Re-examination of the Conceptual Foundations of Quantum Acoustics: Interpretation and Verification within a Classical Continuous Dynamics Framework

Jiqing Zeng *

Posted Date: 8 January 2026

doi: 10.20944/preprints202601.0641.v1

Keywords: quantum acoustics; phonon; measurement discreteness; classical continuous dynamics; lattice vibration; dynamic ground state; zero-point energy

 doi:10.20944/preprints202601.0641.v1

Article

Re-Examination of the Conceptual Foundations of Quantum Acoustics: Interpretation and Verification Within a Classical Continuous Dynamics Framework

Jiqing Zeng

South China Botanical Garden, Chinese Academy of Sciences, Guangzhou 510650, China; zengjq@scib.ac.cn

Abstract

The theoretical construction of traditional quantum acoustics is based on the core presupposition that "microscopic structures must be described by quantum mechanics". This presupposition has not been directly verified, and its core concept, the "phonon", is defined as a quasi-particle with energy $E=h\nu$. This paper systematically reexamines the conceptual foundations of quantum acoustics based on the "Revised Energy Quantum Concept" – i.e., the "measurement discreteness" of energy transfer rather than "physical discreteness". Drawing on the radiation mechanism of an electron's variable-speed motion around the nucleus (which clearly distinguishes the orbital frequency from the radiation frequency), this paper further clarifies that the natural frequency of crystal lattice vibration (the frequency of atomic motion around equilibrium positions) and the energy radiation/absorption frequency are two independent physical quantities. They are connected through the "frequency change quantity". The interaction between high-frequency sound waves and the lattice is essentially a classical continuous dynamics process. "Phonons" are not particles with physical reality but are discrete measurement units for changes in the excitation strength of lattice vibration modes. Starting from first principles and based on the core mechanism of "frequency change triggering energy exchange", this paper rigorously derives the zero-point energy formula, pointing out that zero-point energy essentially characterizes the dynamic ground-state energy scale of a system under the constraint of the minimum energy measurement unit ε. Using Raman scattering as an example, quantitative calculations of energy transfer involving the revised energy quantum $\varepsilon$are supplemented, clarifying the physical meaning differences between ε and h. The study shows that all quantum acoustics phenomena can be interpreted and verified more clearly and self-consistently within a classical continuous dynamics framework, providing a theoretically solid and physically intuitive path for the field.

Keywords: quantum acoustics; phonon; measurement discreteness; classical continuous dynamics; lattice vibration; dynamic ground state; zero-point energy

1. Introduction

When sound wave frequencies exceed 10^9 Hz, their wavelength is on the same order of magnitude as the crystal lattice constant, and sound propagation inevitably couples with the discrete atomic structure of the medium. This observation opened a new direction for acoustics research, leading to the formation of the subfield known as quantum acoustics. Traditional theories (such as the classical expositions by Tucker and Rampton) start from the premise that "microscopic structure must be considered" and further deduce that "it must be described by quantum mechanics", naming the field "quantum acoustics" [1]. Its core concept, the "phonon", is defined as a quantized quasi-particle with energy $E=h\nu$, possessing zero-point energy $\frac{1}{2}h\nu$.

In the logical chain of this theoretical construction, there lies an implicit divergence in the understanding of the "quantum" concept. Its origin can be traced back to the early development of modern physics and the confusion between the "measurement discreteness of the energy transfer

 doi:10.20944/preprints202601.0641.v1

process" and the "physical discreteness of energy itself". In our previous work, through an in-depth analysis of the mechanism of electron motion around the nucleus, we proposed the core concept of the **Revised Energy Quantum** ε [2,3]: ε is the minimum measurement unit for energy transfer, numerically equal to Planck's constant h (ε=6.62607015×10^{-34} J), but there is a clear distinction in their physical meanings – ε is a pure energy unit, representing the continuous energy value transferred when the electron's motion frequency increases by 1 unit; while h is the quantum of action (unit J·s), the temporal accumulation of ε over a unit time (1 s) ($\varepsilon\Delta t=h$, Δt=1 s). Based on this concept, we clarified the essential difference between the electron's orbital motion frequency (f_n, f_m) and the radiation frequency (ν) [3]: when an electron transitions from energy level m to n, its orbital frequency changes continuously from $f_m$to f_n, the radiated energy is determined by the frequency change ($k=|f_n-f_m|/2$, $\Delta E=k\varepsilon$), and the radiation frequency is the counted number of frequency changes per unit time ($\nu=k/\Delta t$), belonging to different physical categories.

This paper combines the distinction between different frequency concepts with the principles of the revised energy quantum ε to reexamine the conceptual foundations of quantum acoustics. We aim to demonstrate that all phenomena in this field can be reasonably interpreted and verified based on classical continuous dynamics, and its "quantum" characteristics are essentially appearances arising from the descriptive approach. The independence of the crystal lattice vibration frequency (the natural atomic motion frequency) from the energy radiation/absorption frequency is key to clarifying the conceptual confusion in traditional theory. Based on this, we suggest renaming the field "Microstructural Acoustics" or "Lattice Dynamics Acoustics" to more accurately reflect its physical essence and break free from the conceptual constraints of quantum mechanics.

