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RESEARCH ARTICLE

QUANTUM MEASUREMENT IN DUAL-FOUR-DIMENSIONAL SPACE-TIME QUANTUM MECHANICS

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ABSTRACT

Using literature (11) (12) (13) (14) we proved that quantum mechanics describes in dual four-dimensional space-time **w(*x,k*)**, matter waves are physical wave, parallel quantum state is the product of the quantum segment. Measuring micro object before and after physical space has changed. Many key basic knowledge are concentrated here. For example, double-slit experiment, delayed choice experiment, the Schrodinger cat paradox, and the non-local quantum communication all are controversial problems today. We think that energy of macro instrument itself is continuous changeable and there is no energy level transition, no constant phase difference. So the instrument itself is of mixed stated and there is no coherence. According to our understanding, Mixed state form is pure states noncoherent hybrid, but mixed state is a product of measurement. Quantum measurement can induce continuous interaction, so one of the mixture states, namely a pure state becomes the collapsed eigenvalue corresponding state during the measurement. There is no constant phase difference in each mixture states, thus there is no energy quantization. The mixture states is not in $w(x,k)$ space but in $M^4(x)$ space. The physical model is changing from field matter sphere model to mass point model and the physical wave is changing to be probability wave, though the probability wave function has the same form as matter wave. We will discussion about these problems in dual four dimensional quantum mechanics.

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INTRODUCTION

The Preparation of Pure State and Mixture State and *U-R* Process in Quantum Measurement

Throughout all the physical and mathematical model of quantum measurement, it is not hard to find that the core problem is focused on how to understand the relationship between the system under test and the macro instrument. The system to be test is in the micro world, so it can be written as pure quantum state. And the coherence is a powerful evidence. But the macroscopic object has no coherence. To satisfy the saying "Quantum mechanics is suit for all kinds of physical system", the macroscopic object is compelled to be a pure quantum state. All sorts of paradoxes appear in succession. One is the famous collapse in measurement. To make this sense, people come up with kinds of ideas to explain why the instrument is de-coherence and let the instrument trigger the system under test to be de-coherence and be observable in macro world. The truth is, no matter how we "rob Peter to pay Paul", the contradictions are more and more. Why not change our thoughts and admit the system itself is a mixture state and has no coherence? Interaction is induced into the system during the measurement. The state of the system to be test is firstly changed and become mixture state, then they can be detected by the instrument which is also of mixture state. Once we have brought insight into the phenomenon of physical phenomena, physical structure, physical model, mechanism of action, theory and described the internal logic of space and time consistency, have understood the pure state, eigenstate, superposition, and mixture state, have clearly differed the space where the pure/mixture state of the micro object is in and the space where mathematic methods is in, the problem will be easy to solve.

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U process in micro quantum level world

U process is of preparation of quantum state and helps us cognating into the microscopic quantum level and observe the quantum motion phenomena of internal material. There, energy, momentum, angular momentum, spin, and the action of field all are quantized. In quantum level, corresponding to the quantization of energy, momentum, angular momentum, spin and the action of field, the space structure of the micro object itself is also quantized. The quantization of energy and momentum should be supported by the quantization of its structure. And the fluctuation feature is the reflection of the motion state in the internal structure. There is no structure concept of the mass point model, and no concept of quantization of its structure. Therefore to describe the fluctuation nature, we can't use the mass point model as in classical dynamic mechanics any more. And the suitable model is field matter sphere model. The rotation of a quantized field matter sphere generates matter wave, and the matter wave contains all the quantization feature in quantum mechanics. This is the physical nature of micro physical phenomena. The quantum transition in micro world is the quantization of the motion from continuous forced state to discontinuous free state. There is no continuous time series in each eigenstates, and all the eigenstates are parallel coexist. This is an abstract similar to the mass point in macro world. Here, the quantum segmentation choose the separated results and kick off the continuous interaction field. Then a multi-dimensional linear space is constituted. In the description of quantum mechanics, the steady wave function $|\psi(x)\rangle$ is decomposed by its eigenstates $|\psi_n(x)\rangle$. $|\psi(x)\rangle=\sum c_n|\psi_n(x)\rangle$, and $A|\psi_n(x)\rangle=a_n|\psi_n(x)\rangle$. The eigenvalue of $|\psi_n(x)\rangle$ is a_n and the probability is $|c_n|^2$.

We have discussed above that it is equivalent between probability description and field matter description. They have the same mathematic forms but in two different physical space. Now people often misuse the concepts of wave function in dual four dimensional complex space-time and four dimensional real Hilbert space-time. In dual four dimensional complex space-time quantum mechanics, we will clearly see the superposition of eigenstates is in dual four dimensional complex space-time which is a physical space, while Hilbert space is the mathematics space. In quantum level world, the eigenstates are parallel coexist, reversible, coherent deterministic and satisfy the Schrodinger equation. The superposition of states is the real reflection of the fluctuation of micro object in quantum level world, also the mathematic treatment of the abstract theory. This is the *U* process in micro quantum level world.

R process in macro level world

R process is by means of introducing interaction of the outfield, making the pure state be mixture state, making the instrument from beginning state to end state and complete the record. Finally these information will be record by observer. The three steps are:

(1) Introduce an outfield of $U(x)=e^{\alpha(x)}$ on the system to be test with pure state $\psi_n(x)$, then the pure state will become mixed state $\phi_n(x)$.

(2) Introduce a unitary transformation $u(t)=e^{iH_{\text{int}}t}$ on the mixed state instrument, then the instrument changes from beginning state to end state and is ready to record the eigenvalue a_n by resonance, in which H_{int} is the interaction between the mixed under test system and the mixed instrument.

(3) The under test system will change from field matter sphere model to mass point model and the matter wave develops to probability wave. The physical space where the pure state and the mixed state are in will not change, and can be concluded into the Hilbert space.

Mass point is of no size, but can be synchronized. Particle's motion can define the movement and the interaction of the locality and continuity, which is characteristic of macro continuous M^4 space-time. In quantum mechanics, the develop process from micro discontinuous changing to macro continuous changing is a process of develop from $w(x,k)$ space to M^4 space meanwhile deleting the non-localization, de- coherence, random, irreversible and invalid of the Schrodinger equation. If we want to come back to the reversible matter wave fluctuation, we have to come back to U process. This is the intrinsic nature of cycloid quantum measurement. *R* process is a process of transition of physical space and physical model. Thus it is easy to understand the random, irreversible and de-coherent in R process.

Transition boundary of the *U-R* process

The transition boundary of the ***U-R*** process is whether we can ignore the "interaction quanta" which can be released or absorbed by the micro object itself in the internal structure and in the internal fluctuation. **No**: The object under research is in the micro quantum level. We use the field matter sphere model. The motion will generate matter wave and have parallel eigenstates. There exists superposition $|\psi(x)\rangle=\sum c_n|\psi_n(x)\rangle$. And it can be described by the Schrodinger equation and Dirac equation in dual four dimensional complex space- time $w(x,k)$ **Yes**: Introduce the continuous outfield, then the pure state $\psi_n(x)$ will change to be mixed state $\phi_n(x)$. The object under research is in the macro classical dynamic mechanics. It is continuous motion and we use mass point model. The superposition will disappear. The time series is recovered in each quantum state and the Schrodinger equation is no longer suitable. Thus the summation $\sum,(\varepsilon\to 0)$ will become integration $\int,(\varepsilon=0)$. It can be described by Newtonian mechanics or Relativistic mechanics in three dimensional or four dimensional space. The probability wave in quantum mechanics actually is the probability distribution function of particle. It can be seen that, the transition boundary from *U* process to *R* process is at the point of the transition from pure state to mixed state under the interaction of outfield. Problems of traditional de-coherence in quantum mechanics is they think the instrument is superposition of pure states, and misunderstand the interaction of continuous outfield as de-coherence. Instrument is always the mixed states (ε = 0) and needn't supposed to be pure state, needn't de-coherence. It is the pure state of the micro object that to be de-coherent. It is a confusion of pure state assumption and the outfield interaction, which can go back to the Von Neumann pure hypothesis.

Integral gauge transformation and the U process in quantum measurement

The spinor wave function of free micro object

Spin in quantum mechanics is totally a hypothesis to satisfied the experimental phenomena. And the spin of electron can't be understood as the mechanical rotation of the sphere. Spin is the intrinsic nature of a micro object. But in dual four dimensional quantum mechanics, because the field matter ball is not a classical mechanical sphere, spin can be understood as the rotation of field matter sphere. And because of the quantization of states, the continuous interaction and time series between two spin directions are cut off. So the changing between two spin states is mutation. Spin is an important variable to decide the motion state of micro object and can be insert into wave function. What we emphasize is the superposition of parallel states:

$$\chi(s_z) = a\alpha + b\beta = \sum_n c_n \chi_z$$

The spinor wave function of micro object is propagating in dual four dimensional complex space-time. In its own reference system, it is linear, inverse, deterministic in line with the Schrodinger equation, and following the U process of wave function.

(2)The integral gauge transformation:

Steady state wave function

$$\psi = \sum_n c_n \psi_n$$

The integral gauge transformation is

$$\psi \to \psi' = \mathrm{e}^{-i\alpha_0}\psi = \mathrm{e}^{-i\alpha_0}\sum_n c_n\psi_n = \sum_n \mathrm{e}^{-i\alpha_0} c_n\psi_n$$

Because $\alpha_0 =$ constant, there is no outfield interaction. This is a shift of coordinate and does not change the feature of inertial system which is built on the free micro object and its eigenstates. The superposition is still valid and the gauge invariance is still reservable. The mathematic form of the integral transformation on the free micro object is as the same. Integral gauge transformation is still the U process in quantum measurement. The spin wave function is plane wave. It is still U process that doing integral gauge transformation on the spin wave function $\chi(s_z)$ in quantum measurement.

