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Research Article

Distant Behind-screen Action of Undamped Temperature Waves (Long-distance Propagation, X-ray Generation, LENR Stimulation)

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Abstract

The physical mechanism of the generation, features of propagation and the possible use of undamped temperature waves are considered. The process of generation of these waves is related to the possibility of reversibility of local relaxation thermodynamic processes of heat transfer. In the course of experiments, it was shown that such waves can exist only at certain frequencies, depending on the relaxation time. The possibility of energy transfer using these waves over a long distance has been investigated. It is shown that using of these waves X-ray generation is possible, and effective stimulation of nuclear fusion in a TiD target located behind a thick metal screen which is remote from the wave source. In this work is also considered a possible physical mechanism for the realization of LENR reactions connected with the formation of coherent correlated states of interacting particles under the action of these temperature waves.

Keywords: Alpha particle generation, Coherent correlated states, LENR, Undamped temperature waves, X-ray generation

1. Introduction

The problem of the realization and use of LENR, which began with simple electrolytic experiments of Fleishman and Pons, is currently being implemented in different material media and based on fundamentally different physical phenomena. One of the interesting and promising methods is the possibility of stimulation of such nuclear processes in remote objects. Previously, such problems were investigated and partially resolved only through the use of ultrashort

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and superpower laser pulses, on the basis of which attempts were made to realize inertial hot nuclear fusion. Years of research have shown that this is an incredibly expensive and very inefficient system.

In contrast to this practically dead-end system, we have proposed a fundamentally new concept for implementing remote LENR using previously unknown undamped temperature waves. Detailed analysis has shown that the base ("standard") equations of thermodynamics are incorrect in the analysis of very fast thermal processes [1–3], due to the fact that these equations do not take into account local the thermal relaxation time in the material propagation medium. Taking into account this very important circumstance has led to the possibility of the existence of undamped heat waves, which can exist only at certain high frequencies [1–3]. After conducting a series of basic studies [4–8] we created and successfully demonstrated a remote LENR system that works on the basis of these waves and this concept [9].

2. Paradox and Realization of Undamped Temperature (Thermal) Waves

Let us look at the typical logic of constructing the thermal diffusivity equation. The standard method for obtaining the thermal diffusivity equation is based on the use of two heat conduction equations. In these "standard" equations, the process of heat transfer is considered as a transition between infinitely small cells, each of which is always in equilibrium state. One of the basic equations for heat transfer is the well known Fourier law, which determines the temperature dependence of the heat flux $\vec{q}(\vec{r},t)$ and has the following form

$$\vec{q}(\vec{r},t) = -\lambda \cdot \mathrm{grad}(T(\vec{r},t)) \tag{1}$$

in any material medium with a constant heat-conduction coefficient λ.

Another basic relationship is the continuity equation

$$\rho c_v \frac{\partial T(\vec{r},t)}{\partial t} = \mathrm{div}\,\vec{q}(\vec{r},t), \tag{2}$$

which causally relates a spatial change in the energy flux to a temperature change in a medium with volume (mass) density ρ and the heat capacity c_v. From these two equations follows the equation of thermal diffusion in a material medium without heat sources

$$\rho c_v \frac{\partial T(\vec{r},t)}{\partial t} = \lambda\,\mathrm{div}\,\{\mathrm{grad}[T(\vec{r},t)]\} \tag{3}$$

The general and well known solution of this equation corresponds to two counter-propagating plane waves

$$T = A\mathrm{e}^{-\kappa x}\mathrm{e}^{\{i(\omega t-\kappa x)\}} + B\mathrm{e}^{\kappa x}\mathrm{e}^{\{i(\omega t+\kappa x)\}}. \tag{4}$$

Here $\kappa = \sqrt{\omega/2G}$ is the spatial attenuation coefficient of these waves, $G = \lambda/\rho c_v$ is the coefficient of thermal-diffusivity.

A very important feature of this solution is the equality of the attenuation coefficient κ and the wave number. It means that the temperature wave attenuates over a spatial interval equal to several wavelengths.

