \geq E,\ 0 \leq q \leq L(E)$.

In the case of low energy $E << \bar{V}$ the condition $L(E) / \delta q >> 1$ is satisfied, then the transparency coefficient of the Coulomb barrier will be extremely small:

.

$$D(E) = \exp\{-L(E) / \delta q\} << 1$$

Correlated coherent states of particles and Schrödinger-Robertson uncertainty relation (1930)

In 1930, Schrödinger and Robertson independently generalized the Heisenberg idea of the quantum-mechanical uncertainty of different dynamical quantities A and B for the case of mutual coherence of the particle states corresponding to each energy level of quantized states and received the more universal condition called the Schrödinger--Robertson uncertainty relation

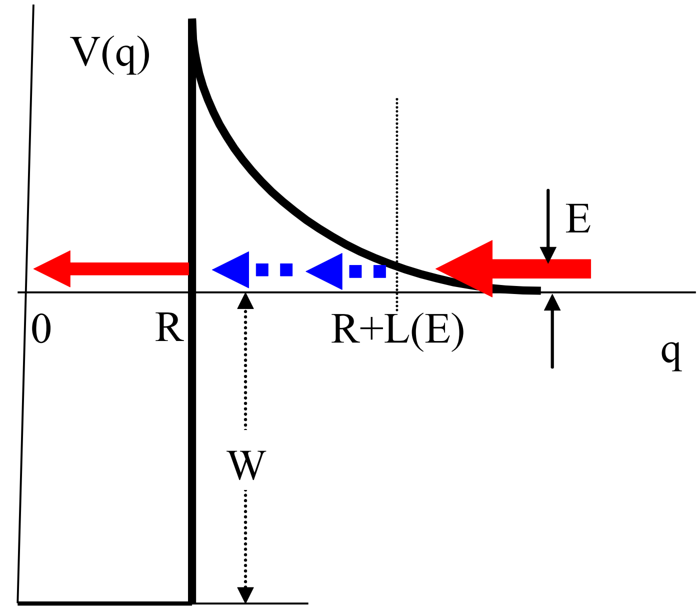
$$\sigma_A \sigma_B \geq \frac{|<[\hat{A}\hat{B}]>|^2}{4(1-r^2)}; \; |r| \leq 1, \; r = \frac{\sigma_{AB}}{\sqrt{\sigma_A \sigma_B}}$$ - coefficient of correlation

$$\sigma_{AB} = \frac{<\{\Delta\hat{A}, \Delta\hat{B}\}>}{2} = \frac{(<\hat{A}\hat{B}> + <\hat{B}\hat{A}>)}{2} - <A><B>$$ - cross dispersion of A and B

$$\delta p \delta q \geq \frac{\hbar}{2\sqrt{1-r^2}} \equiv \hbar_{eff}/2, \quad \hbar_{eff} = \hbar/\sqrt{1-r^2}$$ - effective Planck constant

$$r = \frac{\{<qp> + <pq>\}}{2\sqrt{<p^2><q^2>}}; \quad \delta E \delta t \geq \hbar_{eff}/2$$

For Coulomb potential barrier the modified uncertainty relation is



$$\delta q \geq \frac{\hbar}{2\sqrt{1-r^2}\,\delta p} \equiv \frac{\hbar_{eff}}{2\delta p} =$$

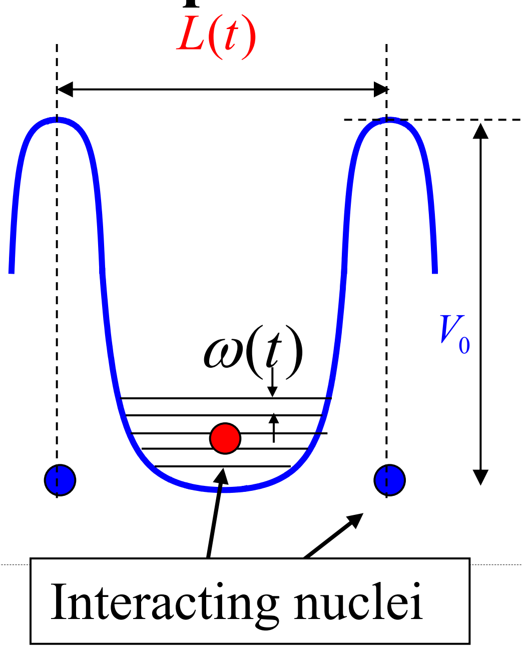
$$= \frac{\hbar}{2\sqrt{1-r^2}\sqrt{8M} < \sqrt{V(q)-E} >}$$

At full correlation |r|→1 the mean square effective coordinate of a particle will be unlimited ($\delta q \to \infty$) at any energy!