Local gauge transformation, time evolution operator and the *R* process in quantum measurement

(1) Stern-Gerlach measurement

In the famous Stern-Gerlach measurement to measure the spin of the electron, before the Silver atoms entering into the non-uniform magnetic field, the spin wave function of the electron is linear, inverse, deterministic, in line with the Schrodinger equation, and following the U process of wave function.

However, after the Silver atoms entered into the non-uniform magnetic field. Firstly, the electron will be forced by the non-uniform outfield and the mutation region will disappear. The orthogonal and linear feature of the spin eigenstate will be broken down. Pure states will become mixed states and the coherence will disappear. Thus the macro time series and causality will be recover. This means the phenomena has entered into the macro level. Secondly, the interaction H_{int} between mixed states of electron and instruments will make the instrument back to end state by the unitary transformation. And then the instrument record the eigenvalue. This is the physical mechanism of R process in quantum measurement. In R process of quantum measurement, the evolution of state is non-linear, irreversible, non-deterministic and not in line with the Schrodinger equation. The pure state of spin will be parted in two mixed states which is observable by the non-uniform magnetic field. And the probability is 1/2 for each. This is the measurement record procession in quantum measurement, where the system under test has interaction with the magnetic field. It is a spontaneous physical process and needn't people's participation. The probability in quantum measurement is decided by the nature of structure of the micro object and its corresponding space-time. What the instrument record is the resonance corresponding to a certain mechanical state of an eigenstate. In dual four dimensional quantum mechanics, the boundary between the process of interaction and the process of record by instrument is clear.

(2) Mathematical model in quantum measurement

(a) Interaction between micro object and field

Set expansion on $\psi(x)$ by its orthogonal and normalization eigenstate ψ_n(x)

$$\psi(x) = \sum c_n \psi_n(x)$$

In dual four dimensional quantum mechanics, the matter wave is propagating in dual four dimensional complex space-time before measurement and which reflects the distribution of structure and density of the micro object. Give local gauge transformation on free micro object

$$\psi \to \psi' = \mathrm{e}^{\alpha(x)}\psi = \mathrm{e}^{\alpha(x)}\sum c_n\psi_n = \sum \mathrm{e}^{\alpha(x)} c_n\psi_n = \sum c_n\phi_n$$

The factor $\mathrm{e}^{\alpha(x)}$ represents the micro object is in a continuous outfield. In the Stern-Gerlach measurement, it is the non-uniform magnetic field $B_x = \lambda x$ at the x direction and the measurement Hamiltonian $H = -\lambda\mu x\sigma_x$ (Zhang, 2012) and the interaction force $F = \lambda\mu\sigma_x$. Under the force of magnetic field, the electron will get accelerated and its quantum mutability will be disappeared. The state of electron will change from pure state ψ_n to mixed state Φ_n and back to the four dimensional real space-time. Because the force F is $F = \partial H/\partial x = \lambda\mu\sigma_x$, the direction is along the x direction and its signal depends on the $\sigma_x = \pm 1$. In the measurement time t, (namely the total time the electron is in the magnetic field) this force will impulse the momentum at the x direction $P_x = Ft$, thus the electron will deviate from the straight line and has a drift along x direction $\Delta x = (F/m)t^2$. By measuring the drift displacement away from a axis, the mixes spin state will show $|x\rangle$ or $|-x\rangle$. The electron with the momentum of P will have a coupled interaction (H_{int}) with the mixed state instrument, this interaction will help to record.

(b) Time evolution operator $U(t)$ and record in quantum measurement

The interaction between the mixed state electron Φ_n and the mixed state instrument $X_n(x)$ is H_{int}. In the time range of $0 \le t < \tau$, the time evolution operator

$$U(t) = e^{i(H_1+H_2+H_{int})t} \approx e^{i(H_{int})t}$$

will operate on the instrument beginning state $X_0(x)$, making the mixed state of electron and instrument be entangled and changing the display state of the instrument.

$$U(t)\sum c_n\phi_n(x)\otimes X_0(x) = \sum\left\{c_n\,\phi_n(x)\otimes e^{i(H_{int})t}\,X_0(x)\right\} = \sum\left\{c_n\,\phi_n(x)\otimes X_n(x_n)\right\}$$

in which $X_n(x_n) = X_n(x-\lambda a_n t)$ is the distinguishable state of the instrument, name- ly the ending state. $x_n = x - \lambda a_n t$ reflects the detective precision of the mixed state instrument. The mixed entangled state

$$\sum c_n\phi_n(x)\otimes X_n(x-\lambda a_n t) = \text{resonance} = \sum c_k\phi_k(x)\otimes X_k(x-\lambda a_k t)$$

represent the resonance researching and record a_k of the mixed state $\phi_k(x)$ and the distinguishable state of the instrument $X_k(x_k) = X_k(x-\lambda a_k t)$. The eigenvalue of $\phi_k(x)$ is a_k, and its probability is $|c_k|^2$ and λ is the resonance factor. Take the spin test experiment as an example, (Zeng, 2000)

$$U(t) \approx e^{i(H_{iHt})t} = \exp\{(i/\hbar)\lambda\mu x\sigma_x t\} = \exp\{(i/\hbar)p_x\Delta x\}$$

So,

$$\exp\{(i/\hbar)p_x\Delta x\}\{[\alpha|+x\rangle+\beta|-x\rangle]\otimes|0\rangle\} \approx [\alpha|+x\rangle\otimes|\Delta x\rangle+\beta|-x\rangle\otimes|-\Delta x\rangle]$$

Here, force induces the displacement and is translated into momentum operator, the deviation at the x direction is $\Delta x = (F/m)t^2$. It is obviously that this physical measurement process can be abstracted as $A\psi_k = a_k\psi_k$. $U(t) \approx e^{i(H_{int})t}$ is the phase factor of the time evolution operator. And obviously, $e^{\alpha(x)}$, $e^{i(H_{int})t}$ can break up the orthogonal and linear superposition, remove the mutation, constant phase difference and the coherence, recover the continuous interaction, causality and the time series. During the interaction, the space is changing and coming back to the outer physical space, the pure state has been changed to the mixed state, mixed state has been entangled with each other and finally the instrument displayed the record. H_1 is the Hamiltonian of the system under test, H_2 is the Hamiltonian of the instrument, H_{int} is the coupling interaction of these two systems. The invariance of a free micro object has been broken down from the integral to the local gauge transformation reflects the *R* process in quantum measurement, in which it contains the transformation from *U* process in dual-four-dimensional complex space-time to *R* process in four dimensional real space-time. *U* process describes the wave state of the inner matter field and it is linear, reversible, deterministic and coherent. R process describes the introduction of outfield, and it reflects the structure and motion state of the micro object transformation from dual-four-dimensional complex space-time to four dimensional real space-time. It is non-linear, irreversible, non-deterministic and de-coherent. *R* process in quantum measurement is to destroy the orthogonal and linear superposition feature, eliminate the mutation and constant phase difference, de-coherent, and recover the causality and time series. It can be seen that there is no collapse into one eigenstate for a wave function in quantum measurement. The mutation between each eigenstate is vanished once the outfield is introduced. Pure state becomes mixed state and instrument searches the eigenstate, all these phenomena are in macro level world. One measurement corresponds to one random record. This is the so called collapse of eigenstate. Quantum measurement is the process of introducing of outfield, eliminating the quantization and non-location, and coming into Minkowshi space-time to represent the original fact. Eigenstate is got from the quantization of a continuous mechanical quantity by orthogonal partition and reservation of the result. Therefore, what is instrument can detect is just the mechanical state corresponding to an eigenstate. The probability in measurement is determined by the structure and its corresponding space-time of the field matter sphere. Quantum measurement is the searching of one mixed state of the micro object by resonance. The specific eigenvalue x_k, p_k is hidden in the pure state x_n, p_n and is also hidden in the mixed state of x_n, p_n. Collapse is the displaying result during the resonance searching between the system under test and the instrument. The physical principle of "invariance of the unitary transformation" in quantum measurement is here. In traditional quantum mechanics, the existence of eigenvalue in quantum measurement is caused by the introduction between wave function and instrument. This is actually wrong. Because the wave function in quantum mechanics is just an assumption, and it is just a probability wave by traditional explanation. This is a mathematical wave and has no clear physical meaning. The record eigenstate cannot generate from a mathematical wave function. So they have to explain this is introduced by the instrument. But how can math interacts with instrument? How can the instrument creates something out of nothing? In dual-four-dimensional quantum mechanics, the matter wave is physical wave. Before measuring, the matter wave is physical indeed and all the eigenvalue is in the physical model. This is easy to understand.

General Expression of Quantum Measurement

In dual-four-dimensional quantum mechanics, it is matter wave not probability wave has the features of expansion, superposition and coherence. But the density of matter and probability is in positive relation, namely where the density of matter is large the density of probability is large, and vice versa. $\left|\psi(x,k)\right|^2$ represents both density of matter and density of probability. And it just depends on which space are we in when discussing. Of course, both of the two wave functions have the same mathematic form and both can be summarized in Hilbert space brings great influence on mathematical calculation. The general expression of quantum measurement in dual-four-dimen- sional quantum mechanics is as follows.

1) Eigenfunction expansion

To measure the quantity A of the state $\psi(x)$, we can set expansion by its orthogonal eigenfunction $\psi_n(x)$

$$\psi(x)=\sum c_n\psi_n(x) \tag{1}$$

In dual 4-dimensional quantum mechanics, $\psi(x)$ and $\psi_n(x)$ are both pure state and have coherence.