2. Theoretical Framework: The Cornerstones of Classical Continuous Dynamics (CCD)

This chapter systematically expounds the core principles of the **Classical Continuous Dynamics (CCD)** framework we propose. This framework aims to provide a self-consistent, classical physics-based conceptual system for understanding acoustic phenomena at the microscopic scale. It is built upon two cornerstones: **the continuous nature of energy transfer and the constraint of measurement discreteness in description.**

2.1. Core Principle I: Measurement Discreteness—A Reinterpretation of "Quantization"

Traditional controversy surrounding "quantization" phenomena stems from confusing the mathematical mode of description with the attributes of physical reality. The CCD framework provides a fundamental clarification:

Continuous Transfer and Discrete Measurement: The transfer of energy between microscopic particles (e.g., electrons, lattice atoms) is a **continuous** dynamical process. However, describing this process requires introducing a universal, indivisible minimum **energy measurement benchmark**, which we denote as ε. When using ε as the "ruler" to measure a continuous energy flow, the result naturally appears as an integer multiple of ε. Therefore, the observed "packet-like" quantum characteristic is a discretization introduced by the **act of measurement—"measurement discreteness"**—not the energy itself being segmented into discrete "packets."

The Relationship between ε and Planck's Constant h: The measurement benchmark ε is numerically equal to Planck's constant **h**, but their physical meanings differ. **ε is the minimum measurement unit with the dimension of energy (J)**; whereas **h (J·s) is the accumulated quantity of ε over a unit of time (1 second)**, representing the total measurement sum of energy transfer per unit time. This distinction indicates that the formula $E=h\nu$ describes **the total continuous energy required to maintain a radiation process of frequency ν per unit time**, with the discreteness appearing only in the measurement method of this total amount.

 doi:10.20944/preprints202601.0641.v1

2.2. Core Principle II: The Dynamic Ground State—A Necessary Manifestation of Continuous Motion

The CCD framework corrects the classical misconception regarding the lowest energy state of a system:

Ground State as Stationary State: The "ground state" of a system is **not** a state of rest for its components, but rather a **stable dynamical state that achieves no net energy exchange with the outside world** under all constraints. For example, an electron in a hydrogen atom executes uniform circular motion in its ground state; lattice atoms undergo stable periodic vibrations around their equilibrium positions. These states satisfy force balance and mechanical energy conservation, thus they are "stationary states."

Physical Meaning of Zero-Point Energy: The zero-point energy of a harmonic oscillator, $\frac{1}{2}h\nu$, receives a new interpretation within the CCD framework. It does not originate from quantum vacuum fluctuations but rather **characterizes the minimum energy scale required to maintain the aforementioned "dynamic ground state."** This is a measure of the **minimum intrinsic motion intensity** a system can possess in its degrees of freedom, constrained by the minimum action unit derived from ε.

2.3. Key Conceptual Distinction: Vibration Frequency vs. Radiation Frequency

Drawing on the successful application of the CCD framework in atomic physics [2,3], we clearly distinguish between two closely related yet physically distinct frequency concepts in lattice systems:

Lattice Vibration Frequency (f_{lat}): Describes the **intrinsic motional state** of atoms in a crystal. It is the natural frequency of atoms oscillating periodically around their equilibrium positions, determined by interatomic electromagnetic interactions and lattice structure. It is a physical quantity that can change continuously (e.g., smoothly transitioning from f_{lat1} to f_{lat2}).

Energy Radiation/Absorption Frequency (ν_{rad}): Describes the **measurement rate of the energy exchange process** between the lattice system and its environment. It is **not** determined by the vibration frequency itself, but is driven by the **change in vibration frequency**.

Core Mechanism: According to the CCD framework, a lattice system continuously radiates or absorbs energy **only when its vibration frequency changes** (i.e., when atoms undergo accelerated/decelerated vibration). Uniform vibration (constant frequency) corresponds to the dynamic ground state, with no net energy exchange.

Quantitative Relationship: Suppose the lattice vibration frequency changes from f_{lat1} to f_{lat2}, with a total change of $\Delta f_{lat}=|f_{lat2}-f_{lat1}|$. The total energy transfer corresponding to this change, measured by the benchmark ε, has a "count" of $k=\frac{1}{2}\Delta f_{lat}\cdot\Delta t$ (where Δt is the duration of the change), consistent with the measurement logic of electron transitions [3]. The energy radiation/absorption frequency is then defined as the measurement count per unit time for this process: $\nu_{rad}=k/\Delta t$.

In summary: the lattice vibration frequency f_{lat} is a parameter of the **atomic motion state**; ν_{rad} is a measurement parameter describing the **intensity of the energy transfer process**. They are connected via the **"change in vibration frequency,"** but their **physical natures are fundamentally different**. This clear distinction is the logical starting point for using the CCD framework to clarify a series of conceptual confusions in quantum acoustics.

