Classical Dynamical Interpretation of the Lamb Shift in Hydrogen Atom

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Abstract: The Lamb shift is an approximately 1057 MHz energy level splitting between the $2S_{1/2}$ and $2P_{1/2}$ states in the n=2 level of the hydrogen atom, regarded as a core experimental evidence for quantum electrodynamics (QED). Based on the Great Tao Model and the Unified Theory of Atomic and Molecular Structure, this paper proposes that the Lamb shift may originate from the difference in spatial average electrostatic potential energy between spherical and ellipsoidal electron orbital dynamic entities. To verify this mechanism, we constructed an initial geometric model for the n=2 level of the hydrogen atom (setting the semi-major axis a=4a_0 and the semi-minor axis b=2a_0). Calculations show that this geometric effect is sufficient to produce energy level splittings on the order of GHz, confirming the feasibility of the mechanism. By comparing with experimental data, a nearly spherical stable ellipsoidal configuration (semi-minor axis b≈3.56a_0) is determined, yielding a theoretical value (1.06 GHz) that precisely matches the experiment. This is not a simple parameter fitting, but rather a parameter determination jointly constrained by theory and experiment, successfully constructing a logically self-consistent classical physics-based "orbital geometry-precession dynamics" explanatory framework. Based on this framework, the model makes testable independent predictions: for the n=3 and n=4 excited states of hydrogen, the analogous energy level splittings will be approximately 0.20 GHz and 0.06 GHz, respectively, following a $1/n^3$ scaling law. This study provides the first first-principles computational example for the key concept of "electron orbital spatial configuration potential energy" in the Unified Theory of Atomic and Molecular Structure, and indicates a feasible classical path for calculating chemical bond energies and even predicting molecular spectra. This work not only provides a new physical interpretation of the Lamb shift based on classical realism, but also accomplishes a proof-of-principle validation from the explanation of a specific phenomenon to the construction of a new physical paradigm. It lays a crucial theoretical foundation for exploring a path toward understanding the microscopic world—one grounded in physical reality and logical consistency—outside the framework of quantum mechanics.

Keywords: Great Tao Model; Unified Theory of Atomic and Molecular Structure; Lamb shift; electron orbital dynamic entity; orbital precession; electron orbital spatial configuration potential energy

1 Introduction

In 1947, Lamb and Retherford, through microwave spectroscopy experiments, first observed an approximately 1057 MHz energy level splitting between the $2S_{1/2}$ and $2P_{1/2}$ states in the n=2 level of the hydrogen atom [1]. This phenomenon was formally named the Lamb shift. This discovery

holds landmark physical significance: it directly challenged the theoretical framework of Dirac's relativistic quantum mechanics—the Dirac equation predicted that the $2S_{1/2}$ and $2P_{1/2}$ states should be degenerate, whereas the existence of the Lamb shift indicated that a more refined theoretical explanation of microscopic energy level structures was required [2].

As the "birth moment and core experimental pillar" of quantum electrodynamics (QED), the explanation of the Lamb shift has become a critical benchmark for testing the validity of microscopic physical theories [3]. Feynman, Schwinger, and Tomonaga, based on quantum field theory concepts such as "vacuum fluctuations," "virtual particle exchange," and "electron self-energy correction," successfully fitted the experimental value of the Lamb shift using renormalization techniques, thus establishing the theoretical foundation of QED [4]. This achievement earned them the 1965 Nobel Prize in Physics [5]. Although the computational precision of QED for the Lamb shift has reached an extremely high level, with the deviation between theoretical and experimental values entering the kHz range [6], and even in high-precision experiments such as those on muonic hydrogen, the measurement of the Lamb shift has become a key method for determining the proton charge radius—as exemplified by the 2022 lattice QCD calculation of the two-photon exchange contribution by the Peking University team, which laid the foundation for understanding the influence of proton structure on the Lamb shift from first principles [7]—within mainstream physics, the Lamb shift is defined as a "typical quantum phenomenon" and its existence is regarded as decisive evidence that "classical physics fails in the microscopic domain," supporting the core position of quantum field theory as the fundamental framework for microphysics [3].

However, QED's interpretation of the Lamb shift has always suffered from profound logical contradictions and a lack of physical picture: concepts like vacuum fluctuations and virtual particles lack direct experimental verification and are essentially mathematical abstractions introduced to fit calculation results [8]; simultaneously, QED's computational process is completely disconnected from classical physical laws, failing to form an intuitive physical picture and resulting in a logical rupture between microscopic and macroscopic physical systems [9]. Although QED has achieved extremely high mathematical precision [10,11], the inherent conceptual problems of its abstract theoretical framework and hypotheses lacking physical reality are not only a focus of controversy in fundamental physics but have also sparked continuous and profound debates in the philosophy of science [12]. In recent years, the academic community continues to explore alternative explanatory paths for the Lamb shift: for example, in 2025, Yordanov proposed a derivation of the Lamb shift based on proton Brownian motion, completely independent of renormalization techniques [13]; Meads re-examined Feynman's self-interaction interpretation, attempting to eliminate unphysical contributions from ultraviolet cutoffs [14]. These explorations indicate that reflecting on and reconstructing the physical picture of the Lamb shift is an active direction in current theoretical physics research.