2) Interaction of the outfield

$$\phi(x)=e^{\alpha(x)}\psi(x)=\sum c_n e^{\alpha(x)}\psi_n(x)=\sum c_n\phi_n(x) \tag{2-1}$$

The outfield (which is also one of the function of the instrument) can change the state of the system under test from pure state $\psi(x)$ and $\psi_n(x)$ into mixed state $\phi(x)$ and $\phi_n(x)$. It can also translate the dual-four-dimensional complex space-time into the four-dimensional real space-time.

$$\phi(x)=\sum c_n\phi_n(x) \tag{2-2}$$

Equation (5.2-2) represents the mixed states and there is no coherence between $\phi(x)$ and $\phi_n(x)$. We will be mixed state ψ(*x*) and $\psi_n(x)$ written $\Phi(x)$ and $\Phi_n(x)$ is to distinguish between physical properties of pure state and mixed state.

3) Entanglement decomposition in measurement

(1) The instrument $X(n)$ is not quantized. Its state is continuous and has time series, and it cannot be decomposed into parallel pure state. It can only be decomposed into mixed state which has no coherence and is continuous. Of course, it can be decomposed into differentiable mixed state namely ending state $X_n(x)$

$$X(n)=\sum c_n X_n(x) \tag{2-3}$$

(2) We can get the non-entanglement state by synthesizing $\phi_n(x)$ and $X_n(x)$

$$\left|\phi(x)\right\rangle\otimes\left|X(n)\right\rangle=\sum c_n\left|\phi_n(x)\right\rangle\otimes\left|X_n(x)\right\rangle$$

• Using the time evolution operator $U(t)=\mathrm{e}^{i(H_1+H_2+H_{\mathrm{int}})}\approx\mathrm{e}^{i(H_{\mathrm{int}})t}$, the mixed state instrument $X(n)$ will be mixed differentiable state $X_n(x_n)$. The mixed entanglement state is

$$\begin{aligned}U(t)\sum c_n\left|\phi_n(x)\right\rangle\otimes\sum\left|X_n(x)\right\rangle&=\sum\left\{c_n\left|\phi_n(x)\right\rangle\otimes e^{i(H_{\mathrm{int}})t}\left|X_n(x)\right\rangle\right\}\\&=\sum\left\{c_n\left|\phi_n(x)\right\rangle\otimes\left|X_n(x_n)\right\rangle\right\}\end{aligned} \tag{3}$$

The separable states are two states with no interaction and substantial relationship. But because of the coupling factor H_{int}, the observable A in the system under test with mixed state and the instrument with differentiable mixed state will be entanglement. $U(t)=\mathrm{e}^{i(H_1+H_2+H_{\mathrm{int}})}\approx\mathrm{e}^{i(H_{\mathrm{int}})t}$ is the phase factor that can recover the time series between the system under test and the instrument. $X_n(x_n)=X_n(x-\lambda a_n t)$ is the differentiable mixed state of the instrument, and $x_n=x-\lambda a_n t$ represents the accuracy of measurement.

4) Resonance

There is resonance between the instrument with differentiable mixed state $X_k(x_k)$ and the mixed eigenstate ϕ_k. And a_k is the eigenvalue.

$$\sum c_n\left|\phi_n(x)\right\rangle\otimes\left|X_n(x-\lambda a_n t)\right\rangle=resonance=\sum\left\{c_k\left|\phi_k(x)\right\rangle\otimes\left|X_k(x-\lambda a_k t)\right\rangle\right\}$$

So far, the abstract description of $A\psi_n(x)=a_n\psi_n(x)\left(=a_n\phi_n(x)\right)$ has a physical measuring process support. One specific measurement will get one specific $\phi_k(x)$ and a_k. After many times measurements, the probability of existence of $\phi_k(x)$ and a_k will be $p_k=\left|C_k\right|^2$.

5) The preparation of the initial state

The resonance state (mixed eigenstate) ϕ_k is the initial state. And its evolution form is as follows: quantitating in a new environment and then coming back to the dual-dour-dimensional complex space-time, finally starting a new quantum measurement.

6) The preparation of the ending state

We can get a collection $\sum\left|\phi_n(x)\right\rangle$ of eigenstate mixed state after many times of repeat measurements on the system under test. This is the mixed state. There is no phase relationship and coherence between each in $\sum\phi_k(x)$. In dual-four-dimensional quantum mechanics, the pure state of matter wave and the mixed state of probability wave is not in the same physical space. So the definition of "mixed state is also called pure states ensemble or collection" is not suitable. The decomposed mixed state of the instrument $X_n\left(x_n\right)$ is actually the accuracy of the spectral, and it exactly contains the mixed state collection.

7) Nature of probability in quantum measurement

In dual-four-dimensional quantum mechanics, "God does not throw the dice". The probability comes from the basic feature, such as the structure, the rotation motion and its corresponding space-time of the micro object itself. Probability is the inevitable result in quantum mechanics from the inner level cognition (field matter sphere in dual-four-dimensional complex space-time) to the outer level cognition (mass point in four-dimensional real space-time). It has great difference from the classic hidden variables. The classic hidden variable can attribute into the external reason of uncertainty, and we can exclude it in theory and experience. While the probability in quantum mechanics is cause by the basic feature, such as the structure, the rotation motion and its corresponding space-time of the micro object itself, and it cannot be excluded. In Copenhagen School, the uncertainty of position is caused by concept transformation from field matter sphere model to mass point model. When using a photon to measure a tangible micro object, the uncertainty of position is just its space structure distribution of this micro object.

8) Four characteristics in quantum resonance

(1) Randomness. The probability in quantum mechanics comes from the basic feature, such as the structure, the rotation motion and its corresponding space-time of the micro object itself and it cannot be eliminated.
(2) Irreversibility. The evolution direction from pure state to mixed state is process of entropy increasing, and it is irreversible.
(3) No-coherence. Because of the continuous interaction, the fixed phase difference and mutation are broken down, thus recovering the time series and eliminating the coherence. So there is probability instead of coherence.
(4) Nonlocality. Superluminal properties of matter wave phase velocity, mutation in quantum transition and transformation from complex space-time to real space-time as well as its corresponding state of micro object, constitute the basic characteristics of quantum mechanics. This is not conflict with the speed limit in theory of relativity. Besides, the quantum space-time and the relativity space-time can transform to each other in specific conditions.

In field matter sphere model, the physical quantity under measured has naturally come into the design of the model. Physical quantum experiment is just to get the physical value by some ways. This is not different from classical experiment. The regularity of statistical result in measurement is also hidden in the design of the model. The uncertainty of position is because of the matter density distribution. And the uncertainty of momentum is hidden in the "structure k and the matter density distribution of the field matter sphere". So we can clearly understand why "the wave function describing the micro object is totally objective and substantial and is independent on the measure type. The anthropic principle in quantum measurement is not in the anthropic during measurement but in the thought when design the model. There is no "Measurement results strongly depends on the subjective choice experiment" and "One final glance". The so called collapse in quantum measurement is actually the transformation of the physical model and its corresponding space-time. The correct understanding of quantum measurement in dual-four-dimensional quantum mechanics is "Zeno effect + quantum teleportation + Swapping = collapse during quantum measurement". "Quantum measurement makes the space-time collapse" (Zhang, 2012). This is understandable and acceptable.

Discussion about Double-Slit Experiment in Quantum Mechanics

1) Copenhagen interpretation and double-slit experiment

According to the Copenhagen interpretation, in double slit experiment, once we have confirmed which slit has the particle passed through, the corpuscular property of in wave-particle dualism is emphasized. And the volatility which is complementarity of particle is excluded, thus the interference fringes will disappear. Specifically, because of the Heisenberg uncertainty relation, once we have known the path such as A (block the B slit), we will know the correct position of this particle perpendicular to the direction of A. If the accuracy is Δx , according to the uncertainty principle

$$\Delta p_x \cdot \Delta x = \hbar \tag{4}$$

there will be a disturbance $\Delta p_x \cdot \Delta x = \hbar$ perpendicular to the direction of A. Therefore, the phase factor will be changed and the interference fringes will disappear. The Standard Copenhagen interpretation is based on Bohr's complementarity principle: Material has the dual nature of both particles and waves, but they two are mutually exclusive in the same experiment. Uncertainty relation is an important reason of the quantum de-coherence (Zeng, 2000).

Copenhagen school's explanation to the double-slit experiment is not a satisfactory explanation. The reasons are as follows:

(1) The experimental results show that a particle itself can produce interference. How does a single electron pass through two slits at the same time?
(2) The probability wave is mathematical wave, while the electron wave has real physical interaction. How can we deal with the mathematical wave and the physical reality?
(3) Heisenberg thinks there is a potential and tendency that can control the quantum probability and this is the mid-level between electron reality and quantum probability. What is the mechanical base of the transformation from probability to reality?

(4) The electron pass through the double-slit has the nature of coherence. When we block one of the slits, why it behaves like particle and there is no single slit diffraction exists? What is the physical nature of the transformation from wave to particle or collapse to wave package?

(5) One important condition to get diffraction and interference is the slit width Δx is smaller or analogous with the wavelength λ of the photon or electron. If the slit width Δx is larger, the diffraction and interference will disappear. On this condition, the electron will obey the classical probability not the quantum probability. Does this belong to automatic de-coherence? What is the difference between quantum de- coherence in physical nature?

All in all, the answer to these question by Copenhagen school is not satisfactory. Or they don't answer, but try to use philosophy principle to avoid the physical reality (Zhao, 2005).

