Coherent correlated states of interacting particles – the possible key to paradoxes and features of LENR

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In this article, the universal mechanism of optimization of low energy nuclear reactions (LENR) on the basis of coherent correlated states (CCS) of interacting particles is discussed. Formation of these states is the result of special nonstationary low energy action to parameters of potential well containing interacting particles. It was shown that in real nuclear-physical systems usage of CCS leads to sharp growth (up to 10^{30}–10^{100} and more) of Coulomb barrier penetrability at very low energy of interacting particles. Several successful LENR experiments based on CCS are discussed.

Keywords: Coherent correlated states, Coulomb potential barrier, low energy nuclear reaction, tunnelling effect.

Introduction

Among the well-known low energy nuclear reaction (LENR) problems, the most important one is connected with overcoming the Coulomb potential barrier during interaction of low energy charged particles. 'Standard' approach of nuclear physics leads to very small probability of the tunnelling effect. Other problems (e.g. sharp change in the ratio of reaction channels' probability, suppression of neutron channel, abnormal sensitivity to variable environment, etc.) are directly connected with the 'barrier problem'. An additional problem is connected with the well-known paradox of 'standard' nuclear physics – for high probability of nuclear reactions we need high energy of charged particles, but the results of LENR are directly connected with low energy of these particles. On the other hand, in majority of LENR experiments success was associated with those experiments in which the perturbation stimulating the nuclear transformations was non-stationary or corresponded to a transient mode. Such non-stationarity can be global (for all objects) or local (for different small parts of an object).

In earlier works[1–7] the general and sufficiently universal mechanism of LENR optimization on the base of coherent correlated states (CCS) of interacting particles was considered. This mechanism ensures the large probability of LENR and can be applied with the same efficiency to different experiments. Below we briefly consider the possible methods of CCS formation and its application to real experiments (including LENR in non-stationary cracks and LENR at external weak controlled laser action).

It is important that the CCS method can unite both paradoxical conditions considered above – the barrier is overcome with high probability during fluctuation with virtual very high energy and the reaction proceeds as real (stationary) low energy.

The general basis of CCS formation in quantum-mechanical systems

Atomic and nuclear physics uses the well-known Heisenberg uncertainty relation for the coordinate and momentum (1927) and its generalization was made in 1929 by Robertson for dynamical variables A and B

$$\sigma_q \sigma_p \geq \hbar^2/4, \tag{1}$$

$$\sigma_A \sigma_B \geq |\langle[\hat{A}\hat{B}]\rangle|^2/4,$$

$$\sigma_C = \langle(\Delta\hat{C})^2\rangle \equiv (\delta C)^2, \quad \Delta\hat{C} = \hat{C} - \langle C\rangle, \tag{2}$$

In 1930, Schrödinger[8] and Robertson[9] generalized eq. (2) and derived a more universal inequality called the Schrödinger–Robertson uncertainty relation[10,11]

$$\sigma_A \sigma_B \geq |\langle[\hat{A}\hat{B}]\rangle|^2/4(1-r^2),$$

$$r = \sigma_{AB}/\sqrt{\sigma_A \sigma_B},$$

$$\sigma_{AB} = (\langle\hat{A}\hat{B} + \hat{B}\hat{A}\rangle)/2 - \langle A\rangle\langle B\rangle, \quad 0 \leq |r| \leq 1, \tag{3}$$

where r is the correlation coefficient between quantities A and B. For coordinate and momentum these expressions have the form

$$\delta q \delta p_q \geq \hbar/2\sqrt{1-r^2},$$

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$$r(t) = \langle q\hat{p}_q + \hat{p}_q q\rangle / 2\delta q \delta p_q,$$

$$\delta q \equiv \sqrt{\langle q^2\rangle}, \quad \delta p_q \equiv \sqrt{\langle p_q^2\rangle}. \tag{4}$$

The effect of correlation at $r \to 1$ is more clearly characterized by the quantity $G = (1 - r^2)^{-1/2}$, which varies in the interval $0 \le G < \infty$ and can be called the correlation efficiency factor. Formally, the change of r in eqs (1)–(4) can be taken into account by the formal substitution

$$\hbar \to \hbar^* \equiv \hbar / \sqrt{1 - r^2} \equiv G\hbar. \tag{5}$$

It was shown[1–7] that the very low barrier transparency (tunnelling probability) for uncorrelated state

$$D_0 \equiv D_{r=0} = e^{-2W(E,\hbar)} \ll 1,$$

$$W(E,\hbar) = \frac{1}{\hbar} \int_R^{R+L(E)} \sqrt{2M\{V(q) - E\}}\, \mathrm{d}q, \tag{6}$$

which corresponds to the conditions $E \ll V_{\max}$, $W(E) \gg 1$ for formation of a strongly correlated superposition particle state can increase to a very large value $D_{|r|\to 1} \to 1$ at the same low energy $E \ll V_{\max}$. In eq. (6), R is the radius of the nucleus, L the barrier width and M is the reduced particle mass.

