# Physical Model for Lattice Assisted Nuclear Reactions

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**Abstract**

Atomic scale description of the electrochemically induced cold fusion is presented. The model consistent with the conditions required for successive experiments and offers physical explanation for the occurrence of nuclear fusion at low energies. Based on this atomic scale description, the vibrational frequency of the $D_2$ molecules in vacancy is calculated. The fundamental frequency of the vibrating Deuterium molecule in a cavity is 21.65 THz, which is almost identical with the observed "sweet spot" in the two laser experiments at 20.8 THz, indicating that this previously unidentified peak represents the self frequency of the Deuterium molecule in vacancy. The fundamental frequencies in vacancies for HD and $H_2$ molecules are also calculated. It is predicted that these frequencies in HD or $H_2$ systems should also activate the reaction and that these fundamental frequencies in cavities should remain unchanged regardless of the hosting lattice.

## 1. Introduction

Fleischmann and Pons [1, 2] reported electrochemically induced excess heat in palladium–deuterium system. No new chemical product have been detected in the experiments. The observed quantity of heat could not have been produced by any known chemical reaction. Fleischmann and Pons speculated that the excess heat might have been the result of nuclear reaction, what they called "cold fusion" of the deuterium. No appropriate technical description of the Fleischmann and Pons experiments were disclosed. The conducted subsequent experiments by other laboratories, had very low reproducibility. The number of publications reporting negative results was 217 compared to the positive experiments 49 in the same time period [3]. Based on the low reproducibility and lack of theoretical support mainstream science rejected cold fusion. In retrospect it is known that successful experiment requires high loading [4]. Out of the 217 publications reporting negative result in refereed journal only 3 had 0.9 or higher D/Pl loading ratio required for successful experiment. Additionally, the majority of these follow up experiments did not measure excess heat, or any nuclear product but rather looked for proton emission, characteristics of hot fusion. This misconception was also a significant contributing factor leading to the negative evaluation and the rejection of Fleischmann and Pons experimental results.

Despite the rejection of mainstream science many laboratory continued the research on cold fusion, which has been renamed to low energy nuclear reaction (LENR), lattice assisted nuclear reaction (LANR) or lattice-induced nuclear reaction. The author believes that the most descriptive name describing the phenomenon is the lattice assisted nuclear reaction (LANR), which is used in this study. In the past three decades many hundreds of successful experiments, producing electrochemically induced excess heat in palladium–deuterium system, have been reported [5, 6]. Along with the excess heat, $^4He$ with qualitative correlation to the produced excess heat has been measured.[7-12]. The collected $^4He$ had the correct magnitude for typical deuterium fusion reaction, which yields $^4He$ as product [13]. The production of $^4He$ was conformed in many independent experiments, and the measured quantity of $^4He$ in many cases exceeded the content, present in air, excluding possible contamination [7, 14-16]. The production of $^3He$ or neutrons in these experiments has not been reported. Thus $^3He$ or neutrons has not been produced or the quantities were below the detection limits [8]. In sixty-one independent experiments the production of tritium above the background value has also been reported [5]. The quantity of Tritium was always too small to generate detectable heat, but sufficient to demonstrate an unexpected nuclear process [17].

The known and detected nuclear fusion processes of deuteriums in plasma and hot fusion reactors are [18]

1./ D + D ➞ T(1.01 MeV) + p (3.02 MeV) (50%),

2./ D + D ➞ $^3He$ (0.82 MeV) + n (2.45 MeV) (50%), and

3./ D + D ➞ $^4He$ (73.7 keV) + (23.8 MeV) ($10^{-7}$).

The two dominant reactions are the first two, 50-50 percent, and the occurrence of the third one is minor $10^{-7}$. In the cold fusion experiments the detected fusion process is D + D ➞ $^4He$ (73.7 keV) + (23.8 MeV) (No gamma). The production of excess heat correlates with the measured amount of $^4He$, however, no nuclear radiation has been observed and the produced $^4He$ is essentially at rest.

The energy of the electrolysis is very small. Thus x-ray radiation from the process is unexpected. However, X-ray emission from well focused point source has been detected [19]. The spectra of the emitted x-ray is consistent with the K-alpha radiations of the elements present on the surface of the cathode along with some Bremsstrahlung [20-22]. The radiation flux correlates with the produced heat [23, 24]. In H-Ni system neutron and gamma ray emissions have also been reported [25].

Based on the high number of successful experiments, reporting the amount of excess heat, not explainable by chemical reactions, the production of new elements, such as tritium and helium four, the emission of x-ray, and the correlation of these independent measurements indicates that nuclear reaction at low temperatures can occur, eventhough the reproducibility is a problem and the expected high energy radiation is absent [26]. No viable theory for low temperature nuclear reactions is known [27, 28]. Here an attempt is made to present one.

