Beyond Mass–Energy Conversion: A Structural Interpretation of Nuclear Energy

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Abstract

The conventional interpretation of mass-energy equivalence considers that the energy released during nuclear reactions originates from the conversion of mass into energy according to Einstein's relation $E = Mc^2$. Although mathematically successful, this interpretation does not provide a realistic physical description of how mass disappears and energy appears. The present work proposes a reality-based alternative founded on the structural concept of light particle. In this model, photons possess finite mass in a photonic mass unit together with an internal mass-space structure. During nuclear reactions, the apparent mass defect corresponds to the disintegration of matter into an enormous number of photons of an extremely fine domain rather than annihilation of mass. Each photon possesses kinetic energy by virtue of motion and internal energy associated with the non-equilibrium mass-space structure. The total energy released is obtained by summing these two contributions while maintaining independent conservation of both mass and energy. Accordingly, mass is regarded as a fundamental constituent of matter, whereas energy is treated as a state property arising from the structural and dynamical condition of matter. This interpretation offers a unified conceptual framework consistent with the author's reality-based structural model of light particles and mass-space interaction.

Keywords: *Mass–energy equivalence, Photonic mass, Photon structure, Mass conservation, Nuclear energy.*

Reality-based framework replacing the concept of mass–energy equivalence

The equations for kinetic energy and thermal energy explicitly contain the mass component of the material body. In these cases, energy is possessed by matter by virtue of its state property described through velocity or temperature. The mass of the body remains conserved while its energy changes according to its physical state. In contrast, the conventional interpretation of nuclear fission and fusion assumes that a portion of the mass disappears and is converted into energy. The reaction products consist of massive particles together with photons, which are conventionally regarded as massless carriers of energy.

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According to the Standard Model of particle physics, photons and gluons are assigned zero rest mass. The strictly massless nature of the photon is closely connected with gauge invariance and the renormalizability of Quantum Electrodynamics (QED). However, experimental observations do not establish that the photon mass is exactly zero; they only impose increasingly stringent upper limits on any possible non-zero rest mass. Astrophysical and magnetohydrodynamic studies constrain the photon mass to extremely small values, with independent investigations based on galactic plasma dynamics and measurements of the galactic vector potential providing still tighter limits.

A finite photon mass would modify Maxwell's equations through additional terms, as described by the Proca formulation and could produce observable effects in galactic plasma and electromagnetic fields. Since such effects have not been detected, progressively stronger upper bounds have been established. These results, however, do not constitute experimental proof that the photon mass is exactly zero; they indicate only that any non-zero mass must be extraordinarily small. Thus, the possibility of a finite photon mass cannot be excluded solely on experimental grounds.

The present formulation therefore considers whether future developments in physics might require a reassessment of the strictly massless-photon assumption. Although the Standard Model has achieved remarkable success within its established domain, it need not represent the final description of nature. A reality-based framework founded on conceptual consistency, uniformity of nature and cause-and-effect reasoning may merit consideration if it provides a broader physical interpretation.

In the proposed reality-based model, light is treated as a material particle possessing both mass and an internal mass-space structure [1]. This eliminates the need for wave-particle duality and provides a common structural basis for matter across different physical domains. Within this framework, electric charge is regarded as a manifestation of a nonequilibrium state of mass-space association, giving rise to different non-electric charges [2]. Accordingly, conservation of charge may involve possible interconversion between electric and non-electric charge states [2].

The model further assumes that every physical entity is fundamentally an integrated mass-space system, making mass and space universal constituents of existence [3] [4]. Physical theories should therefore seek to describe nature in terms of these fundamental constituents rather than relying exclusively on abstract mathematical formalism.

Suppose that the apparent mass defect in a nuclear reaction represents the disintegration of matter into an enormous number of photons. If one gram of matter produced approximately (10^{22}) photons, the mass of an individual photon would be of the

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order of 10^{-22}g. This estimate introduces the concept of a **photonic mass unit**, analogous to the atomic mass unit, while maintaining the principle of structural continuity across different domains of matter.

A comparable distinction occurs in ordinary thermodynamic processes. One gram of steam contains more internal energy than one gram of water or ice, although its mass remains essentially unchanged. The difference arises from changes in molecular binding and energy states, while mass and energy are not simply regarded as mutually annihilating quantities. By analogy, the energy released in nuclear reactions could arise from the reorganization and disintegration of matter into constituents belonging to a much finer physical domain. If these constituents possess masses below present experimental detection limits, the apparent loss of mass may reflect the limitations of measurement rather than the destruction of matter itself.