In a simplified form, this effect can be taken into account by the formal (not quite correct) substitutions

$$W(E,\hbar) \to W(E,\hbar^*) = W(E,\hbar)\sqrt{1 - r^2}, \tag{7}$$

in eq. (6). The changed tunnelling probability has the form

$$D_{r\neq 0} \approx (D_{r=0})^{\sqrt{1-r^2}}, \tag{8}$$

from which it follows that

$$D_{|r|\to 1} \to 1 \text{ even if } E \ll V_{\max}. \tag{9}$$

In this case, the potential barrier transparency increases by a factor of

$$(D_{r=0})^{\sqrt{1-r^2}} / D_{r=0} = 1/D_{r=0}^{1-\sqrt{1-r^2}} \gg 1, \tag{10}$$

which is close order-of-magnitude to the result of the exact calculation of potential barrier transparency using rigorous quantum-mechanical methods[1]. Although these estimates with the substitution $\hbar \to \hbar^*$ (eq. (5)) are not quite correct, are purely illustrative, and must be justified every time, they clearly demonstrate a high efficiency of CCS used for solving the applied tunnelling-related problems in the case of high potential barrier $V(q)$ and low particle energy $E \ll V_{\max}$.

Figure 1 *a* shows the results of precise quantum-mechanical calculation (eq. (1)) of the averaged (by the period $T_0 = 2\pi/\omega_0$) normalized distribution of quantum-mechanical probability density $\bar{D}(x = 10x_0, r) \equiv \langle D(x = 10x_0, t, r)\rangle_t$ of a particle in the region with coordinate $x = 10x_0$ deep under the potential barrier $V(x) = (\hbar\omega_0/2)(x/x_0)^2$ and approximation (eq. (8)) for the same barrier at different r values. Here $x_0 = \sqrt{\hbar/M\omega_0}$ is 'standard' parameter of parabolic potential.

From the presented data it follows that eqs (7) and (8) are the sufficiently close approximations of real change of very small tunneling probability $\bar{D}(x,r)$ and the relative error of such approximation $|\ln \bar{D}(x,r) - \ln D_{r\neq 0}| / |\ln \bar{D}(x,r)| \ll 1$ is small, if $\bar{D}(x,r) \ll 1$. Such approximation can be used for simple estimations in the case of very small tunnelling probabilities. For exact calculation of tunneling probability in the presence of CCS it is necessary to use rigorous methods of quantum mechanics (e.g. Dodonov and Dodonov[12]).

The physical reason for the increase in the probability of tunnelling effect is related to the fact that the formation of CCS leads to the cophasing and coherent summation of all fluctuations of the momentum for various eigenstates forming the superpositional correlated states. This leads to great dispersion of the momentum of CCS, large fluctuations of kinetic energy of the particle in the potential well and increase in the potential barrier penetrability.

CCS can be formed in various quantum systems. The most easy way to form such a state is when the particle is in a non-stationary parabolic potential well[1–7,10,11]. In this case $r(t)$ is the result of the solution of Schrödinger

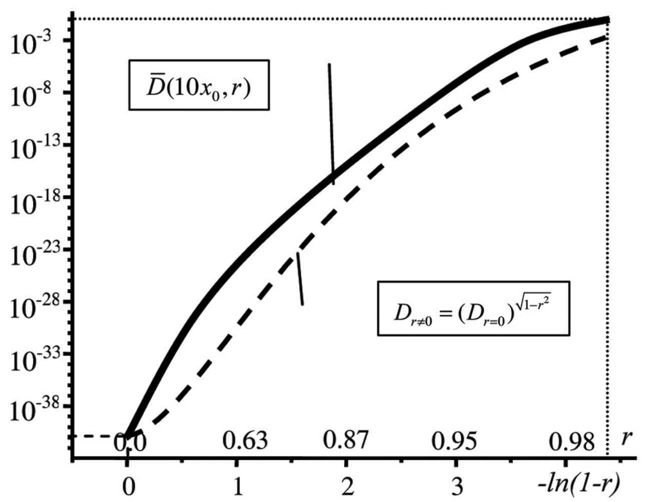

Figure 1. Averaged precise quantum mechanical density of probability (tunnelling probability) $\bar{D}(10x_0, r)$ versus correlation coefficient r in sub-barrier region with coordinate $x = 10x_0$ (ref. 1). Broken line is the result of approximation (eq. (8)).