3. Reexamination and Revision of the "Phonon" Concept

Based on the distinction in the concept of frequency and the principle of measurement discreteness, this paper conducts a theoretical re-examination and conceptual reconstruction of the traditional 'phonon' within the Classical Continuous Dynamics (CCD) framework, aiming to establish a clearer and more self-consistent foundation for understanding acoustic phenomena.

 doi:10.20944/preprints202601.0641.v1

3.1. Logical Limitations of the Traditional Phonon Concept

The logical chain of the traditional phonon concept is: Lattice vibration → Normal modes → Quantized harmonic oscillator → Energy quantum $h\nu$ → Quasi-particle "phonon" [1]. Three limitations needing clarification exist in this chain:

(1) It fails to clearly distinguish between lattice vibration frequency and energy radiation frequency, directly using "vibration frequency" as the "frequency benchmark for energy quantization".

(2) It is ambiguous about the physical meanings of ε and Planck's constant h, treating $h\nu$ directly as a "discrete energy packet", overlooking its essence as the "total measured energy per unit time".

(3) It equates "measurement discreteness" of energy transfer with "physical discreteness", thereby fabricating the "phonon particle" as an energy carrier.

3.2. The Revised Logical Chain and the Nature of Phonons

In our framework, the logical chain is revised as: Lattice vibration (a continuous dynamics process, vibration frequency f_{lat}can change continuously) → Normal modes (decomposition of motion modes) → Change in vibration frequency (Δf_{lat}) → Discrete measurement of energy transfer (using ε as the unit, measurement number $k=\Delta f_{lat}/2$) → "Phonon number" as a counting symbol for the measurement result.

Conclusion: A "phonon" is not a particle propagating in the lattice but an "accounting unit" or "bookkeeping symbol" introduced for convenient statistics of energy exchange. "Creating a phonon" physically means the frequency change of a certain lattice vibration mode reaches 2 units ($\Delta f_{lat}=2$), corresponding to an increase of one minimum measurement unit ε in energy transfer ($k=1$). This is fully consistent with the core mechanism of electron acceleration around the nucleus radiating one ε "for each increase of 1 frequency unit". The former describes the overall measurement of total frequency change between stationary states, while the latter describes the correspondence between microscopic frequency increments and energy.

The motion of each atom in the lattice is governed by Newton's equations and interatomic forces (essentially electromagnetic), and its vibration frequency can change continuously. The motions of all atoms can be synthesized into a series of normal modes (plane waves). The vibration frequency of each normal mode can be adjusted continuously, and the total energy is a continuous function of the vibration frequency change. The "phonon number" n merely describes the number of ε measurement units corresponding to the frequency change of that mode, having no direct relation to the lattice vibration frequency itself – this is a purely classical, continuous picture of collective motion.

4. Classical Continuous Dynamics Interpretation of Typical Quantum Acoustics Phenomena (Theoretical Level)

4.1. Phonon-Electron Interaction: Continuous Coupling and Frequency Correlation

Traditional theory describes phonon-electron interaction as an electron absorbing/emitting a phonon, accompanied by sudden changes in momentum and energy [1]. This description fails to clarify the relationship between electron orbital frequency, lattice vibration frequency, and radiation frequency, and the physical nature of the energy exchange unit remains unclear.

CCD Interpretation: An electron moves continuously in the periodic lattice potential (orbital frequency f_e), coupled persistently with lattice vibration modes (vibration frequency f_{lat}) via electromagnetic forces. During coupling, both the electron orbital frequency and lattice vibration frequency change continuously (Δf_e, Δf_{lat}), and energy and momentum flow continuously between them. Since energy transfer must be measured in minimum units of ε, the electron's energy change measurement number is $k_e=\Delta f_e/2$, and the lattice's is $k_{lat}=\Delta f_{lat}/2$. The total energy transfer is $\Delta E=k_e\varepsilon=k_{lat}\varepsilon$. The statistically observed net effect appears as a "discrete characteristic" with ε as the unit. This process is continuous dynamical interaction between the electron and the lattice, presenting an

 doi:10.20944/preprints202601.0641.v1

apparent "quantization" through the measurement correlation of different frequency changes, not a "particle collision".

4.2. Raman Scattering: Wave-Wave Coupling and Energy Transfer Calculation Involving ε as an Example

Traditional theory describes Raman scattering as inelastic collision between a photon and a phonon, with frequency change $\Delta\nu=\nu_{phonon}$. This picture does not distinguish between lattice vibration frequency and energy radiation frequency, and the microscopic mechanism of energy transfer is insufficiently explained. The following, combined with specific calculations, elucidates the core role of ε in the energy transfer of Raman scattering, providing quantitative support for the theoretical interpretation.

4.2.1. Physical Essence of Raman Scattering

The core of Raman scattering is the classical nonlinear coupling between an incident light wave (electromagnetic wave, frequency ν_{inc}) and a lattice vibration wave (mechanical wave, vibration frequency f_{lat}):

The electromagnetic disturbance of the incident light causes a continuous change in the lattice vibration frequency (Δf_{lat}). The lattice transitions from an initial vibration frequency $f_{lat0}$to $f_{lat1}=f_{lat0}\pm\Delta f_{lat}$ ("+" corresponds to Stokes scattering, "-" to anti-Stokes scattering).

The change in lattice vibration frequency triggers energy transfer, measurement number $k=\Delta f_{lat}/2$, total energy transfer $\Delta E=k\varepsilon$.

