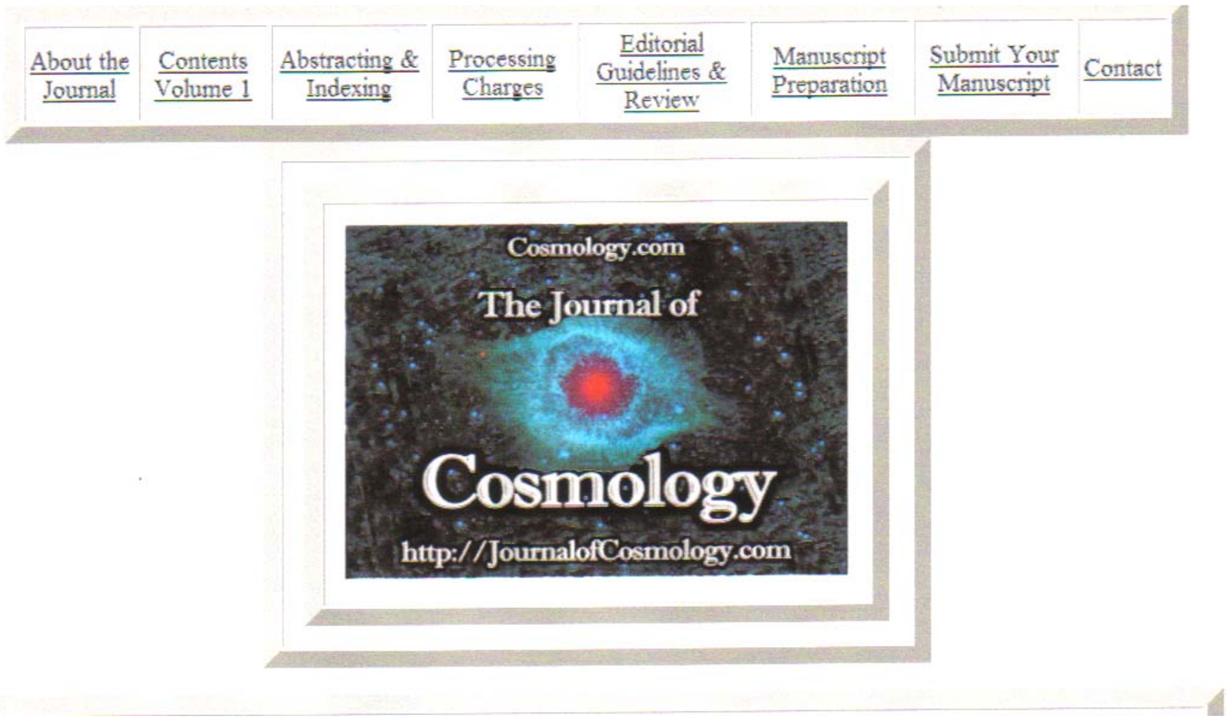

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THE PHOTON CARRIES THE ARROW OF TIME

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Abstract

In order to describe the quantum electrodynamic measurement process in a relativistic observer-participant manner, an operator symmetry of "microscopic observer-participation" called Measurement Color (MC) is incorporated into the field theoretic structure of Quantum Electrodynamics (QED) in the Heisenberg Picture. It is found that the resultant Measurement Color Quantum Electrodynamics (MC-QED) contains a microscopic quantum electrodynamic arrow of time that emerges dynamically, independent of any thermodynamic or cosmological assumptions. This occurs because the Measurement Color symmetry within MC-QED implies that the photon carries the arrow of time. In this context the physical requirement of a stable vacuum state in MC-QED dynamically selects operator solutions containing a causal, retarded, quantum electrodynamic arrow of time, which causes a spontaneous symmetry breaking of both T and CPT to occur. Spontaneous CPT symmetry breaking is consistent with the observed CP symmetry invariance seen in quantum electrodynamic particle interactions since, in the CPT symmetry breaking context of the

MC-QED formalism, CP invariance is not physically equivalent to T invariance. In this manner the existence of the microscopic arrow of time in MC-QED offers a quantum electrodynamic explanation for the existence of irreversible phenomena which complements that supplied by the statistical arguments in phase space associated with the Second Law of Thermodynamics. In this context further development of the MC-QED formalism may lead to a resolution of the problems associated with: a) the connection between the description of the microscopic and macroscopic "Arrows of Time" in the universe, b) the connection between the description of microscopic quantum objects and macroscopic classical objects, and (c) the search for a physical explanation of how macroscopic conscious observers emerge from the microscopic laws of quantum physics.

Key Words: Quantum Field Theory, Elementary Particles, Cosmology, Philosophy of Science, Consciousness Studies

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SECTION I. INTRODUCTION

In justifying the validity of the Copenhagen Interpretation of Quantum Theory (CI-QM), Niels Bohr emphasized that it was meaningless to ascribe a complete set of physical attributes to a microscopic quantum object prior to the act of quantum measurement being performed on it. Hence in the context of the CI-QM only the probability of an outcome of a quantum measurement could be predicted deterministically.

These probabilities represented quantum potentia, associated with the expectation values of various physical operators over the quantum wave function, whose structure and unitary time evolution was described by the Schrodinger equation. Hence it followed from the CI-QM that the physical nature of "Objective Reality", associated with the quantum actua generated from the quantum potentia by the quantum measurement process, could never be described in a deterministically predictable manner.

However this picture of the universe represented by the CI-QM remains problematic because of the logical asymmetry built into it which states that: a) large classical macroscopic systems associated with measuring instruments have local objective properties independent of their observation, while at the same time b) microscopic quantum systems have non-local properties which do not have an objective existence independent of the "act of observation", generated by their quantum measurement interaction with the large classical macroscopic measuring instruments.

This is paradoxical because macroscopic measuring instruments are made up of large numbers of atomic micro-systems and because of this fact the direct coupling of these macro-aggregates of atomic micro-systems to nonlocal quantum micro-systems must occur in Nature. Hence the entire Universe, at both the macroscopic and microscopic level, is susceptible to the ghostly non-local quantum weirdness which lies at the heart of Quantum Theory.

Given this fact the puzzle is why we don't experience this macroscopic non-local quantum weirdness in our daily lives. Most physicists believe that there can be only one unified set of laws for the whole Universe and that in this context the quantum laws are more fundamental than the classical laws. In this picture the quantum laws should apply to everything, from atoms to everyday objects like tables and chairs and macroscopic conscious living beings. However this can lead to contradictory predictions when macroscopically objective systems are directly coupled to microscopic quantum systems in a superposition of states.

In the early days of quantum theory Bohr and Heisenberg debated about this problem in regard to the relationship of the CI-QM to the existence of conscious macroscopic observers. In the context of these discussions Heisenberg felt that the CI-QM was incomplete since it was unable to explain the existence of living conscious observers. Bohr replied that the CI-QM could be considered to be complete if the existence of physical systems and living conscious observers were considered to be complementary and not contradictory ways of looking at Nature. However Heisenberg was unsatisfied with Bohr's reply and remained convinced that the problem of the describing the existence macroscopic conscious observers implied that the CI-QM was incomplete.