equation and can be obtained by analysing the complex equation of motion for classical harmonic oscillator with a variable frequency that in dimensionless form ($\omega_0 t \to t$, $x/x_0 \to \varepsilon$) is

$$\frac{d^2\varepsilon}{dt^2} + \tilde{\omega}^2(t)\varepsilon = 0, \ \ \varepsilon(0) = 1, \ \ \left.\frac{d\varepsilon}{dt}\right|_0 = i,$$

$$\tilde{\omega}(0) = 1, \ \ \tilde{\omega}(t) = \omega(t)/\omega_0. \tag{11}$$

Here

$$\varepsilon(t) = e^{\varphi(t)}, \ \ \varphi(t) = \alpha(t) + i\beta(t), \tag{12}$$

is the complex amplitude of the harmonic operator normalized to $x_0 = \sqrt{\hbar/M\omega_0}$.

The correlation coefficient is defined by the expressions[1–7,10,11]

$$r = \mathrm{Re}\{\varepsilon^* d\varepsilon/dt\}/|\varepsilon^* d\varepsilon/dt|, \ \ r^2 = 1 - 1/|\varepsilon^* d\varepsilon/dt|^2. \tag{13}$$

The evolution of the same time-dependent oscillator excited in the presence of damping (damping coefficient γ) and the stationary delta-correlated stochastic force $F(t)$ (in the dimensionless form $f(t) = F(t)/\sqrt{\hbar M\omega_0^3}$) which corresponds to averaging over time and stochastic force with the intensity S is described by the following system of equations[3,5]

$$dm_{00}/dt = m_{01} + m_{01}^*, \tag{14}$$

$$dm_{01}/dt = m_{11} - 2\gamma m_{01} - \omega^2(t)m_{00}, \tag{15}$$

$$dm_{11}/dt = -4\gamma m_{11} - \omega^2(t)\{m_{01} + m_{01}^*\} + 2S, \tag{16}$$

$$\langle f(t)\rangle = 0, \ \ \langle f(t)f(t+\tau)\rangle = 2S\delta(\tau), \tag{17}$$

for the corresponding moments

$$m_{00} = \langle\varepsilon^*\varepsilon\rangle, \ \ m_{01} = \langle\varepsilon^*(d\varepsilon/dt)\rangle,$$

$$m_{10} = m_{01}^* = \langle(d\varepsilon^*/dt)\varepsilon\rangle, \ \ m_{11} = \langle(d\varepsilon^*/dt)(d\varepsilon/dt)\rangle.$$

The initial conditions for the moments

$$m_{00}(0) = 1, \ \ m_{01}(0) = i, \ \ m_{01}^*(0) = -i, \ \ m_{11}(0) = 1, \tag{18}$$

follow from initial conditions i.e. eq. (11) for ε and $d\varepsilon/dt$. The solutions of the system of equations above, i.e. eqs (14)–(17) make it possible to determine the correlation coefficient[3,5] in the presence of damping and stochastic force as

$$r(t) = (m_{01} + m_{10})/2\sqrt{m_{00}m_{11}} \equiv (m_{01} + m_{01}^*)/2\sqrt{m_{00}m_{11}}. \tag{19}$$

Formation of CCS on deformation of the potential well

Formation of CCS at limited increase in the width of the potential well

We find the solution of eqs (11) and (12) at a limited (in the interval from L_0 to $L_{max} \equiv L_0(1 + g^{(+)})$ increase in the width of the parabolic well

$$L(t) = L_0(1 + g^{(+)})/(1 + g^{(+)}e^{-t/T}),$$

$$L_0 = \sqrt{8V_{max}/M(\omega_0^{(+)})^2}, \ \ g^{(+)} = (L_{max}/L_0 - 1), \tag{20}$$

which corresponds to a decrease in the oscillator frequency

$$\omega(t) = \omega_0^{(+)}(1 + g^{(+)}e^{-t/T})/(1 + g^{(+)}), \tag{21}$$

from $\omega_{max} = \omega_0^{(+)}$ to $\omega_{min} \equiv \omega(\to\infty) = \omega_0^{(+)}/(1 + g^{(+)})$.