The conventional interpretation describes nuclear energy release through the conversion of mass into energy, expressed by ($E=Mc^2$) where M refers to mass loss in nuclear reaction. The present model proposes a different physical interpretation: energy is liberated through the reorganization, excitation and disintegration of matter into finer constituents, rather than through the complete destruction or disappearance of mass. This perspective seeks to preserve the continuity of matter while offering an alternative reality-based interpretation of the origin of released energy.

In this framework, photons possess mass when measured in a photonic mass unit [4], although their mass is effectively zero when expressed in conventional atomic mass units because of its extremely small magnitude. If (m_p) denotes the mass of a photon, its kinetic energy at velocity ‘c’ is

$$KE = \frac{1}{2}(m_p c^2) \qquad eq^n - 1$$

If a total mass loss (M_L) is disintegrated into photons during a nuclear reaction, the total kinetic energy becomes

$$KE = \frac{1}{2}(m_p c^2).\frac{M_L}{m_p} = \frac{1}{2}(M_L c^2) \qquad eq^n - 2$$

This result accounts for only one part of the energy predicted by Einstein's mass-energy relation. The remaining half cannot be explained if the photon is assumed to be a structureless particle. The present work therefore proposes that, in addition to kinetic energy arising from translational motion, the photon possesses internal energy associated with changes in its mass-space structure. Recognition of this structural

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contribution provides a possible physical basis for accounting the remaining part of energy released during nuclear reactions and forms the basis for the reality-based interpretation developed in the following sections.

Energy of photon

The wave description of light has been highly successful in explaining many optical phenomena and the energy aspect of light. However, the very feasibility of high frequency light-wave in space medium is questionable particularly when the medium is incapable of rendering the elastic modulus required to sustain the wave propagation of light. On the other hand, the particle concept of light is feasible and it permits a realistic interpretation based on structural organization. The principle of uniformity of nature suggests that all centrally organized physical systems should exhibit structural similarity irrespective of the domain to which they belong. In view of the above, the present work is based on the particle concept with a deeper understanding of its structure [1].

According to the proposed model, a photon is a material particle consisting of a central nucleus surrounded by an extra-nuclear space structure. When the photon is at rest, this extra-nuclear structure exists in its equilibrium state. In the neutral state, photon remains passive and fails to reveal its tiny existence in any scientific experiment. When a photon is accelerated to velocity (c), the extra-nuclear space structure is assumed to be completely stripped off, while the central nucleus remains intact. This behavior differs from the conventional physical process since the existence of the extra nuclear space structure remains yet to be explored.

Any departure of the extra-nuclear space structure from its equilibrium state defines the charge-state/energy-state of the photon. The photonic charge state is represented by the ratio of the lost space content from the equilibrium space holding to the equilibrium space holding. The degree of nonequilibrium in the structural state of mass and space determines the charge potential or the energy level of the photon, whereas the energy of photon involves the net extent of mass-space non-equilibrium. The said energy level and energy correspond to the internal energy of the photon. The extent of space holding by the nucleus of photon is a function of the mass content of the nucleus because the extra nuclear space structure surrounding a nucleus is formed by mass-space attraction. Therefore, the mass of photon becomes a parameter for evaluating energy from energy level for both kinetic energy and internal energy. Thus, the internal energy of photon is the product of the mass of the photon and the charge state of the photon, where the charge state corresponds to the energy level.

In the existing concept the energy of a photon is given by

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$$E = h\nu$$

where, E is the energy of photon, ν is the frequency of waves and h is plank's constant.

Presumably the energy in the above expression is the sum of internal energy and kinetic energy. Since the mass term is absent in the above energy equation, the so-called energy corresponds only to the energy level of the photon and the true significance of frequency of light wave corresponds only to the photonic charge state in the realistic particle concept of light.

If photon has insignificant mass, then no theoretical model can make it zero, however the model can only assume its mass to be zero which is not the reality. If m_p is the mass of photon in photonic scale unit then the internal energy of photon is given by:

$$E_i = k.m_p \times Energy\ level$$

$$\text{or } E_i = k.m_p.s \qquad eq^n - 3$$

where, s represents the energy level (charge potential state) of photon and k is proportionality constant.

