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Theoretical Analysis of Electromagnetic Waves, Nuclear Fission and Nuclear Fusion to State that Mass-Energy Equivalence has Exception

Birudev Hajare[1], Sandip Bhokse[2], Mahesh Borkar[3], Laxman Bagal[4], Arvind Maske[5], Tushar Mergu[6]

[1, 2, 3, 4, 5, 6]HIT, Pune, Maharashtra, India

Abstract: ***With the advent of 20th century the focus of study for major scientific group was 'electromagnetic waves'. There were varied opinions between the group for supporting Newton's theory of light as a particle and Maxwell's theory of light as a wave. With the development of Planck's constant and Einstein's theory of relativities it became profound that light, which is type of electromagnetic wave, behaves both as a particle and as wave, and thus the theory of wave-particle duality came into existence. In mid-20th century after the attacks on Hiroshima and Nagasaki, the theory and analysis of nuclear fission became profound. During this time the voids in the chain reaction for the tremendous amount of energy available were filled with the conclusion that a part of mass is getting converted into energy, according to $E = mc^2$. In this paper we are making an attempt, through theoretical analysis, to conclude that electromagnetic radiation and thus its energy can only be produced by accelerating a charged particle and not by conversion of any type of mass, as is given the current nuclear fission and nuclear fusion reactions.***

1. Introduction

The discovery of Planck's constant and Einstein's acknowledgement for the same revolutionized the aspects of physics which mainly concerned with the properties of light and electromagnetic waves. Experimental validation by Millikan [1] confirmed the theory put forward by Einstein and thus led them to receive a Nobel Prize.

These developments along with Einstein equation $E = mc^2$ proved helpful for Hahn and Strassman in analyzing the energy released during the fission process. The scientists, including Meitner and Frisch, Bohr and Wheeler, provided ways for understanding the nuclear fission process through various research papers [2, 3].

In this paper we have provided an overview of electro-magnetic waves, it's classification and production techniques in Section II, along with our analysis for the same. In Section III we have presented a brief description of nuclear fission, equations and processes affiliated to it. In this section an effort has been made to conclude our analysis for nuclear fission with reference to Section II and Section IV consists of theoretical analysis of nuclear fusion.

2. Electromagnetic Waves

As proposed by James clerk Maxwell, electromagnetic waves are a type of transverse wave, also known as photons, which have a varying electric and magnetic field [4]. These fields are in-phase and perpendicular to each other and to the wave. These waves travel at the speed of light 'c' in vacuum and their energy can be determined by their frequency and/or wavelength that are inversely proportional to each other. This energy is given by the equation

$$E = h\nu = hc/\lambda \tag{1}$$

where, h is plank's constant,
ν is the frequency of the electromagnetic wave
λ is the wavelength of the electromagnetic wave.

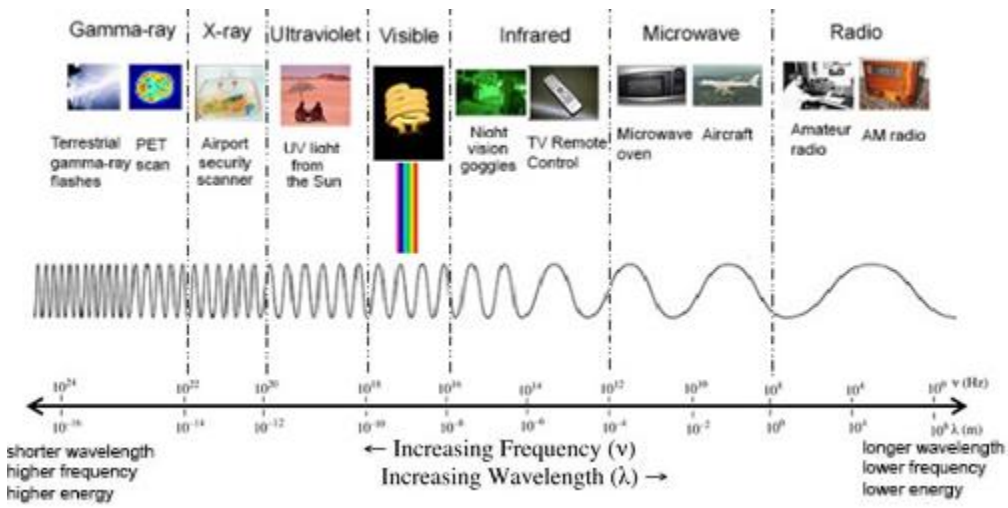

Figure 1: Electromagnetic Spectrum

Depending on the frequency and the wavelength, the electromagnetic waves are classified as: radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays [5]. The classification is called the electromagnetic spectrum and is arranged such that the radio waves have the least frequency and maximum wavelength while gamma rays have maximum frequency and least wavelength.

A. Generation of various types of electromagnetic wave

1) Radio Waves:
Radio waves are having longer wavelength than infrared light in electromagnetic spectrum. Radio waves have frequency as high as 300 GHz for wavelength 1mm and 30 Hz for wavelength 10,000 km. These waves are generated by acceleration of charged particle such as time varying electric current [6]. Radio waves are naturally emitted by lightning and astronomical objects.

2) Microwave:
Electromagnetic wave with wavelengths ranging from 1m to 1mm with corresponding frequency of 300 MHz and 300 GHz respectively. Hertz was one of the first scientist who discovered the generation of microwaves with the help of spark gap experiment, in which the electrons accelerated by using high differential potential [7].