Figure 2 shows the time dependence of the correlation coefficient $r(t)$ with a monotonic increase in the width of the potential well in the range $L_{max}/L_0 = 11–10^3$ at various

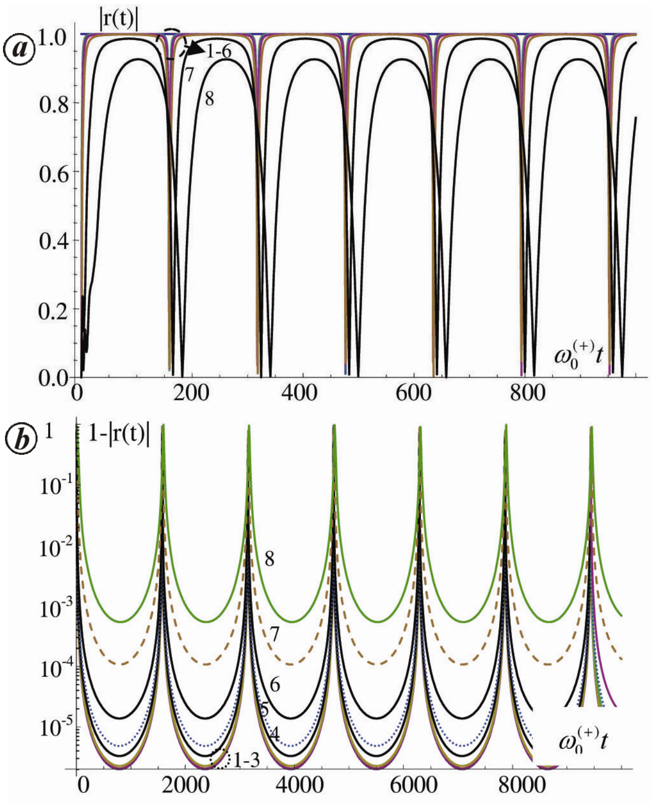

Figure 2. Time dependence of the correlation coefficient in expanding well at $g^{(+)} = 10$, $L_{max}/L_0 = 11$ (***a***, linear scale) and $g^{(+)} \approx L_{max}/L_0 = 10^3$ (***b***, logarithmic scale) and $T\omega_0^{(+)} = 0.1, 0.25, 0.5, 1.0, 1.33, 2, 5, 10$ (see graphics 1–8).

characteristic durations $T = (10^{-1}/\omega_0^{(+)}) \cdots (10/\omega_0^{(+)})$ of variation in the width. The change in the size of the well L_{max}/L_0 corresponds to the range $\omega_0^{(+)}/\omega_{min} = 11–10^3$ of variation of the oscillation frequency of the particle in the well.

According to the results, expansion of the L_{max}/L_0 interval is accompanied by a significant increase in the amplitude of oscillations of the correlation coefficient in the direction of the maximum possible value $|r|_{max} \to 1$. Narrow dips in the $|r(t)|$ plot are due to the fast interference transitions between values $r(t)$ and $-r(t)$ with an increase in time. The width of these dips vanishes rapidly with the increase $|r(t)|_{max} \to 1$. Another significant factor of increase in $|r(t)|_{max}$ is the use of the minimum time T of deformation of the well.

In particular, at a comparatively small change in the size of the well (at $L_{max}/L_0 = 11$ and $T = (0.1–1)/\omega_0^{(+)}$, the maximum correlation coefficient $|r|_{max}$ and the maximum correlation efficiency factor G_{max} are ≈ 0.98 and 5 respectively. With an increase in this interval to $L_{max}/L_0 = 10^3$ (this corresponds, for example, to an increase in the width of a micro-crack from the 'bare' value $L_0 \approx$ 5–10 A to $L_{max} \approx 0.5–1$ μm), $1 - |r|_{max} \approx 2 \times 10^{-7}$ and $G_{max} \approx 500$. The hypothetical case of larger change $L_{max}/L_0 = 10^5$ corresponds to the CCS with almost ideal characteristics $1 - |r|_{max} \approx 10^{-9}$ and $G_{max} \approx 20,000$.

