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Research Article

Generation and Detection of Undamped Temperature Waves at Large Distance in LENR Related Experiments

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Abstract

In this paper we describe the process of detecting undamped (self-channeled) high-frequency heat waves generated and propagated in air from the cavitation of a water jet in a closed chamber, and the results of action of these waves on low energy nuclear fusion in a remote deuterated polycrystalline titanium sample with grain sizes of not more than 50 microns. These waves are formed on the reverse side of the metal target, which is affected by the jet of water in a state of cavitation, and are characterized by strictly defined frequencies (in air under normal conditions and different humidity, the minimum frequency of such a wave is equal to MHz) [1–7] Such waves can propagate in air for a long distance (in the laboratory - more than 2 meters and this distance was limited only by the size of our laboratory). Under the influence of such waves to the remote target, effective quasicontinuous nuclear dd-fusion with a concomitant generation of alpha-particles process takes place.

Keywords: Cavitation, Distant dd–fusion, LENR, Temperature waves, Thermal relaxation

1. Generation and Detection Of Undamped Temperature Waves At Large Distance

During water cavitation experiments simultaneously with the detection of X-rays we have detected previously unknown undamped thermal waves in air at a great distance.

The photograph of the experimental setup, its schematic and the view of signals registered in air by broadband acoustic piezoceramic detector at different distances L from the outer surface of the target made of tungsten [8] are presented in Fig. 1.

These unknown waves in the air beyond the metallic target were recorded by a wide-band acoustic receiver – a TsTS-19 (VA-500) piezoelectric 20 mm in diameter with a resonance frequency of $\omega_{\text{res}} = 1$ MHz. The receiver was moved along the facility axis in the distance range from 5 mm up to 198 cm from the outer surface of the metallic

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target. Measurements were conducted with steps of 1 cm. The receiver during reference measurement was turned relative to the facility axis at angles of 0°C, 20°C, 90°C, and 180°C. The experiments were carried out with the use of a tungsten target (or in some experiments, molybdenum).

In these experiments, we detected with confidence at all distances a frequency-ordered system of quasimonochromatic signals in the frequency interval $\omega \approx 75 - 900$ MHz and more! It is very important to note that the amplitude of these waves is relatively independent of their frequency over a very wide range.

On the other hand, the detection of an acoustic signal even with minimal frequency $\omega \approx 75$ MHZ at distances $L = 1 - 200$ cm from the back side of the target is the paradox that cannot be explained by standard acoustics.

It is easy to see that these are not standard acoustic waves of high frequency. The standard formula for absorption (dissipation) of ultrasound

$$\delta(T) = \frac{\omega^2}{2\rho\{c(T)\}^3}\left[\left(\frac{4}{3}\eta + \xi\right) + \lambda(T)\left(\frac{1}{C_{\rm V}} - \frac{1}{C_{\rm p}}\right)\right] \quad (1)$$

has shown that at such high frequency the coefficient of ultrasound absorption in the air is very large ($\delta \geq 10^4 \text{cm}^{-1}$) and the mean free path $\bar{l} \leq$ 1–2 μm is very small! Here $c(T) \approx (331.3 + 1.21T^0) \times 10^2$ cm/s is the velocity of acoustic waves, ρ the density of air, $c_{\rm p} = 1000$ (J/kg K) and $c_{\rm v} = 717$ (J/kg K) is the specific heat of air at room temperature and normal pressure at constant pressure and volume, $\eta = 1.9 \times 10^{-5}$ (Pa s) and $\xi = 17.2 \times 10^{-6}$ (Pa s) – coefficients of shear and bulk viscosity of air, temperature in °C.

This result becomes still more surprising when we take into account the relative low resonance frequency of the used broadband acoustic detector $\omega_{\rm res} \approx 1$ MHz, which is 75 times less than the frequency of the recorded signal! This condition is evidence of a much lower recording efficiency, which is proportional to the Q factor of acoustic resonance in the detector. From this it is evident that the real amplitude of the signal in the distant acoustic detector was very great.

This paradox can be resolved if we assume that it is not usual acoustic (ultrasound) waves but the special type of thermal (temperature) waves - undamped thermal waves [1–7]

The existence of undamped temperature waves that can propagate without dissipation in environments with small time τ of local temperature relaxation was theoretically predicted for the first time in [1–3]. It was shown that such waves have a minimal characteristic eigen frequency $\omega_{\rm opt} \approx \pi/2\tau$ and can be excited in an environment under the influence of short heat pulses with duration $(\Delta t < \tau)$. This relaxation time (the time of thermalization) differs significantly for different media.