## 2. Conditions for experimental success

Any theory must be consistent with experiments. In the past three decades the conditions required for successful experiment are mapped out almost completely for the palladium–deuterium system [17, 28, 29]. Analyzing these previous successful experiments a comprehensive list of the reported conditions has been collected. The experimental conditions (E) reported from successful low energy nuclear reactions are:

E1./ very slow loading

[The diffusion of the deuterium into the palladium crystal structure introduce significant volume change. In order to accommodate this volume increase without damaging the crystal structure the loading should be very slow. The loaded palladium should be free of cracks. Otherwise the deuterium would live the metal.]

E2./ the $D_2O$ should be pure containing the least $H_2O$ possible

E3./ the loading of D/Pd should be higher than 0.85% [30]

E4./ deuterium molecules ($D_2$) should be present in the palladium deuteride

[The interaction of the Deuterium atoms require the presence of $D_2$ molecules. Many experiments, with very high loading, produced no excess heat, indicating that the bulk PdD is not active. However, excess power had been reported immediately after Pd Co-deposition [19, 31], allowing $D_2$ molecules to be loaded.]

E5./ the presence of mono-vacancies

[The formation of $D_2$ requires mono-vacancies because the electron density in PdD is too high for molecular $D_2$ formation. The $D_2$ molecule in the vacancy are stable only if all of the O-sites are occupied, which requires 0.85 or higher loading [32].]

E6./ higher than a trash hold current density

[The current density has to be above a critical trash hold value in order to start the reaction and to compensate for the loss of deuterium from the cathode.]

E7./ laser excitation and laser induced phonon vibration at 8.2, 15.1, and 20.8 THz frequencies

[Optical phonon vibrations induced by laser/s can trigger the reaction under conditions where the cathode was below threshold for the excess power production. In the PdD system the called “sweet spots”, where excess heat production were initiated, are 8.2, 15.1, and 20.8 THz [33, 34]. The observed 8.2 and 15.1 THz frequencies correlates well with the $\Gamma$ and L point vibration of the PdD lattice respectively. Thus these vibrations can be associated with optical phonon frequencies of PdD with zero group velocities. There are no optical phonon modes in PdD, which would associate with the peak in the excess power spectrum at 20.8 THz. It has been speculated that the response at 20.8 THz is due to deuterium in vacancies in the gold coating, or due to hydrogen contamination [35].]

E8./ The reaction can be enhanced by increasing the current density [36], by increasing the temperature [37], and by the application of magnetic field.

[Even relatively small external magnetic fields can enhance the excess heat. The application of a large magnetic field results in substantial increase of excess heat.]

E9./ The laser induced phonon frequencies initiated heat production remains and continues despite the laser turned off.

[It has been speculated that this could be explained if the nuclear energy goes into optical phonon mode and maintains the reaction [38].]

E10./ The heat production is localized, like hot spots, which are associated with mini explosion [39].

The first two conditions (E1, and E2) are technical and has no relevance to theory. Based on the conditions (E3-10) it can be concluded that the low energy fusion reaction of deuterium requires the presence and the continuous supply of $D_2$ molecules to the vacancies and the excitation of these molecules above a certain activation energy. Thus the reaction occurs in the mono-vacancies and induced by vibration with energy higher than the activation energy. It should be mentioned that the experiments still have problem with reproducibility. Thus eventhough all the conditions required for successful experiments are satisfied (E2-8) the reaction might not be start.

**3. Theoretical expectations from a successful model**

The list of theoretical problems (T) raised against cold fusion has also been collected. John Huizenga [40] wrote a book, with the viciously unscientific title, Cold Fusion: Scientific Fiasco of the Century. In this book he listed "three miracles", which must be satisfactorily answered by any theory of cold fusion. The three miracles are:

T1./ much enhanced tunneling through Coulomb barrier,

T2./ suppress p + t, and n + $^{3}$He pathways to make $^{4}$He + gamma,

T3./ disappearance of 24 MeV.

Analyzing the successful experiments of LANR, Edmund Storms [41] put together a list or facts, which should be explained by any theory.

T4./ (Fact #1) Helium is generated without significant radiation

T5./ (Fact #2) The effects are occur either light hydrogen or deuterium

T6./ (Fact #3) Tritium is produced in the same environment as the Helium without significant proton or radiation

T7./ (Fact #4) Helium -3 is not produced as a primarily product - eliminating p + d fusion

T8./ (Fact #5) Transmutations occur with either light hydrogen of deuterium

T9./ (Fact #6) Reactions occur at special localized sites

Thus any successful theoretical model on one hand must be consistent with the experimental conditions required for successful reaction, and on the other hand must satisfactory explain or answer the theoretical obstacles raised by the current interpretation and understanding of the fusion process.