While mainstream physicists strive to perfect the mathematical formalism of quantum mechanics, another research path—reinterpreting "quantum phenomena" within the realistic framework of classical physics—has also continued to make new progress. In recent years, the Existence Field Theory [15] and the Unified Theory of Atomic and Molecular Structure [16], developed on the basis of the "Great Tao Model," have provided logically consistent classical physical explanations

for a series of microscopic phenomena once widely believed to necessitate the probabilistic interpretation of quantum mechanics. These works have successfully elucidated the quantum origin of the structure of hydrogen and hydrogen-like atoms [17,18], the mechanisms of electron transitions and the emission/absorption of light quanta [17], and constructed a unified picture of atomic and molecular structure based on the interaction of electron orbital dynamic entities and spin magnetic forces [16], thus restoring the physical picture of the microscopic world on the basis of the continuity and determinism of classical physics. These preliminary results suggest that the root causes of many phenomena considered "quantum-specific" are likely deeply embedded in overlooked classical electromagnetic interactions and many-body dynamics.

Therefore, a natural and crucial theoretical advancement is to apply this classical explanatory framework to the ultimate touchstone of its explanatory power—the Lamb shift of the hydrogen atom. If the Lamb shift, regarded as the "Holy Grail" of quantum electrodynamics, can also be quantitatively explained within a classical framework that eschews abstract concepts like "vacuum fluctuations" and "renormalization," it will not only represent a new understanding of the phenomenon itself but also serve as a powerful challenge to the traditional assertion that "classical physics fails at the atomic scale," providing decisive support for constructing a new, macro-micro-unified paradigm based on physical reality.

This paper, grounded in the Great Tao Model [15] and the Unified Theory of Atomic and Molecular Structure [16], and proceeding solely from the spatial averaging effect of classical orbital geometry and the charge existence field, provides a completely self-consistent, intuitive, and quantitative unified classical physical explanation of the Lamb shift.

2 Theoretical Basis

2.1 Charge Existence Field and Potential Energy Formula

According to the Existence Field Theory of the Great Tao Model [15], the charge of a charged particle, as an intrinsic physical quantity, continuously diffuses physical information into space, forming a charge existence field. The field intensity generated by the atomic nucleus at a distance r is:

$$E_e(r) = \frac{e}{4\pi\varepsilon_0 r^2}$$

The electrostatic potential energy of an electron in this field is:

$$E_p(r) = -\frac{e^2}{4\pi\varepsilon_0 r} \quad (1)$$

2.2 Geometric Differences of Electron Orbital Dynamic Entities

According to the Unified Theory of Atomic and Molecular Structure [16], electrons move in high-speed periodic orbits around the nucleus, forming spatially distributed dynamic entities due

to orbital precession. The orbital radius is always a definite value; electrons do not undergo sudden changes, "jumps," or approach/recede from the nucleus. Only when absorbing or emitting light quanta does the orbital radius change continuously.

The n=2 energy level of the hydrogen atom has two different electron orbital dynamic entities:

Great Tao Model Concept	Quantum Mechanical Counterpart	Spatial Geometric Feature	Orbital Precession Mode	Charge Flow Density Distribution
Spherical dynamic entity	$2S_{1/2}$ state	Spherically symmetric	Orbital plane precesses around diameter	Uniform distribution
Ellipsoidal dynamic entity	$2P_{1/2}$ state	Ellipsoidal distribution	Orbital plane precesses around semi-major axis	Maximum at vertices, minimum at equator

The above differences arise solely from the geometric symmetry of orbital precession and are purely classical geometric effects. For ease of comparison with experiments, this paper explicitly notes the origin when mentioning quantum mechanical terms, but the explanation of all physical mechanisms is based on the classical concepts of the Great Tao Model.

It should be noted that the "ellipsoidal dynamic entity" in the Great Tao Model describes the spatiotemporal envelope surface of the electron trajectory, not the probability density cloud of quantum mechanics. These are geometric descriptions under two different physical pictures; one should not directly compare the geometric shapes but rather the ultimately observable energy level splitting values. The core argument of this model is that the non-uniform surface charge distribution of the ellipsoidal dynamic entity leads to an increase in the average equivalent radius, thereby generating energy level splitting.

2.3 Spatial Average Potential Energy and Average Equivalent Radius

According to the Great Tao Model, the electron orbital dynamic entity is the spatiotemporal accumulation effect of the electron's high-speed periodic motion. On the observational timescale, the electron forms a surface charge density distribution $\sigma(\theta)$ on the surface of the dynamic entity, satisfying total charge conservation:

$$\oint_S \sigma(\theta) \cdot dS = e \tag{2}$$

The interaction energy between the electron and the atomic nucleus is the total potential energy of the surface charge distribution $\sigma(\theta)$ in the nuclear potential:

$$\overline{E}_p = \oint_S \sigma(\theta) \cdot \left(-\frac{e}{4\pi\varepsilon_0 r(\theta)}\right) dS \tag{3}$$

This is the standard expression for the potential energy of a surface charge distribution in classical electrostatics: the total potential energy equals the integral of the charge element σdS multiplied by the electric potential at its location.

To concisely express the above total potential energy in the form of an equivalent point charge, we define an **average equivalent radius** $\overline{r}$, such that:

$$\overline{E}_p = -\frac{e^2}{4\pi\varepsilon_0}\cdot\frac{1}{\bar{r}} \quad (4)$$

Combining (3) and (4) yields:

$$\frac{1}{\bar{r}} = \frac{1}{e}\oint_S \sigma(\theta)\cdot\frac{1}{r(\theta)}dS \quad (5)$$

Equation (5) defines the reciprocal of the average equivalent radius as the charge-weighted average of the surface charge density and $1/r(\theta)$. The physical meaning of $\bar{r}$ is: it is the distance from the equivalent point charge to the nucleus such that the electrostatic potential energy between this point charge and the nucleus equals the total potential energy of the actual surface charge distribution. This is the key bridge connecting the classical spatiotemporal average picture and energy level splitting.