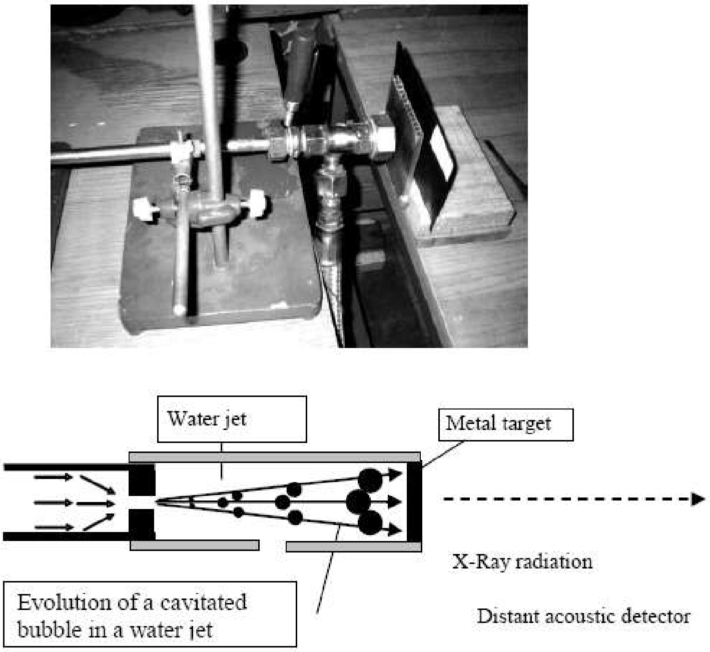
In a plasma the relaxation time to the equilibrium (Maxwellian) distribution within the electronic subsystem in a small space region is equal to

$$\tau^{\rm ee} \approx \sqrt{m_{\rm e}}(k_{\rm B}T_{\rm e})^{3/2}/4\pi\Lambda n_{\rm e}e^4, \quad (2)$$

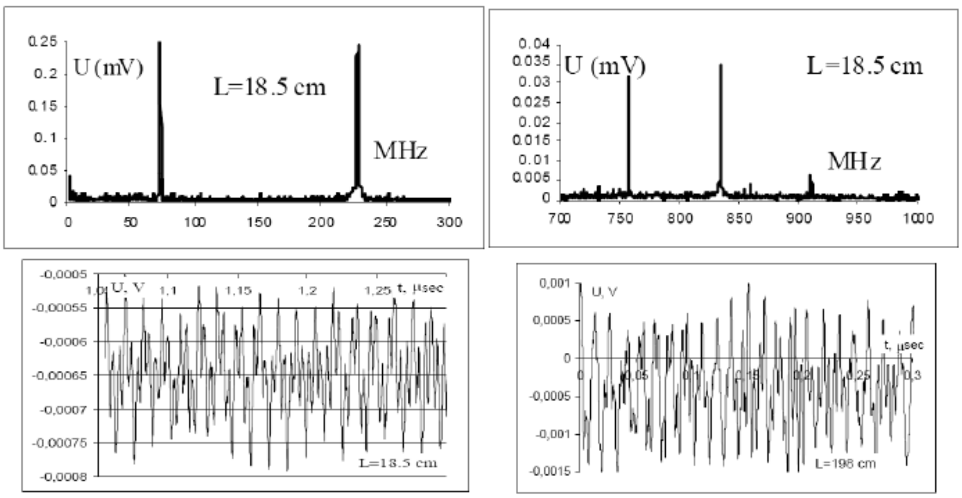
where $n_{\rm e}, m_{\rm e}, t_{\rm e}$, respectively, the electron concentration, electron mass and electron temperatures, $\Lambda \approx 15$ is the Coulomb logarithm. For the ionic subsystem in a plasma, the relaxation time is equal to

$$\tau^{\rm ii} \approx \sqrt{m_{\rm i}/m_{\rm e}}\tau^{\rm ee}. \quad (3)$$

A typical relaxation time for metals and semiconductors is determined by relaxation of degenerate electron gas and corresponds to $\tau \approx 10^{-14} - 10^{-12}$ s [1–3].