**4. Proposed model for lattice assisted nuclear reactions**

In the past thirty years many hundreds experiments verified the occurrence of LANR. Based on this accumulated experimental evidences the existence of LANR is undeniable. Based on our current understanding of physics, low energy nuclear reaction is impossible. Investigating what might cause the discrepancy between the detected LANR and theory it is suggested that the current description of the electronic structure of the element should be modified. Experimental evidences, like the stability of the atoms in the time frame of the universe, shows that the point charge nature of the electron around the nucleus is not attainable. Therefore, it has been suggested that in the vicinity of the atom the electron is not a point charge but rather a surface charge forming an electron halo around the nucleus [42]. This electronic shell description of the elements were investigated for the Hydrogen atom. The velocity of the propagating wave on the surface of the electron halo was calculated from first principles. The calculated velocity of the wave in the electron halo is identical with the velocity of the point charge electron calculated from the Bohr's model. Thus the point and surface charge description of the electronic structure is compatible. The only difference between the two description is that not the electron but rather the triggered vibrational wave propagates in the electron shell. The electron halo description of the electronic structure is further supported by offering physical explanations for many previously not explained features of the atoms, including the emission and the absorption of electromagnetic radiations of the atoms (Fig. 1), the uniformity and stability of the atoms, the physics of the particle-wave duality nature of the matter, the correct value for the ground state angular momentum, and the correct ionization energy of Hydrogen atom. Additionally, the electron halo model is consistent with the classical electromagnetism and shows that there is no need to limit the extent of these laws at atomic scale. It is investigated that how this electronic structure description of the elements fits to the observations required for successful experiments and how can explain or answer the theoretical objections raised against LANR.

Experiments show that the occurrence of LANR requires the presence of vacancies (E5) filled with deuterium molecules (E4) and the vibrational energy should be higher than the activation energy (E6-8). The physical process consistent with these observations is proposed. The inclosed $D_2$ molecule in mono-vacancy is excited by the vibration of the surrounding lattice, which eventually leads to the fusion of the two deuterium nucleus producing $^4He$ (Fig. 2).

Edmund Storms introduced the nuclear active environment description and suggested that the reaction occurs on the surface of the metal in small nano meter sized cracks. The fusion mechanism in the cracks should be the same as the one described in vacancy. Thus LANR can be active regardless the $D_2$ molecule is hosted in a mono-vacancy or in nano size cavity.

It is investigated that how the proposed model, vibrationally induced fusion of the deuterium molecules in vacancy, can explain the theoretical objections raised against LANR.

T1./ "much enhanced tunneling through Coulomb barrier is required"

One of the strongest arguments against cold fusion is that the energies corresponding to room temperature reactions could not overcome on the strong Coulomb repulsion [40]. The electron shell structure of the Hydrogen atoms offers an explanation how the two nucleus can get very close to each other without any repulsion. The two positively charged nucleus is shielded by the negative electron shell, allowing a very close encounter with no repulsion (Fig. 2). Thus the existing electron shell allows much much enhanced tunneling through Coulomb barrier comparing to nucleus-nucleus interactions.

This possible fusion reaction is in line with experiments, which shows that at low energies the targeted Deuterons absorbed in metallic matrix strongly enhance the fusion reaction rates. The cross-section enhancement in the presence of electrons, compared to the bare nuclei, is known as the "electron screening puzzle" [43 and ref. 1-11 their in]. No theoretical explanation is known why the presence of electrons enhance the reaction rate. The shielding effect of the electron shell model offers a feasible explanation for the experimentally detected electron screening puzzle.

T2./ "suppress p + t, and n + $^3$He pathways to make $^4$He + gamma"

Huizenga assumed that low energy nuclear reaction should produce the same fusion products as high energy reactions. This assumption is inconsistent with experiments, which reports 99.9% probability for the occurrence of reaction 3 in LANR. Thus in low energy nuclear reactions the dominant fission process is D + D → $^{4}$He (73.7 keV) + (23.8 MeV) [44, 45].

It is speculated that in hot fusion the high energy of the colliding nucleus is sufficient to detach either a proton or a neutron. Based on probability, the chances are 50-50 percent for either proton or neutron detachment. This is consistent with the probabilities of reactions 1 and 2 in hot fusions. Even in hot fusions, experiments in few cases result in reaction 3, in which neither of the nucleons has enough energy after the collision to be detached. At low energy fusion the energy is not sufficient to detach any of the nucleons, therefore, reaction 3 becomes the dominant fusion process. Thus suppressing p + t, and n + $^{3}$He pathways to make $^{4}$He + gamma does not require any miracle except acknowledging that high and low energies nuclear fusions are governed by different physical processes.

T3./ “disappearance of 24 MeV”

T4./ “Helium is generated without significant radiation”

These two requirements (T3 and T4) raises the same question how the produced 24 MeV energy of fusion can disappear. It should be stated that the energy produced by the D + D → $^{4}$He (73.7 keV) fusion process does not disappear but rather transferred the energy to the lattice observed as heat. The measured excess heat shows qualitative correlation with the produced $^{4}$He [7-12]. Thus more precisely, the obstacles of T3 and T4 should be raised as: How does the produced energy in the nuclear fusion is transferred to the lattice?