3 Physical Mechanism of the Lamb Shift: Geometric Potential Energy Difference Model

3.1 Mechanism Overview

Based on the physical framework established in Section 2, the stationary states of electrons in a hydrogen atom correspond to specific "electron orbital dynamic entities," whose stable shapes are determined by orbital precession dynamics [16]. For the n=2 energy level, there exist two different stable precession modes, forming spherical and ellipsoidal dynamic entities, respectively. The core task of this chapter is to elucidate how the energy level difference (the Lamb shift) between these two dynamic entities arises from their geometric shape differences.

3.2 Derivation of Geometric Potential Energy Difference

According to Equation (4), for a dynamic entity with a surface charge distribution $\sigma(\theta)$, its average electrostatic potential energy with respect to the nucleus can be expressed as $\overline{E}_p = -e^2/(4\pi\varepsilon_0\bar{r})$, where the reciprocal of the average equivalent radius $1/\bar{r}$ is defined by Equation (5).

For the spherical dynamic entity at the n=2 energy level, its radius is r_s=4a_0 and the charge distribution is uniform, so its average equivalent radius is simply its own radius:

$$\bar{r}_{\text{sphere}} = r_s = 4a_0, \quad \overline{E}_p(\text{sphere}) = -\frac{e^2}{4\pi\varepsilon_0\cdot 4a_0} \quad (6)$$

For the ellipsoidal dynamic entity, its shape (described by the semi-major axis a and semi-minor axis b) and the non-uniform charge distribution $\sigma(\theta)$ caused by precession together determine its average equivalent radius $\bar{r}_{\text{ellipsoid}}$ and its average potential energy:

$$\overline{E}_p(\text{ellipsoid}) = -\frac{e^2}{4\pi\varepsilon_0 \cdot \overline{r}_{\text{ellipsoid}}}, \quad \frac{1}{\text{ellipsoid}} = \frac{1}{e}\oint_S \sigma(\theta) \cdot \frac{1}{r(\theta)} dS \tag{7}$$

where $r(\theta)$ is the distance from a point on the ellipsoid surface to the nucleus located at the focus.

3.3 Analytical Formula for the Lamb Shift

Define the difference in the reciprocals of the average equivalent radii between the spherical and ellipsoidal dynamic entities:

$$\Delta\left(\frac{1}{r}\right) = \frac{1}{\overline{r}_{\text{sphere}}} - \frac{1}{\overline{r}_{\text{ellipsoid}}} \tag{8}$$

Substituting Equations (6) and (7), the difference in their average potential energies, i.e., the Lamb shift energy level difference, is:

$$\Delta E_{\text{lamb}} = \overline{E}_p\text{ellipsoid}) - \overline{E}_p(\text{sphere}) = \frac{e^2}{4\pi\varepsilon_0} \cdot \Delta\left(\frac{1}{r}\right) \tag{9}$$

Equation (9) is the core physical formula of this study. It establishes a direct quantitative relationship between the observable Lamb shift ΔE_{lamb} and a purely geometric physical quantity—the difference in the reciprocals of the average equivalent radii of the spherical and ellipsoidal dynamic entities, $\Delta(1/r)$.

3.4 Qualitative Influence of Geometric Shape on the Energy Level Difference

The physical meaning of Equation (9) is very clear: the magnitude of the Lamb shift is proportional to $\Delta(1/r)$. Moreover, the value of $\Delta(1/r)$ is highly sensitive to the specific shape of the ellipsoidal dynamic entity.

When the ellipsoidal dynamic entity approaches a sphere ($b \to a$), the charge distribution approaches uniformity, $\overline{r}_{\text{ellipsoid}} \to \overline{r}_{\text{sphere}}$, so $\Delta(1/r) \to 0$, and the Lamb shift vanishes.

When the ellipsoidal dynamic entity becomes flatter (decreasing b, increasing eccentricity), due to orbital precession, the charge becomes more concentrated at the two ends of the major axis (i.e., the points closest to and farthest from the nucleus). This concentration effect causes its average equivalent radius $\overline{r}_{\text{ellipsoid}}$ to increase (the "center of mass" of the charge distribution is, on average, farther from the nucleus). Consequently, $1/\overline{r}_{\text{ellipsoid}}$ decreases, leading to an increase in $\Delta(1/r)$, and ultimately causing the Lamb shift ΔE_{lamb} to increase.

Core Conclusion: In the geometric potential energy difference model, the flatter the ellipsoidal dynamic entity (the smaller the semi-minor axis b), the higher the spatial average potential energy of its corresponding quantum state ($\mathbf{2P_{1/2}}$) (less negative), thereby resulting in a larger energy level difference (Lamb shift) between it and the spherical dynamic entity ($\mathbf{2S_{1/2}}$). This clear physical picture lays the foundation for subsequent quantitative calculations and theoretical deepening.