Further progress toward a better understanding of the quantum measurement process in the context of the CI-QM was made by John Wheeler who pioneered the development of a new paradigm called "The Observer Participant Universe" (OPU). Within the context of the OPU macroscopic living conscious observers directly participate in the process of irreversibly actualizing the elementary quantum phenomena which make up the universe. Wheeler emphasized that in the context of the OPU "No elementary quantum phenomenon is a phenomenon until it is an irreversibly recorded phenomenon".

However the previously described logical asymmetry associated with the interpretation of the CI-QM remained in Wheeler's version of the Observer-Participant Universe, since the dynamical manner in which macroscopic living conscious observers irreversibly actualize microscopic elementary quantum phenomena was still unexplained. In order to address this problem the structure of this paper is as follows:

Section II presents a brief review of the structure of standard QED formalism in order to make it easier for the reader to better understand the issues discussed in the Introduction. The key points discussed in this brief review of QED will allow the reader will find it easier to understand the development of the observer-participant MC-QED formalism discussed in Section III

Section III uses the results of section II and generalizes them to in order to develop the MC-QED formalism (Leiter, D., 2009). This is done by requiring that the Abelian operator gauge symmetry of microscopic operator observer-participation called Measurement Color (Leiter, D., 1983, 1985, 1989) be incorporated into the operator equations of quantum electrodynamics in the Heisenberg picture. In this manner we show how a logical symmetry in regard to the quantum field theoretic definition of the “observer” and the “object” can be formally created at the microscopic level.

Section IV concludes by pointing out that the challenge of determining what is ultimately possible in physics will require the resolution of three fundamental issues : (1) the origin of the arrow of time in the universe; (2) the nature of objective existence in the context quantum reality, and (3) the spontaneous emergence of macroscopic conscious minds in the universe. It is then argued that in the context of the new paradigm of MC-QED the resolution of these three fundamental issues may be found within the paradigm of an observer-participant universe where the photon carries the Arrow of Time. It is then pointed out that the existence of the causal microscopic arrow of time in MC-QED represents a fundamentally quantum electrodynamic explanation for irreversible phenomena associated with the Second Law of Thermodynamics which complements the one supplied by the well-known statistical arguments in phase space

SECTION II. THE STANDARD FORM OF QUANTUM ELECTRODYNAMICS

The problem about the logical asymmetry between the object and observer discussed in the introduction makes itself felt directly within the context of the Copenhagen Interpretation of Quantum Electrodynamics (CI-QED).

In the CI-QED in the physical world is assumed to be arbitrarily divided into two complementary components: a) a microscopic quantum field theoretical world consisting of electrons positrons and photons , and b) a macroscopic classical world of macroscopic measuring instruments in which “macroscopic conscious observers” reside.

Clearly the validity of the Copenhagen Interpretation division of the world in CI-QED is limited to physical situations where, during the period of time between their preparation and detection, the microscopic quantum systems have no significant influence upon the classically described macroscopic measuring instruments.

However this cannot be always be the case since, as the physical size of an aggregate of microscopic quantum systems under consideration increases, a point must eventually be reached where the aggregate of quantum systems is neither small enough to have a negligible influence on the classically described measuring instruments, nor large enough to be able to be described in purely classical terms. For physical situations of this type, the basic assumption about the asymmetric nature of the classical/quantum interface which underlies the CI-QED is no longer valid. In order to resolve this paradox it is clear that a new formulation of the observer-participant quantum electrodynamic measurement paradigm is needed which is able to go beyond the limitations of the Copenhagen Interpretation. This new formulation of the quantum electrodynamic measurement process will be discussed in detail in Section III.

However in order to make it easier for the reader to better understand the manner in which this new paradigm of Measurement Color is inserted into the quantum electrodynamic operator formalism of QED in the Heisenberg Picture, Section II will be devoted to presenting a brief review of the structure of standard QED formalism. Then by using this discussion of standard QED as our logical baseline, we will find that the development of the observer-participant MC-QED formalism in Section III will follow in a natural easy to understand manner.

In Section II and Section III we will be using the metric signature (1,-1, -1,-1), and natural $(h/2\pi) = c = 1$ units. The relativistic notation, operator sign conventions, and operator calculation techniques, used below to generalize and extend the standard QED theory into the MC-QED theory, will be formally similar to those used in the book "Introduction to Relativistic Quantum Field Theory" by (Schweber, S., 1962).

We begin our brief review of the structure of the QED formalism in the Heisenberg picture starting with the standard charge-conjugation invariant QED action given by

$$I = \{- \int dx^4 \; [(1/4[\psi^{\dagger}\gamma^{o}, (-i\gamma^{\mu}\partial_{\mu}+m)\psi] + \text{Hermetian conjugate}) + (1/2\partial_{\mu}A^{\nu}\partial^{\mu}A_{\nu} + J_{\mu}A^{\mu})]\}$$

In the QED action written above, ψ is the electron-positron field operator, A^{μ} is the electromagnetic field operator, and $J_{\mu} = -e[c\psi^{\dagger}\gamma^{o}, \gamma_{\mu}\psi]$ is the electromagnetic current operator. In the Heisenberg picture, by applying standard second quantization methods applied to the above action, we find that the QED Heisenberg operator equations of motion are given by

$$[(-ih / 2\pi)\gamma^{\mu}\partial_{\mu} + mc + (e / c]\gamma^{\mu}A_{\mu})\psi = 0 \quad \text{(Heisenberg equation for } \psi \text{ fermion operator)}$$

$$\Box^{2}A_{\mu} = -e[c\psi^{\dagger}\gamma^{o}, \gamma_{\mu}\psi] \quad \text{(Heisenberg equation for the } A_{\mu} \text{ photon operator)}$$

For the convenience of scientific engineering readers who wish to check the dimensional consistency of the above QED operator equations of motion, we have written them using the (cgs) unit values of Planck's constant (h / 2π) and the speed of light c. However from this point on in order to maintain simplicity these and all other operator equations will be expressed in terms of the natural units where (h/2π) = c =1.

In the indefinite metric Hilbert space of QED, the Heisenberg Picture State Vector $|\psi\rangle$ is required to obey the Subsidiary Condition

$$\langle\psi| (\partial_\mu A^\mu) |\psi\rangle = 0$$

In addition the Heisenberg Picture operator equations of MC-QED are invariant under the Abelian Measurement Color gauge transformation

$$\psi'(x) = \psi(x) \exp(ie\Lambda(x))$$
$$A_\mu'(x) = A_\mu(x) + \partial_\mu\Lambda(x)$$

where $\Lambda(x)$ is a scalar field obeying $\Box^2\Lambda(x) = 0$. Hence the current operator J_μ is conserved as $\partial^\mu J_\mu = 0$ which implies that the total charge operators Q = $\int dx^3\, J_0$ commutes with the total Hamiltonian operator of the theory.
Following the standard procedures for the canonical quantization of fields applied to CED leads to the canonical equal-time commutation and anti-commutation relations in the QED formalism as

$$[A_\mu (x, t), \partial_t A_\nu (x', t)] = i\eta_{\mu\nu}\delta^3(x' - x)$$

$$\{\psi (x, t) , \psi^\dagger(x', t)\} = \delta^3(x' - x)$$

$$[A_\mu (x, t) , \psi(x', t)] = [A_\mu (x, t) , \psi^\dagger(x', t)] = 0$$

where sig($\eta_{\mu\nu}$) = (1, -1, -1, -1, with other equal-time commutators and anti-commutators vanishing respectively.