It was shown in our works (e.g. [1–3]) that the "standard" heat conduction equations (1)–(3) of classical thermodynamics are incorrect at the analysis of very fast thermal processes. This is due to the fact that these equations do not take into account the final (non-zero) local thermal relaxation time τ in the material propagation medium.

Let us consider in more detail the two initial equations. The first of them is quite logical and determines the energy flow based on the spatial distribution of the temperature of the medium. In this ratio, a non-uniform temperature distribution produces an instantaneous value of the heat flux. In contrast, the second equation (continuity equation) contains an internal contradiction, since it follows that the temperature change is determined by the magnitude of the heat flux at the same time *t*. In the general case, this is an incorrect assumption, since the very concept of "temperature" corresponds to a locally equilibrium state of the system, the implementation of which requires a certain time – the time of thermal relaxation.

Obviously, if we consider processes with a slow change in temperature, then the relaxation process is insignificant. But if the temperature changes rapidly, then such an assumption (ignoring the final relaxation time) can lead to very significant errors.

The thermal relaxation time depends completely on the type of material medium and the nature of the interaction of particles in it. The shortest relaxation time corresponds to metals in which it does not exceed $\tau \approx 10-100$ fs. In water, it is determined by the quantity $\tau \approx 1-10$ ps, and in gas it can be calculated by the simple formula $\tau \approx 10/n\langle\sigma(\nu)v\rangle$, in which $\sigma(\nu)$ is a scattering cross section of the molecules, n is the concentration of molecules, v is the speed of molecules. In air under normal conditions (atmospheric pressure and room temperature), the relaxation time is equal to $\tau \approx 10$ ns and may change with changes in humidity and impurities of other gases.

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 temperature $T(\vec{r}, t+\tau)$ over time

$$\rho c_v \frac{\partial T(\vec{r}, t+\tau)}{\partial t} = -\text{div}\, \vec{q}(\vec{r}, t), \tag{5a}$$

or a change in the flow of thermal energy $\vec{q}(\vec{r}, t+\tau)$ in space

$$\text{div}\, \vec{q}(\vec{r}, t+\tau) = -\rho c_v \frac{\partial T(\vec{r}, t)}{\partial t}. \tag{5b}$$

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 Eqs. (1) and (5) leads to a modified equation of thermal conductivity

$$\frac{\partial T(\vec{r}, t\pm\tau)}{\partial t} = G\nabla^2 T(\vec{r}, t), \tag{6}$$

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

If we use the general form of the wave solution of this equation

$$T(\vec{r}, t) = A\mathrm{e}^{i(\omega t + \vec{g}\vec{r})} + B\mathrm{e}^{i(\omega t - \vec{g}\vec{r})},$$

then in 1D case we arrive at the system of dispersion equations for the real and imaginary parts of wave number $g = g' + ig'' \equiv k + i\delta$

$$g^2 = -i(\omega/G)\,\mathrm{e}^{\pm i\omega\tau}, \tag{7}$$

$$(g')^2 - (g'')^2 = \pm(\omega/G)\sin\omega\tau, \quad g'g'' = -(\omega/2G)\cos\omega\tau.$$

From these equations follow expressions for the actual wave number k and coefficient of attenuation δ of the temperature wave

$$k = \kappa|\cos(\omega\tau/2) \pm \sin(\omega\tau/2)|, \quad (8a)$$

$$\delta = \kappa|\cos(\omega\tau/2) \mp \sin(\omega\tau/2)|, \quad \kappa = \sqrt{\omega/2G}. \quad (8b)$$