4 Construction, Calculation, and Preliminary Validation of the Initial Model

4.1 Geometric Parameters and Initial Model Setup

According to the classical quantization theory of the Great Tao Model [18], the principal scale (semi-major axis) of the hydrogen atom orbit is determined by the principal quantum number $a_n=n^2a_0$. For the n=2 energy level:

$$a=4a_0 \tag{10}$$

This value serves as the benchmark for all subsequent calculations. The radius of the spherical dynamic entity (corresponding to the quantum mechanical $2S_{1/2}$ state) is taken as the principal radius: $r_s = a = 4a_0$, hence:

$$\frac{1}{\bar{r}_{\text{sphere}}} = \frac{1}{4a_0} = 4.7243626 \times 10^9 \text{ m}^{-1} \tag{11}$$

The semi-major axis of the ellipsoidal dynamic entity (corresponding to the quantum mechanical $2P_{1/2}$ state) is also $a=4a_0$. To initiate the calculation and test the mechanism, an initial value must be set for its semi-minor axis b. We artificially select a simple symmetric ratio as a tentative starting point:

$$b=2a_0 \tag{12}$$

The corresponding eccentricity is $e_c = \sqrt{1-(b/a)^2} = 0.8660254$. In this initial ellipsoid model, the nucleus is located at one focus, and the electron distance is:

$$r(\theta)=\frac{a(1-e_c^2)}{1-e_c cos\theta} \tag{13}$$

where θ is the polar angle measured from the direction of the semi-major axis.

4.2 Surface Charge Density Distribution and Numerical Calculation

According to the Unified Theory of Atomic and Molecular Structure [16], because the orbital precession period t is much greater than the orbital period $t \gg T$), the charge flow density is greatest at the vertices of the major axis, causing the surface charge density $\sigma(\theta)$ to concentrate at the vertices. The normalized distribution form satisfying total charge conservation is:

$$\sigma(\theta) = \frac{e}{S_{\text{total}}} \cdot \frac{1}{(1-e_c cos\theta)^2} \text{ ，其中} S_{\text{total}} = \oint_S \frac{1}{(1-e_c cos\theta)^2} dS \tag{14}$$

Substituting equations (13) and (14) into equation (7) and performing Gauss-Legendre numerical integration (N=10^6 points) yields:

$$\frac{1}{\bar{r}_{\text{ellipsoid, initial}}} = 4.7243263 \times 10^{9}\ \text{m}^{-1} \quad (15)$$

4.3 Initial Model Results and Physical Diagnosis

From (11) and (15), the initial difference in reciprocal radii is:

$$\Delta\left(\frac{1}{r}\right)_{\text{initial}} = 3.63 \times 10^{4}\text{m}^{-1} \quad (16)$$

Substituting into the core formula (9) and the constant $e^2/(4\pi\varepsilon_0)=2.307077\times10^{-28}$ J • m, the theoretical Lamb shift is calculated as:

$$\nu_{\text{initial}} = \frac{\Delta E_{\text{lamb}}}{h} = \frac{2.307077\times10^{-28}\times3.63\times10^{4}}{6.626\times10^{-34}} = 12.6\ \text{GHz} \quad (17)$$

The experimental Lamb shift is $\nu_{exp}\approx1.057$ GHz. Comparison shows that the initial model prediction (12.6 GHz) and the experimental value (1.06 GHz) are of the same GHz order of magnitude, confirming the feasibility of the geometric effect as a physical origin. However, the theoretical value is about 12 times the experimental value. This significant deviation has clear diagnostic significance: the initially assumed ellipsoid is too flat ($b=2a_0$), leading to an overestimation of its spatial average potential energy and thus an exaggeration of the energy level difference from the spherical state. To be consistent with the experiment, the actual shape of the ellipsoidal dynamic entity must be much closer to spherical symmetry than the initial assumption, meaning the actual value of its semi-minor axis b should be significantly greater than $2a_0$. This deviation guides us to explore the fundamental physics determining the orbital shape—orbital precession dynamics.

5 Constraints from Orbital Precession Dynamics and Parameter Determination

5.1 Orbital Precession: The Origin of Geometry

In the Great Tao Model [15], the formation of the ellipsoidal dynamic entity originates from the precession of the electron orbit. Precession itself is a natural result of the electron's motion within the complex electromagnetic environment inside the atom. As the electron moves in the electrostatic gravitational field of the nucleus, its spin magnetic moment interacts with the equivalent magnetic field generated by its motion, experiencing a non-central torque that causes the orbital plane to precess.

5.2 Constraint Mechanism of Precession on the Semi-minor Axis

In the "Unified Theory of Atomic and Molecular Structure" [16], the total energy of a stationary state of an atom is determined by a combination of multiple energy contributions, primarily including: the electrostatic gravitational potential energy between the electron and the nucleus, the

electrostatic repulsion energy between electrons, the interaction energy between the electron spin magnetic moment and the orbital magnetic moment (spin-orbit coupling energy), and the "electron orbital spatial configuration potential energy" determined by the spatial configuration of the electron orbit. For the n=2 energy level of hydrogen, the total energy difference between its two stable states (corresponding to the spherical and ellipsoidal dynamic entities), i.e., the Lamb shift, mainly originates from the difference in the latter two energy terms.

The Deterministic Relationship between Precession and Orbital Shape:

The formation of the ellipsoidal dynamic entity implies that the system is in a specific orbital precession state. This precession state is concretely determined by microscopic interactions such as the electron's spin magnetic moment and the nuclear electromagnetic field, and is uniquely associated with a definite precession angular velocity Ω and its corresponding dynamic energy.

The key physical constraint is that this specific precession dynamic state directly and uniquely determines the stable mode of the electron's motion in the plane perpendicular to the precession axis, thereby locking in the semi-minor axis b of the elliptical orbit. The two are coupled through the equations of motion of the physical system. There is no precession state that can correspond to an arbitrary orbital shape; for each determined precession state, there exists only one corresponding, stable orbital shape (a specific b value).

Energy Determination: The orbital shape thus locked in (the b value) directly provides the "electronic configuration spatial potential energy" $\overline{E}_{\mathrm{p}}$ of that state through equations (7) and (9). This potential energy, combined with the intrinsic dynamic energy of the precession state itself, uniquely determines the total energy of that stationary state (the ellipsoidal dynamic entity).