In QED the most general operator solution to the operator equations of motion for A_μ is given by

$$A_\mu = A_\mu(+) + A_\mu^{(0)} = A_\mu(\text{ret, adv}) + A_\mu(\text{in, out})$$

where

$$A_\mu(+) = (A_\mu(\text{ret}) + A_\mu(\text{adv})) / 2$$

and $A_\mu^{(0)}$ is the time symmetric free uncoupled photon operator.

It is useful to write A_μ in the equivalent form as

$$A_\mu = [(1+p) / 2]\, A_\mu(\text{ret}) + [(1-p) / 2]\, A_\mu(\text{adv}) + A_\mu(\text{rad}, p)$$

where p is a c-number, and

$$A_\mu(\text{rad}, p) = A_\mu^{(0)} - p\, A_\mu(-)$$

With

$$A_\mu(-) = (A_\mu(\text{ret}) - A_\mu(\text{adv})) / 2$$

The operator solution A_μ to the Maxwell operator equations are separately invariant under the "Radiation Flow Symmetry Operator" T_p which changes the effects of "retarded fields into advanced fields by taking the value of the c-number p in the above equations and changing it into the c-number -p.

In addition the operator equations are separately invariant under the Wigner Time Reversal operation T_W for which the combination of $t \rightarrow -t$ and complex conjugation occurs.

Hence the above QED formalism in the Heisenberg Picture is invariant under the generalized Time Reversal operator $T = T_W \times T_p$ which is the product of the Wigner Time Reversal Operator T_t and the Radiation Flow Symmetry Operator T_p .

In addition the operator fields and their operator equations of motion of the QED formalism in the Heisenberg Picture in (1-a) and (1-b) above are also invariant under the action of the Charge Conjugation operator C, the Parity operator P. Thus it follows that QED is invariant under the CPT symmetry where $T = T_W \times T_p$.

In solving the above Wigner Time Reversal Operator T_W invariant QED formalism to obtain the S-matrix one usually defines the "in-out" operator field solutions by imposing the "Asymptotic Condition" on the expectation values of the operator equations of motion . This is done first in the $t \rightarrow -\infty$) limit where $\psi(x, t \rightarrow -\infty) = \psi(\text{in})$ as

$$\langle A_\mu (x, t \rightarrow -\infty)\rangle = \langle\left(\int dx^3\, (J_\mu(x', t \rightarrow -\infty) / 4\pi\, |\mathbf{x}-\mathbf{x}'|\right) + A_\mu(\text{in}) \rangle \quad \text{(kinematic condition)}$$

$$\langle\partial_t J_\mu (x, t \rightarrow -\infty)\rangle = 0 \quad \text{(dynamic stability condition)}$$

where under these conditions the expectation value of the operator equations of motion become

$$<(-i\gamma^{\mu}\partial_{\mu} + m - e\gamma^{\mu}A_{\mu}(x, t \rightarrow -\infty))\psi(in)> = 0$$

$$<\Box^{2}A_{\mu}(in)> = -e <[\psi(in)^{\dagger}\gamma^{o}, \gamma_{\mu}\psi(in)]>$$

and then second in the limit as $t \rightarrow \infty$) where $\psi(x, t \rightarrow \infty) = \psi(out)$ as

$$<A_{\mu} (x, t \rightarrow +\infty)> = <(\int dx^{3} (J_{\mu}(x', t \rightarrow +\infty) / 4\pi |\mathbf{x}-\mathbf{x'}|) + A_{\mu}(out) > \quad \text{(kinematic condition)}$$

$$<\partial_{t}J_{\mu} (x, t \rightarrow \infty)> = 0 \quad \text{(dynamic stability condition)}$$

where under these conditions the expectation value of the operator equations of motion become

$$<(-i\gamma^{\mu}\partial_{\mu} + m - e\gamma^{\mu}A_{\mu}(x, t \rightarrow -\infty))\psi(out)> = 0$$

$$<\Box^{2}A_{\mu}(out)> = -e <[\psi(out)^{\dagger}\gamma^{o}, \gamma_{\mu}\psi(out)]>$$

where in the above

$$A_{\mu} (in, out) = A(rad, p = \pm 1) = A_{\mu}^{(0)} - [\pm A_{\mu}(-)]$$

and hence

$$A_{\mu}out) = A_{\mu}(in) + 2 A_{\mu}(-)$$

The kinematic components of the Asymptotic Conditions then respectively determine the values of the c-number p in the operator equations of motion to be either p =1 or p = -1. However, because of the presence of the time symmetric free radiation field operators $A_{\mu}^{(0)}$ in QED, the dynamic stability components of the Asymptotic Conditions cannot physically distinguish between the p =1 and p = -1 cases. To see this more clearly we note that under the Wigner Time Reversal Operator T_W we have respectively that

$$T_W A_{\mu}(in) T_W^{-1} = A^{\mu}(out)$$

$$T_W A_{\mu}(ret) T_W^{-1} = A^{\mu}(adv)$$

Hence it follows that A_{μ} is invariant under T_W since

$$T_W A_{\mu}T_W^{-1} = T_W [A_{\mu}(ret) + A_{\mu}(in)]T_W^{-1} =[A_{\mu}(adv) + A_{\mu}(out)] = A^{\mu}$$

In addition A_{μ} is invariant under since $T_p A_{\mu}T_p^{-1} = A_{\mu}$, Hence we see that QED is invariant under the generalized time reversal symmetry $T = T_W \times T_p$ as well as being separately invariant under both the T_t and T_p operations.

Since QED is also invariant under the parity operation P and the Charge Conjugation operation C it follows that QED is also invariant under the CPT symmetry operation where $T = T_W \times T_P$. This is due to the presence of the time-symmetric the free photon field operator $A_\mu^{(0)}$ in QED which allows a stable vacuum state to exist in the context of the CPT invariance of the formalism.

Since QED is a local, relativistic, quantum field theory it obeys the CPT symmetry. The CPT symmetry is a fundamental property of all local, relativistic, quantum field theories, where T is the Wigner Time Reversal symmetry, P is the Parity Inversion symmetry, and C is the Charge Conjugation symmetry.