Now comparing the light energy in conventional wave concept and that proposed in the particle concept, it is found, the term $h\nu$ in Plank's equation for wave energy has the significance of photonic energy level/charge potential state in the particle concept. The Plank's constant h corresponds to the proportionality constant k in the particle concept. But the mass term m_p is missing in Plank's energy equation. Conventionally the energy per unit mass is considered as the energy level and energy of the particle is obtained by multiplying the mass of the particle with energy level. The very fact that the term mass is missing in Plank's energy equation, the term E corresponds to energy level. More precisely Plank's equation gives the energy level of photon and not the energy of photon [5].

Since the mass of photons may vary in a manner analogous to atomic masses, photons of different masses may possess different energies even when they have the same energy level and charge state. If photons are assumed to have identical mass, the photon energy becomes proportional to its energy level and the distinction between energy level of photon (E_{Lp}) and energy of photon (E_p) becomes only a matter of normalization through different constants of proportionality.

The structural model of the photon has previously been employed by the author to provide a unified explanation to different optical phenomena without invoking wave-particle duality. The same structural concept also provides a natural explanation for the origin of photon energy. According to this model, a photon possesses energy in two distinct modes:

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1. **Kinetic energy mode**, arising from the translational motion of the photon mass.
2. **Internal energy mode**, arising from the detachment of the extra-nuclear space structure from its equilibrium structure where energy is released by recombination of the space structure. This has similarity with the release of energy by recombination of ion and electron within atomic plasma.

The extra-nuclear space structure is assumed to be highly elastic due to the compressible nature of the physical space medium. Photon at rest has equilibrium space structure in a given background space potential. When the photon reaches the velocity (c), the associated extra nuclear structure is stripped off. When the photon is subsequently absorbed by matter and comes to rest, it reconstructs its equilibrium structure by acquiring the required space entities from the surrounding medium, in a manner analogous to the restoration of equilibrium in the author's structural model of neutral atoms.

Consequently, a moving photon possesses kinetic energy because of its mass and velocity, while simultaneously possessing internal energy due to the deformation and detachment of its extra-nuclear structure. Since both forms of energy arise from the same physical cause of motion of the photon particle, the two different modes of energy can be clubbed into one at velocity (c).

The total energy of a photon is therefore

$$E_p = \frac{1}{2} m_p c^2 + k m_p s \qquad eq^n - 4$$

The energy level is directly proportional to the loss of space content from the extra nuclear space structure which is proportional to dynamic pressure and in turn proportional to v^2. Now substituting v^2 in place of s we get:

$$E_p = \frac{1}{2} m_p c^2 + k m_p v^2$$

$$= \left(k + \frac{1}{2}\right) m_p c^2, \ at\ v \sim c \qquad eq^n - 5$$

If the mass loss in nuclear reaction produces ‘n’ number of photons the total energy liberated is

$$E_L = n. \left(k + \frac{1}{2}\right) m_p c^2 \qquad eq^n - 6$$

From nuclear fission and fusion experiment, the value of k is found to be ½.

Hence $E_L = n.\, m_p c^2$

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where E_L = Energy of disintegrated mass.

Since the total mass of all photons equals the disintegrated mass (M_L)

$$n.m_p = M_L$$

the total liberated energy becomes

$$E_L = M_L c^2 \qquad eq^n - 7$$

The equation- 7 has the expression of mass energy equivalence equation $E = Mc^2$.

Within this interpretation, Einstein's mass-energy relation is recovered without requiring the conversion of mass into energy. Instead, the released energy arises because the disintegrated mass is redistributed into an enormous number of photons, each possessing both kinetic and internal structural energy. Thus, mass and energy remain independently conserved throughout the process.

In the present reality-based framework, mass is regarded as a fundamental constituent of matter, whereas energy is considered a state property arising from the dynamical and structural condition of matter. Consequently, mass is not converted into energy; rather, energy is released through the structural disassociation of matter into finer constituents while the total mass is conserved in the photonic domain.

Conclusion

The present study proposes a reality-based interpretation of mass-energy equivalence by introducing a structural model of the photon and the concept of photonic mass. Instead of assuming that mass is transformed into energy, the analysis suggests that matter disintegrates into an enormous number of photons belonging to a finer domain of nature. The released energy originates from two physical contributions: the kinetic energy associated with the motion of photons and the internal energy arising from changes in their mass-space structure. Under this interpretation, mass and energy remain independently conserved, with energy viewed as a state property of matter rather than an entity equivalent to mass. Although the proposed model differs fundamentally from the conventional interpretation based on the Standard Model and Special Relativity, it aims to provide a physically intuitive explanation consistent with the author's broader reality-based framework. Since the equation $E = Mc^2$ has been tested experimentally and the new interpretation predicts the same equation doesn't require any further test to establish the new reality-based concept.

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