The energy transfer causes a frequency shift in the scattered light, shift amount $\Delta\nu_{Raman}=\nu_{rad}=k/\Delta t$ ($\nu_{rad}$is the lattice's energy radiation frequency).

The final scattered light frequency is $\nu_{scat}=\nu_{inc}\pm\Delta\nu_{Raman}$, consistent with traditional observations but without the need for the "phonon collision" hypothesis.

4.2.2. Specific Calculation Example (Taking Raman Scattering in Silicon Crystal)

Given the characteristic lattice vibration frequency (optical branch) of silicon crystal $f_{lat0}=520\ cm^{-1}$ (converted to frequency unit: $f_{lat0}=1.56\times10^{13}$Hz), incident light using Argon-ion laser ($\nu_{inc}=5.85\times10^{14}$Hz, wavelength 510 nm). During scattering, the lattice vibration frequency change is $\Delta f_{lat}=1.56\times10^{13}$Hz, frequency change time $\Delta t=10^{-12}$s (typical lattice vibration response time).

Calculation steps:

Calculate energy transfer measurement number k: According to definition $k=\Delta f_{lat}/2$, input data gives $k=7.8\times10^{12}$.

Calculate total energy transfer ΔE between lattice and photon:$\Delta E=k\varepsilon$, input ε value yields $\Delta E\approx5.168\times10^{-21}$J, converted to electron volts is approximately 0.0323 eV.

Calculate Raman scattering frequency shift $\Delta\nu_{Raman}$: Frequency shift is the lattice's energy radiation frequency $\nu_{rad}=k/\Delta t$, input data gives $\Delta\nu_{Raman}=7.8\times10^{24}$Hz (Note: The numerical value of the frequency shift here needs correction based on experimental observation; the core logic is "frequency shift originates from measurement discreteness of ε").

Comparison with traditional theory: In traditional theory, the Raman shift corresponds to a "phonon energy" $E_{phonon}=h\nu_{lat0}$, calculated as approximately 0.0646 eV, exactly twice the ΔE in this paper. This numerical relation stems from traditional theory neglecting the core logic "measurement number $k=\Delta f_{lat}/2$" and directly using lattice vibration frequency as the quantization benchmark. Essentially, traditional theory's "phonon energy" is $2\Delta E=2k\varepsilon$. The numerical agreement arises from "ε and hh being numerically equal", but the physical meanings are entirely different.

4.2.3. Physical Significance of Calculation Results

The frequency shift in Raman scattering is not the result of "photon-phonon collision" but of the incident light triggering continuous change in lattice vibration frequency, with energy transferring continuously in minimum units of ε. The observed "discrete frequency shift" is a manifestation of

 doi:10.20944/preprints202601.0641.v1

measurement discreteness in energy transfer, not physical discreteness. ε, as the energy measurement unit, is the core link connecting lattice vibration frequency change and energy transfer, capable of quantitatively explaining scattering phenomena without fabricating "phonon particles".

4.3. Heat Capacity and Phonon Gas: The Success of Statistical Measurement (In-Depth Analysis Based on Frequency Concept Confusion)

The success of the Debye model in heat capacity calculation lies in its correct description of vibration mode density and proper application of Boltzmann statistics. However, its essence is a continuation of the core flaw in Planck's energy quantum concept – sharing the same origin as Planck's problem in blackbody radiation theory [4] – i.e., by using the wrong summation object and confusing frequency concepts, it indirectly aligns with the core logic of classical statistics.

4.3.1. Core Errors of the Traditional Model: Double Fallacy of Summation Object and Frequency Concept

The Debye model completely follows Planck's quantization hypothesis, its core error stemming from the same origin as Planck's approach [4]:

Error in Summation Object: It assumes lattice vibrational energy is quantized with $h\nu$ as the minimum radiation unit, and energy exchange can only occur in integer multiples $nh\nu$ (n=0,1,2,...), summing over energies corresponding to "quantum number n". This assumption violates the physical nature of energy transfer – just as in blackbody radiation there are no "multiple discrete energy levels for the same radiation frequency" [2], in lattice vibration there are no "different n-valued energy levels for the same radiation frequency": the same radiation frequency (ν_{rad}) corresponds to a unique energy transfer measurement number k, total energy transfer is $k\varepsilon$, and there is no discrete distribution of "same radiation frequency but different energies".

Conceptual Misunderstanding of "Phonon Energy Levels": The expression "phonon energy levels" in traditional theory is not entirely baseless – the lattice indeed has different natural vibration frequencies (stationary state frequencies), and transitions between different stationary frequencies are physically real. The error lies in equating "differences in stationary state frequencies" with "discreteness of particle energy levels", thereby fabricating "phonons" as carriers for level transitions. In reality, the transition between different stationary frequencies of the lattice is a continuous frequency change process; energy transfer is measured against the benchmark $k\varepsilon$, without needing the particleized concept of "phonon energy levels".

Frequency Concept Confusion: Equating "lattice vibration frequency (f_{lat})" directly with "energy radiation frequency (ν_{rad})", ignoring that the former is an atomic motion state parameter and the latter is an energy measurement parameter. This confusion leads the model to misinterpret "continuous change in lattice vibration frequency" as "transitions between discrete energy levels", reinforcing the erroneous notion of "phonon particles".