The final solution of the modified equation of thermal conductivity (6) corresponds to two oncoming plane waves and takes the form

$$\begin{aligned} T(\omega,x,t) &= A_\omega \mathrm{e}^{-\delta x}\mathrm{e}^{i(\omega t-k'x)} + B_\omega \mathrm{e}^{\delta x}\mathrm{e}^{i(\omega t+kx)} \\ &\equiv A_\omega \exp\left(-\kappa\left|\cos\frac{\omega\tau}{2} \pm \sin\frac{\omega\tau}{2}\right|x\right)\exp\left\{i\left(\omega t-\kappa\left|\cos\frac{\omega\tau}{2} \mp \sin\frac{\omega\tau}{2}\right|x\right)\right\} \\ &+ B_\omega \exp\left(\kappa\left|\cos\frac{\omega\tau}{2} \pm \sin\frac{\omega\tau}{2}\right|x\right)\exp\left\{i\left(\omega t+\kappa\left|\cos\frac{\omega\tau}{2} \mp \sin\frac{\omega\tau}{2}\right|x\right)\right\}. \end{aligned} \quad (9)$$

In the case of instant thermal relaxation (at $\tau = 0$), the resulting Eq. (9) corresponds to the "standard" solution (4) of the classical equation of thermal diffusivity (3) with a very strong spatial attenuation of the temperature waves.

From expressions (8) and (9) it follows that the coefficient of attenuation and actual wave number of the temperature wave in the considered arbitrary material medium depend on the frequency of this wave and thermodynamic relaxation time. The most important conclusion from these results is the following – when the condition $\omega_n = (n + 1/2)\pi/\tau$, $n = 0, 1, 2, \ldots$ is satisfied, the attenuation coefficient δ becomes equal to zero, which corresponds to non-dissipative propagation of the temperature wave. For air, the minimum frequency of such wave ω_0 depends on pressure, humidity and average equilibrium temperature and lies in the interval $\omega_0 \approx 75 - 85$ MHz. This fundamental result was first predicted in the works [1–3], and was experimentally observed in [4–7].

The physical mechanism for this unique regime of dissipation-free propagation of a temperature (thermal) wave is the mutual co-phasing and reversibility of two alternative processes - variation of energy flow $\vec{q}(\vec{r}, t)$ (1) due to the variation of temperature $T(\vec{r}, t)$ and non-stationary change of temperature (5) due to the influx (outflow) of energy flow $\vec{q}(\vec{r}, t)$ into a given microvolume.

The generation of such waves can be associated with different processes. The first of them occurs when using a modulated heating source (for example, a laser beam with a modulation frequency equal to one of the frequencies $\omega_n = (2n + 1/2)\pi/\tau$ of possible undamped waves). Another, simpler method involves the use of pulsed heat sources, if the duration Δt of each of these pulses should be quite short and $\Delta t \leq \tau = (2n+1/2)\pi/\omega_n$. In this case, undamped temperature waves will be present in the Fourier spectrum of the thermal pulse.

In our studies, we used short acoustic pulses as sources of pulsed heating. These pulses were generated in the volume of the cavitation chamber by the cavitation of water jet. The pulses generated during cavitation formed very short shock waves in the volume of the outlet wall of the cavitation chamber, which generated very short thermal pulses at the outer boundary of this wall. The action of these pulses leads to at least two important processes.

The first one is associated with the ionization and excitation of atoms on the outer surface, which leads to generation of X-ray radiation in the space near this surface [5]. The other process is associated with the generation of the undamped temperature waves discussed above that propagate in air.

Earlier we investigated the process of the excitation of undamped temperature waves and their detection at a long distance without an additional screen [5–8]. The fragment of the spectrum of these waves generated by cavitation of water jet and registered at $L = 20$ cm from the area of its excitation (the outer wall of the cavitation chamber) is presented in Fig. 1.