(**a**)



(**b**)

Figure 1. General view and scheme of experimental setup and the view of signals (frequency spectrum and structure of time dependence) registered in air by broadband acoustic piezoceramic detector at distances $L = 18.5$ cm and $L = 198$ cm from the outer surface of the tungsten target.

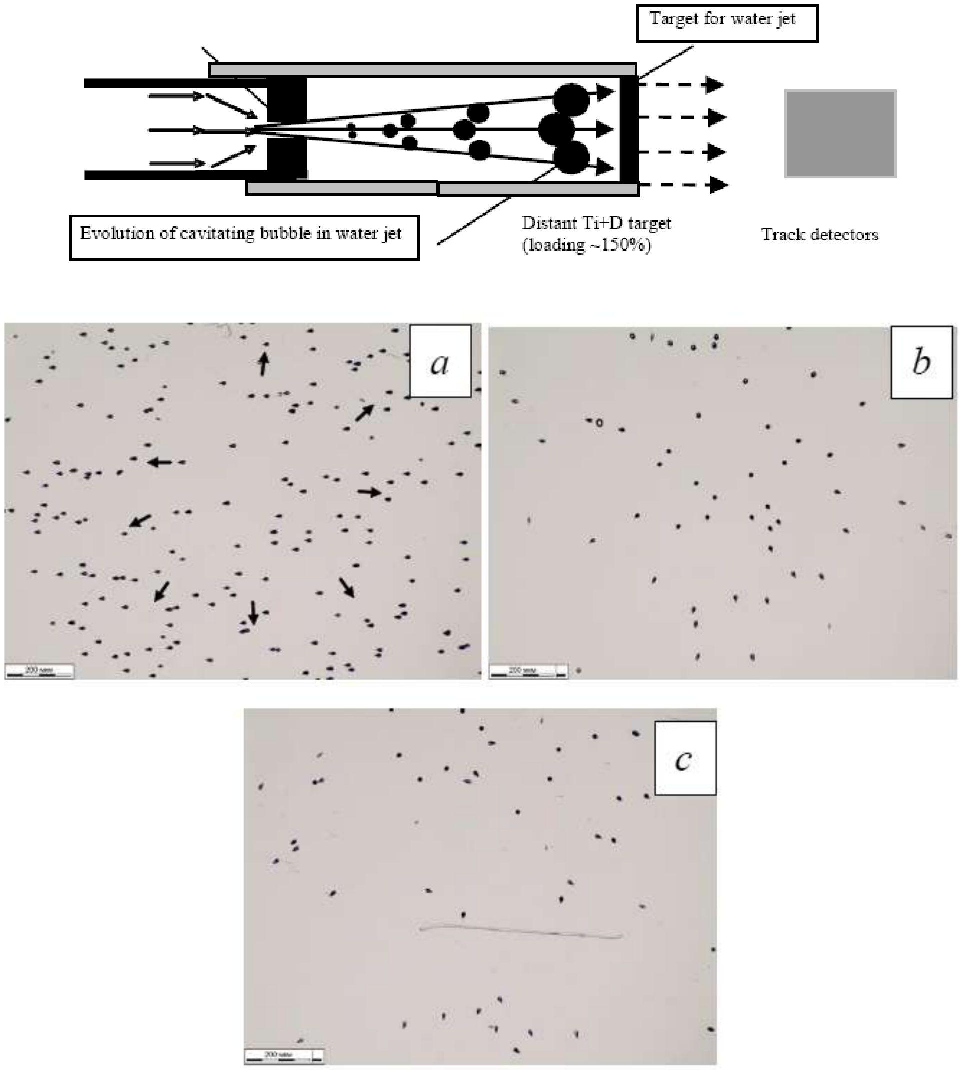


Figure 2. Experimental setup and microscopic track analysis of the spatial distribution of tracks and the direction of motion of alpha particles in samples subjected to the action of a thermal wave for 40 min when the track detector is located near the end and lateral (cylindrical) surfaces of the deuterated sample (Fig. 2a,b). (c) Corresponds to a control measurement using an alpha emitter based on a combination of three radionuclides (U^{233}, Pu^{238} and Pu^{239}).