The fact that QED is CPT invariant implies that a CPT transformed version of the universe is an observable solution to the QED formalism. A CPT transformed version of the universe is one in which: a) positions of all objects are reflected by an imaginary plane mirror (parity inversion P); b) momenta of all objects are reversed (corresponding to time inversion T) and; c) all matter is replaced by antimatter (corresponding to charge conjugation C). The preservation of the CPT symmetry implies that every violation of the combined symmetry of two of its components (such as CP) must have a corresponding violation in the third component (such as T). Since QED and its Standard Model generalizations obey the CPT symmetry, in this context the observation CP symmetry in particle interactions is interpreted to be physically equivalent to the observation of T symmetry.

Because QED does not have a dynamically chosen microscopic arrow of time one must insert an arrow of time by hand. A causal retarded arrow of time can be imposed on the QED formalism in the Heisenberg picture by appealing to the Thermodynamic arrow of increasing entropy. This justifies the use of a low entropy boundary condition on the expectation values of the $A_\mu(in)$ operators in the far past of the Heisenberg Picture such that that all photons vanish for the $|\psi\rangle$ state vector at $t \rightarrow -\infty$ as

$$\langle\psi|A_\mu(in)|\psi\rangle = 0.$$

Hence in the context of the QED formalism in the Heisenberg Picture, the imposition of the Asymptotic Condition does not dynamically determine a Physical Arrow of Time and this implies that the Thermodynamic arrow of increasing entropy is the master time asymmetry in the universe .

III. MEASUREMENT COLOR QUANTUM ELECTRODYNAMICS

In this section will generalize and extend the results of section II and show that the requirement of a logical symmetry in regard to the definition of the “observer” and the “object” can be accomplished at the microscopic level by requiring that an Abelian operator gauge symmetry of microscopic operator observer-participation called Measurement Color (Leiter, D., 1983, 1985, 1989) be incorporated into the operator equations of quantum electrodynamics in the Heisenberg picture.

In this context we will show that the resultant formalism Measurement Color Quantum Electrodynamics (MC-QED) (Leiter, D. 2009) takes the form of a nonlocal, microscopically observer-participant quantum field theory, in which a microscopic electrodynamic arrow of time dynamically emerges independent of any external thermodynamic or cosmological assumptions.

We will also show that the MC-QED quantum electrodynamic arrow of time emerges dynamically because the microscopic observer-participant operator structure of the formalism implies that the local time-symmetric "free photon operator" is non-physical since it cannot be given a Measurement Color description. Instead it must be replaced by a Measurement Color Symmetric Total Coupled Radiation Charge-Field photon operator which is non-local and carries a negative time parity under the Wigner Time Reversal operator T_W.

However because of this difference between the QED and MC-QED photon operator structure, we will find that the physical requirement that a stable vacuum state exists dynamically constrains the MC-QED Heisenberg operator equations of motion to contain a causal retarded quantum electrodynamic arrow of time independent of external thermodynamic or cosmological assumptions*.*

In this manner the existence of the microscopic arrow of time in MC-QED will be shown to represent a fundamentally quantum electrodynamic explanation, for irreversible phenomena associated with the Second Law of Thermodynamics, which complements the one supplied by the well-known statistical arguments in phase space.

Measurement Color Quantum Electrodynamics (Leiter, D., 2009) is constructed by imposing an Abelian operator gauge symmetry of microscopic operator observer-participation called Measurement Color onto the operator equations of motion of standard Quantum Electrodynamics (QED) in the Heisenberg picture.

The Measurement Color symmetry is an Abelian operator labeling, associated with the integer indices k = 1,2, …, N in the limit as N --> ∞, which is imposed in an operational manner onto the both the electron-positron operators and the photon operators within the quantum field structure of the standard QED formalism. However since MC-QED is a theory of mutual quantum field theoretic observer-participation, its action principle must be constructed in a manner such that self-measurement interaction terms of the form $J_\mu^{(k)} A^{\mu(k)}$ (k=1,2,… , N→ -∞) are dynamically excluded from the formalism.

The MC-QED formalism which emerges operationally describes the microscopic observer-participant quantum electrodynamic process, between the electron-positron quantum operator fields $\psi^{(k)}$ and the charge field photon quantum operator fields $A_\mu^{(j)}$ ($k \neq j$) which they interact with, in the Heisenberg Picture operator field equations.

Generalizing from the discussion in Section II about the QED formalism in the Heisenberg picture, it follows in this Measurement Color context that this can dynamically accomplished by constructing the charge-conjugation invariant MC-QED action principle given by

$$I = \{- \int dx^4 \; [\Sigma_{(k)} \left(1/4[\psi^{(k)\dagger}\gamma^o, (-i\gamma^\mu\partial_\mu+m)\psi^{(k)}] + \text{Hermetian conjugate}\right)$$
$$+ \Sigma_{(k)} \Sigma_{(j \neq k)} (1/2\partial_\mu A^{\nu(k)} \partial^\mu A_\nu^{(j)} + J_\mu^{(k)} A^{\mu(j)})]\}$$

where ($k, j = 1,2,\ldots , N \rightarrow -\infty$) and $h / 2\pi = c = 1$ natural units are being used. In the Heisenberg picture applying the standard second quantization methods taken to the above action for MC-QED we find that the MC-QED Heisenberg operator equations of motion are given by

$$(-i\gamma^\mu\partial_\mu + m - e\gamma^\mu A_\mu{}^{(k)}{}_{(obs)})\psi^{(k)} = 0$$ (Heisenberg equation for $\psi^{(k)}$ fermion operator)

$$A_\mu{}^{(k)}{}_{(obs)} = \Sigma_{(j \neq k)} A_\mu{}^{(j)}$$ (electromagnetic operator field $A_\mu{}^{(k)}{}_{(obs)}$ *observed* by $\psi^{(k)}$)

$$\Box^2 A_\mu{}^{(k)} = J_\mu{}^{(k)} = -e\, [\psi^{(k)\dagger}\gamma^o, \gamma_\mu\psi^{(k)}]$$ (Heisenberg equation for the $A_\mu{}^{(k)}$ operator)

where the Measurement Color labels on the operator fields $\psi^{(k)}$, and $A_\mu{}^{(k)}$ range over ($k = 1,2, \; , N \rightarrow \infty$). In the context of an indefinite metric Hilbert space, the Subsidiary Condition

$$<\psi| (\partial^\mu A_\mu{}^{(k)}) |\psi> = 0 \qquad (k = 1,2, \ldots , N \rightarrow \infty))$$

must also be satisfied. Then the expectation value of the Heisenberg Picture operator equations of MC-QED are will be invariant under the Abelian Measurement Color gauge transformation ($k = 1,2, \ldots , N \rightarrow -\infty$)

$$\psi^{(k)'}(x) = \psi^{(k)}(x) \exp(ie\Lambda(x))$$

$$A_\mu{}^{(k)'}(x)_{(obs)} = A_\mu{}^{(k)}(x)_{(obs)} + \partial_\mu\Lambda(x)$$

where $\Lambda(x)$ is a scalar field obeying $\Box^2\Lambda(x) = 0$

Hence the individual Measurement Color currents $J_\mu^{(k)}$ are conserved as $\partial^\mu J_\mu^{(k)} = 0$ (k =1,2, … , N→ -∞) which implies that the individual Measurement Color charge operators

$$Q^{(k)} = \int dx^3 \, J_0^{(k)} \quad (k = 1,2, \dots , N \rightarrow -\infty)$$

commute with the total Hamiltonian operator of the theory.