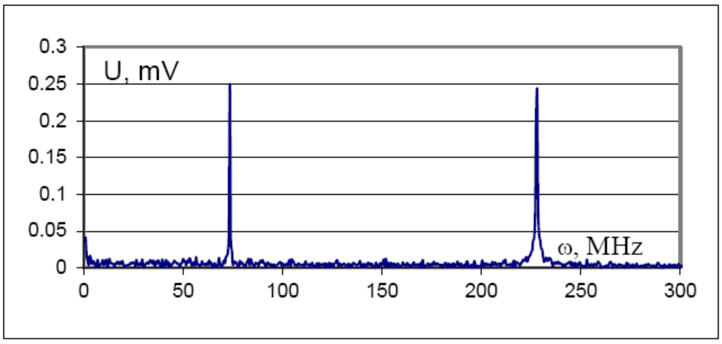

Figure 1. The low-frequency part of the spectrum of temperature waves recorded at a distance of 20 cm from the outer surface of cavitation chamber wall.

The maximum frequency of these waves at such a distance corresponded to about 2000 MHz. The specific values of these frequencies corresponded very well with the formula $\omega_n = (2n + 1/2)\pi/\tau$.

3. Effective Behind Screen X-ray Generation and Nuclear Fusion in Remote Targets

The current paper presents the results of experiments with undamped temperature waves in the presence of an additional thick screen located between the region of wave formation and a distant TiD target. These experiments were carried out with the active participation of Hagelstein. The experimental setup is shown in Fig. 2.

It should be noted that the presence of an additional thick screen significantly affects the propagation of these waves. The process of reflection of these waves from any boundary (e.g., air–metal) was theoretically considered in [7,8]. It was shown that the transmission coefficient depends on thermophysical parameters of both media, as well as on the quality of the input surface (small for a polished surface and large for inhomogeneous (unpolished) surface). The reflection coefficient of the temperature wave from the sharp air–metal boundary is determined by the formula

$$R_\omega = 1 - \frac{\lambda_{\rm air}}{\lambda_{\rm metal}}\sqrt{\frac{2G_{\rm metal}}{G_{\rm air}}} = 1 - \sqrt{\frac{2(\lambda\rho c_V)_{\rm air}}{(\lambda\rho c_V)_{\rm metal}}} \approx 1. \tag{10}$$

In contrast, in the case of a boundary with smoothly changing thermodynamic parameters, an enlightenment effect and an increase in the transmission coefficient $1 - R_\omega$ takes place. For an unpolished surface, the reflection coefficient decreases due to the presence of a pass-through (enlightening) layer, the thickness of which should be comparable with the length of this heat wave in air (1–2 μm). This effect is similar to quasiclassical enlightenment of the boundary in quantum mechanics. It is obvious that an increase in the coefficient of transmission of the initial temperature wave into the volume of the remote screen leads to the formation of a more intense acoustic wave in this screen and, as a result, to a higher amplitude of both the secondary temperature wave and the X-ray radiation in the area behind the screen.

At the beginning of the experiments, we investigated the features of X-ray generation in this area. Figure 3 shows two possible orientations of the remote steel screen relative to the cavitation chamber, as well as X-ray images and the type of the recorded signal (temperature wave with frequency about 83 MHz) at these orientations.

The wave was recorded by a piezoelectric acoustic detector. The process of such registration is due to the fact that when a wave hits the surface of a piezocrystal, it periodically heats and cools, which causes elastic vibrations in

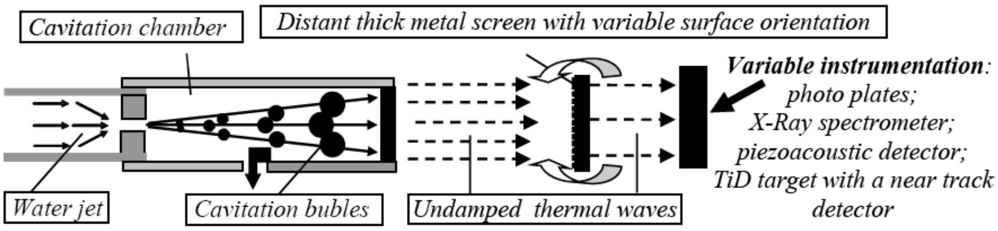

Figure 2. Scheme of experiments on the measurement of undamped temperature waves, the study of X-ray radiation, as well as the stimulation of nuclear fusion at a great distance from the source of the waves in the region behind a thick steel screen.

the detector. A slight difference between this frequency and the frequency of 75 MHz of a similar wave shown in Fig. 1 is due to the fact that these experiments were carried out at different times and the frequencies are different due to different air conditions (humidity, pressure P and equilibrium temperature T), which significantly affects the relaxation time $\tau \sim 1/P\sqrt{T}$. The frequency of this X-ray radiation corresponded to 1.5 keV. The X-ray spectrum was completely similar to our previous results for targets made of Fe (Fig. 4) [5–8].