Such a process of CCS formation with monotonic decrease in the harmonic oscillator frequency $\omega(t)$ can be connected with different physical phenomena (e.g. with local non-stationary processes of formation of micro-cracks in metal hydrides at hydrogen loading). Duration of typical decrease in micro-crack width at hydrogen loading from initial value $L(0) \approx 5$ A (for which $\omega_0 \approx 10^{12}$ Hz) to the final width of a typical micro-crack $L(\Delta t) \approx 0.1$ mkm (for which $\omega(\Delta t) \approx \omega(0)L(0)/L(\Delta t) \approx 5 \times 10^9$ Hz) equals to $\Delta t \approx L(\Delta t)/v_p \approx 1.6 \times 10^{-11}$ s. Here $v_p \approx 6 \times 10^5$ cm/s is the speed of sound in metal. Using such parameters and approximation (eq. (21)) we have $T \approx \Delta t/\ln\{\omega(0)/\omega(\Delta t)\} \approx 3 \times 10^{-12}$ s or $T \approx 3/\omega_0$, that is in a good agreement with the data presented in Figure 2 and leads to the fast formation of CCS. Formation of CCS for hydrogen ions in the volume of growing micro-cracks leads to a large increase in the nuclear interaction with participation between protons (deuterons) and protons with nuclei of matrix of metal hydride (e.g. Ni, Pd, Li). A similar process probably takes place in Rossi experiments[13]. Energy release in these experiments can be connected with the cascade of reactions

$$Li^7 + p = Be^8 \to 2He^4 + \Delta Q, \quad (22)$$

$$Ni^A + p = Cu^{A+1} + \Delta Q_{Ni+p}, \quad (23)$$

$$Cu^{A+1} + \beta^- = Ni^{A+1} + \nu + \Delta Q_{Cu+\beta^-}, \quad (24)$$

$$Cu^{A+1} = Ni^{A+1} + \beta^+ + \nu + \Delta Q_{Cu \to Ni+\beta^+}, \quad (25)$$

the first two of which are stimulated by CCS formation during growth of micro-cracks in Ni at hydrogen loading[5].

CCS at a limited monotonic decrease in the width of the potential well

The reduction in the width of the potential well in which the particle is located is an alternative regime of the formation of CCS owing to the variation of the parameters of the potential well[5]. We seek the solution of the system of equations, eqs (11) and (12) at a limited decrease in the width of the potential well:

$$L(t) = L_0(1 + g^{(-)}e^{-t/T})/(1 + g^{(-)}),$$

$$L_0 = \sqrt{8V_{max}/M(\omega_0^{(-)})^2}, \; g^{(-)} = (L_0/L_{min} - 1). \quad (26)$$

from L_0 to $L_{min} \equiv L_0/(1 + g^{(-)})$, which corresponds to an increase in oscillator frequency

$$\omega(t) = \omega_0^{(-)}(1 + g^{(-)})/(1 + g^{(-)}e^{-t/T}), \quad (27)$$

from $\omega(0) = \omega_0^{(-)}$ to $\omega_{max} \equiv \omega_0^{(-)}(1 + g^{(-)})$.

The calculations for two coefficients $g^{(-)} = 10, 10^3$, which correspond to a similar decrease in the size of the parabolic well and an increase in the frequency of oscillations inside this well, as well as for various characteristic durations T of contraction of the well, are shown in Figure 3.

According to these results, the maximum correlation coefficient, as in the case of the expanding well, increases with an increase in the contraction interval L_{max}/L_0 and with a decrease in the contraction time T. In particular, at a comparatively small contraction of the well in the interval $L_0/L_{min} = 11$ at $T\omega_0^{(-)} = 10^{-3}–10^{-2}$, the maximum correlation coefficient and maximum correlation efficiency factor are $|r|_{max} \approx 0.98$ and $G_{max} \approx 5$ respectively. With the expansion of the contraction interval to $L_0/L_{min} = 10^3$ owing, for example, to a decrease in the width of the micro-crack from 1 μm to $L_0/L_{min} = 10^3$, $1 - |r|_{max} \approx 10^{-5}$, $G_{max} \approx 220$ at $T = 0.001/\omega_0^{(-)}$ and $1 - |r|_{max} \approx 10^{-4}$, $G_{max} \approx 70$ at $T = 0.005/\omega_0^{(-)}$.