Following the standard procedures for the canonical quantization of fields applied to MC-CED leads to the canonical equal-time commutation and anti-commutation relations in the MC-QED formalism as

$$[A_\mu^{(k)} (x, t), \partial_t A_\nu^{(j)}{}_{(obs)} (x', t)] = i\eta_{\mu\nu}\delta^{kj} \delta^3(x' - x)$$

$$\{\psi^{(k)} (x, t) , \psi^{(j)\dagger}(x', t)\} = \delta^{kj} \delta^3(x' - x) \qquad (k, j = 1,2, \dots , N \rightarrow \infty)$$

$$[A_\mu^{((k)} (x, t) , \psi^{(j)}(x', t)] = [A_\mu^{((k)} (x, t) , \psi^{(j)\dagger}(x', t)] = 0$$

with all other equal-time commutators and anti-commutators vanishing respectively, (k, j =1,2, … , N→ ∞).

In this context the structure of the MC-QED operator equations of motion and the equal-time commutation and anti-commutation relations dynamically enforces a form of mutual operator observer-participation which dynamically excludes time-symmetric Measurement Color self-interaction terms of the form $e\gamma^\mu A_\mu^{(k)}\psi^{(k)}$ (k =1,2, … , N→ ∞) from the operator equations of motion.

In solving the Measurement Color Maxwell equations for the charge-fields $A_\mu^{(k)}$ within the context of the multi-field theoretic Measurement Color paradigm upon which MC-QED is based, "local time-symmetric free radiation field operators uncoupled from charges" $A_\mu^{(0)}$ must be excluded from the $A_\mu^{(k)}$ charge-field solutions since the $A_\mu^{(0)}$ fields cannot be defined in terms of Measurement Color charge-fields. This is in contrast to the case of QED where $A_\mu^{(0)}$ cannot be excluded from A_μ since Measurement Color does not play a role in its Maxwell field operator structure.

Hence in solving the Maxwell field operator equations for the electromagnetic field operators $A_\mu^{(k)}$ the MC-QED paradigm implies that a universal time-symmetric boundary condition, which mathematically excludes local time reversal invariant free uncoupled radiation field operators $A_\mu^{(0)}$ from contributing to the charge-field operators $A_\mu^{(k)}$ must be imposed on <u>each</u> of the $A_\mu^{(k)}$ operator solutions to the Maxwell operator equations. However since the operator boundary condition requirement which excludes $A_\mu^{(0)}$ operators is time-symmetric it does not by itself choose an arrow of time in the MC-QED formalism.

Hence within MC-QED "free uncoupled radiation field operators" $A_\mu^{(0)}$ are operationally excluded from MC-QED and in their place the physical effects of radiation are operationally described in a microscopic observer-participant manner by the measurement color symmetric, time anti-symmetric, total coupled radiation field operator"

$$A_\mu^{(TCRF)} = \sum_{(k)} A_\mu^{(k)}(-) \neq 0.$$

where

$$A_\mu^{(k)}(-) = 1/2 \int dx^{4'} (D_{(ret)}(x-x') - D_{(adv)}(x-x'))J^{(k)}(x')$$

In this context it follows that, in the operational observer-participant context of the MC-QED, that the Heisenberg operator field equations, the electron-positron operator fields $\psi^{(k)}$ (k = 1,2, … N) "observe" the electromagnetic charge-field operator $A_\mu^{(k)}{}_{(obs)}$ given by

$$A_\mu^{(k)}{}_{(obs)} = \sum_{(k\neq j)} A_\mu^{(j)} = \sum_{(j\neq k)} A_\mu^{(j)}(+) + pA_\mu^{(TCRF)} \quad (k = 1,2, \ldots, N \to \infty))$$

where

$$A_\mu^{(j)}(+) = 1/2 \int dx^{4'} (D_{(ret)}(x-x') + D_{(adv)}(x-x'))J^{(j)}(x') \ , (j\neq k = 1,2, \ldots N)$$

and

$A_\mu^{(TCRF)} = \sum_{(k)} A_\mu^{(k)}(-) \neq 0$ is the negative time parity total radiation charge-field operator In the above the quantity p is a c-number constant whose value determines the amount of mixing between the time-symmetric and time anti-symmetric charge field operators which occur in the charge-field operator $A_\mu^{(k)}{}_{(obs)}$.

For our purposes it is also useful to also write the $A_\mu^{(k)}{}_{(obs)}$ charge-field operator in the equivalent form

$$A_\mu^{(k)}{}_{(obs)} = [(1+p)/2]\, A_\mu^{(k)}{}_{(obs)}(ret) + [(1-p)/2]\, A_\mu^{(k)}{}_{(obs)}(adv) + A_\mu^{(k)}{}_{(obs)}(rad, p)$$

where the $A_\mu^{(k)}{}_{(obs)}(rad, p)$ are the negative time parity coupled charge-field photon "in and out" operators are defined as

$$A_\mu^{(k)}{}_{(obs)}(rad, p) = p\, [\, A_\mu^{(TCRF)} - \sum_{(j\neq k)} A_\mu^{(j)}(-)\,] = p\, A_\mu^{(k)}(-)$$

Note that while the time-symmetric local free radiation field uncoupled to charges $A_\mu^{(0)}$ vanish in the MC-QED formalism, the time reversal violating nonlocal total coupled radiation field $A_\mu^{(TCRF)} = \sum_{(k)} A_\mu^{(k)}(-) \neq 0$ and its associated in-out fields do not vanish.

For this reason a consistent MC-QED quantum electrodynamic formalism is possible. Now in the absence of non-operational free radiation fields $A_\mu^{(0)}$, the presence of the negative time parity Total Coupled Radiation Field operator $A_\mu^{(TCRF)}$ in MC-QED implies that the MC-QED operator equations violate the following symmetries:

a) The "Radiation Flow Symmetry Operator" T_p , for which $p \rightarrow -p$ occurs, is violated in the operator equations (3) since they have a negative parity under the T_p operation

b) The Wigner Time Reversal operator symmetry T_W , for which the combination of $t \rightarrow -t$ and complex conjugation occurs, is violated in the operator equations since by virtue of the presence of the Total Coupled Radiation Field operator $A_\mu^{(TCRF)}$ they have a negative parity under the T_W operation

However, even though equations separately violate the T_p and the T_W symmetry, they are invariant under the generalized Time Reversal operator $T = T_W \times T_p$ which is the product of the Wigner Time Reversal Operator T_W and the Radiation Flow Symmetry Operator T_p. Since the operator field equations of motion of the MC-QED formalism in the Heisenberg Picture are also invariant under the respective action of the Charge Conjugation operator C, and the Parity operator P, then even though it violates the T_W time reversal symmetry, we find that MC-QED is CPT invariant where the T symmetry is generalized to become $T = T_W \times T_p$.