2) Dual-four-dimensional quantum mechanics and double-slit experiment

(1) Preparation of electron wave

When the structure of electron cannot be ignored, we must use the matter wave to describe the electron and there is no orbital motion of electron. At this time, the background space $W(x,k)$ and the structure space of the object cannot be separated. The curvature k_1 to describe the structure of the object and its mapping $k_i\,(i=2,3,4)$ in three-dimensional space are the important part of the background space $W(x,k)$ (the imaginary part coordinates), as well as the phase factor of the wave function to describe the object state. In dual-four-dimensional quantum mechanics, set a single slit before the double-slit. Then the electron will be wave after it passed through the single slit and the wave function propagates in the space $W(x,k)$. Once the electrons have entered into the double-slit, they become matter wave and describe the structure and field matter density of electron.

To measure a mechanical quantity A, decompose the $\psi(x)$ by its orthogonal eigen-functions $\psi_n(x)$

$$\psi(x)=\sum c_n\psi_n(x) \tag{5}$$

$$A\psi_n(x)=a_n\psi_n(x) \tag{6}$$

(2) Identification of the wave or particle by the double-slit

Double-slit is an instrument to detect the volatility or particle nature of a micro object such as photon and electron. Given the slit width Δx and the wavelength λ,

According to the uncertainty relation

$$\Delta p_x \cdot \Delta x = \hbar \tag{7}$$

According to the De Broglie Relation

$$p \cdot \lambda = h \tag{8}$$

Because of $\Delta p_x \le p$, we have

$$\Delta x \ge \lambda \tag{9}$$

Equation (9) shows that the slit width Δx should be larger than the wavelength λ, or they are of the same size. This is the basic condition to generate double-slit interference. But experiments show that when $\Delta x \square \lambda$ or $\Delta x \square \lambda$, both single slit diffraction and double-slit interference cannot occur. In the case of $\Delta x \square \lambda$, the "form" of a micro object shows little influence and can be ignored. According to the abstract of mass point in Newtonian mechanics, photon and electron both can be a particle. In the case of $\Delta x \square \lambda$, the photon and electron will be rebounded such as particles. This is just what the experiment shows. As Bohr has said, double-slit is an instrument that can be designed to generate a wave or a particle. Only when Δx and λ is comprisable, can the interference be occurred. This is the physical meaning of Equation (9). In double-slit, the "form" structure of electron cannot be ignored, which represents the structure space of the micro object and the background space cannot be separated. The wave that has passed through the double-slit is still matter wave, and the double slit is the coherent wave source just the same as a cylindrical wave or spherical wave.

It must be emphasized that the wave function of the electron in double-slit has been segmented by the slit and can be decomposed into superposition of each eigenstates $\psi(x)=\sum c_n\psi_n(x)$. According to experiment fact, only when the wavelength λ is comprisable to the slit width Δx, can the eigenstate get the chance to pass through the slit in wave form and becomes the double slit interference waves. This is a little like the resonant cavity. And this has excluded the assumption of the spin wave function that acts as the resonant double slit interference waves.

Because the spin wave function is defined in its own reference of system and the wavelength is not in a same order of magnitudes as the slit width. What we have observed in double-slit experiment is not the fluctuation motion of spin wave function, and this is at most can be understood as some relationship with the mapping in spin wave function 3-dimensional space. The structure of micro object and the background space cannot be separated means the micro object cannot be abstracted as mass point and broken away from its background space. In other words, the background has important relationships with the structure of the micro object. Space-time contains the background as well as the micro object itself. While the complex space-time in dual-four-dimensional quantum mechanics exactly has such function. The description of inner fluctuation motion of field matter is in dual-four-dimensional complex space-time.

(3) Wave interference and de-coherence after the double-slit

The coherent wave after the double-slit is matter wave. The phase factors of the two different waves are different when they arrived at the scene. The amplitude will band together and where the amplitude is large where the field matter density and the existence probability of electron is larger, and vice versa. If the amplitude is zero, this means the field matter density and the existence probability is also zero. The electron waves after the electron has passed through the double-slit are spherical wave (or cylindrical wave). The two waves propagate parallel and are pure states and self-coherence before they hit the scene. This is the U process.

$$\psi(x)=\sum c_n\psi_n(x)(n=A,B)$$

After they have hit onto the scene (the spherical wave will become plane wave), there will be a continuous hinder interaction $U(x)=\mathrm{e}^{\alpha(x)}$ by the scene.

$$\phi(x)=\mathrm{e}^{\alpha(x)}\psi(x)=\sum c_n\mathrm{e}^{\alpha(x)}\psi_n(x)=\sum c_n\phi_n(x)$$

And the pure state $\psi(x)$ will develop into mixed state $\Phi(x)$. During the time $0\le t<\tau$, the coupling interaction between the mixed state of electron $\Phi(x)$ and the scene $X(x)$ can be calculated by the unitary transformation $U(t)=e^{iH_{\text{int}}t}$. And the initial state X_0 of the scene will be the ending state $X_n(x_n)$.

$$U(t)\sum c_n\Phi_n(x)\otimes X_0(x)=\sum c_n\Phi_n(x)\otimes \mathrm{e}^{iH_{\text{int}}t}X_0(x)=\sum c_n\Phi_n(x_n)\otimes X_n(x_n)$$

in which $X_n(x_n)=X_n(x-\lambda a_n t), x_n=x-\lambda a_n t$ and $\sum c_n\Phi_n(x_n)\otimes X_n(x_n)\overset{resonance}{=}\sum c_k\Phi_k(x_k)\otimes X_k(x_k)$

The electron will get de-coherence and come back to the real space-time and show as particle. Meanwhile its momentum will decrease to 0. According to the wave function that $\psi(x,k)=A\exp\{-i[k_{234}\cdot x_{234}-k_1x_1]\}$, because of $k_{234}\to 0$

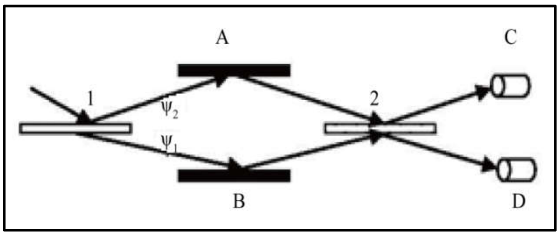
$$\psi=A\mathrm{e}^{-i(ik_1x_1)} \tag{10}$$

is a rotating electron who is reaching to its own frame of reference. Meanwhile, the radius $R_1=1/mc\to R_0=1/m_0c$ is far smaller than the scene in size and can be ignored. So the electron hitting on the scene can be seen as a point electron. Whether the electron is hitting onto point A or B in a single measurement, it is just random. And the probability is determined by the phase difference and superposition of the amplitude. And because the physical space has been changed, electron can only be seen as particle on the scene.

Now we can understand when blocking one of the two slits, the electron will show as particle but bot single slit diffraction. Once one slit is block, there is a continuous interaction potential $\mathrm{e}^{\alpha(x)}$ and $U(t)=\mathrm{e}^{i(H_{\text{int}})t}$. And the state of electron will be changed into mixed. On the blocking slit, it represents as particle and its momentum will decrease to 0. On the opening slit, it will pass through directly. And the probabilitys of the two cases are 1/2. But if the scene is a pellicle mirror (the lattice constant is similar to the wavelength), the experimental phenomena will be completely different. We will discuss about this later. It is the continuous interaction of the scene that has broken down the coherence between the double slit wave sources. And the disappearance of the fixed phase difference caused the disappearance of the coherence of the wave function. The wave is stopped by hinder of the scene U, and this is the de-coherence process of the electron wave. And the particle electron is described by the Equation (10). The hinder effect of the scene after the double-slit is an important condition in the transformation from dual-four-dimensional complex space-time quantum mechanics to four-dimensional real space-time quantum mechanics. This is the R process of quantum measurement. Obviously, there are two important conditions in the transformation from “fluctuation form in the all-around space” to “particle form in local space” in quantum measurement. One is “the wavelength is comprisable to the slit width” and the other one is “continuous outfield interaction”. And the boundary between U and R process is whether the continuous outfield interaction is introduced or not. We think in the double-slit experiment, the cognition change of the form of a micro object has blended in the built of physical phenomenon, the phenomenon of the entity, the physical model, the phenomenon of space-time structure, action mechanism and theory. It is the unification of human and nature. As long as we do not confuse the cognitive level and distinguish their own background space-time, there is no logical mess and it is easy to understand. Obviously, now we have seen in the invisible transmission, do the Bell base joint measurement on the particle 1 - 2 at the first place, and then do unitary transformation U(t) on the particle 3 at the second place, actually means we treat the particle 3 as the instrument and detect the coupling between 1 and 3 by particle 2. The state information cognition and record of the particle 1 is not a direct move of itself. If we can use the density matrix to analysis the entanglement of the system under test and the instrument, it is clearer at a glance. There are both diagonal entries and non-diagonal entries in the pure state matrix of the system under test. When the continuous interaction U has been introduced, the system under test will be mixed state and the non-diagonal entries will disappear. While the non-diagonal entries are always 0 for an instrument. So there is only diagonal entries entanglement and absolutely no coherent item. But at this time, it demands the instrument has the ability to differ and display the resonance. This is the basic demands of accuracy for instrument.

4. Newanalysis on Mach-Zehnder interferometer-delayed choice experiment

Profile of the Mach-Zehnder interferometer experiment is presented as below. A photon comes from left and incidents on a pellicle mirror 1. Then two pathways generate and one is transmission light ψ_1 and the other one is reflection light ψ_2. After two holophote reflecting mirror A and B, they two incident on a pellicle mirror 2 and finally they are collected by the detector C and D.