At the wider contraction interval L_0/L_{min} and at the corresponding decrease in the duration T of the contraction process, the quantities $|r|_{max}$ and G_{max} increase efficiently as in the case of expansion of the well. Such mechanism of CCS formation can occur in different systems with relaxation (e.g. during 'healing' of crystal nano-cracks or in molecular biological nano-wells during growth of microbiological systems[14]).

CCS formation at periodical (harmonic) disturbance of harmonic oscillator

Alternative method of controlled CCS formation takes place for a harmonic law of change in $\omega(t)$ in a limited range of the oscillator frequency

$$\omega(t) = \omega_0(1 + g\cos\Omega t), \ |g| \ll 1. \tag{28}$$

This regime can be provided, for example, at a constant depth of the potential well $V_{\max}$ in which the particle is located and for a periodic change in its width $L(t)$

$$L(t) = L_0(1 - g\cos\Omega t), \ L_0 = \sqrt{8V_{\max}/M\omega_0^2}. \tag{29}$$

The efficiency of excitation of CCS greatly depends on a ratio of ω_0 and Ω. On the basis of the numerical analysis of eqs (11)–(13), we had studied the dependence $r(t, \Omega)$ in the range of frequencies of modulation $0 < \Omega/\omega_0 \le 100$ with small step $\Delta\Omega/\omega_0 = 10^{-3}$ (refs 2, 6, 7). It was shown that there are only two resonances of CCS formation – at $\Omega = \omega_0$ and $\Omega \approx 2\omega_0$. Analysis of the received results for $|r(t, \Omega)|$ testifies to absence of other maxima of correlation coefficient $|r(t, \Omega)|$ versus Ω. The results of calculation of averaged correlation coefficient

$$\langle |r(t,\Omega)| \rangle_t \equiv \frac{1}{\Delta t}\int_{t_0-\Delta t/2}^{t_0+\Delta t/2} |r(t,\Omega)|\,dt, \tag{30}$$

are presented on Figure 4 *a* and *b* for $\Delta t = 10^3/\omega_0$ and different values of modulation depths: $g = 0.1$ ($t_0 = 1500/\omega_0$) and $g = 0.01$ ($t_0 = 10^4/\omega_0$). In Figure 4 *b*, the results of calculation of the averaged coefficient of barrier transparency

$$\langle\langle D(t,\Omega)\rangle_t\rangle = \frac{1}{\sqrt{\pi}\delta\Omega}\int\left\{\frac{1}{\Delta t}\int_{t_0-\Delta t/2}^{t_0+\Delta t/2} D(t,\Omega')\,dt\right\} \times \exp[-(\Omega-\Omega')^2/(\delta\Omega)^2]d\Omega', \tag{31}$$

at non-monochromatic (Gaussian) modulation of $\omega(t)$ with $\Omega/\delta\Omega = 10$ are also presented.

From these results two important statements follows:

(a) In any experiment with the use of periodic limited frequency modulation Ω of vibrational state of interacting