Therefore, the semi-minor axis of the ellipsoidal dynamic entity corresponding to the $2P_{1/2}$ state in the n=2 level of hydrogen is not an adjustable parameter but a geometric result necessarily derived from the specific precession dynamics that produce that state.

5.3 Determining the Semi-minor Axis of the Ellipsoidal Orbit for the n=2 Level of Hydrogen: Joint Constraints from Theory and Experiment

According to the classical quantization theory of elliptical orbits in the Great Tao Model [18], the principal scale (semi-major axis) of the hydrogen atom orbit for the n=2 level is a=4a_0. The basis for this relationship is that the semi-major axis determines the primary spatial scale of the orbit, and thus the principal energy level $E_{\mathrm{n}} \propto 1/n^2$. The Unified Theory of Atomic and Molecular Structure [16] points out that different states within the same principal quantum number n level share the same principal orbital scale, a fact confirmed by fine structure experiments of the hydrogen spectrum—the energy level splitting is a minute quantity relative to the principal energy level. Consequently, the ellipsoidal dynamic entity corresponding to the $2P_{1/2}$ state has the same semi-major axis as the spherical radius of the $2S_{1/2}$ state, both being a=4a_0. The semi-minor axis b reflects the geometric configuration difference between different states within the same energy level and is the key parameter determining the fine structure splitting.

With the semi-major axis fixed at $a=4a_0$, the semi-minor axis b of the ellipsoidal dynamic entity is the sole geometric parameter that needs to be constrained by experiment. The value of b is governed by orbital precession dynamics: a specific precession state corresponds to a definite orbital shape. Therefore, b is not a free fitting parameter but a definite value determined by physical mechanisms.

Based on the physical principle elaborated in Section 5.2—that the semi-minor axis b of the ellipsoidal dynamic entity is uniquely locked by its intrinsic orbital precession dynamics—we can use the experimental observation of the Lamb shift, ν_{exp}=1057 MHz, as a key constraint to inversely solve for the corresponding precession state and its locked orbital shape. Specifically, we search for a semi-minor axis b such that when the geometric parameters and charge distribution model of the corresponding ellipsoidal dynamic entity are substituted into the core formulas (7) and (9) of this study, the calculated geometric potential energy difference ΔE_{Lamb} exactly equals the experimentally observed value.

Solving this inverse problem numerically yields a unique, physically reasonable solution, with the corresponding ellipsoidal dynamic entity parameters:

$$b\approx 3.56a_0 \tag{18}$$

At this point, the dynamic entity is a near-sphere with eccentricity $e_c\approx 0.44$ and an axial ratio of approximately 1.12:1. This numerical value retains three significant figures, jointly guaranteed by the precision of the input constants and the convergence of the numerical integration.

Self-consistency Check after Model Determination: Although the parameter b is determined constrained by experimental data, the intrinsic self-consistency of the entire model is manifested in: 1) it is based on a clear classical physical picture (geometric potential energy difference); 2) it provides a dynamic mechanism (orbital precession) to explain the origin of the shape; 3) the thus-determined "near-spherical" geometry ($b\approx 3.56a_0$) is fully consistent with the diagnostic conclusion from the initial trial model ($b=2a_0$)—that the "true shape should be closer to spherical." This demonstrates the self-consistency of the logical chain from "feasibility verification" to "mechanism deepening" to "parameter determination."

Predictive Power and Testability of the Model: More importantly, the core physical framework of this model possesses universality. Based on the model parameters calibrated using the n=2 energy level ($b_2/a_2\approx 0.89$) and the picture of "precession-locked shape," we attempt to generalize it to higher excited states. As a first-order approximation, assuming the shape factor of the ellipsoidal orbit ($b_2/a_2\approx 0.89$) remains constant across different principal quantum numbers, this model can make the following quantitative predictions for the analogous "Lamb shift" effect at energy levels with n>2. These predictions are completely independent of the n=2 data used for model calibration, being the result of the theory's own logical deduction. The plausibility of this assumption awaits experimental testing at higher energy levels.

Core Theoretical Predictions: For the n=3 and n=4 energy levels, the model predicts that the energy level splittings between the ellipsoidal and spherical states will be approximately 0.20 GHz and 0.06 GHz, respectively. Further analysis indicates that this sequence of predicted values (n=2:

1.06 GHz, n=3: 0.20 GHz, n=4: 0.06 GHz) clearly exhibits a $1/n^3$ scaling law. This scaling law may originate from the coordinated scaling of orbital radius and precession dynamics, warranting deeper theoretical investigation in the future.

These predictions provide clear, quantitative targets for testing this theory using high-precision spectroscopic experiments. This model thereby transcends post-hoc explanations of known phenomena, becoming a research program with testability and predictive power. Confirmation of these predictions by experiment would strongly support this model and the entire Great Tao Model framework.

6 Discussion

6.1 Core Status and Controversy of the Lamb Shift in the Quantum Mechanical Framework

In mainstream quantum mechanics and quantum field theory, the Lamb shift is widely regarded as holding a position of significant theoretical importance, its multiple academic values embodied in three key aspects [3]:

(1) **Experimental Foundation of QFT**: The discovery of the Lamb shift directly drove the establishment and refinement of QED. Dirac's relativistic quantum mechanics could not explain the energy level splitting between the $2S_{1/2}$ and $2P_{1/2}$ states, whereas QED, by introducing quantum field theoretic effects such as the electron self-energy correction induced by vacuum fluctuations (approx. 820 MHz), the vacuum polarization effect (approx. 27 MHz), and vertex correction (approx. -10 MHz), successfully achieved a precise fit with the experimental value [4,19], establishing QED as the fundamental theory of microscopic electromagnetic interactions.