In this ideal case the tunnel transparency of arbitrary potential barrier will be close to 1 at any low energy E of the particle (!):

$$D_{r\neq 0} = \mathrm{e}^{-W(E)} \approx e^{-\sqrt{1-r^2}L(E)/\delta q} = (D_{r=0})^{\sqrt{1-r^2}} \to 1 \; at \; |r| \to 1$$

The simple estimation of efficiency the effect of correlated state



$$\delta q \delta p \geq \frac{\hbar}{2\sqrt{1-r^2}} \equiv \frac{G\hbar}{2};$$

$$\delta T \equiv \frac{(\delta p)^2}{2M} \geq \frac{\hbar^2}{8M(\delta q)^2(1-r^2)} \equiv \frac{G^2\hbar^2}{8M(\delta q)^2} - \textit{fluctuation of energy};$$

$$If\ \delta q \approx a/2 \approx 1\,A\ \ than: \begin{cases} at\ r=0\ (G=1) \quad \delta T_{r=0} \geq \dfrac{\hbar^2}{2Ma^2} \approx 0.002\, eV \\ at\ G = 10^3 \ldots 10^4: \quad \delta T_r \geq \dfrac{G^2\hbar^2}{2Ma^2} \approx 2 \ldots 200\, keV \end{cases}$$

The physical reason for the increase of the probability of tunneling effect is related to the fact that the formation of a coherent correlated state leads to the cophasing and coherent summation of all fluctuations of the momentum $\Delta\vec{p}(t) = \sum_n^N \Delta\vec{p}_n(t)$

for various eigenstates the superpositional correlated state $\sum_n^N c_n(t)\Psi_n(r)e^{-iE_n t/\hbar}$

This leads to a very great dispersion of the momentum

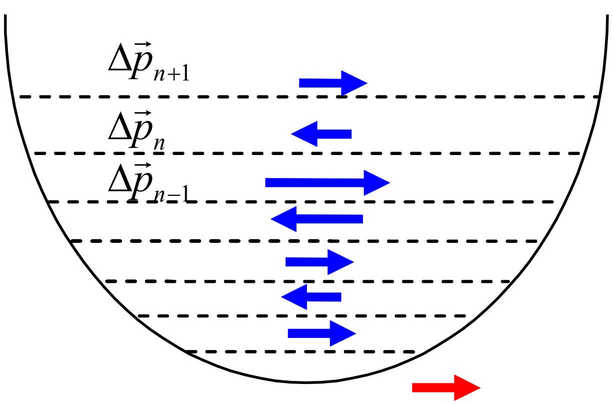
$$\sigma_p \equiv <\{\vec{p}(t) - <\vec{p}(t)>\}^2> = <\left\{\sum_n^N \Delta\vec{p}_n(t)\right\}^2> = N\left\langle(\Delta\vec{p}_n)^2\right\rangle + N^2\left\langle\Delta\vec{p}_n\Delta\vec{p}_m\right\rangle$$

and very great fluctuations of kinetic energy

$$<\Delta T> = <\Delta\vec{p}(t)^2>/2M = N^2\left\langle\Delta\vec{p}_n\Delta\vec{p}_m\right\rangle/2M + N\left\langle(\Delta\vec{p}_n)^2\right\rangle/2M \sim N^2$$

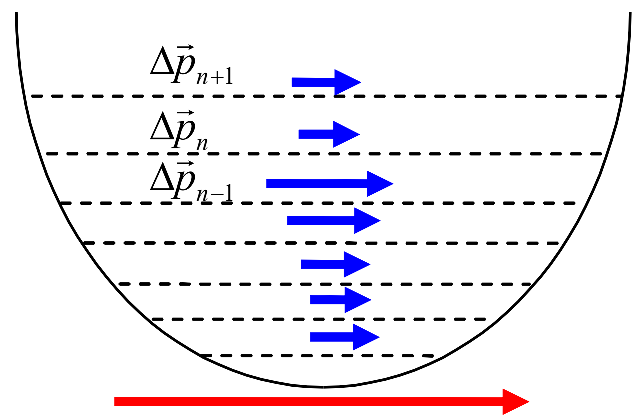
of the particle in the potential well and **increasing of potential barrier penetrability**.