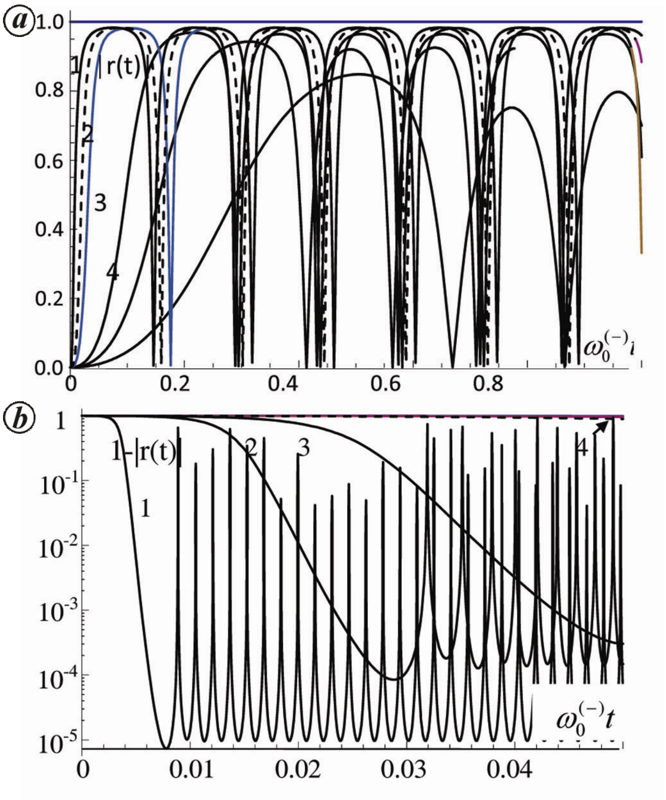

Figure 3. Time dependence of the correlation coefficient in expanding (narrowing) potential well at $g^{(-)} = 10$, $L_0/L_{\min} = 11$ (*a*, linear scale) and $g^{(-)} \approx L_0/L_{\min} = 10^3$ (*b*, logarithmic scale) and $T\omega_0^{(-)} = 0.001, 0.005, 0.01, 0.05, 0.1, 0.25$ (see graphics 1–6).

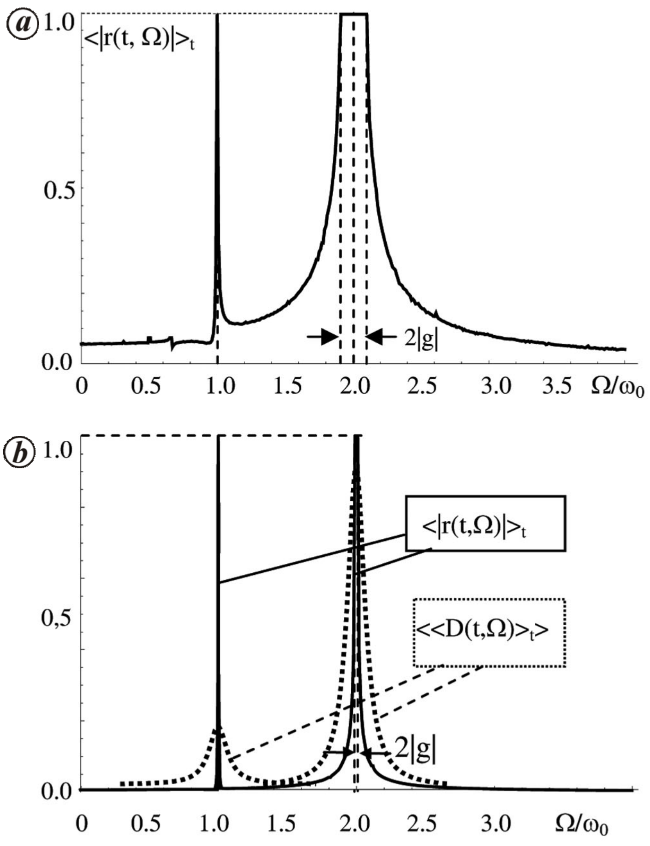

Figure 4. Dependence of averaged correlation coefficient $\langle |r(t, \Omega|) \rangle_t$, (*a*, *b*) and normalized averaged coefficient of barrier transparency $\langle\langle D(t, \Omega\rangle_t \rangle$ (*b*) on frequency Ω at $|g| = 0.1$, $t_0 = 1500/\omega_0$ (*a*) and at $|g| = 0.01$, $t_0 = 10^4/\omega_0$ (*b*).

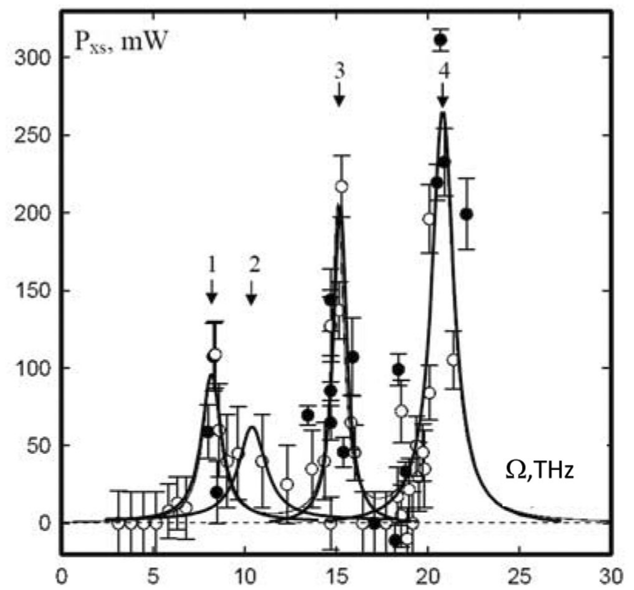

Figure 5. Frequency dependency of excess energy at action of variable beat frequency Ω of two different low-power laser diodes on surface of Pd cathode during electrolysis in D_2O (refs 15, 16).

particles with initial frequency ω_0, two resonances of excess energy (energy release) on frequencies $\Omega = \omega_0$ or $|\Omega - 2\omega_0| \le g\omega_0$ should be observed.