According to the electron shell description of the atoms the fusion of the two nucleus should burst the electron shells by the released energy. This process might be responsible transferring the released nuclear energy to the lattice. This speculation is consistent with experiments, which reports electron emission instead of gamma ray radiation at low energies. Relatively low energy proton beam (260 keV) in the proton-deuterium fusion reaction produced electron emission with high energy (5.6 MeV) instead of gamma ray emission [46]. Many LANR experiments also reported electron mediated radiation [47, 48]. Theoretical models are also allowing the transfer of energy between nucleus and the lattice [49, 50]. Thus electron emission could explain how the energy from the nuclear reaction transferred to the lattice.

T5./ "The effects are occur either light hydrogen or deuterium"

T8./ "Transmutations occur with either light hydrogen or deuterium"

Both of these theoretical expectations requires an equivalency between $H_2$ and $D_2$ process. Based on the proposed physical process, the reaction is induced by the vibration of a molecule in the cavity or mono-vacancies of the host lattice. The enclosed molecule can be $D_2$, HD, or $H_2$, which changes only the fundamental frequencies of the molecules (explained later) but not the process itself. The compatibility of D and H in transmutation to other elements can be explained in the same manner.

T6./ "tritium is produced in the same environment as the Helium without significant proton or radiation"

The explanation of T6 is similar to T2. The energies of the reacting particles in LANR are not high enough to detach of protons. Thus reaction 1 is very-very minor in LANR from D-D fusion. The produced tritium in the LANR experiments should be the result of H-D fusion. This speculation is supported by experiments, which reports formation of tritium only if both deuterium and hydrogen are present [51].

T7./ “Helium -3 is not produced as a primarily product - eliminating p + d fusion”

The energies in LANR experiments are below the ionization energy of the Hydrogen (13.6 eV), therefore, no protons are formed. Therefore, in a pure deuterium system p + d fusion at low energies should not occur. On the other hand Helium-3 might be produced in LANR experiments if HD is present. The lack of He-3 in the LANR experiments might be rooting in technology, since the detection of He-3 is much more difficult than He-4.

T9./ “Reactions occur at special localized sites”

The theoretical requirement T9 address the observations reported in E10. Experiments showed that the heat production is localized, like hot spots, which are associated with mini explosion [39]. This observation is consistent with the proposed cavity vibration of $D_2$ model. The reaction is a random event, occurring in isolated vacancies. These isolated events does not induce chain reaction. This might be the reason behind the reproduce-ability problem.

It is concluded that the electronic shell description of the atoms with the physical model, vibrating $D_2$ molecule in the cavity or mono-vacancy of Palladium, offers a feasible explanation for LANR, which is consistent with experiments and theoretical requirements (Fig. 2).

## 5. Predictions of the model

The origin of the third “sweet spot” detected in the two laser experiments [38] at 20.8 THz, triggering  the reaction under conditions where the cathode was below threshold for the excess power production is unknown. Based on the presented model the reaction should be triggered by the self resonance frequency of the molecule (Fig. 3/a). This possibility is investigated. The usual way calculating the vibrational frequency of the diatomic Deuterium molecule is

$$G(v) = \omega_e\left(v+\frac{1}{2}\right) - \omega_e Xe\left(v+\frac{1}{2}\right)^2, \quad v = 0, 1, 2, 3 \ldots \tag{5.1}$$

where $\omega_e$, and $\omega_e X_e$ are the harmonic frequency and the first anharmonicity constant, respectively, and v is the vibrational quantum number with non negative integer values. The zero point energy (ZPE) of a diatomic molecule is then

$$ZPE = G(0) = \frac{1}{2}\omega_e - \frac{1}{4}\omega_e X_e. \tag{5.2}$$

The experimental values of the vibrational ZPE energies for $D_2$, DH, and $H_2$ are $4.636\times10^{13}$ Hz, $5.667\times10^{13}$ Hz, and $6.533\times10^{13}$ Hz respectively [52]. All these zero point vibrational energies, including $D_2$ (46.36 THz) is far off from the observed 20.8 THz triggering frequency. The possibility of beat frequency, with one of the observed lattice related vibrations is unlikely. Thus the diatomic vibrational frequency of $D_2$ does not seem to explain the observed "sweet spot" at 20.8 THz.

Investigating the vibration of the $D_2$ molecules in cavity it is concluded that the diatomic molecular vibration (Fig. 3/a) can not develop in a cavity. The molecule constantly bouncing back from the wall of the cavity, which prevents the development of diatomic vibration. It is suggested that the vibration of the Deuterium molecule in a cavity can be depicted as the vibration of one of the Deuterium atom, which has the mass of the molecule attached to its electron shell (Fig. 3/b). Thus in "cavity vibration" the electron shell of one of the deuterium vibrates with the mass of the molecule attached to it. This vibration is described by stretching out the electron shell, like a string, and the mass of the Deuterium molecule is attached in the middle the string (Fig. 3/b). The length of the stretched electron shell is equal with the circumference of the great circle of the sphere, and can be calculated as:

$$L = 2\pi a_o, \tag{5.3}$$

where $a_o$ is the Bohr's radius. It is assumed that the radius of the Deuterium is the same as the Hydrogen atom. This assumption has no significance, because the radius falls out when the formula is simplified [Eq. 5.8]. The stretching tensile force is generated by the surface tension of the electron shell. It is assumed half of the total force acts on both sides. It is calculated as:

$$T_{shell} = \frac{1}{2} 2\pi a_o \sigma, \tag{5.4}$$

where σ is the uniform surface stress in the electron shell. Assuming that the surface stress of the electron halo in the Deuterium atom is the same as in the Hydrogen atom, the surface tension can be calculated [42] as:

$$\sigma = \frac{e^2}{16\pi^2 \varepsilon_o a_o^3}, \tag{5.5}$$

where e is the elementary charge, and $\varepsilon_o$ is the permittivity of free space, which has the value $8.854187817... \times 10^{-12}$ $C^2/N \cdot m^2$ [53]. The angular velocity (ω) of this vibrating system can be calculated then as:

$$\omega = \sqrt{\frac{2T_{shell}}{mL}}, \tag{5.6}$$

where m is the mass of the object, equal with the mass of the Deuterium molecule:

$$m = m_{D2} = 2(m_e + m_p + m_N), \tag{5.7}$$

where $m_e$, $m_p$, and $m_N$ are the masses of electron, proton and neutron respectively.

The frequency of the vibrating electron shell with the attached Deuterium molecule to its surface is:

$$f_{D2} = \frac{1}{2\pi}\sqrt{\frac{2T_{shell}}{m_{D2}L}} = \frac{1}{2\pi}\sqrt{\frac{\sigma}{m_{D2}}} = \frac{1}{8\pi^2}\frac{e}{\sqrt{\varepsilon_o m_{D2} a_o^3}}, \tag{5.8}$$

The calculated fundamental frequency of the vibrating Deuterium molecule in a cavity is $2.165\times10^{13}$ Hz (21.65 THz). This frequency is almost identical with the observed sweet spot at 20.8 THz (Fig. 4). Based on this agreement it is suggested that the third sweet spot or triggering frequency detected in the two laser experiments represent or relate to the self frequency of the Deuterium molecule in a cavity. The self frequencies of HD and H2 in cavity are also calculated based on the same assumptions. The calculated frequencies of HD and H2 are $2.500\times10^{13}$ Hz (25.0 THz), and $3.062\times10^{13}$ Hz (30.62 THz) respectively.

If the vibrational frequency of Deuterium molecules in cavity represents the reported sweet spot at 20.8 THz as suggested, then this frequency should remain the same regardless of the lattice. Like in NiD system, the two lattice related peaks should be different, however, the 20.8 THz triggering frequency should remain the same. It can also be predicted that the calculated cavity frequencies for HD and H2 should trigger the reaction, and these frequencies should also be independent from the the vibration of the lattice.

The temperature relating to the same energy as the fundamental vibrational energy of the molecules can be calculated. This temperature, that I will call activation temperature, can stimulate the reaction based on resonance. The diatomic vibration and the vibration in cavity both have two degrees of freedom. The activation temperature (T) relating to the vibrational energy can be calculated then as:

$$T = \frac{hf}{k_B}, \qquad (5.9)$$

where h is the Planck constant, and $k_B$ is the Boltzmann constant. The activation temperatures relating to the cavity fundamental vibrational frequencies of $D_2$, HD, and $H_2$ are 1039, 1200, and 1470 Kelvin respectively. These temperatures should be the optimum values for stimulating the reactions. Previous electrochemically induced experiments did not reach these temperature because the boiling temperature limit of the water. However, experiments showed that the increase of the temperature enhance the reaction. The calculated frequencies in cavity, the experimental vibrational ZPE energies, and the equivalent temperatures for $D_2$, DH, and $H_2$ are listed in Table 1.

## 6. Conclusions

The many hundreds experiments reporting excess heat, which is beyond the quantity, which can be explained by chemical reaction, the measured $^4He$ fission product with the correct magnitude for typical deuterium fusion demonstrates that cold fusion is real, eventhough, the reproducibility is problem.

Based on the literature review, the conditions required for successful experiments in the Palladium, Deuterium system are collected, along with the theoretical objections. Analyzing these experimental and theoretical conditions it has been suggested that fission occurs between the two atoms of the molecule trapped in a cavity or nano-size crack when the excitation reaches the required activation energy. The fusion process between the deuteriums at low energy is D +

D → $^4He$ (73.7 keV) + (23.8 MeV) no gamma. The fusion is possible because the uniform charge distribution of the electron/s around the nucleus shields the repulsion of the protons. Without this shielding effect, the fusion would be practically impossible at the low energies of the experiments. The enhance tunneling at low energies between the deuterium beam and the targeted Deuterons absorbed in metallic matrix has been detected. The effect is known as electron screening puzzle, which can be explained by the shielding effect of the electron shells. The proposed model is consistent with all the conditions required for successful experiment, and gives reasonable explanations for all the theoretical concerns.