Now in the context of expectation values of the operator equations of motion in the Heisenberg Picture taken over the Heisenberg state vector $|\psi\rangle$, one can define the "in-out" operator field solutions to MC-QED by imposing time-symmetric same kind of Asymptotic Conditions as that which is done in the case of standard QED.

Hence the "In-Asymptotic Condition" is imposed in the limit as

$$\psi^{(k)}(x, t \rightarrow -\infty) = \psi^{(k)}(in) \qquad (k = 1, 2, \ldots, N \dashrightarrow \infty)$$

From which it follows that

(In-kinematic condition)

$$< A_\mu^{(k)}{}_{(obs)}(x, t \rightarrow -\infty)> = <(\int dx^3 \, (J_\mu^{(k)}{}_{(obs)}(x', t \rightarrow -\infty) / 4\pi \, |\mathbf{x}-\mathbf{x}'|) + A^{(k)}{}_{(obs)}(in)>$$

(in-dynamic stability condition)

$$<\partial_t J_\mu^{(k)}(x, t \rightarrow -\infty)> = 0$$

Then in the limit as $t \rightarrow -\infty$ of the operator equations become

$$<(-i\gamma^\mu \partial_\mu + m - e\gamma^\mu A_\mu^{(k)}{}_{(obs)}(x, t \rightarrow -\infty))\psi^{(k)}(in)>= 0$$
$$<\Box^2 A_\mu^{(k)}(in)> = <J_\mu^{(k)}(in)> = -e <[\psi^{(k)}(in)^\dagger \gamma^o, \gamma_\mu \psi^{(k)}(in)]>$$

In addition we also impose the "Out-Asymptotic Condition" as

$$\psi^{(k)}(x, t \rightarrow +\infty) = \psi^{(k)}(out) \quad (k =1, 2, \ldots , N\text{-->} \infty))$$

(out-kinematic condition)

$$< A_\mu^{(k)}{}_{(obs)}(x, t \rightarrow +\infty)> = <(\int dx^3 \, (J_\mu^{(k)}{}_{(obs)}(x', t \rightarrow +\infty) / 4\pi \, |\mathbf{x}-\mathbf{x}'|) + A^{(k)}{}_{(obs)}(out)>$$

(out-dynamic stability condition)

$$<\partial_t J_\mu^{(k)}(x, t \rightarrow +\infty)> = 0$$

Then in the limit as $t \rightarrow +\infty$ of the operator equations become

$$<(-i\gamma^\mu \partial_\mu + m - e\gamma^\mu A_\mu^{(k)}{}_{(obs)}(x, t \rightarrow +\infty))\psi^{(k)}(out)> = 0$$
$$<\Box^2 A_\mu^{(k)}(out)> = <J_\mu^{(k)}(out)> = -e <[\psi^{(k)}(out)^\dagger \gamma^o, \gamma_\mu \psi^{(k)}(out)]>$$

Now by applying these Asymptotic Conditions to the MC-QED operator equations of motion it follows that a retarded quantum electrodynamic arrow of time emerges dynamically. This is because within the $A^{(k)}{}_{\mu\,(obs)}$ defined above we find that :

a) *The kinematic component of the Asymptotic Condition* formally determines two possible values for the c-number p which controls the arrow of time in the operator equations to be either $p =1$ or $p = - 1$, where

$$A^{(k)}{}_{\mu\,(obs)}(in, out)^{(k)} = A^{(k)}{}_{(obs)}(rad, p = \pm 1) = \pm A_\mu^{(k)}(-)$$

b) *The dynamic component of the Asymptotic Condition*, which is associated with the stability of the vacuum state, dynamically requires that the physical value of the c-number p which appears in the operator equations to be p=1 associated with a retarded, causal, quantum electrodynamic arrow of time.

We can see this more specifically by noting that for the case of p =1 the Heisenberg Picture operator equations of motion have the form

$$<(-i\gamma^{\mu}\partial_{\mu} + m - e\gamma^{\mu}A_{\mu}{}^{(k)}{}_{(obs)})\psi^{(k)}> = 0$$
$$<A_{\mu}{}^{(k)}{}_{(obs)} > = < \Sigma_{(j \neq k)}A_{\mu}{}^{(j)}(ret) + A^{(k)}(-)> \qquad (k, j = 1,2, \dots , N\text{-->} \infty))$$

The expectation value of the above operator equations physically describe the situation where charge field photons are *causally emitted and absorbed* between the $\psi^{(k)}$ and $\psi^{(j)}$ $k \neq j$ fermion operators, while *being spontaneously emitted into the vacuum* by the $\psi^{(k}$ fermion operators, (k, j = 1,2, … , N--> ∞)). For this reason these operator equations predict that electron-positron states can form bound states which spontaneously decay into charge field photons.

Hence the p = 1 operator equations will satisfy the dynamic stability component of the Asymptotic Condition because they predict that a stable vacuum state exists.

On the other hand for the case of p = -1 the Heisenberg Picture operator equations of motion have the form

$$<(-i\gamma^{\mu}\partial_{\mu} + m - e\gamma^{\mu}A_{\mu}{}^{(k)}{}_{(obs)})\psi^{(k)}> = 0$$
$$<A_{\mu}{}^{(k)}{}_{(obs)} > = < \Sigma_{(j \neq k)} A_{\mu}{}^{(j)}(adv) - A^{(k)}(-)> \qquad (k, j = 1,2, \dots , N\text{-->} \infty))$$

On the other hand the expectation value of these operator equations physically describe the situation where charge field photons are *acausally absorbed and emitted* between the $\psi^{(k)}$ and $\psi^{(j)}$ $k \neq j$ fermion operators, while *being spontaneously absorbed from the vacuum* by the $\psi^{(k}$ fermion operators, (k, j = 1,2, , N--> ∞)).
For this reason these operator equations predict that electron-positron states will be spontaneously excited from the vacuum.

Hence the p = -1 operator equations cannot satisfy the dynamic stability component of the Asymptotic Condition because they predict that a stable vacuum state cannot exist.

Hence in MC-QED the action of the nonlocal negative time parity Total Coupled Radiation Field $A_{\mu}{}^{(TCRF)} = \Sigma_{(k)} A_{\mu}{}^{(k)}(-) \neq 0$, in conjunction with the time-symmetric Asymptotic Condition on the operator field equations, implies that the requirement of a stable vacuum state in the MC-QED formalism dynamically determines the choice of a retarded quantum electrodynamic Physical Arrow of Time associated with the p =1 operator equations in, independent of requiring that any Thermodynamic or Cosmological boundary conditions (Zeh, D., 2007) be imposed on the MC-QED formalism.