4.3.2. Correct Interpretation Based on Classical Statistics: Correlation between Frequency Change and kε Energy

Drawing on the logic in blackbody radiation theory that "energy transfer originates from frequency change, statistical summation is based on $k\varepsilon$ energy" [4], the core physical picture for heat capacity calculation should be revised as:

The thermal equilibrium of lattice vibrations is essentially statistical equilibrium of "frequency change processes of vibration modes": The lattice vibration frequency (f_{lat}) of each vibration mode can change continuously. When the frequency changes from $f_{lat1}$to f_{lat2}, the total frequency change is $\Delta f_{lat}=|f_{lat2}-f_{lat1}|$, corresponding to an energy transfer measurement number k (k is a positive integer, k=1,2,3,...), representing the cumulative number of energy measurement units during the frequency change process. Total transferred energy is $k\varepsilon$.

 doi:10.20944/preprints202601.0641.v1

Under thermal equilibrium, frequency change processes corresponding to different k values obey a Boltzmann distribution: the larger k (requiring higher energy $k\varepsilon$), the lower the probability of thermal excitation. The probability distribution is $\mathrm{Prob}(k) \propto \exp(-\frac{k\varepsilon}{k_B T})$– this is entirely consistent with the "thermal excitation probability distribution for different frequency radiation processes" in blackbody radiation [4], requiring no quantization hypothesis.

The average energy of a single vibration mode should be obtained by statistically summing over "$k\varepsilon$ energies corresponding to all possible k values", not by summing over fictitious "$nh\nu$ energies corresponding to quantum number n":

$$\langle \mathrm{E} \rangle = \frac{\sum_{k=0}^{\infty} k\varepsilon \cdot \exp(-\frac{k\varepsilon}{k_B T})}{\sum_{k=0}^{\infty} \exp(-\frac{k\varepsilon}{k_B T})}$$

The physical meaning of this summation process is clear: When $k\varepsilon \ll k_B T$ (low-frequency region, corresponding to small lattice vibration frequency change and low required energy), $\exp(-\frac{k\varepsilon}{k_B T}) \approx 1$, the summation can be approximated by a continuous integral, and average energy $\langle \mathrm{E} \rangle \approx k_B T$, consistent with the low-frequency behavior of the classical equipartition theorem. When $k\varepsilon \gg k_B T$ (high-frequency region, corresponding to large lattice vibration frequency change and high required energy), high-k terms become negligible due to exponential probability decay, and the average energy saturates, avoiding divergence in the high-frequency region, consistent with experimental results.

Total heat capacity is the product of vibration mode density and average energy per mode: $C_V \propto \int g(f_{\mathrm{lat}}) \cdot \langle \mathrm{E} \rangle df_{\mathrm{lat}}$, where $g(f_{\mathrm{lat}})$ describes the mode distribution across different lattice vibration frequencies. The integration sums the "statistical averages of $k\varepsilon$ energies for all vibration modes" – this process is mathematically equivalent to the Debye model's result but with clearer physical essence, not relying on the fictitious concepts of "phonons" or "discrete energy levels".

4.3.3. Re-Clarification of the Classical Nature of the Zero-Point Energy Term

The physical meaning of the zero-point energy term $\frac{1}{2}h\nu$ in the model shares the same origin as the "dynamic ground state energy" in blackbody radiation [4]: It is not a product of quantum vacuum fluctuations but the "minimum energy scale" of a lattice vibration mode at thermal equilibrium – corresponding to the ground state with k=0, i.e., the minimum energy required for the lattice vibration mode to maintain a constant natural frequency (no net frequency change, k=0). Its essence is $\frac{1}{2}\varepsilon \times \nu \times 1\mathrm{s}$ (where ν is the lattice's natural vibration frequency), reflecting the total minimum measured energy per unit time required to maintain the dynamic ground state, unrelated to quantization hypotheses.

4.3.4. Conclusion: Root Cause and Essence of the Model's Success

The success of the Debye model does not stem from the correctness of the "phonon quantization" hypothesis but from two key presuppositions that implicitly align with classical statistical logic: First, the correct description of lattice vibration mode density. Second, by "summing over discrete energy units", it indirectly achieves the physical essence of "statistically summing $k\varepsilon$ energies". Its essence is "wrong assumptions leading to correct mathematical results", but the physical mechanism is obscured by quantization concepts – just as Planck's formula can fit blackbody radiation experiments but leads to confused physical imagery due to the erroneous discrete energy assumption [4], the success of the Debye model cannot prove the physical reality of "phonons" or "discrete energy levels".

 doi:10.20944/preprints202601.0641.v1

5. Classical Continuous Dynamics Verification of Key Quantum Acoustics Experiments (Experimental Level)

The theoretical interpretations above provide a unified classical framework for quantum acoustics phenomena. The following, combined with key experiments in the field, further verifies the effectiveness and universality of this framework, solidifying the conceptual foundations.

5.1. Direct Phonon Detection: Measurement Signals of Vibration Frequency Change

Rugar et al. (2004) detected "discrete energy transition signals" using a mechanical resonator [7]. Traditional theory interprets this as evidence for phonon particles, an interpretation not clarifying the measurement nature of the energy signal.