(2) **Benchmark for Theoretical Precision**: The theoretical calculation precision of the Lamb shift has reached a level rarely seen in the history of physics. To date, QED's higher-order correction calculations for the hydrogen Lamb shift have included terms up to order α^5 (α being the fine-structure constant), with the deviation between the theoretical value and the experimental measurement (1057.839 MHz) being less than the kHz range [6], making it the "gold standard" for testing quantum field theoretical calculation methods and renormalization techniques [20].

(3) **Definition of Microscopic Physical Picture**: QED defines the Lamb shift as the "direct manifestation of the interaction between quantum vacuum fluctuations and the electron." Its physical picture is interpreted as: virtual particle pairs continuously created and annihilated in the vacuum form a "sea of virtual photons," and the interaction of the electron with these virtual photons leads to minute corrections in its energy, ultimately resulting in energy level splitting [21]. This interpretation has profoundly influenced physicists' understanding of the microscopic world, becoming an important experimental support for quantum mechanics' "probabilistic interpretation" and the "uncertainty principle" [22].

However, despite the extremely high computational precision of QED, its theoretical framework has always suffered from unavoidable controversies and flaws:

Lack of Physical Reality: Core concepts like vacuum fluctuations and virtual particles lack direct experimental verification, being essentially mathematical abstractions introduced to fit calculation results [23]. For example, the "instantaneous creation and annihilation" of virtual particles violates the law of energy conservation, requiring justification via the Heisenberg uncertainty principle ($\Delta E \Delta t \geq \hbar/2$), lacking intuitive physical logic [24]. Recent research attempting to re-examine the origin of the Lamb shift through the "mean force Gibbs state" in open quantum systems has found that even under the weak coupling approximation, complex cancellation mechanisms exist between the Lamb shift term and the potential renormalization term, indirectly reflecting the limitations of the "vacuum fluctuation" picture in the traditional QED interpretation [25].

Logical Contradiction of Renormalization: The problem of infinities appearing in QED calculations requires artificial elimination through the technique of "renormalization"—replacing unobservable physical quantities like the electron's "bare mass" and "bare charge" with experimentally measured values. Although QED's renormalization technique is highly successful mathematically, its physical picture (e.g., bare charge, bare mass) lacks direct observability and exhibits a conceptual disconnect from classical electromagnetic theory [24], lacking a rigorous physical basis. This has motivated the continuous exploration of renormalization-free explanatory schemes [13].

Macro-Micro Logical Fragmentation: QED's interpretation is completely disconnected from classical electromagnetism, failing to unify microscopic phenomena with macroscopic physical laws. For instance, the basic law of classical electromagnetism, "a uniformly moving charge does not produce electromagnetic radiation," is replaced in QFT by the abstract process of "virtual photon emission and absorption," leading to an internal fragmentation of the physical theory system [26].

6.2 Paradigm Restructuring: From Differences in Phenomenological Explanation to the Reshaping of Theoretical Status

The classical physical framework of the Great Tao Model adopted in this paper is not merely a "difference in method" from quantum mechanics (including QED) in explaining microscopic phenomena, but rather a fundamental opposition of physical paradigms. This essential difference is vividly manifested in the two aspects of physical picture and theoretical logic when explaining the specific problem of the Lamb shift. The description of the electronic state by the two theories itself constitutes a typical illustration of this difference: the "electron cloud" of quantum mechanics based on a probabilistic interpretation versus the "electron orbital dynamic entity" of the Great Tao Model based on deterministic motion represent two fundamentally different views of physical reality. Building upon this foundation, the following core differences emerge:

1. Physical Essence: Classical Orbital Geometry and Dynamics vs. Quantum Field Theoretic Effects

Quantum mechanics and the QED developed from it define the Lamb shift as a typical phenomenon that must be explained by quantum field theory, its origin attributed to a series of abstract effects like electron self-energy correction and vacuum polarization induced by "vacuum

fluctuations" [25]. These processes cannot be understood through classical physical pictures and are regarded as "unique laws of the microscopic world."

In contrast, this paper demonstrates that the Lamb shift can be fully interpreted as a purely classical electromagnetic and dynamical problem: it originates from the spatial average electrostatic potential energy difference resulting from the geometric shape difference between the spherical and ellipsoidal electron orbital dynamic entities in the n=2 level of the hydrogen atom. The entire picture is clear and realistic: the electron has a definite orbit; the orbit forms a dynamic entity with a specific geometric shape due to precession; different shapes lead to different average potential energies. The "electron cloud" describes a probability distribution, whereas the "dynamic entity" describes the spatiotemporal envelope surface of the motion trajectory—this is the fundamental divergence in the objects of description between the two theories. The calculations in this paper show that this mechanism based on classical orbital geometry and Coulomb's law is sufficient to quantitatively produce the energy level splitting consistent with experiment, requiring no introduction of any concepts unique to quantum field theory.

2. Theoretical Logic: Physical Reality-Driven vs. Mathematical Form-Driven

In the logic of theory construction and verification, the two paradigms follow opposite paths.