This is because, in contradistinction to the case of QED, the existence of a causal arrow of time in MC-QED does not require the boundary condition $<A^{(k)}_{\mu\ (obs)}(in)^{(k)}> = 0$ associated with the low entropy assumption that the contribution of all photons, which occur in the expectation value of the Heisenberg state vector, must vanish as time goes to minus infinity as

In the context of the multi-field-operator theoretic Measurement Color paradigm upon which MC-QED is based, a microscopic, causal, electrodynamic arrow of time exists in the universe, (independent of any additional external thermodynamic or cosmological assumptions), because the dynamic role of the free photon operator (which is absent in MC-QED since it cannot be given a Measurement Color description) is replaced by the measurement color symmetric, negative time parity Total Coupled Radiation Charge-Field Photon operator in the MC-QED formalism.

This result can be understood as being due to the phenomenon of spontaneous symmetry breaking with respect to time reversal invariance which occurs in terms of the following logical sequence in the MC-QED formalism:

a) In the parameterized solutions to the time-symmetric MC-QED operator equations of motion, the Measurement Color symmetry in MC-QED ruled out the existence the local time-symmetric photon operator in favor of the negative time parity total coupled radiation charge-field photon operator;

b) Application of standard time-symmetric asymptotic conditions to these parameterized time-symmetric solutions to the MC-QED operator equations of motion selected out the time-symmetric pair of operator causal and acausal operator charge-field solutions which were parameterized respectively by the c-numbers $p = 1$ and $p = -1$;

c) Because of the presence of the negative time parity total, coupled radiation charge-field photon operator within the time symmetric $p = \pm 1$ pair of parameterized solutions to the MC-QED operator equations of motion, the physical requirement of a stable vacuum state spontaneously broke this time-reversal symmetry by dynamically selecting the $p = 1$ solution with a causal, retarded, quantum electrodynamic arrow of time.

On a more general level since MC-QED is a relativistic quantum field theory then CPT symmetry is conserved by the operator solutions to the operator equations of motion. However the T symmetry in MC-QED is generalized to become the product of the Wigner Time Reversal Tw and Radiation Flow Reversal Tp operators as T = Tw x Tp.

Then in this context the physical requirement of a stable vacuum state in MC-QED spontaneously breaks the T and the CPT symmetry by dynamically selecting the operator solution containing a causal, retarded, quantum electrodynamic arrow of time.

Since MC-QED is a non-local quantum field theory in which the photon carries the arrow of time, the requirement of a stable vacuum state spontaneously breaks the CPT symmetry and leads to solutions which are CP invariant but not T invariant. The spontaneous breakdown of CPT symmetry in MC-QED implies that the CPT transformation cannot turn our universe into its "mirror image". This occurs because the photon carries the arrow of time in MC-QED which implies that time in the universe can only run forward in a causal sense and not backward. For MC-QED and its Standard Model generalizations, C, P , and CP symmetry is preserved but CPT symmetry is spontaneously violated. Hence it follows that in the context of the MC-QED formalism, the observed invariance of CP in quantum electrodynamics is not physically equivalent to T invariance.

Having used the MC-QED formalism to resolve the apparent asymmetry in the description of the microscopic and macroscopic "Arrows of Time" in the universe, we can next apply it to the problem of the asymmetry between microscopic quantum objects and macroscopic classical objects inherent in the laws of quantum physics.

We begin by first noting that the origin this problem lies within the nature of Copenhagen Interpretation of QED. This is because within QED macroscopic bodies, associated with macroscopic measuring instruments and macroscopic conscious observers, are assumed to obey a strict form of "Macroscopic Realism", on a complementary classical level of physics external to the microscopic quantum electrodynamic system. Macroscopic bodies that satisfy the strict form of Macroscopic Realism are assumed have the property that they are at all times in a macroscopically distinct state which can be observed without affecting their subsequent behavior.

However this concept of strict Macroscopic Realism is not valid for the case of MC-QED because its Measurement Color symmetry implies that the photon operator carries the arrow of time. This fact has a profound effect on the nature of the time evolution of the state vector in the Schrodinger Picture of the MC-QED formalism.

In particular it has been shown (Leiter, D,. 2009) that this causes the Hamiltonian operator in the Schrodinger Picture of MC-QED to contain a time reversal violating quantum evolution component and a time reversal violating retarded quantum measurement interaction component. The time reversal violating quantum measurement interaction part of the Hamiltonian operator contains components which have causal retarded light travel times, connected to the values of the physical sizes and/or spatial separations associated with the physical aggregate of Measurement Color symmetric fermionic states into which the fermionic sector of state vector is expanded.

For the retarded light travel time intervals in between the preparation and the measurement, the expectation values of the time-reversal violating retarded quantum measurement interaction operator will be negligible compared to the expectation values of the time reversal violating quantum evolution operator and the net effect generates the "quantum potentia" of what may occur.

On the other hand for the retarded light travel time intervals corresponding to the preparation and/or the measurement, the expectation values of the time-reversal violating retarded quantum measurement interaction operator will be dominant compared to the expectation values of the time reversal violating quantum evolution operator and the net effect causes the "quantum potentia" to be converted into the "quantum actua" of observer-participant measurement events.

In this context it can be shown (Leiter, D., 2009) that for a sufficiently large aggregate of atomic systems, described by the by the bare state component of MC-QED Hamiltonian and assumed to exist in an "environment" associated with the retarded quantum measurement interaction component of the Hamiltonian, the net effect of the quantum measurement interaction in MC-QED will generate time reversal violating decoherence effects on the reduced density matrix in a manner which can give large aggregates of atomic systems apparently classical properties.

Hence, in contradistinction the Copenhagen Interpretation of QED with its strict form of "Macroscopic Realism", it follows that MC-QED obeys a dynamic form of Macroscopic Realism in which the classical level of physics emerges dynamically in the context of local intrinsically time reversal violating quantum decoherence effects which can project out individual states since they are generated by the time reversal violating quantum measurement interaction in the formalism.

This is in contrast to the time reversal symmetric case of QED where the local quantum decoherence (Schlosshauer, M., 2007) effects only appear to be irreversible. This occurs in the time symmetric description of decoherence in QED because a local observer does not have access to the entire wave function and, while interference effects appear to be eliminated, individual states have not been projected out.

Hence we conclude that the resolution of the problem of the asymmetry between microscopic quantum objects and macroscopic classical objects inherent in the laws of quantum physics can be found in the MC-QED formalism, because the intrinsically time reversal violating quantum decoherence effects inherent within it imply that MC-QED does not require an independent external complementary classical level of physics obeying strict Macroscopic Realism in order to obtain a physical interpretation.

IV. CONCLUSIONS

In this paper it has been shown that order to describe the quantum electrodynamic measurement process in a relativistic, observer-participant manner, an Abelian operator symmetry of "microscopic observer-participation" called Measurement

Color (MC) was incorporated into the field theoretic structure of the Quantum Electrodynamics (QED).