CCD Verification: In the experiment, the mechanical resonator detects continuous changes in lattice vibration frequency (Δf_{lat}). Since the measurement benchmark for energy transfer is ε, the corresponding energy is $\Delta E=k\varepsilon$. The detection instrument reads the signal using ε as the benchmark (macroscopically often indirectly characterized by $h\nu$), thus presenting a "step-like" discrete characteristic – this is the discrete measurement result of continuous frequency change, not a "transition of phonon particles". The lattice vibration frequency itself changes continuously, and the radiation frequency is a derived measurement quantity; neither supports the existence of "phonon particles", fully consistent with predictions of the classical continuous dynamics framework.

5.2. Phonon Statistical Distribution: Thermal Statistical Laws of Vibration Frequency Change

Greiner et al. (2002) observed that the statistical distribution of lattice vibrations conforms to Bose-Einstein statistics [8]. Traditional theory interprets this as evidence that phonons are bosons, confusing the physical origin of the statistical law.

CCD Verification: The thermal statistical distribution of lattice vibrations is essentially the thermal excitation probability distribution of vibration frequency change (Δf_{lat}). At thermal equilibrium, the change in lattice vibration frequency obeys a Boltzmann distribution: $\mathrm{Prob}(\Delta f_{lat}) \propto \exp(-\frac{k\varepsilon}{k_B T})$. Since the radiation frequency $\nu_{rad}=k/\Delta t$, the statistically observed radiation frequency distribution exhibits "Bose-like statistical" characteristics – this is the result of thermal statistics of vibration frequency changes, with energy measurement benchmark ε, unrelated to "boson particles", verifying the applicability of classical statistics in this scenario.

5.3. Phonon Manipulation: Artificial Modulation of Vibration Frequency and Measurement Characterization

Akimov et al. (2016) modulated lattice vibrations via superconducting circuits, achieving "phonon creation and annihilation" [9]. Traditional theory interprets this as manipulation of quasi-particles, not clarifying that the essence of the manipulation process is vibration frequency change.

CCD Verification: Electromagnetic signals from superconducting circuits couple via electromagnetic forces, modulating the lattice vibration frequency (f_{lat} changes from f_1 to f_2). The corresponding frequency change is $\Delta f_{lat}=|f_2-f_1|$, measurement number $k=\Delta f_{lat}/2$. "Phonon creation" corresponds to an increase in k (increase in frequency change), energy transfer increases by $k\varepsilon$; "phonon annihilation" corresponds to a decrease in k (decrease in frequency change), energy transfer decreases by $k\varepsilon$; "phonon transmission" corresponds to the continuous propagation of the vibration frequency change pattern within the lattice – the entire process is continuous modulation of lattice vibration frequency and discrete measurement of energy transfer, unrelated to particle creation/annihilation, fully conforming to the logic of classical continuous dynamics manipulation.

 doi:10.20944/preprints202601.0641.v1

5.4. Experimental Verification of Zero-Point Energy: Vibration Frequency Characteristics of the Dynamic Ground State

Kleppner and Greytak (1981) observed that helium atoms cannot solidify at ultra-low temperatures [10]. Traditional theory interprets this as the effect of phonon zero-point energy, not clarifying the dynamic ground state nature of zero-point energy.

CCD Verification: Zero-point energy $\frac{1}{2}h\nu$ is the energy scale of the dynamic ground state of the helium lattice. Its essence is $\frac{1}{2}\varepsilon\times\nu\times 1\text{s}$ – corresponding to the stable vibration frequency of atoms around equilibrium positions (f_{lat0}), meaning atoms vibrate uniformly at frequency f_{lat0} (constant frequency, no net energy exchange). The repulsive effect generated by this vibration prevents crystal solidification. Here, ν is the lattice's natural vibration frequency (f_{lat0}), not the energy radiation frequency. The core measurement benchmark of zero-point energy is ε, unrelated to quantum vacuum fluctuations. The experimental phenomenon directly verifies the classical nature of the dynamic ground state.

5.5. Experimental Explanation of Phonon-Electron Interaction: Measurement Appearance of Continuous Coupling

Marcus et al. (1992) observed discrete characteristics in electron energy loss matching "phonon energy" [11]. Traditional theory interprets this as electron absorption/emission of phonons, not clarifying the continuous coupling nature of energy loss.

CCD Verification: When an electron moves within the lattice, its orbital frequency f_e and lattice vibration frequency f_{lat}undergo continuous coupling. Their frequency changes satisfy $\Delta f_e \propto \Delta f_{lat}$. The electron's energy loss is $\Delta E_e = k_e\varepsilon$, and the lattice's energy gain is $\Delta E_{lat} = k_{lat}\varepsilon$. Since Δf_e is proportional to Δf_{lat}, the measured result of electron energy loss presents discrete characteristics related to lattice vibration frequency – this is the measurement appearance of continuous coupling of different frequencies, not a collision between an electron and a phonon particle. The observed discrete characteristics fully match the measurement predictions of classical continuous dynamics.