The proposed lattice assisted low energy fusion model allows to make testable predictions. Calculating the fundamental vibrational frequency of the $D_2$ molecule in cavity agrees well with the reported sweet spot frequency measured by the two laser experiments at 20.8 THz. Based on this agreement it is suggested that the detected sweet spot, or triggering frequency relates to fundamental vibrational frequency of Deuterium molecule in cavity. The fundamental vibrational frequencies of HD, and $H_2$ in cavity are 25.0 THz and 30.6 THz. These frequencies should trigger the reaction in HD, and $H_2$ systems. Further prediction of the proposed model is that the fundamental vibrational frequencies of molecule should remain the same regardless of the hosting lattice. All these predictions can be tested by experiments.

Based on energy equivalency the activating temperature for the reaction was calculated from the vibrational frequencies. The activating or optimum temperatures for the reactions of $D_2$, HD, and $H_2$ are 1039, 1200, and 1470 Kelvin respectively.

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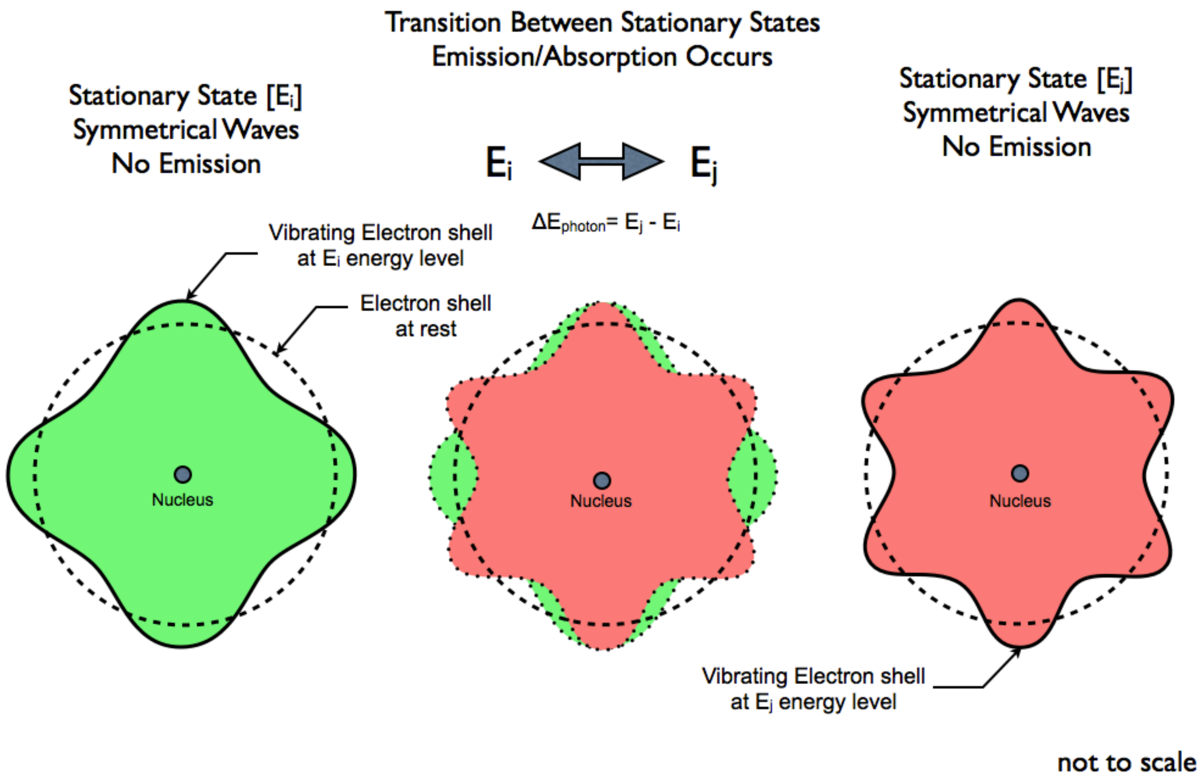


**Figure 1.** Schematic 2D figure of the uniformly distributed electron shell model showing the transition between two states. As long as the vibration of the electron halo around the nucleus is symmetrical, stationary energy levels, no emission occurs resulting from destructive interference. However, when transition occurs between one symmetrical vibration state to the another symmetric one then the vibration in the transition is asymmetrical resulting in electromagnetic radiation. The electromagnetic radiation can be either emitted or absorbed depending on the energy state of the states. The presented surface charge distribution of the electrons explains the emission and absorption of photons without violating classical laws, which remains valid at atomic scale.