1) The formation of Superposition state in experiment

In this experiment, because the photon wavelength has the similar size with the lattice constant (the same as the double slit), the observation is at the level of inner field matter. And it shows as the De Broglie-Schrodinger wave. One photon comes from left and incidents on a pellicle mirror 1, and then it will decompose into two light paths: transmission light ψ_1 and reflection light ψ_2. The time series between two eigenstates will be deleted and form the superposition state (pure state)

$$\left|\psi(x)\right\rangle = \sum c_i \left|\psi_i(x)\right\rangle \ (i=1,2) \tag{11}$$

The transmission light and the reflection light will propagate parallel and have no time series. Their phase difference is fixed at $\pi/2$. This system is at the formation of matter wave in dual-dour-dimensional complex space-time.

2) The holophote reflecting mirror A and B

The holophote reflecting mirror A and B are like the scene and the necessary condition that the wavelength is at the similar size with the lattice constant is absent. Holophote is quantum measurement and introduces the hinder potential of $U = \mathrm{e}^{\alpha(x)}$. The photon will get de-coherence and enter into the macro observation level, namely the four-dimensional real space-time. And the fluctuation in the inner of the photon can be totally ignored. The holophote reflection photon will be particle. For the equivalence property of the density distribution of the photon wave field matter, the transmission light ψ_1 and reflection light ψ_2 has the equaling probability, and the show the same wave function mathematical:

$$\left|\psi(x)\right\rangle = \sum c_n \left|\psi_n(x)\right\rangle (n=1,2) \tag{12}$$

The transmission light ψ_1 (ψ_2) is reflected by the holophote reflecting mirror A (B) and will develop into particle, then absorbed by the detector C (D). For ψ_1 and ψ_2 represent the field matter fluctuation state of the same photon and are parallel coexist with a fixed phase difference of $\pi/2$, so the chance of particle existence at mirror A and B is equal. $\psi(x)$ is the so called probability wave. Because of the interaction of the hider potential U of the holophote reflecting mirror, the space-time will universal collapse and the pure state will develop into mixed state. Holophotal reflection is a position quantum measurement. The reflected particle at A or B has the time series, so the particle cannot exist at A and B at the same time. After A and B, the photon can chose only one of the two light paths. And the probability is equal. There is no wave package collapse. It is the space-time that has changed at the holophote reflecting mirror A and B. Eigenvalue, eigenstate and mixed state are the results of the continuous interaction and recovery of time series in measurement. It is a completely understandable physical process.

3) The pellicle mirror 2

If we add a pellicle mirror 2, the cognition condition will be changed again and is the same as in pellicle mirror 1. The reflecting photon, no matter comes from A or B, will show its fluctuation nature because the cognition condition will come back to the inner quantum level. Then we discuss the coherent motion of field matter in the dual- four-dimensional complex space-time.

What the pellicle mirror 2 received is a photon with superposition of mixed state. This is the initial state in measurement. The pellicle mirror 2 will decomposed into 4 parallel eigenstates, thus the photon will have pure state coherence. The reflected photon from A will decomposed into transmission wave and reflection wave, and so it is from B. The time series between each eigenstates will be deleted again, and the superposition is

$$\left|\psi(x)\right\rangle = \sum c_n \left|\psi_n(x)\right\rangle$$

Further, the reflection wave ψ_2 from A and the transmission wave ψ_1 from B will form a pair of coherent wave source. Finally they will arrived at detector C. The reflection wave ψ_2 from B and the transmission wave ψ_1 from A will form another pair of coherent wave source. Finally they will arrive at detector D. Both light paths will show its coherence and the phase of the wave will be their hidden memory. Detector C and D are the potion measuring instrument. The phase will add i after one time of reflection. At detector C, the phase is $i + i^3 = i + (-i) = 0$, so the amplitude is zero and there is no photon. At detector D, the phase is $i^2 + i^2 = -2$ which is a real number, so the photon will always be detector D. At this time, the cognition space-time is changed at C and D. The measurement is just the same as what we have discussed and agrees with our theory logical.

5. Schrodinger's Cat and the EPR Ideal Experiment

1) Origin of the Schrodinger' cat paradox

Physicists hope that quantum mechanics is a universal theory of the universe, which can describe the micro physical system as well as the macro instrument. And it is also hoped that the instrument follows the evolution law of quantum mechanics as the micro system under test. Von Neumann and Wigner are the first ones to come up with the quantum measurement theory covering the instrument as well as the system under test. In Von Neumann's theory, the system under test and the instrument can be treated as an integral system because of the interaction. When the integral system is reduced into the system under test, we can observe the quantum de-coherence and wave package collapse phenomena. There is major deficiency in Von Neumann's theory. He didn't take a full consideration on the macro properties of the instrument. If we want to realize the wave package collapse, we must introduce an infinite chain of instrument and finally we have to use the concept of God or Mind to make the last instrument collapse and then realize the quantum de-coherence successively. The first scientist to suspect on this theory is Schrodinger. In 1935, he came up with a Thought Experiment. There is a cat and a bottle filled with poison in an enclosed cage. Whether the bottle is broken or not is dependent on an atomic radiation device. The probability of a atomic decay or not is equal. If the atom is in excited state $\left|\uparrow\right\rangle$, the bottle will not be broken and the cat is alive. If the atom is in ground state $\left|\downarrow\right\rangle$, a photon will be released along this transition and then trigger a hammer to smash the bottle and the poison will kill the cat.

According to the wave function explanation in quantum mechanics, $\left|\uparrow\right\rangle$ and $\left|\downarrow\right\rangle$ are both probability waves and reflect the probability of the transition of electron. For the principle of superposition, the atom can be in a superposition state of

$$\left|\psi_{atom}\right\rangle = \alpha\left|\uparrow\right\rangle + \beta\left|\downarrow\right\rangle \qquad (13)$$
$$\alpha^2 + \beta^2 = 1$$

Equation (13) indicates the atom can be in a superposition state of release a photon and not release a photon. Thus the cat can be in the superposition state of alive and dead. Because we think the quantum mechanics is a universal theory, and the state of the cat can be described by the wave function in quantum mechanics. It also obeies the evolution law of quantum probability, namely the coherent. If $\left|alive\right\rangle$ and $\left|dead\right\rangle$ are the two eigenstates of cat, then

$$\left|\psi_{cat}\right\rangle = \alpha\left|alive\right\rangle + \beta\left|dead\right\rangle \qquad (14)$$

For the compound system of both cat and atom, the state is

$$\left|\psi_{compound}\right\rangle = \alpha\left|alive\right\rangle + \beta\left|dead\right\rangle \qquad (15)$$

Equation (15) indicates the cat can be in a state of both dead and alive in the cage. According to the Copenhagen interpretation of quantum measurement, the cat in the cage is alive or not before we open the box is not dependent on the objective existence, but the observation after we open the box. At the moment when we open the box, the superposition state of both dead and alive can collapse into real dead or alive state. The intrinsic nature here is observation. Because of the interaction of our mind, the transition from quantum state to classic state is successfully triggered. Our mind determines the cat's life, this is obvious absurd. This is the origin of Schrodinger's cat paradox.

2) De-coherence of macro object

There is a de-coherence view on that paradox that when we talk about the cat's death or live, it just represents two collection states; and when we talk about cat, it means the cat constitutes mounts of micro particles. Thus there are many degrees of freedom to describe the Schrodinger's cat and it cannot be simplified as

$$\left|\psi\right\rangle = \alpha\left|alive\right\rangle + \beta\left|dead\right\rangle \qquad (16)$$

And the correct form should contain the inner state of dead $\left|D_j\right\rangle$ or alive $\left|L_j\right\rangle$, in which $j = 1, 2, \cdots, N$. So we can get

$$\left|\psi\right\rangle = \alpha\left|alive\right\rangle \otimes \prod_{j=1}^{N}\left|L_j\right\rangle + \beta\left|dead\right\rangle \otimes \prod_{j=1}^{N}\left|D_j\right\rangle \qquad (17)$$

If we just discuss on the dead of not of the cat and don't care what the inner condition is, we should use the reduced density matrix:

$$\begin{aligned} P &= tr\left|\psi\right\rangle\left\langle\psi\right| \\ &= \alpha^2\left|alive\right\rangle\left\langle alive\right| + \beta^2\left|dead\right\rangle\left\langle dead\right| \\ &\quad + \alpha * \beta\left|dead\right\rangle\left\langle alive\right|\prod_{j=1}^{N}\left|L_j\right\rangle\left\langle D_j\right| + h\cdot e \end{aligned} \qquad (18)$$

For arbitrary normalized state $\left|\left\langle L_j\right|\left|D_j\right\rangle\right| \le 1$, when dead state $\left|D_j\right\rangle$ or live state $\left|L_j\right\rangle$ becomes orthogonality or $N \to \infty$, the de-coherence factor

$F(N,t) = \prod_{j=1}^{N}\left|\left\langle L_j\right|\left|D_j\right\rangle\right|$ will possibly tend to be 0. And the coherent superposition state of macro Schrodinger' cat will lose coherence properties (Zeng, 2000). It is not difficult to find the purpose to rewrite the cat's wave function: in the transition from Equation (16) to (17), we are actually aimed at the state transition from to pure quantum state to mixed state ton classic probability state. Put the transition from quantum probability to classic probability onto the cat has an important triggering state that $\left|L_j\right\rangle$ and $\left|D_j\right\rangle$ becomes orthogonal, or the de-coherence factor and integral is 0 when $N \to \infty$. This has eliminated the idealism of God. But on one hand, it leaves some leeway for coherence. On the other hand it needs an additional constraint: $\left|L_j\right\rangle$ and $\left|D_j\right\rangle$ becomes orthogonal. Though people have analyzed the inevitability, there is still room for discussion. A cat which is constituted of two levels of atoms, has continuous energy when the atom quantity N is limited to infinite, thus proving the inner state of $\left|L_j\right\rangle$ and $\left|D_j\right\rangle$ are impartible. In an inner state with continuous energy, there must be $\left|D_j\right\rangle=\left|L_j\right\rangle$. This is also reasonable. In the evolution of dead and alive, we couldn't distinguish which state of an atom corresponds to the dead of the collection state, and which corresponds to the alive. The inner state is undistinguishable for the collection state. Thus there is no measurement and no de-coherence.