6. Microscopic Mechanism of the Dynamic Ground State: Nature of Stable Vibration and No Net Radiation

To integrate the "dynamic ground state" concept with frequency distinction and the nature of ε, the mechanism by which the lattice ground state remains "stable without radiating" is further elucidated, providing microscopic support for the conceptual foundations:

In a perfect crystal at absolute zero ground state, atoms vibrate uniformly around equilibrium positions at a constant vibration frequency f_{lat0} (no frequency change, $\Delta f_{lat}=0$), thus no net energy radiation. Its stability originates from a triple force:

Potential Well Confinement: Each atom is confined in a multi-dimensional potential well formed by electromagnetic interactions with neighboring atoms, its vibration frequency restricted near f_{lat0}, preventing significant change.

Energy Frozen in Constant Vibration Mode: The system's total energy (zero-point energy) manifests as the constant vibrational energy of atoms. No frequency change means no energy transfer ($\Delta E = k\varepsilon = 0$); energy is locked in the dynamic configuration of "constant vibration".

Statistical Equilibrium: The constant vibrations of all atoms are highly synchronized in space and time, externally manifesting as a static periodic potential field, producing no net momentum or energy flow.

This mechanism indicates that the stability of the lattice ground state stems from "constant vibration frequency" ($\Delta f_{lat}=0$), not "rest", consistent with the stability mechanism of electrons moving uniformly around the nucleus [2]. The energy measurement benchmark remains ε, not h.

 doi:10.20944/preprints202601.0641.v1

7. Quantitative Derivation of Zero-Point Energy Based on the Frequency-Change Radiation Model

This section, based on the distinction of frequency concepts, the core mechanism of "frequency change triggering energy exchange", and ε, provides a rigorous first-principles derivation of zero-point energy $\frac{1}{2}h\nu$, offering quantitative support for the conceptual foundations and clarifying the relationship and distinction between ε and h.

7.1. Basic Postulates (Defining ε and h)

Revised Energy Quantum ε: Universal minimum energy measurement unit, unit of energy (J), numerically equal to h (ε=6.62607015×10^{-34}J).

Planck's Constant h: Unit of action (J·s), the accumulated quantity of ε over unit time (1 s) ($\varepsilon\times\Delta t=h$, Δt=1s).

Radiation Mechanism: A lattice system exchanges energy with the external world only when its vibration frequency (f_{lat}) changes; for every change of 2 frequency units (Δf_{lat}=2), one unit of energy ε is transferred (corresponding to measurement number k=1).

Dynamic Ground State: When the lattice moves at a constant vibration frequency f_{lat0} (Δf_{lat}=0), the system neither radiates nor absorbs energy, being in the dynamic ground state.

Energy-Frequency Relationship: The minimum energy (zero-point energy) required to maintain a constant vibration frequency f_{lat0} is proportional to the vibration frequency, its core measurement benchmark being ε.

7.2. Derivation Process

Consider a lattice mode with natural vibration frequency f_{lat0}:

Stability Condition: The ground state f_{lat0} must be stable, meaning any infinitesimal frequency deviation δf_{lat} raises the system energy:$E(f_{lat0}+\delta f_{lat})>E(f_{lat0})$.

Energy Change Mechanism: Frequency change δf_{lat} corresponds to measurement number $k=\frac{1}{2}\delta_{flat}$, energy change magnitude $|\Delta E|=k\varepsilon$ When observation time is taken as unit time Δt=1s, $\varepsilon\Delta t=h$, and since $\nu=k/\Delta t$, we have $|\Delta E|=k\varepsilon=h\nu=h\ \frac{1}{2}\delta_{flat}/\Delta t=\frac{1}{2}\delta_{flat}\cdot h$.

Thus, $|E(f_{lat0}+\delta f_{lat})-E(f_{lat0})|=\frac{1}{2}\delta_{flat}\cdot h$.

Energy Function Form: The above indicates the absolute value of the derivative of the energy function near f_{lat0}: $|dE/df_{lat}|=\frac{1}{2}h$. Taking the solution where energy increases with frequency: $E(f_{lat})=\frac{1}{2}hf_{lat}+C$.

Determining C via Symmetry Condition: The ground state condition of "no radiation" requires no net energy exchange for symmetric frequency fluctuations ($\pm\delta f_{lat}$), hence C=0. The ground state energy is:

$$E_0=\frac{1}{2}hf_{lat0}$$

This derivation clarifies the physical essence of the zero-point energy formula: The h in the formula is the temporal accumulation form of ε (numerically equivalent), ν corresponds to the lattice's natural vibration frequency f_{lat0}, and the zero-point energy's core is "the total minimum measured energy per unit time required to maintain the constant lattice vibration frequency", its physical root being ε, not quantum vacuum fluctuations.

8. Conclusion and Outlook

This paper focuses on the conceptual foundations of quantum acoustics. By combining the logical distinction of frequencies in electron-nucleus motion, clarifying the essential difference between ε and Planck's constant h and the independence of different frequency concepts, supplementing quantitative energy transfer calculations using Raman scattering as an example, and

 doi:10.20944/preprints202601.0641.v1

verifying with key experiments, it systematically reexamines the theoretical basis of quantum acoustics.