The resultant formalism, called Measurement Color Quantum Electrodynamics (MC-QED), was constructed by defining a particle-field Measurement Color operator labeling symmetry associated with the integer indices ($k = 1,2, \ldots , N \geq 2$, and imposing this labeling symmetry onto <u>both</u> the electron-positron operators $\psi^{(k)}$ <u>and</u> their electromagnetic charge-field operators $A_{\mu}^{(k)}$, in an mutual observer-participant manner which dynamically excluded time-symmetric self interactions from the formalism.

Within the multi-charge-field operator theoretic structure upon which the paradigm of MC-QED was based, “local time-symmetric free photon field operators uncoupled from charges” could not be operationally defined in terms of the Measurement Color charge-fields in the MC-QED formalism and hence were dynamically excluded from the formalism.

Mathematically this required that universal time-symmetric boundary conditions had to be imposed on <u>each</u> of the $A_{\mu}^{(k)}$ operator solutions to the $N \geq 2$ Maxwell operator equations, which prevented local the time reversal invariant free uncoupled photon operator $A_{\mu}^{(0)}$ from contributing to the $N \geq 2$ charge-field operators $A_{\mu}^{(k)}$. In this context the physical effects of radiation in MC-CED were generated in the operator equations of motion by a Total Coupled Radiation Charge-Field operator $A_{\mu}^{(TCRF)} \neq 0$, which obeyed an operator field equation $\Box^2 A_{\mu}^{(TCRF)} = 0$ with $\partial^{\mu} A_{\mu}^{(TCRF)} = 0$ similar to that obeyed by the $A_{\mu}^{(0)}$.

However $A_{\mu}^{(TCRF)}$ was found to be fundamentally different from $A_{\mu}^{(0}$ since by virtue of being Measurement Color symmetric it was non-locally coupled to the sum of the all the currents $\Sigma_{(k)} J^{(k)}(x')$ $k = 1,2, \ldots, N$ ($N \geq 2$) in a manner which gave it <u>a negative parity under Wigner reversal</u> T_W .

In this context the MC-QED formalism and its “in-out” charge-field structure was found to be invariant under the generalized Time Reversal operator $T = T_W \times T_p$ (where T_W is the Wigner time reversal operator and T_p is the radiation flow reversal operator) while at the same time having a negative time parity for b<u>oth</u> the T_W <u>and</u> the T_p symmetry operations taken separately.

Then by applying same time-symmetric Asymptotic Conditions to MC-QED as is done in standard QED, it was shown that a causal, retarded electrodynamic arrow of time emerged dynamically from the stability conditions within the formalism independent of any Thermodynamic or Cosmological assumptions.

In this manner the new paradigm of Measurement Color upon which MC-QED was based implied that the arrow of time in the universe was quantum electrodynamic in origin. This result can be understood in a more general manner as follows::

a) MC-QED is a nonlocal, relativistic quantum field theory whose operator solutions obey CPT symmetry where $T = T_W \times T_p$, and the Total Coupled Radiation Charge-Field photon operator $A_\mu^{(TCRF)}$ is non-local and has a negative parity under both T_W, and T_p symmetries;

b) Because the photon operator in MC-QED has a negative time parity under both the T_W, and T_p symmetries, the physical requirement of a stable vacuum state in dynamically requires the charge-field operator solutions in MC-QED to contain a causal, retarded, classical electrodynamic arrow of time;

c) For this reason the Measurement Color symmetry within the nonlocal quantum field theoretic structure of MC-QED dynamically leads to its CPT symmetry being spontaneously broken, and this is what causes the photon to carry the arrow of time.

The spontaneous breakdown of CPT symmetry in MC-QED implies that the CPT transformation cannot turn our universe into its "mirror image". This occurs because the photon carries the arrow of time in MC-QED which implies that time in the universe can only run forward in a causal sense and not backward. For MC-QED and its Standard Model generalizations, C, P , and CP symmetry is preserved but CPT symmetry is spontaneously violated. Hence the observed invariance of CP in particle interactions is not physically equivalent to T invariance in the context of the MC-QED formalism.

Hence using only time-symmetric boundary conditions, within the context of the Measurement Color paradigm underlying the MC-QED formalism, a dynamic explanation for the existence of a microscopic quantum electrodynamic arrow of time has been found in terms of the spontaneous symmetry breaking of both the T and the CPT symmetry in the formalism, independent of any Thermodynamic arguments.

In this manner the existence of the causal microscopic arrow of time in MC-QED represents a fundamentally quantum electrodynamic explanation for irreversible phenomena associated with the Second Law of Thermodynamics which complements the one supplied by the well-known statistical arguments in phase space (Zeh, D., 2007). Hence from the point of view of MC-QED, the Thermodynamic arrow of increasing entropy is not the source of the master time asymmetry in the universe.

This is because the MC-QED formalism implies the dynamic existence of a causal radiation arrow in the universe which automatically implies that the entropy associated with spontaneous emission of a cloud of photons from a aggregate of fermions will always increase. Hence the dynamic radiation arrow of time inherent in the MC-QED formalism implies the Second Law of Thermodynamics in the fundamental form which states that the heat associated with radiation is an irreversible process which will spontaneously flow from hot to cold and not the other way around.

In addition, since the microscopic observer-participant paradigm of Measurement Color with its dynamically generated microscopic dynamic arrow of time is a general concept, its application can be applied to quantum gauge field theories which are more general than Quantum Electrodynamics. Hence Measurement Color generalizations of higher symmetry quantum gauge particle field theories associated with the Standard Model and Grand Unified Models should be attainable, within which the gauge bosons as well as the photon would carry the Arrow of Time.

In future papers on MC-QED we will demonstrate in more detail how, in addition to being able to the explain the origin of the arrow of time, MC-QED can explain the existence of macroscopic objective reality in a quantum field theoretic context, as well as being able to offer two possible approaches to explain the apparently spontaneous emergence of macroscopic conscious minds in the universe from the microscopic laws of quantum physics.

The first approach is a global one which can be found by noting the fact that MC-QED describes the universe in terms of myriads of microscopic, time reversal violating, observer-participant quantum field theoretic interactions which span both the classical and the quantum world. On the other hand living, macroscopic conscious observers also appear to have physical properties which simultaneously span both the classical and the quantum world.

Because of this similarity it follows that the MC-QED formalism has the capability of being able to explain how macroscopic conscious observer-participant entities emerge in a microscopic observer-participant universe. Since this occurs a Measurement Color quantum field theoretic manner, it implies that a global quantum holographic description of consciousness may exist which connects the "minds of macroscopic conscious observers" to the "mind of the universe" as a whole.

The second approach is a local one which can be found by extending the Measurement Color paradigm into the recently developed quantum field theoretic domain of consciousness research called Quantum Brain Dynamics QBD, (Jibu, M., and Yasue, K., 1995) , (Vitiello, G., 2001). Since MC-QED is a quantum field theoretic formalism which contains both the effects of quantization and dissipation, it may be possible that the ideas underlying QBD can be consistently generalized into a (MC-QBD) formalism. In this way it may be possible to find a local cybernetic description of how macroscopic conscious observer-participant entities emerge in a microscopic observer-participant universe.

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