In fact, in the Schrodinger' cat paradox, the states of the hammer and the bottle are also couldn't be seen as the same as the atom decay. Hammer has the state of $|move\rangle+|not\_move\rangle$ and bottle has the state of $|broken\rangle+|not\_broken\rangle$, both are superposition quantum state. They can't exist at the same time. According the Von Neumann hypothesis, the hammer and the bottle also need a de-coherence process. If not, the macro real interaction will not be realized. It still needs an entanglement between macro collection state and micro inner state to realize the transition from quantum probability to classic probability. The pure state of poison can't go back to real world. Even if the cat take regardless of the "collective spirit", and go back to the real world alone by de-coherence, it is useless. And it is more difficult to realize the entanglement between collection state and inner state of hammer and bottle. Its automatic de-coherence is more difficult than cat. How can we find the amounts of atoms corresponding to "broken and not-broken" state?

3) Schrodinger's cat in dual-four-dimensional space-time quantum mechanics

The existence of Schrodinger cat paradox is not because we have ignored the infinite inner degrees of freedom of the cat, but that have been confused by the microcosmic quantum state and the macro classic state. Though quantum mechanics may be a universal theory for the system from macro and cosmic world, when it has touched the macro experience of human, we have to consider the suitableness of quantum phenomenon for macro experience, and have to consider of the intrinsic difference between quantum phenomenon and macro phenomenon and its description space. Take the dice as an example, in micro quantum state, we can get "1" and "2" state individually, as well as the state that "1" and "2" show up at the same time. The time series between the transitions from "1" to "2" and the interaction are deleted. But the macro world has time series, and the dice can only be "1" or "2", no superposition is existed. And there must be an interaction with time series during the transition from "1" to "2". The thought experiment of Schrodinger' cat consists of two parts. One is the decayed atom described in dual-four-dimensional complex space-time, which shows the quantization phenomenon and obeys the quantum evolution law ($h\neq 0$), and the eigenstates are parallel and coherent. The other part is the macro object described in four-dimensional real space-time including hammer, bottle, poison and cat, which obeys the classic evolution law ($h\neq 0$) and has time series and no coherence. The transition between each state has a corresponding interaction. In atomic level world, the continuous time series between each state has been deleted by the quantum transition. We actually don't consider the interaction of field, but consider the interaction result, namely the eigenstates which are described in dual-four-dimensional complex space-time. The atom has the superposition of both decayed and not-decayed $\left|\psi_{atom}\right\rangle=\alpha\left|\uparrow\right\rangle+\beta\left|\downarrow\right\rangle$. And this superposition state is the solution of the Schrodinger equation. This is the U process before quantum measurement.

However in macrocosmic level world, the bottle, hammer and cat has no energy transition and the energy gap, interaction are all continuous. "Move" and "not-move" of the hammer, "broken" and "not-broken" of the bottle, "dead" and "live" of the cat has no mutation. There is a transition process and has its corresponding time series. The inner interaction in the transition of itself makes up the self-entanglement. The individual coherent wave sources are disappeared and the macro object will accomplish the quantum measurement in the self-entanglement. Thus they show the macro classic state.

The motion of hammer, bottle and cat can be simplified by the mass point model and are deterministic. There is no mutation and superposition of $|move\rangle+|not\_move\rangle$, $|broken\rangle+|not\_broken\rangle$ and $|dead\rangle+|alive\rangle$ (Zhao, 2005). Herein, the root causes of the Schrodinger' cat paradox are as follows.

(1) The superposition of eigenstates in quantum mechanics is because of the deleting time series, ignoring the field but consider the interaction result. Such a theoretic operation makes eigenstate to be the free micro object plane wave. And this is the U process. In the thought experiment of Schrodinger's cat, suppose the excited state of $\left|\uparrow\right\rangle$ can release a photon which means the fundamental condition of superposition has been violated. Once a photon is excited to released, the eigenstate must has been interacted by some outfield (may be caused by the atomic nucleus). The appearance of $U\left|\uparrow\right\rangle$ state (in which $U=\mathrm{e}^{\alpha(x)}$) is a quantum measurement. It destroys the orthogonality of the wave function and the characteristics of the linear superposition, thus entering the R process of quantum measurement. At this moment, the state of the atom is mixed not pure and the description space-time is four-dimensional real space-time. Then, the superposition of hammer, bottle and cat are all be wanting. So the quantum measurement by field's excitation in Schrodinger assumption has been realized in the inner part of atom.

(2) The macro object can't be decomposed into superposition of pure eigenstate and there is no de-coherence. The cat doesn't have the superposition of $|dead\rangle+|alive\rangle$.

(3) It is a mistake that we treat the "opening the bottle" as the key transition from quantum state to macro classic state in quantum measurement, because we have ignored the discussion (1) and (2).

(4) To eliminate the Schrodinger's cat paradox, we can put the operation of "open the bottle" onto the decayed atom. And let the place of the transition from quantum state to macro classic state locate in the atom. If the atom is excited and release a photon, the cat is dead. If the atom is not excited, the cat is alive. When opening the cover, whether the cat is dead or not has no relationship with whether we have looked at it. Schrodinger's cat ideal experiment is obviously a false proposition.

2) EPR paradox

In 1935, Einstein, B.Podolsky and N.Rosen published a short article. They criticize the basic principle and the interpretation of traditional quantum mechanics. The questions in this article are called EPR paradox. There are two points in this article.

(1) The description of "physical reality" in quantum mechanics is incomplete. Einstein was against the uncertainty principle and thought "God won't roll the dice". Einstein stuck to determinism.
(2) Quantum mechanics is not self-consistent. This is actually involves the multi- particle system entangled state. In quantum mechanics it is shown as "nonlocality". Einstein adhere to the "locality", namely the superluminal information transmission could not exist.

Einstein defined the "physical reality" as follows.

- If we can certainly predict the value of a physical quantity in the absence of any disturbance to the system, this quantity corresponds to the physical factor.
- Physical theory is to describe the object of "physical reality". Objects of physical reality in the Newtonian mechanics are the representative of "particle". Energy and momentum, location and time and so on are the important elements. Einstein claimed the quantity in physical theory and "the elements of physical reality" must be one to one correspondence, and must have a certain value, otherwise the theory is not perfect (Zeng, 1995).

According to the above definition, Einstein gave a one-dimensional quantum states:

$$\psi = \mathrm{e}^{ip_0 x/\hbar} \tag{19}$$

It is the eigenstate of momentum $p = -i\hbar\partial/\partial x$ and is physical reality. The eigenvalue is p_0, (caution: $p\psi = p_0\psi$). At this point, the particle has a certain momentum value p_0. Therefore, the particle's momentum "*p*" is the element of the "physical reality" in the "physical reality ψ state" in quantum mechanics. However, because $\hat{x}\psi = x\mathrm{e}^{ip_0 x/\hbar} \neq const \cdot \psi$, ψ is not the eigenstate of coordinate *x* and ψ can't be used to predict the coordinates of the particles exactly. And if we want to know the coordinates of the particles, we can only rely on the measurement. But measurement is a kind of external disturbance, after measuring the coordinates of the particles, the particle will no longer be in its original quantum states. Therefore, Einstein thought the coordinate *x* has an uncertain value at the ψ state. So the coordinates of the particles is not "the elements of physical reality". In particle appearance, the coordinates of the location of the particle can be determined, but the momentum of a particle cannot be determined completely, so the particle's momentum is not the elements of the "physical reality". Einstein has also discussed a general situation. He set the two mechanical quantity to describe the micro object are non-commuting: $[A,B] \neq 0$. Then A and B will not share the same eigenstate. Due to the uncertainty relations, once a physical quantity is confirmed, the other physical quantity will not be surely determined. A and B can't be elements of "physical reality" at the same time. The description of "physical reality" is incomplete in quantum mechanical, so the quantum mechanics is incomplete. Einstein's argument for the description of the "physical reality" is not complete in quantum mechanics, was actually against the Copenhagen "uncertainty principle", think "God won't roll the dice". Einstein's criticism is right. The problem is whether there is "uncertainty principle" without God. In other words, is there "uncertainty principle" based on physical realism? The answer is yes! This is the field matter sphere model in dual-four-dimensional complex space-time. The sphere model has a distribution in space, the position uncertainty is in the diameter of this sphere ($D = \Delta x = 2r$). Micro object is not a point, the position uncertainty can't be ruled out and is "natural". It is decided by the spatial distribution of the micro object itself. "Position uncertainty" is a micro object itself! In dual-four-dimensional complex space-time, the momentum uncertainty is determined by the momentum ($p = \Delta P$) of the micro object itself too. It is inevitable when building the quantum mechanics such as the quantization division, the parallel and co- exist at the same time of the eigenstate. All the eigenstate and eigenvalue are co-exist at the same time, but probability in different level is different. "Momentum uncertainty" is not only the experimental phenomena, but also a product of the theory.