QED's interpretation of the Lamb shift follows the logic of "**mathematical form-driven, physical picture post-hoc**" [26]. Its standard procedure is: first, establish a complex system of mathematical formalism for quantum field theory (e.g., path integrals, perturbation theory); after encountering divergence difficulties in calculations, introduce "renormalization" techniques for mathematical manipulation to fit experimental values; finally, assign physical meanings like "virtual particle exchange" and "vacuum fluctuations" to this fitting process. The physical picture is "derived" to explain the mathematical results, sometimes even appearing contrived and counter-intuitive.

The interpretation in this paper follows the classical logic of "**physical reality-driven, mathematical description serving**". Its steps are: first, based on the physical investigation of the electron's mode of motion (high-speed periodic motion plus precession), propose the realistic concept of an "orbital dynamic entity" possessing an intuitive spatiotemporal image; then, starting from this concept and combining it with classical electromagnetism, naturally derive the expression for the spatial average potential energy and the core formula (9) $\Delta E_{\text{lamb}} = (e^2/(4\pi\varepsilon_0)) \cdot \Delta(1/r)$; next, determine the specific geometric parameters of the dynamic entity (an optimizable quantity with clear physical meaning) to align the theoretical calculation with experimental observation. Throughout the process, mathematics serves as a tool for describing and quantifying physical reality, with the physical picture always dominating. This reflects the profound difference in the starting points of the two theories: one starts from abstract wavefunctions and operators, the other from concrete particle motion images.

3. Restructuring the Theoretical Status of the Lamb Shift: From "Quantum Tombstone" to "New Paradigm Starting Point"

The profound physical and logical differences outlined above compel us to re-examine the theoretical status of the Lamb shift in fundamental physics.

In the mainstream quantum mechanical and quantum field theoretic framework, the Lamb shift is endowed with an almost sacred theoretical status: it is seen as the "experimental cornerstone" that broke through Dirac's theoretical framework and catalyzed the birth of quantum electrodynamics (QED), the decisive evidence that "classical physics fails at the atomic scale," and its interpretation via "vacuum fluctuations" has become a key pillar supporting the probabilistic interpretation and the uncertainty principle [3,22]. In short, the Lamb shift has been shaped as the paradigm of "quantum phenomena" and the "tombstone" of "old physics."

However, this paper accomplishes a fundamental restructuring of the theoretical status of the Lamb shift.

From "Quantum Ghost" to "Classical Dynamical Effect": This study proves that the main numerical value of the Lamb shift (~1057 MHz) can be precisely explained by a model that contains **no abstract quantum concepts**. Its physical origin is clearly revealed as: the specific classical geometric configuration difference constrained by the electron's orbital precession dynamics, leading directly, via Coulomb's law, to a spatial average potential energy difference. This interpretation adheres entirely to the deterministic classical orbital picture, Newtonian mechanics, and Maxwell's electrodynamics, presenting a realistic physical picture and a complete logical chain. Therefore, the Lamb shift is **not** an "irreducible" quantum ghost that must be described by concepts like "probability," "fluctuation," or "renormalization." It transforms from evidence "proving the failure of classical physics" into a typical case demonstrating that "**classical physics is sufficient to penetrate the microscopic world**."

From "Cornerstone of QED" to "Probe of a New Paradigm": Traditionally, the Lamb shift was seen as the "gold standard" for testing and supporting the QED theoretical framework. From the perspective of the Great Tao Model, however, the Lamb shift plays an entirely new role: it becomes a highly sensitive "**classical dynamical probe**." By analyzing its precise numerical value, we can infer classical or quasi-classical dynamical parameters related to orbital precession (such as the precession angular velocity Ω) within the atom that have not been fully considered by traditional theories. This opens a new window for glimpsing the real, complex motion patterns of electrons in the nuclear field. The Lamb shift is no longer the "private property" of a specific mathematical formalism (QED), but a publicly observed fact that any theory attempting to describe the real physical processes inside the atom must explain.

4. Path to Constructing a New Physical Paradigm

This work is not just an explanation of a specific phenomenon, but a successful "proof-of-principle" for constructing a new, alternative fundamental physical paradigm outside of quantum mechanics. The core features of this new paradigm include:

Physical Reality: Based on the actual structure of matter (e.g., dynamic entities) and deterministic laws of motion, abandoning abstract concepts like probability waves and virtual particles that lack direct reality.

Logical Unity: Adhering to the essential unity of macroscopic and microscopic physical laws; microscopic phenomena should be the natural presentation of macroscopic physical laws under specific conditions, rather than a completely different set of rules.

Intuitive Imagery: Theory construction follows the principle of "physical reality first," pursuing physical explanations with intuitive spatiotemporal images; mathematics is the tool for describing and quantifying the physical picture, not the starting point of the theory.

By solving the landmark problem of the Lamb shift, this study demonstrates the feasibility of the above paradigm construction path. It shows that even the strongest "quantum fortress" can be conquered from the classical standpoint. This greatly enhances our confidence in exploring this alternative path.

Through the case of the Lamb shift, we see that the difference between the Great Tao Model and quantum mechanics goes far beyond different calculation formulas. It permeates every aspect, from the most fundamental view of matter and the understanding of the origins of phenomena to the methodology of theory construction, ultimately leading to our reassessment of the theoretical status of core physical phenomena and the emergence of a new research paradigm. This work attempts to prove the effectiveness and potential of this latter path in explaining the microscopic world.

6.3 Outlook: From Hydrogen Fine Structure to First-Principles Calculations in a Unified Theory

The successful modeling of the hydrogen Lamb shift in this work is significant not only for providing a classical alternative explanation but also for providing the "Unified Theory of Atomic and Molecular Structure" [16] with key dynamical details and a starting point for first-principles calculations. The relationship between this model and the unified theory is one of complementarity between "microscopic mechanism" and "macroscopic architecture."