In air and liquid, the duration of the maxivelization process $\tau \approx 10/n\langle\sigma(\nu)\nu\rangle$ is determined by the cross section $\sigma(\nu)$ of elastic scattering, the current velocity ν of the medium particles, taking into account their heating by the thermal wave and the concentration n of these particles. When the temperature and, especially, the density and composition of the air change (e.g., in the presence of water vapor), the value τ can vary over a wide range ($\tau = 10^{-7} - 10^{-8}$ s).

In the framework of the density matrix formalism, this process corresponds to the relaxation of diagonal and nondiagonal elements of the density matrix.

If we take into account the finite (non-zero) time of local thermodynamic relaxation, then the heat transfer equation with delay takes the form [1–3]

$$\frac{\partial T(x,t+\tau)}{\partial t} = G\frac{\partial^2 T(x,t)}{\partial x^2}, \tag{4}$$

where G is the coefficient of thermal diffusivity. The solution of this equation with small time τ of local temperature relaxation is superposition of colliding thermal waves [1–3]

$$T(\omega,x,t) = A_\omega \exp\left(-\kappa\frac{\cos\,\omega\tau}{\sqrt{1+\sin\,\omega\tau}}x\right)\mathrm{e}^{\{i(\omega\tau-\kappa\sqrt{1+\sin\,\omega\tau})\,x\}} + B_\omega \exp\left(\kappa\frac{\cos\,\omega\tau}{\sqrt{1+\sin\,\omega\tau}}x\right) \mathrm{e}^{\{i(\omega\tau+\kappa\sqrt{1+\sin\,\omega\tau})\,x\}}, \tag{5}$$

$$\cos\omega\tau \geq 0, \tag{6}$$

which fundamentally differ from solution of standard' heat equation without this relaxation (delay)

$$T(\omega,x,t) = A_\omega \mathrm{e}^{-\kappa x}\mathrm{e}^{i(\omega t-\kappa x)} + B_\omega \mathrm{e}^{\kappa x}\mathrm{e}^{i(\omega t+\kappa x)} \tag{7}$$

which determines the thermal waves with very strong damping coefficient $\delta \equiv \kappa = \sqrt{\omega/2G}$. For typical air parameters ($G \approx 0.15$ cm^2/s), the damping coefficient of such a wave at $\omega \approx 1$ MHz is equal $\delta \approx 1700\,\mathrm{cm}^{-1}$. When the frequency is increased to the experimental value $\omega \approx 75$ MHz, this coefficient increases to a very large value $\delta \approx 2\times10^4$ cm^{-1}, for which the mean free path does not exceed $\bar{l} = 1/\delta \approx 0.5$ m km!

For a system with relaxation the damping coefficient and phase velocities of colliding waves

$$\delta = \kappa\cos\,\omega\tau/\sqrt{1+\sin\,\omega\tau}, \quad \nu_{\mathrm{p}} = \pm\sqrt{2G\omega/1+\sin\,\omega\tau} \tag{8}$$

depend on the thermal diffusivity G, time delay τ and frequency ω of the wave [1–3]. Waves with the frequencies $\omega_{\mathrm{opt}(n)} = (n+1/2)\pi/\tau$ corresponding to the conditions $\cos\omega_{\mathrm{optr}}\tau = 0$, $|\sin\omega_n\tau| = 1$ are characterized by the real wavenumbers $k \equiv \kappa\sqrt{\omega/2G}$ and a complete lack of damping, which corresponds to $\delta \equiv 0$.

2. Stimulation of Effective Fusion Under the Action of Undamped Heat Waves on a Remote Target

We have conducted many experiments studying the action of undamped thermal waves on a distant target made of deuterated polycrystalline titanium (loading about 150%). The diameter and length of the cylindrical target were about 1 cm. It was shown for the first time that the action of such waves on the remote target leads to the generation of alpha particles in LENR reaction of dd-fusion. To conduct the alpha-track analysis, a plastic detector of polycarbonate (polyallyl diglycol) type CR-39 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. During the experiments, the detector was placed at a distance of 5 mm behind the back surface of the sample (relative to the source of the thermal wave).

Experimental setup and photos of the fragments of track detectors after its exposure for 40 min near the nuclear target are shown in Fig. 2 (a,b) – LENR experiments with the action of thermal waves, 2(c) – control experiment with similar track detector and laboratory alpha-source on the base U^{233}, Pu^{238} and Pu^{239} of and alpha-active isotopes [8]). The experiments were carried out when the track detectors were located near (∼5 mm) the end (2a) and lateral (2b) surfaces of the cylindrical target. The thermal wave acted on the front (opposite to the position of the detector) target surface.