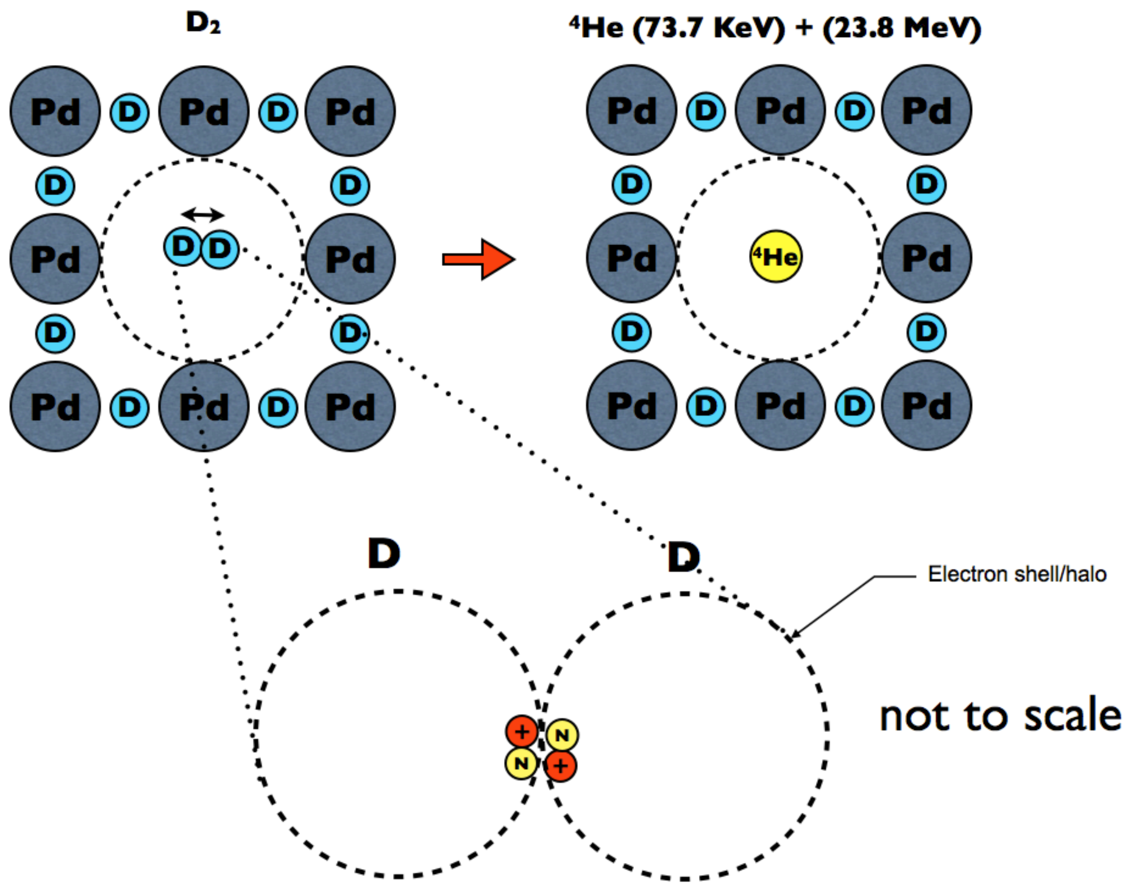


**Figure 2.** Schematic figure of the reaction. The Deuterium molecule is in a mono-vacancy. The loading of the surrounding Palladium is 0.9 or higher preventing diffusion. The vibration of the lattice triggers the vibration of the deuterium molecule. Close encounter of the two deuterium nucleus can result in fusion, producing 4He. The energy produced by the fission dissipates in the lattice most likely through electron emission process.