The analysis of uncertainty principle in dual-four-dimensional complex space-time is based on the physical model. The physical realism is field matter sphere. The quantity changing is dependent on the state of the field matter sphere. And this is in a different physical space as the mass point defined by Einstein. We can't ask for the physical realism in dual-four-dimensional complex space-time and in four-dimen- sional real space-time has the same properties. On the contrary, the uncertainty relation of momentum and position in field matter sphere model is precisely the root cause of the statistical properties in quantum mechanics (Mo, 1986). Uncertainty principle has the explanation of realism. The physical reality in quantum mechanics and in macro classic mechanics has both relationship and difference. The physical reality in quantum mechanics is a field matter ball and the unity of wave-particle duality. The physical reality in classic mechanics is a particle and embodies the orbital motion. The uncertainty in quantum mechanics results from the quantization and transition of different models. Though it is born not to be eliminated, it is not given by the God. Thus Einstein's "God does not roll the dice" problem is solved. The physical reality in dual-four-dimensional quantum mechanics is field matter sphere and its description is complete. But the concept of physical reality and element of physical reality is defined is quantum mechanics space-time $W(x,k)$ but in $M^4(x)$ which is suitable for mass point model. The misunderstanding results from that we don't differentiate the quantum mechanics space-time $W(x,k)$ and relativistic space-time $M^4(x)$. The second part of the EPR paradox arguments is about its not self-consistent in quantum mechanics theory. Especially, the description of the wave function in quantum mechanics is not self-consistent (Zeng, 2000). Consider a system composed of two particles □ + □ has interaction in the time range of (0,T). After $t>T$, □ and □ will keep away from each other, and there is no interaction any more. Suppose the quantum states of □ and □ are given at the moment of $t=0$, we can know the quantum state at any moment of $t>T$ with the help of the Schrodinger equation. Set $\psi(x_1,x_2)$ is the quantum state of this two particles' system. x_1 and x_2 are the coordinates of the two particles.

At the time of $t>T$, give measurement on the mechanical quantity $\hat{A}$ and $\hat{B}$, ($\left[\hat{A},\hat{B}\right]\neq 0$)

(1) The mechanical quantity $\hat{A}$ of particle □

Set $\hat{A}u_n(x_1)=a_n u_n(x_1)$, a_n and $u_n(x_1)$ are the eigenvalue and eigenstate of $\hat{A}$ (n = 1, 2, 3…), respectively. Decomposed the $\psi(x_1,x_2)$ by eigenstates $u_n(x_1)$ of $\hat{A}$, then we will get

$$\psi(x_1,x_2)=\sum_n \psi_n(x_2)u_n(x_1) \tag{20}$$

in which $\psi_n(x_2)$ is the expansion coefficient.

The wave function in Equation (20) is in accordance with the quantum probability evolution law, and has the coherence (in the $W(x,k)$ space according to our understanding). In quantum measurement, if the measurement result is a_k, the wave package will be collapsed into

$$\psi(x_1,x_2)\rightarrow\psi_k(x_2)u_k(x_1) \tag{21}$$

After measurement, $\psi_k(x_2)$ and $u_k(x_1)$ will be mixes state and conforms to the classical probability evolution with no coherence (in the $M^4(x)$ space according to our understanding). The measurement makes $\psi_n(x_2)$, $u_n(x_1)$ and $\psi_k(x_2)$, $u_k(x_1)$ transform from pure quantum states and mixed states. The space also changes from $W(x,k)$ to $M^4(x)$.

(2) The mechanical quantity $\hat{B}$ of particle □

Set $\hat{B}V_s(x_1)=b_s V_s(x_1)$, b_s and $V_s(x_1)$ are the eigenvalue and eigenstate of $\hat{B}$ (n = 1, 2, 3…), respectively. Decomposed the $\psi(x_1,x_2)$ by eigenstates $V_s(x_1)$ of $\hat{B}$, then we will get

$$\psi(x_1,x_2)=\sum_s \psi_s(x_2)V_s(x_1) \tag{22}$$

in which $\psi_s(x_2)$ is the expansion coefficient.

The wave function in Equation (22) is in accordance with the quantum probability evolution law, and has the coherence (in the $W(x,k)$ space according to our understanding). In quantum measurement, if the measurement result is b_r, the wave package will be collapsed into

$$\psi(x_1,x_2)\rightarrow\psi_r(x_2)V_r(x_1) \tag{23}$$

After measurement, $\psi_r(x_2)$ and $V_r(x_1)$ will be mixes state and conforms to the classical probability evolution with no coherence (in the $M^4(x)$ space according to our understanding). The measurement makes $\psi_s(x_2)$, $V_s(x_1)$ and $\psi_r(x_2)$, $V_r(x_1)$ transform from pure quantum states and mixed states. The space also changes from $W(x,k)$ to $M^4(x)$. The above Copenhagen interpretation of quantum measurement makes Einstein confused. He thought when $t>T$, the particle □ and □ will keep away from each other and there is no interaction at all. Thus the measurement on particle □ will not change the particle □. So why the particle □ will be collapsed, namely the particle □ is measured? Is there superluminal phenomenon between □ and □? In addition, there is an embarrassing thing in traditional quantum mechanics. When measuring particle □, the state of particle □ which is has no associated interaction will change from $\psi_k(x_2)$ to $\psi_r(x_2)$. Is that possible? So Einstein believes that quantum mechanics is not self-consistent. Einstein's analysis just means the interaction introduced by the quantum measurement can make all the quantum state "collapse" at the same time. The universal model transformation from field matter sphere model to particle model and the space-time transformation from $W(x,k)$ to $M^4(x)$ occur also. When measuring the particle □, the state of particle □ will change from $\psi_k(x_2)$ to $\psi_r(x_2)$ as well. This is because the pure states can co-exist in $W(x,k)$ space-time, but the mixed state in $M^4(x)$ space-time has the time series. This precisely confirms to the core thought in dual-four-dimensional complex

space-time quantum mechanics.
In fact, Einstein's theory of "(1) and (2) the particles away from each other, there is no longer any interaction", just Constitute a conditions of a coexist quantum state of the so-called "mutations ". The particle (1) and (2) at the same time into the Dual four dimensional space-time W (x, k) at this time, measuring the particle (1), must be the introduction of continuous interaction, Restore the sequential time series, Let particle (1) and (2) at the same time into the four dimensional space-time M^4(x), Make (1) and (2) into the macroscopic cognitive form. Quantum measurement make W(x, k) space all quantum state "collapse" to the four dimensional space-time M^4 (x) at the same time. It is the superluminal Physical meaning .There no real superluminal information transmission, is a conversion operation in time and space. Bohm has simplified the EPR paradox. Consider a two particles system with 1/2 spin value, there is no interaction between the two particles when $t > T$ and the measurement on will has no impact on the particle .

In the measurement, when the particle collapsed into spin up state of $u_k(x_1)$, namely $\psi(x_1,x_2)\rightarrow\psi_k(x_2)u_k(x_1)$, the particle will collapsed into spin down. When the particle collapsed into spin down state of $u_k(x_1)$, namely $\psi(x_1,x_2)\rightarrow\ \psi_r(x_2)V_r(x_1)$, the particle will collapsed into spin up.

Bohm's expression is more simple and clear than the original EPR paradox by Einstein attached. So it becomes a mostly discussed object when talking about EPR paradox. The understanding of the EPR paradox actually involves the understanding of entanglement in quantum mechanics. Entanglement is caused by the linear superposition of eigenstate in two particle system. According to the traditional quantum mechanics, entangled state should be a probability wave entanglement. What is the meaning of entanglement in mathematical wave? This is difficult to understand. In dual-four- dimensional quantum mechanics, the wave function describes the density distribution of its structure of matter density. And the entanglement is in matter wave (Zhao, 2014). No matter how the two particles are away from each other, and no matter there is interaction or not, the matter wave entanglement in universal space will keep them as an integral system. Measurement is by introducing outfield in the space-time where matter wave is in to make the pure state become mixed state. When measuring one of two particles system, the other one will surely be disturbed because of the entanglement. The spin state of and are pure state in $W(x,k)$ space-time.

There are four basic states co-existing. In measuring, the mutation between two states is lose. The two particles transform from pure state to mixed state, and the description space-time will transform from dual-four-dimensional complex space-time to four-dimensional real space-time. They have the time series and the states of and can only be the same one (up or down). In the measurement of the electron spin state, there is Pauli Exclusion Principle limit. That is to say, there can't be two electrons in a same state: one spin up, one spin down (Wu, 2005).

6. The Reconsideration of Quantum De-Coherence

The quantum de-coherence interpretation of is making progress on solving the problem of quantum measurement. But the specific model for quantum de-coherence, the entanglement state between the system under test and macro instruments are not logical self-consistent in the theoretical system of de-coherence. Rebuilding the practical interpretation model for de-coherence is still necessary. John Bell pointed out that, in the theory of quantum measurement, quantum coherent disappearence is the foundation problem of philosophical discussion (Bell, 1975). Copenhagen school of traditional explanation thought the complementary principle and the uncertainty relation is an important cause of quantum de-coherence. However, people are still asking if this is the only direct cause of de-coherence. Although Von Neumann measurement theory has embodies the universality of the quantum theory. The collapse of wave packet eventually will need the help of God or man's thinking. This is more difficult to understand. Some are not satisfied with the subjective interpretation of wave packet collapse. David Joseph Bohm and Everett came up with the "Hidden variable theory" and the "many world explanation" in 1952 and 1957, respectively. In the 80-90s of the 20th century, further research by W.H. Zurek *et al*. suggested the de-coherence phenomena of macro level object is caused by the environmental induction (Li, 2005). Their research caused the interpretation of quantum de-coherence. This is an important development in quantum theory.

1) The basic ideas of quantum de-coherence

The basic ideas of quantum de-coherence can be concluded as follows.

(1) There is quantum coherence in macro object

As a universal theory, quantum mechanics can describe the micro and even the cosmic world. The macro object and cosmic evolution can be written as pure state wave function meeting the Schrodinger equation. Therefore, macro object has quantum coherence in principle.

(2) External and internal environment both can induce de-coherence

Because of the influence of the external or internal environment, macro object can often be quickly de-coherent (Li, 2005). Therefore in real life, we can't see the coherent superposition of macroscopic object. The external environment can be the air molecules, atoms, and also can be the photons. And even the cosmic microwave background radiation can also be included.