Uncorrelated state



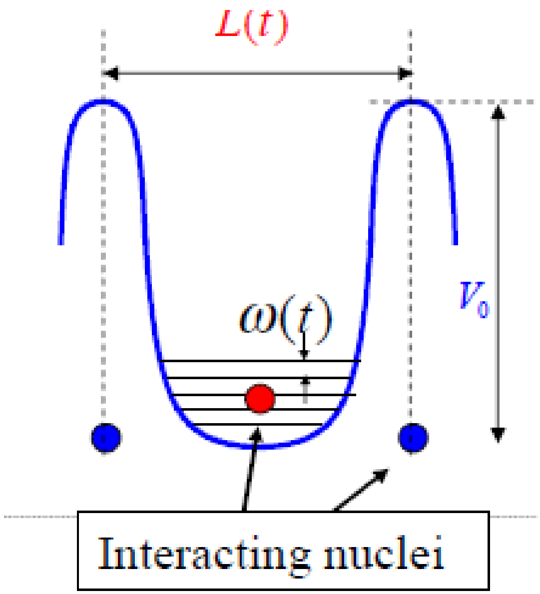
$$\delta p_{uncorr} = \sqrt{\sum_n (\Delta\vec{p}_n)^2} = \sqrt{N}\sqrt{<(\Delta\vec{p}_n)^2}$$

Correlated state



$$\delta p_{corr} = \sqrt{\sum_n (\Delta\vec{p}_n)^2} = N\sqrt{<(\Delta\vec{p}_n\Delta\vec{p}_m)^2} + \sqrt{N}\sqrt{<(\Delta\vec{p}_n)^2}$$

Formation of coherent correlated states at monotonous deformation of potential well



A.Monotonously increasing potential well

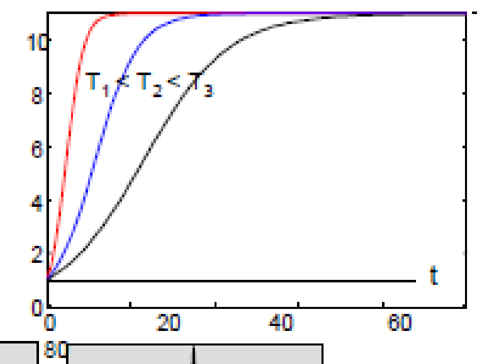
(e.g. growing crack in metal hydride)

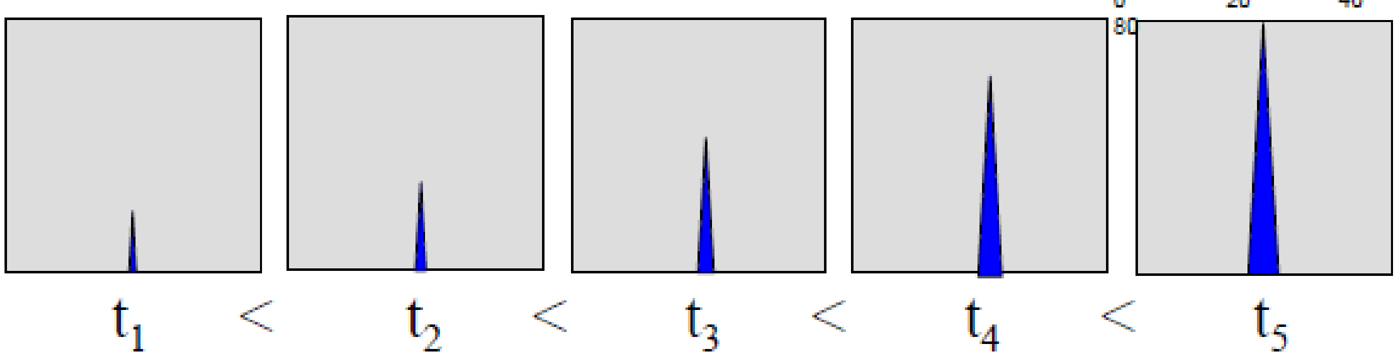
$L(t) = L_0(g+1)/(g+e^{-t/T})$ – width of crack;

T – *duration of growth of crack*

$L_{\max}/L_{\min} = (g+1)/g \approx 1/g, \; g = (L_{\max}/L_o - 1), g << 1$

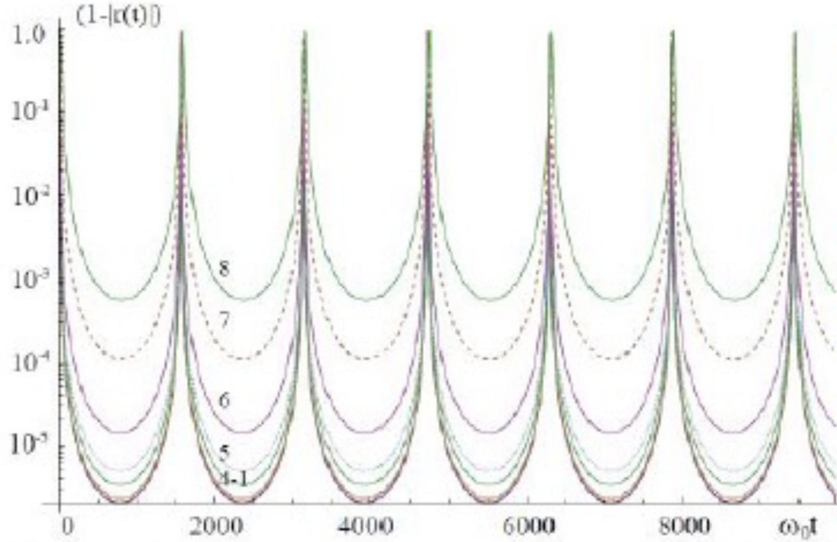
$\omega(t) = \omega_0(g+e^{-t/T})/(g+1)$