From these data, it can be seen that the results of theoretical analysis coincide with the experimental data – the X-ray radiation and the temperature wave behind the screen with an input matted (unpolished) surface (the results presented in the left column in Fig. 3) are more intense than with the opposite screen orientation (right column for polished input surface).

The last (main) part of the research relates to the stimulation of nuclear fusion in a remote (off-screen) target by stimulation with temperature waves. In this case instead of X-ray and piezoacoustic detectors, a TiD target (length, 10 mm, diameter, 7 mm, saturation ~150%) was installed at a distance about 5–7 mm together with a nearby track detector.

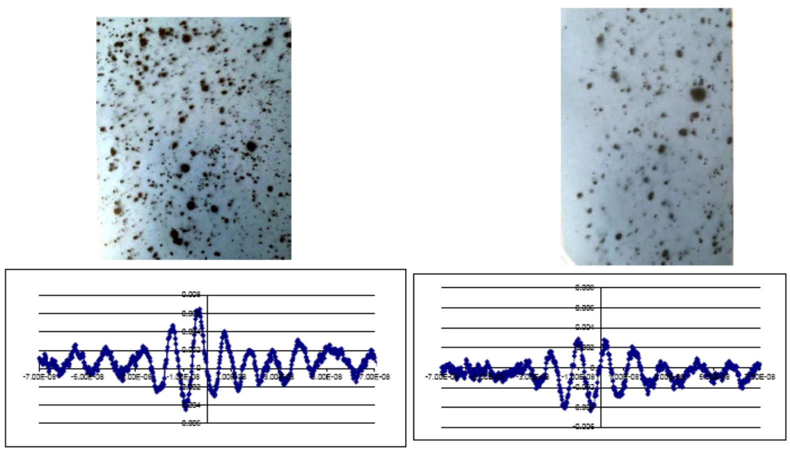

Figure 3. Registration of undamped temperature waves and X-ray behind thick steel screen at different screen surface orientation: the left column – the unpolished surface is directed to the source of temperature waves (cavitation chamber), the right column – the polished surface of the screen is directed to the source.

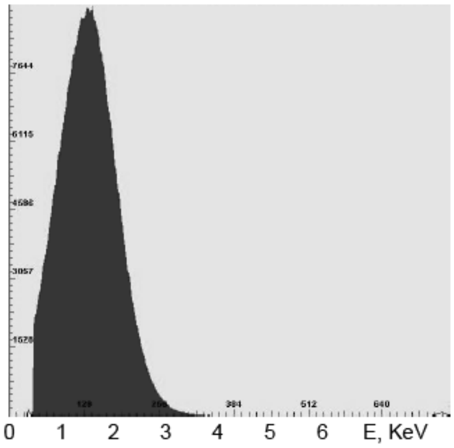

Figure 4. Spectrum of X-ray radiation recorded behind the back of a screen (plate) made of Fe.

For carrying out the alpha-track analysis, a plastic detector made of polycarbonate of the CR-39 type with a density of 1.3 g / cm^3 was used. The thickness of the "TASTRAK®" detector 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 (about 1 h).