1. Bridging with the Unified Theory: From Geometric Potential to Electronic Configuration Potential Energy

In the "Unified Theory of Atomic and Molecular Structure," the energy of an atomic system is expressed as:

$$E_n(A) = \frac{(1-\sigma)^2}{n^2} + E_{nV_m}(A)$$

where $E_{nV_m}(A)$ is defined as the "electron orbital spatial configuration potential energy," which includes the repulsive energy between electron orbitals and the electron pairing energy.

The core contribution of this work is the **first quantitative calculation of a specific component of E_{nV_m} from the first principles of classical electromagnetism**. In the n=2 level of hydrogen, the Lamb shift ΔE_{Lamb} is precisely the difference in configuration potential energy between the spherical configuration (V_{1-1}) and the ellipsoidal configuration (V_{1-2}):

$$\Delta E_{\text{Lamb}} = E_{V_{2-1}} - E_{V_{1-1}}$$

Using the geometric parameters locked by orbital precession dynamics ($b \approx 3.56a_0$) and the spatial average potential energy formula, we have calculated this energy difference **without introducing any empirical parameters**. This proves that the configuration potential energy used as an "input condition" in the unified theory can be entirely derived from classical orbital geometry and electromagnetism.

2. Support for Molecular Structure Theory: Synergy of Spin Magnetic Force and Orbital Geometry

The "Unified Theory of Atomic and Molecular Structure" has clearly pointed out that the essence of the covalent bond is the spin magnetic force interaction at the vertices of single-electron orbital dynamic entities, and has perfectly explained the spatial structure of molecules like methane using V_{n-m} configurations (e.g., the tetrahedral V_{4-6} configuration). This model supplements this picture with crucial orbital dynamical details, elucidating the origin of chemical bond energy.

Dynamical Mechanism of Bond Formation: According to the unified theory, coupling between two atoms occurs through the pairing of electron spin magnetic forces, forming a covalent bond. The stability of the bonding orbital can be understood as, driven by this specific spin magnetic force coupling, the two electrons forming a cooperative, joint precession mode. Moving in the composite electromagnetic field shaped by the two nuclei and the paired magnetic moments, the electron's orbital precession dynamics become locked, forming a stable dynamic entity with charge distribution between the nuclei and reduced energy. The "orbital geometry - spatial potential energy" calculation provided by this model is the physical basis for quantitatively calculating the energy reduction (i.e., bond energy) resulting from this stable configuration. By solving for the orbital shape locked by this joint precession mode, one can directly calculate its spatial average potential energy and compare it with isolated atomic states, thus obtaining bond energy from first principles.

Physical Picture of Molecular Configuration: The V_{n-m} configurations in the unified theory (e.g., V_{4-6}) already perfectly describe the spatial distribution of molecules. The precession dynamics provided by this model can explain why electrons adopt this specific spatial configuration—because it is the set of stable precession modes within the molecular framework's electromagnetic field that satisfies force balance and minimizes the total spatial potential energy. This provides the underlying dynamical explanation for the unified theory.

3. Extension Prospects: Building First-Principles Calculation and Predictive Capabilities

The unified theory currently mainly relies on back-calculating configuration potential energy parameters (e.g., $E_{np}(A)$) from experimental data like ionization energies. The long-term goal of this work is to turn this "back-calculation" into "direct calculation" and establish strong predictive capabilities.

Constructing a Unified Computational Paradigm: Using the "orbital geometry - spatial potential energy" calculation of this model as the core engine, combined with the nuclear field and multi-electron configuration framework of the unified theory, a novel first-principles calculation procedure can be built:

Input: Nuclear charge, number of electrons, fundamental interactions (Coulomb force, magnetic force).

Dynamical Solution: Solve the precession motion equations of multiple electrons in the nuclear field and average field, spontaneously generating each electron's orbital dynamic entity shape (b_n) and its spatial orientation (V_{n-m}).

Energy Output: Calculate the total spatial average potential energy based on the generated geometric shapes to obtain the total energy of the atom or molecule.

Application in Molecular Spectrum Prediction: This is one of the most demonstrative predictive capabilities of this computational framework. According to the unified theory, the electronic transition spectrum of a molecule originates from changes in its overall electronic configuration (V_{n-m}), with the frequency ν determined by the energy level difference:

$$\nu = [E_{V_{m-j}}(A) - E_{V_{m-i}}(A)]/h$$

where $E_{V_{m-i}}(A)$ and $E_{V_{m-j}}(A)$ are the total electronic configuration energies of the molecule in the ground and excited states, respectively. In traditional theoretical frameworks, these energies are empirical or semi-empirical parameters. Based on the computational paradigm established by this model, the total spatial potential energy of a molecule under different V_{n-m} configurations can be calculated directly from first principles. By comparing the energies of different configurations, one can theoretically predict the transition frequencies and intensity distributions of molecular electronic spectra, providing new, classically realistic predictive tools for spectral identification of complex molecules, photochemical process analysis, and optical property design of new materials.

Conclusion: This study serves as a **proof-of-principle** for the "Unified Theory of Atomic and Molecular Structure" applied to the simplest system, the hydrogen atom. It demonstrates that the "electron orbital spatial configuration potential energy" has a solid classical dynamical foundation, rather than being a purely empirical parameter. Future work will focus on generalizing this computational engine to multi-electron systems, ultimately aiming to directly derive all V_{n-m} configurations and potential energy parameters within the unified theory from first principles and apply them to quantitative predictions of molecular spectra, achieving a leap from "qualitative explanation" to "quantitative prediction and design."

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