It can be seen from Fig. 2a that the trajectory of motion of the detected particles was characterized by a central symmetry, which agrees well with the assumption of an axially symmetric expansion of the products of the nuclear reaction (the axial direction of emission of these particles corresponds to the geometry and orientation of the target).

3. Conclusion

In our opinion the possible mechanism for low energy reaction optimizing and the course of this reaction is associated with the formation of coherent correlated states [9–23] of deuterons in nonstationary microcracks (formed during the loading and migration of deuterium in the matrix of titanium or existing between individual grains of a polycrystalline titanium target) that change (e.g., when compressed and then decompressed) under the action of shock waves generated by action of thermal wave. In the process of such deformation, the coherent correlated states of the protons present in the volume of such nanocracks are formed.

When the deuteron is localized in an interatomic space typical for condensed media with a period $a = 1.5$ Å, the energy fluctuation in the coherent correlated state exceeds the value [11–23]

$$\delta E^{(\min)} \approx G^2\hbar^2/2Ma^2 \approx 50 - 100 \text{ keV} \tag{9}$$

that even at this lower threshold is much more that the temperature which is planned for future TOKAMAKS. Here $G = 1/\sqrt{1-r^2} \approx 10^4$ is the realistic coefficient of correlation efficiency, r – coefficient of correlation [11–23]. It should be noted that the realistic amplitude of this energy fluctuation can significantly exceed this minimal value.

Another method, which makes it possible to determine the increase in the probability of a nuclear reaction in the presence of such correlation, consists in modifying

$$D_{G\gg 1}(E) \approx \{D_{G=1}(e)\}^{1/G}, \tag{10}$$

the standard expression $D_{G=1}(E)$ for the Coulomb barrier transparency coefficient. This substitution was confirmed by comparing it with the result of an exact quantum-mechanical calculation [11,15,20] In this case, the effectiveness of LENR in the presence of correlation follows from a simple estimation. If the barrier transparency at low energy in usual noncorrelated state is very small (e.g. $D_{G\gg 1}(E)) \approx 10^{-100}$ then in the realistic case of a correlated state with $G = (2 - 10) \times 10^3$ it increases to a large value $D_{G=2500}(E) \approx 0.01 - 0.1$, which provides very effective nuclear fusion. What type of nuclear reaction has been observed in these experiments is a very important question, as well as what type of particles have been detected by track detectors.

It is well known that for a high deuteron energy a large and approximately the same probabilities has two reactions

$$\text{d} + \text{d} = \text{p} + \text{t} + 4.03 \text{ MeV}, \tag{11a}$$

$$\text{d} + \text{d} = \text{n} + \text{He}^3 + 3.27 \text{ MeV}. \tag{11b}$$

The cross section for these reactions at high energy is about 0.09 b. The third possible reaction

$$\mathrm{d} + \mathrm{d} = \mathrm{He}^4 + 23.8\ \mathrm{MeV}. \tag{11c}$$

at a high energy of interacting particles has a very small probability (its cross section is 10^{-26}b). A fundamentally different situation can occur in the case of formation of a correlated state of interacting particles.

In such a correlated state, the probability of reaction (11c) due to the specific use [15–18] of virtual energy (9) may exceed the probability of standard reactions (11a) and (11b). This is mainly due to the fact that in the case of the coherent correlated state, a very specific situation takes place – very large fluctuations of energy (9) can exist for a long time $\delta t \geq G\hbar/2\delta E^{(\min)}$, which opens the way to realization LENR using large virtual energy (9). This is the direct results of the modified uncertainty relation – the relation of the Schrödinger–Robertson [9–22]

$$\delta E \delta t \geq G\hbar/2. \tag{12}$$

We note that for the case of uncorrelated states with $G = 1$, such a process is impossible because of the very short lifetime of this fluctuation. For this reason, fast reactions whose duration satisfies the condition become quite real. Among such reactions, there may be a reaction (11c).

It is also important to note that the parameters and main characteristics of the alpha tracks in the experimental (2a,b) and control (2c) detectors were almost identical, which is a good confirmation of the course of the reaction with the generation of alpha particles.

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 controlled nuclear fusion at low energy.

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