Figure 5 shows the general view of the track detector, on which the areas of track analysis are highlighted, as well as the location of tracks in some of these areas. It is seen that during the process of irradiating the target with a temperature wave, very significant nuclear reactions took place in it, the products of which are alpha particles. Effective registration of alpha tracks in the target under the influence of temperature waves indicates the possibility of stimulation of nuclear fusion reactions

$$\mathrm{d} + \mathrm{d} = \mathrm{He}^3 + \mathrm{n}, \quad \mathrm{d} + \mathrm{d} = \mathrm{He}^4 \tag{11}$$

in the target located behind a thick steel screen. The mechanism of stimulation of these LENR by action of temperate waves is may be connected with different processes. According to our analysis these LENR are associated with the influence of temperature waves on the dynamic structure of TiD target and, possible, on formation of coherent correlated states [10–21] of interacting particles during such structural and topological processes in the target lattice.

Such influence can take place in several stages. Initially, during the interaction of a temperature wave with a distant target, a shock waves is excited in the target volume, and then this shock wave affects the state of deuterium localized in the volume of nanocracks in the target or in the space between titanium atoms in the lattice. The modulation of the parameters of these potential wells at the nanoscale, as shown by a direct analysis, conducted in our works [12–21], leads to the formation of a coherent correlated state of deuterons. This process can be greatly enhanced. if we take into account the additional influence of high-frequency phonons that can form during such reactions on the base of phonon-nuclear coupling mechanism of LENR (e.g. [22,23]).

When the deuteron is localized in an interatomic space typical for any condensed media with a period $a \approx 2A$, the energy fluctuation in the coherent correlated state exceeds the value

$$\delta E = G^2\hbar^2/8M(\delta x)^2 \approx 30 - 50\,\mathrm{keV}, \tag{12}$$

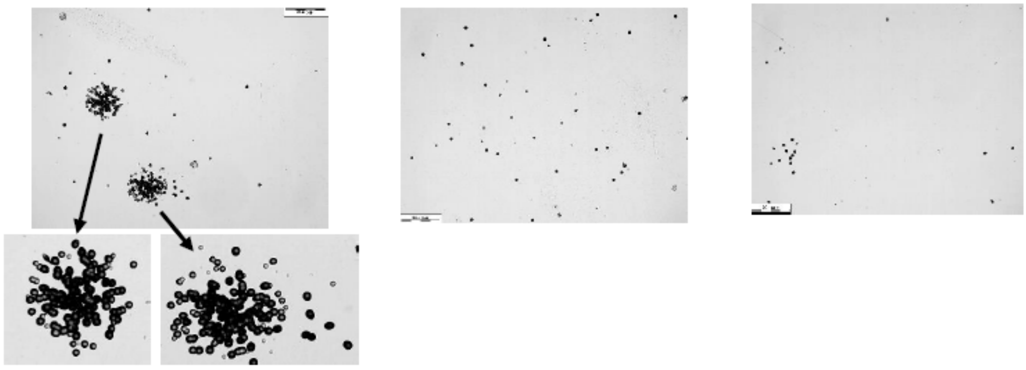

Figure 5. The general view of track detector and tracks at the areas 5, 9, 4 (*from left to right*).

that is much more than the temperature in a "standard" TOKAMAK.

Here

$$\delta x \approx a/2 \approx 1A, \quad G \equiv 1/\sqrt{1-r^2} \approx 10^4$$

is the realistic coefficient of correlation efficiency, r – coefficient of correlation [12–20].

Such a very large increase in particle energy fluctuation δE during the formation of a coherent correlated state is directly related to the Schrödinger–Robertson uncertainty relation [10,11] and is connected with the further development of the method of such states as applied to problems of quantum mechanics and nuclear physics [12–21].

It is very important that in the coherent correlated state formed by such a modulation of the potential well, not only energy fluctuations δE will increase very significantly (by many orders of magnitude), but very significantly increase the duration δt of these fluctuations as compared to the "usual" Heisenberg uncertainty relation [19]. It is obvious that without such increase of δt, no reaction would be possible.

It should also be noted. that if all the conditions for LENR realization related to the formation of correlated deuteron states in the lattice are fulfilled, the probability of a neutron-free reaction d + d = He^4 (11), which is very small for "hot" fusion, can very significantly increase and such reaction can become the main one for LENR.

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