Internal environment influence is the large number of degrees of freedom in the macroscopic object because of the mounts of no regulation motion. Macroscopic object can be entangled with the outside environment ae well as the internal environment, thus resulting in the loss of coherence (Li, 2005; Guan, 2005).

(3) If there is no internal dissipation of the system, there is no de-coherence

Macro objects and environment has the energy dissipation when coupling. In general, if there is dissipation, there is de-coherence. If there is no internal dissipation, there will be no de-coherence, and the quantum interference will be reserved. It can be used to illustrate superconductor and superfluid. Though they have many degrees of freedom, they can keep the macroscopic quantum superposition.

Overall, type Brown movement fluctuation and energy dissipation are the sources of de-coherence, but the former one is the most important one (Li, 2005; Guan, 2005).

2) The specific use of quantum de-coherence in quantum measurement model

(1) Connection of the instrument and the system under test

According to the Von Neumann measurement theory, the quantum measurement is the read operation on the instrument to get the state of the system under test (Sun, 2000). To read the connection in quantum mechanics, we have to know the connection between the instrument and the system under test. If $\left|\psi\right\rangle = \sum_n c_n \left|n\right\rangle$ is the state of the system under test, and $\left|e_n\right\rangle$ is the corresponding state of the instrument, n = 1, 2, …, k, then the wave function of the integral system is

$$\left|\psi_{\text{integral}}\right\rangle = \sum_n c_n \left|n\right\rangle \left|e\right\rangle \tag{24}$$

Quantum entanglement tell us once the instrument has detected a $\left|e_k\right\rangle$, we will know the integral system is on $\left|k\right\rangle\left|e_k\right\rangle$, namely the integral wave function has entangled into $\left|k\right\rangle\left|e_k\right\rangle$. The system under test is on the state of $\left|k\right\rangle$. Great attention should be taken that the wave function in equation (24) represents the pure quantum state which obeys the Schrodinger equation evolution law. According to the de-coherence interpretation, the quantum measurement can be summarized as a short form that, the system and the instrument are in the pure state of $\left|n\right\rangle$ and $\left|e_n\right\rangle$. $\rightarrow$ The entanglement between the system under test and the instrument is formed. $\rightarrow$ The macro instrument is decomposed into many possible state $\left|e_n\right\rangle$ and self-de-coherence. $\rightarrow$ The instrument is detected to be state of $\left|e_k\right\rangle \rightarrow$ The system under test is de-coherent to mixed state $\left|k\right\rangle$. This is the specific use of quantum de-coherence in quantum measurement model. As an applicable model, Equation (24) has a clear thinking, but its logical is not self-consistent. As we have pointed out, it still contains the difficult of wave package collapse. Firstly, the instrument is mixed state but not pure state. Secondly, because there is no pure state instrument in measurement, the Equation (24) has only mathematical meaning and shows no physical significance. Thirdly, de-coherence of macro instrument goes against the irreversible transformation from pure state to mixed state. Fourthly, because the Equation (24) is not self-consistent, the coherence time has no contribution on wave package collapse. So the difficult in wave package collapse is not eliminated. According to the above four points, we consider the de-coherence operation of Equation (24) is just a mathematical operation and represents no real physical process (Bell, 1975). The difficult in wave package collapse is still not cleaned.

(2) Connection in macro collective state and internal state

In recent years, some scholars give further in-depth study of the macro instruments de-coherence process. They point out that the no regulation motion of micro particles to constitute the macro object and the no regulation motion of the macro environment will couple with the collective degree of freedom, thus forming the quantum entanglement. If we treat the instrument as a macro object with *N* number of micro particles in which there is no interaction, its state is *N* heavy direct product, namely

$$\left|e\right\rangle = \prod_{j=1}^{N} \left|e(j)\right\rangle \rightarrow \left|e_n\right\rangle = \prod_{j=1}^{N} \left|e_n(j)\right\rangle$$

The de-coherence factor is

$F_{mn}(t) = \prod_{j=1}^{N} F_{mn}(j,t) \equiv \prod_{j=1}^{N} \left\langle e_m(j) \middle| e_n(j) \right\rangle$. Because the factor $F_{mn}(j,t) = \left\langle e_m(j) \middle| e_n(j) \right\rangle \le 1$, when N tends to infinity, the product may be 0. $\lim_{N\to\infty} F_{mn}(t) = 0$ the coherence is lose. The number N is infinite means the instrument is macro. So when N tends to infinity, the macro object will de-coherence automatically. However, due to Equation (24) is not self-consistent logically, no matter whether it is worth to be discussed on the way to de-coherence, it has no use for use of Equation (24). Imagine an instrument is formed of from particles with no interactions, its internal state and macro collective state are indistinguishable or not, the de- coherence factor oscillatory around 0, the orthogonality between each two atoms are worth to be discussed. For the automatic de-coherence analysis on cat, it can't not escape the fate as above as well. In the Schrodinger's cage, cat is the instrument to drive the atom be de-coherent. The poor cat, either waits for neither dead nor alive, once the decayed atom system is put into the cage, it begins to de-coherence and drive the atoms back to atomic level world. Or be automatic de-coherence alone, once the decayed atom system is put into the cage, it comes back to the neither dead nor alive state and be de-coherent. Both this two cases are contrary to the basic principles of quantum mechanics. Obviously, the existing operating model of quantum de-coherence interpretation can't solve the quantum measurement problem logical self-consistently.

We believe the causes of the difficulty result from that we do not properly understand the interaction mechanism. In fact, no matter the external environment or the internal rules with a large number of degrees of freedom, is a process of entropy increase (the disorder increase). The large number of no regulation motion creates a physical condition of $h=0$. Its truth physical meaning is to tell us macro instrument is of mixed state without coherence. The instrument produces a continuous interaction which is different to the mechanism of creating pure state on the system to be test. Such a continuous interaction prompts the system under test to be de-coherent and be identified by the instrument resonance. The above thinking offers us a new pattern of quantum de-coherence.

3) New thinking on the quantum de-coherence

Firstly, the instrument is mixed state but not pure state. Secondly, the connection between the mixed state system and the mixing instruments are caused by continuous interaction, thus the system under test will from the mixed state. Thirdly, the instrument identifies the system under test is by resonance recognition, and resonance is random. Fourthly, the transition from pure state to mixed state represents the transformation from micro quantum world to the macro classical world, as well as the transformation of description space and physical model. The quantum measurement in dual-four-dimensional space-time can be briefly stated as follows. (1) Needn't wave package collapse. The continuous interaction makes all the eigenstates of the system under test come back to the mixed states. And there is no wave package collapse. $A\psi_n(x)=a_n\psi_n(x)$ just represents the find of the cognitive object of the system under test by instrument resonant searching. (2) Quantum measurement makes the microscopic object description from fual-four-dimensional space- time to four-dimensional real space-time. This is transformation from U process to R Process. (3) Quantum measurement (producing the interaction) makes microscopic object from integral wave form to local macroscopic particles.

This is a process from wave to particle. On the contrary, the process from particle to wave is by cutting the continuous interaction between each state. De Broglie's dream of "wave goer into particle" and "particle shows wave" process finally get ideal state here. (4) In measurement, the recognition of eigenstate is random. The continuous interaction of instrument is like to make many eigenstates translate to macro world at the same time and be de-coherent automatically. As to which eigenstate will be caught by the instrument, it is random. The probability of this randomness is related to the structure of field matter density. When the eigenvalue of the energy level is caught by the instrument, the probability becomes 1. (5) We human beings and the macro instruments are objects and both belong to macro world. The record of instrument is the record of people's cognition. Quantum measurement is the process of making the quantum state translate to the macro classical state and let we get the experience. It needn't many worlds in dual-four-dimensional complex space-time quantum mechanics. It just needs macro and micro world. People's observation has no relationship with the de-coherence phenomena of system under test and the instrument.

Dual-four-dimensional quantum mechanics is likely to eliminate the deep contradiction between relativity and quantum mechanics. Its direct result is as follows. (1) In microscopic field, the electron is always changing in atom, and the form of electron is variable. The electron in atom is different from the electron escaping from the atom. The traditional analysis is limited. (2) Physical reality described in quantum mechanical is different from particles in classical mechanics. Physical reality in quantum mechanics is a field matter sphere as well as the unity of the wave-particle duality.

The process of quantum measurement is illustrated as follows

Pure states coherent	$a_1,a_2,\cdots,a_n \quad \psi_1,\psi_2,\cdots,\psi_n \quad \psi_1+\psi_2\cdots$ $\lvert\psi_1\rvert^2+\lvert\psi_2\rvert^2+\psi_1^*\psi_2+\psi_2^*\psi_1\cdots$
$\downarrow$	Quantum measurement, continuous interaction, Disappearance of mutation and coherent source Wave $\rightarrow$ particle, come back to the macro state
Mixed states No coherence	$a_1,a_2,\cdots,a_n \quad \psi_1,\psi_2,\cdots,\psi_n$ $\lvert\psi_1\rvert^2+\lvert\psi_2\rvert^2\cdots$
$\downarrow$	Random record
	Record operation of instrument $a_k\psi_k$

(3) Macro particle abstract principles are not suitable for the micro object. (4) We can't put the object in different cognition level into the same cognition level. Different cognition levels have different description space. Dual-four-dimensional space-time is the description space-time in quantum mechanics. What we can do is to find the logical channel between different cognition levels. (5) Considering the matter wave is physical wave, the realization of quantum communication and quantum com- puter is only a matter of technology in the dual-four-dimensional quantum mechanics (www.gpcpublishing.com; http://cirworld.com/index.php/jap/article/view/5230; http://www.scirp.org/journal/jmp).

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