(b) In all cases, the magnitude of excess energy parametric resonance with $|\Omega - 2\omega_0| \le g\omega_0$ should essentially exceed the similar magnitude of excess energy of the fundamental resonance with frequency $\Omega = \omega_0$.

These statements are in good agreement with 'terahertz' laser experiments[15,16] on the stimulation of nuclear reaction on joint action of two low-power laser beams with variable beat frequency Ω = 3–24 THz on the surface of Pd cathode during electrolysis in D_2O. Sharp increase in the thermal excess power in a cell from background value $P_{xs} \le 10$ mW to $P_{xs} \ge 300$ mW corresponded to four resonances of energy release: $\Omega_1 \approx 7.8$–8.2, $\Omega_2 \approx 10.2$–10.8, $\Omega_3 \approx 15.2$–15.6 and $\Omega_4 \approx 20.2$–20.8 THz (see Figure 5).

Comparison of frequencies of all four resonances Ω_k of excess energy shows that the ratios between these frequencies are $\Omega_3 \approx 2\Omega_1$ and $\Omega_4 \approx 2\Omega_2$ with good accuracy. From the given experiments it follows that the amplitudes of high-frequency maxima in each of these pairs (accordingly Ω_3 and Ω_4) greatly exceeded those of the maxima corresponding to the 'basic' frequencies Ω_1 and Ω_2. The reason for this directly follows from a comparison of Figures 4 *b* and 5. These experimental results completely correspond to the theoretical model of CCS.

In PdD compound in terahertz laser experiments, such mechanism of CCS formation can be connected with plasmon excitation by the following two-steps process:

(a) Excitation of surface electron plasmon and modulation of electron density

$$n_e(x,t) \approx \langle n_{e0}\rangle (1 + g_{e\Omega}\cos(\Omega t - k_z x)e^{-z/\delta}), \qquad (32)$$

on the surface of the PdD compound on combined action of two coherent laser beams with different frequencies. Such action in the presence of stationary external magnetic field leads to the excitation of longitudinal oscillations of electrons with beat frequencies $\Omega = \omega^{(2)}_{\text{laser}} - \omega^{(1)}_{\text{laser}}$ (refs 15 and 16) and magnitude $\Delta x = eE_\Omega/m_e\Omega^2 \approx 10^{-19}$ cm. For such parameters the index of electron-density modulation can reach sufficiently high values, $g_{e\Omega} \approx 10^{-1}$–$10^{-2}$.

(b) Modulation of frequencies $\omega_0^{(k)}$ of optical phonon modes of deuterons in Pd matrix under the action of electron density oscillations (eq. (32)) in the volume of elementary cells

$$\omega^{(k)}(r,t) = \omega_0^{(k)}\{1 + g_\Omega^{(k)}\cos(\Omega t - k_z x)e^{-z/\delta}\}, \quad g_\Omega^{(k)} \approx g_{e\Omega}. \qquad (33)$$

The possibility of such modulation is related to the influence of electron screening to parameters of parabolic potential well (e.g. to the depth of the well) in charged harmonic oscillators formed by interaction of Pd^+ and D^+ ions in PdD elementary cells.

Here $E_\Omega = \sqrt{4\pi P/Sc} \approx 30$ V/cm is the magnitude of electric field intensity of laser beam with power $P \approx$ 25 mW, which is focused in area $S \approx 0.01$ cm^2, m_e is the electron mass, and $\delta \approx 10$–50 nm is the thickness of skin-layer of surface plasmon.

Summary

The analysis performed and the estimates obtained in this study testify to the real influence of the process of CCS formation on the probability and character of LENR. These results clearly demonstrate the large increase in potential barrier transparency with increase in correlation coefficient. It is noteworthy that the action of a possible stochastic force on the oscillator in the process of formation of the CCS worsens these characteristics[3,5]. Alternative mechanism of low temperature collective picnonuclear fusion in the laboratory that takes place at Coulomb collapse of small-sized target[17–19] does not depend on influence of such stochastic force, but requires concentrated and focused energy input.

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