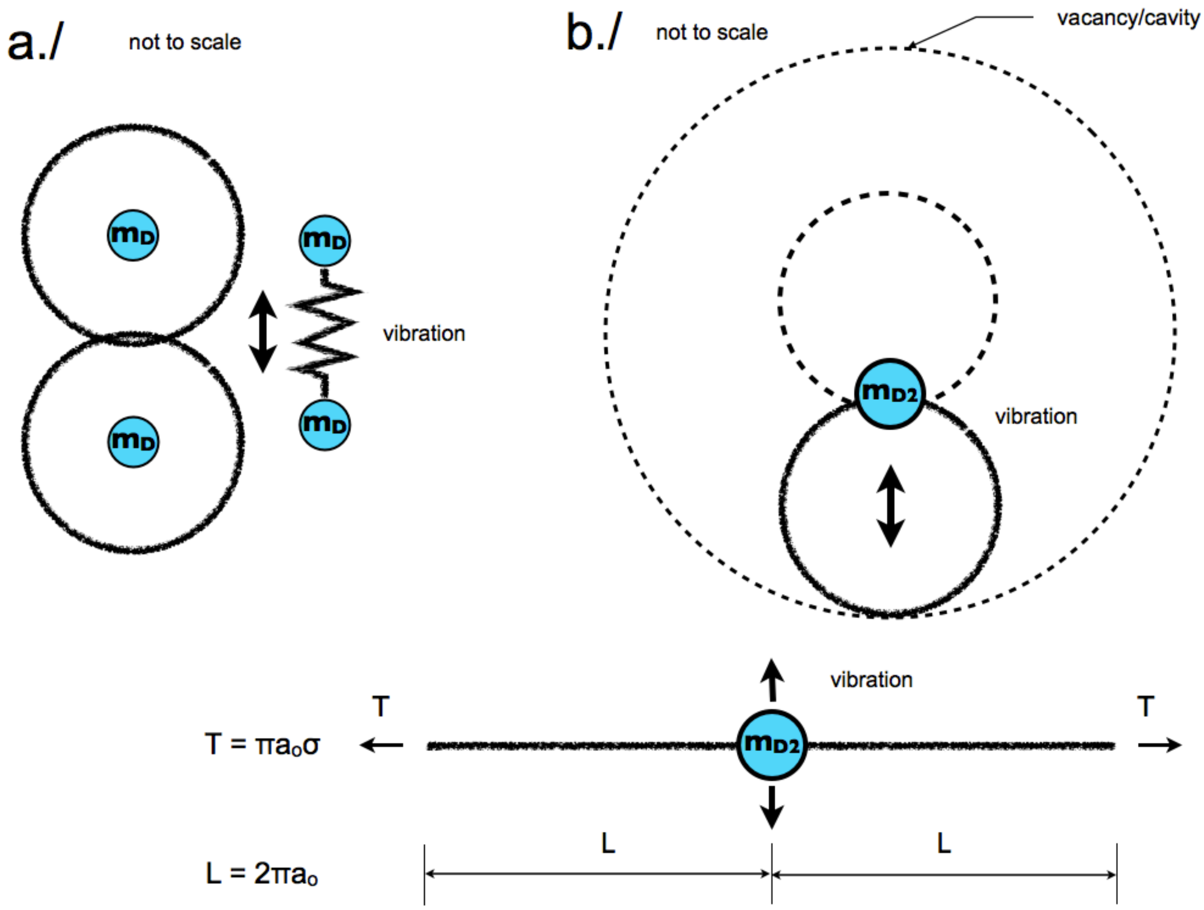


**Figure 3.** The vibration of the deuterium molecule. a.) diatomic vibration b.) vibration in the cavity.

Inside the cavity the molecule bouncing back and force from the wall, which prevents the development of diatomic molecular vibration. The vibration of the molecule can be depicted as the vibration of the electron shell of one atom with a mass equivalent with the mass of the molecule attached into its surface. This vibration is depicted by assuming that the electron shell acts as a string, and the mass of the molecule is attached to this string.

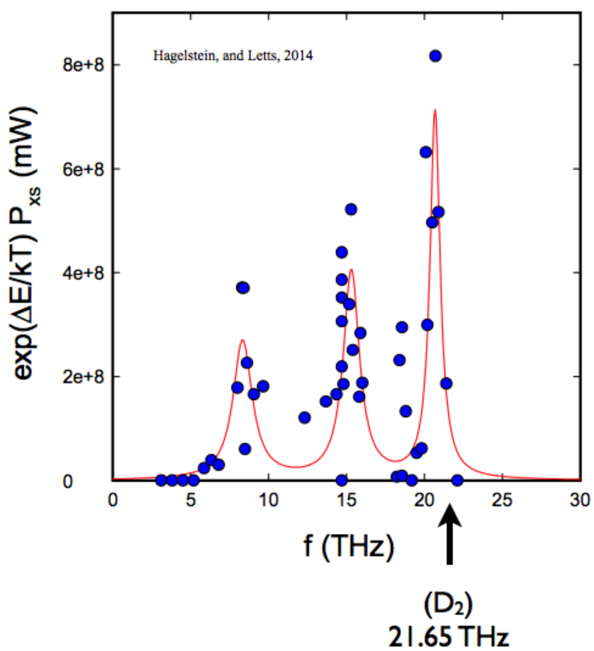


**Figure 4.** The calculated fundamental frequency of the vibrating deuterium molecule in vacancy is 21.65 THz. The detected sweet spots (triggering frequencies) of the two laser experiments are shown [54].

| **vibration in vacancy** | **$D_2$** | **HD** | **$H_2$** |
|---|---|---|---|
| fundamental frequency (THz) | 21.65 | 25.00 | 30.62 |
| wave number ($cm^{-1}$) | 722 | 834 | 1,021 |
| activating temperature (K) | 1,039 | 1,200 | 1,470 |
| **diatomic vibration** | **$D_2$** | **HD** | **$H_2$** |
| ZPE frequency (Hz) [52] | 46.36 | 56.67 | 65.33 |
| ZPE wave number ($cm^{-1}$) | 1546.50(8) | 1890.3(2) | 2179.3(1) |
| activating temperature (K) | 2,225 | 2,720 | 3,135 |

**Table 1.** The fundamental vibrational frequencies in cavity, the zero point energy of the diatomic vibration [52], and the activation or optimum temperatures relating to these vibrations for $D_2$, HD, and $H_2$ are shown.