Increasing potential well

$$L(t) = L_0(g+1)/(g+e^{-t/T}); \qquad \omega(t) = \omega_0(g+e^{-t/T})/(g+1)$$



$g = 0.001;\ L_{max}/L_0 \approx 1000$

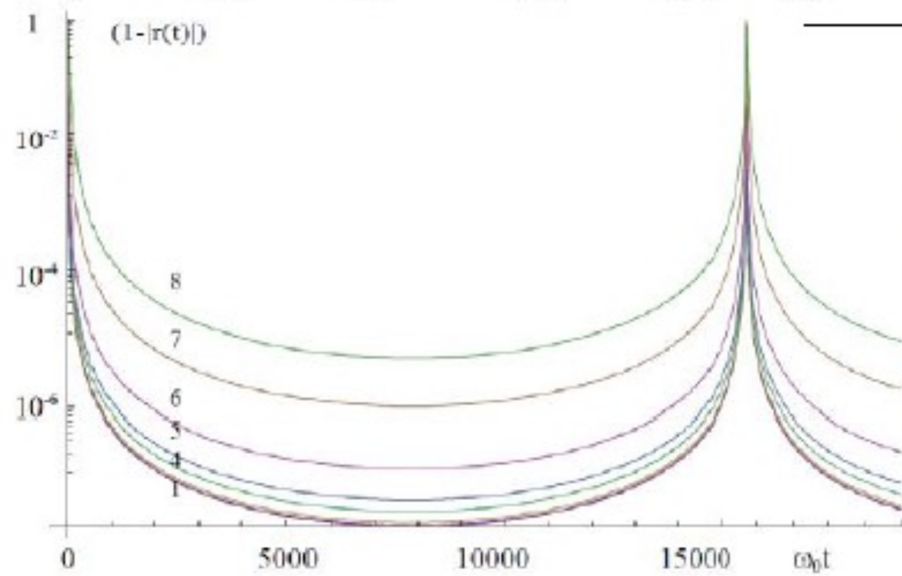
$(2A \to 2000A)$

$T = 0.1/\omega_0,\ 0.25,\ 0.5, 1, 1.33,\ 2,\ 5,\ 10$

$r_{max} \approx 0.999998;$

$d + d; D_{dd}(kT, r_{max}) \approx 0.85$

$Ni + p; D_{Ni+p}(kT, r_{max}) \approx 10^{-2}$



$g = 0.0001;\ L_{max}/L_0 \approx 10000$

$(2A \to 2mkm);$

$T = 0.1/\omega_0,\ 0.25,\ 0.5, 1, 1.33,\ 2,\ 5,\ 10$

$r_{max} \approx 0.9999998;$

$d + d; D_{dd}(kT, r_{max}) \approx 0.98$

$Ni + p; D_{Ni+p}(kT, r_{max}) \approx 0.6$

Conclusions

The obtained results show that undamped temperature waves with a frequency determined by the specific parameters of the medium (composition, pressure, and temperature gases) may exist in media with temperature relaxation.

For each material medium, there are several characteristic frequencies that correspond to continuous heat waves . These frequencies are determined by the local thermal relaxation time τ. In metals, semiconductors and hot dense plasma, the values of τ are very small, and can be excited only by ultrashort thermal pulses $\tau \le 10^{-10} ... 10^{-13}\ s$

In air under the normal conditions (P=1atm, T=300 K) the relaxation time is about $\tau \approx 10\ ns$ and $\tau \sim 1 / P\sqrt{T}$

To excite undamped wave it is necessary that there is a pulse heat disturbance of air media with a duration of $\Delta t \le 10\, ns$, which is in good agreement with the known characteristics of duration of shock wave front at cavitation in water. Such undamped temperature waves may play the important role in the problems of heat exchange for the case of pulse thermal processes.

These waves can be used to stimulate pulsed LENR (including dd-fusion) in distant targets!

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Thank you for attention