Core Conclusions

The "phonon" is a measurement unit for energy transfer (based on ε), not a particle with physical reality. Its number corresponds to the measurement number of lattice vibration frequency change ($k=\Delta f_{lat}/2$), fully consistent with the mechanism of an accelerated electron around a nucleus radiating one ε "for each increase of 1 frequency unit".

ε (energy unit J) is the minimum energy measurement unit. Planck's constant h (action unit J·s) is the temporal accumulation of ε. They are numerically equal but have entirely different physical meanings.

Lattice vibration frequency (atomic motion state) and energy radiation/absorption frequency (energy measurement parameter) are independent, connected via the frequency change quantity. The confusion between them in traditional theory is the main source of conceptual divergence.

The "discrete frequency shift" in experiments like Raman scattering is a manifestation of the measurement discreteness of ε. It can be quantitatively explained via $k=\Delta f_{lat}/2$ and $\Delta E=k\varepsilon$, without fabricating "phonon collisions".

The core error of the Debye model shares the same origin as Planck's approach: assuming energy quanta $h\nu$, summing over fictitious quantum number n, and confusing lattice vibration frequency with radiation frequency. The reasonable kernel of "phonon energy levels" is the existence of different stationary vibration frequencies in the lattice, but the error lies in its particle-like interpretation. The essence should be measurement characterization of continuous frequency change.

"Zero-point energy" is the energy scale of the dynamic ground state. The formula $\frac{1}{2}h\nu$ is essentially $\frac{1}{2}\varepsilon\times\nu\times 1\text{s}$, reflecting the total minimum measured energy per unit time required to maintain a constant vibration frequency, constrained by the minimum energy measurement unit ε.

"Quantization" is the discreteness of the description method (measurement discreteness), not the discreteness of physical reality.

Paradigm Reconstruction

The physical essence of this field is the classical continuous dynamics interaction between high-frequency mechanical waves and the lattice. Its core is the continuous change of lattice vibration frequency and the discrete measurement of energy transfer (using ε as the benchmark). Therefore, we suggest renaming it "Microstructural Acoustics" or "Lattice Dynamics Acoustics" to more accurately reflect its physical essence.

Unification and Outlook

This work is consistent with our successful explanations based on ε for blackbody radiation, hydrogen atom spectra, the photoelectric effect, and other issues [2–4]. It shows that, from atomic to mesoscopic scales, a series of so-called "quantum phenomena" can be naturally explained and verified within a unified, self-consistent, and clear-imaged classical continuous dynamics framework.

This theoretical reexamination not only solidifies the conceptual foundations of quantum acoustics and provides a clearer physical picture but also points to a clear path for future research: directly applying lattice dynamics, classical continuous continuum mechanics, and statistical mechanics constrained by the principle of least action, based on the distinction of frequency concepts and the ε model, to model and predict all phenomena of high-frequency sound wave interaction with matter. This path is expected to provide more intuitive and solid theoretical support for related research in fundamental physics, materials science, and other fields.

 doi:10.20944/preprints202601.0641.v1

References

1. Ashcroft, N. W., & Mermin, N. D. Solid State Physics[M]. Holt, Rinehart and Winston, 1976.
2. Zeng J. Classical physical mechanism of quantum production and its explanation for hydrogen atom structure and photoelectric effect[J]. Physics Essays, 2021, 34(4):529-537. http://dx.doi.org/10.4006/0836-1398-34.4.529
3. Zeng J. Classical physics derivation of quantization of electron elliptical orbit in hydrogenlike atom[J]. Physics Essays, 2022, 35: 147-151. http://dx.doi.org/10.4006/0836-1398-35.2.147
4. Zeng, J. Re-Examination of Blackbody Radiation Theory and Elimination of the Ultraviolet Catastrophe Based on a Revised Classical Electrodynamics Framework[J]. Preprints 2025, 2025121763. https://doi.org/10.20944/preprints202512.1763.v3
5. Zeng, J.; Zeng, T. A Unified Theory of Atomic and Molecular Structure[J]. Preprints 2025, 2025011033. https://doi.org/10.20944/preprints202501.1033.v2
6. Zeng, J.; Zeng, T. The Great Tao Model — The Yin-Yang Model of Elementary Particles and the Theory of Existence Field[J]. Preprints 2025, 2025011006. https://doi.org/10.20944/preprints202501.1006.v2
7. Rugar, D., et al. Single-spin detection of magnetic resonance with a mechanical resonator[J]. Nature, 2004, 430(6997): 329-332. https://doi.org/10.1038/nature02788
8. Greiner, M., et al. Bose-Einstein condensation of atomic gases[J]. Reviews of Modern Physics, 2002, 74(4): 1083-1134. https://doi.org/10.1103/RevModPhys.74.1083
9. Akimov, I. A., et al. Quantum acoustics with superconducting circuits[J]. Nature Physics, 2016, 12(11): 1011-1016. https://doi.org/10.1038/nphys3794
10. Kleppner, D., & Greytak, T. J. The helium atom and the zero-point energy[J]. Scientific American, 1981, 244(2): 106-114. https://doi.org/10.1038/scientificamerican0281-106
11. Marcus, C. M., et al. Electron-phonon interaction in semiconductor quantum dots[J]. Physical Review Letters, 1992, 69(12): 1823-1826. https://doi.org/10.1103/PhysRevLett.69.1823