3) Infrared Radiation:
Infrared radiation sometime called as infrared light. They are the electromagnetic radiation with longer wavelength than visible light therefore invisible to human eye. Infrared radiation have wavelength ranging from 700nm to 1mm and frequency 430THz to 300GHz. Most of the thermal radiation emitted by objects near room temperature is infrared. Infrared radiation is emitted or absorbed by molecules when they change their rotational-vibrational movements [8].

4) Ultraviolet Radiation:
Ultraviolet rays are electromagnetic waves with short wavelength ranging nearly from 10 nm to 400 nm. Their wavelengths are shorter than violet light in but longer than x-rays. Ultraviolet radiation is present in sunlight, and contributes about 10% of the total light output of the Sun. Ultraviolet radiation are produced by excitation of atoms and molecules [9].

5) X – rays:
X-rays are high energy electromagnetic waves having very short wavelength ranging from 0.01 to 10 nm. Frequency of x-rays varies from $3x10^{16}$Hz to $3x10^{19}$ Hz. X –rays are produced by carrying electrons at the speed of light which gives a brilliant burst of bright radiation [10].

6) Gamma Rays:
Gamma rays are penetrating electromagnetic radiation emitted from radioactive decay of atomic nuclei. The gamma rays are high energy waves having high frequency. The gamma waves can be generated by bombarding metal targets with high energy electron beams, which forces electrons to give off gamma ray photons. Such high energy electron beam is obtained via linear accelerators, with energy of multiple MeV. This method can generate gamma ray of energy up to tens of MeV [11].

Thus, by studying the generation of various waves we can conclude that, waves are produced only when there is acceleration of a charged particle. The acceleration may be due a natural phenomenon or manually created in laboratory equipment for varied purposes, but it is thus by far the only reason for generation of electromagnetic wave.

3. Nuclear Fission

Nuclear fission is a process in which heavy atomic nucleus of massive atom like uranium or plutonium breaks apart to form two or more lighter nuclei as fission products [12]. This process releases by-products too which includes the particles like free neutrons, protons, deuterons or alpha particles and/or electromagnetic radiations usually in the form of gamma rays.

When isotope ^{235}U is bombarded with neutron, nuclear fission process takes place and isotope ^{235}U forms ^{236}U compound by absorbing the bombarded neutrons. Nucleus of ^{236}U is unstable and it oscillates which lead to divide the nucleus into two fragments, usually of unequal sizes. The neutron- proton ratio for heavy nucleus is higher than lighter one which causes emission of two or three neutrons to reduce excess neutrons from the heavy nucleus and make it stable. Common pair of fragments from the fission of uranium-235 is xenon and strontium [13]. A typical fission reaction is given by eq.(2),

$$^{235}_{92}U + \, ^{1}_{0}n \rightarrow \, ^{236}_{92}U^{*} \rightarrow \, ^{140}_{54}Xe + \, ^{94}_{38}Sr + \, ^{1}_{0}n + \, ^{1}_{0}n \quad \ldots(2)$$

The number of neutrons produced is more than consumed in fission raise the possibility of chain reaction. The neutron produced triggering another fission reaction. Such a rapid reaction is used in nuclear bomb.

Major portion of energy released in fission process is kinetic energy of fission fragments which is almost equal to 83% of total energy [14]. Moreover out of remaining 17% of energy, 2.5% released as kinetic energy of neutrons, 3.5% released in the form of instantly emitted gamma rays and 11% released as subsequent gamma and beta decays of the fission fragments.

As per the conventional theory for energy generation in fission reaction [15], release of energy is accompanied by decrease in mass which is given by Einstein's equation $E = (M_o - M_i)c^2$ where, M_o and M_i are masses of original and product nuclei, at rest and unexcited.

The release of energy is mainly in the form of electromagnetic radiation, taking into account what we have concluded in the section II that electromagnetic radiation can only be released by acceleration of charged particles. Thus, it can be stated that the release of energy, the electromagnetic radiation, during the fission process is not a result conversion of mass but only due to acceleration of charged particles.

4. Nuclear Fusion

Nuclear fusion is the process in which two lighter nuclei combine to form larger nucleus. The fusion reaction in the sun is a multistep in which hydrogen is burnt to form helium [16]. This occurs by proton-proton (p-p) cycle.

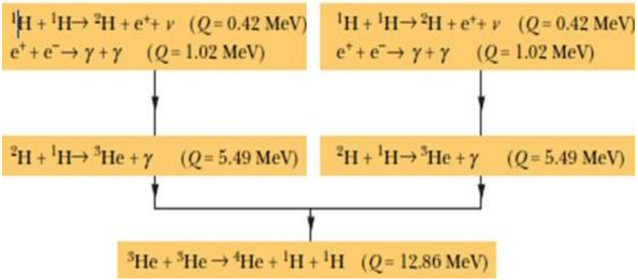

Figure 2: Proton-proton cycle

The proton cycle start with collision of two protons ($^1H + {}^1H$) to form a deuteron (^2H), with simultaneous creation of a positron (e^+) and neutrino (ν) the positron quickly encounter free electron (e^-) in the sun and both particles annihilate, their mass energy as two gamma rays photon(γ).

This is not in relation to what we have concluded in Section I because gamma rays are produced only due to acceleration of electron between different energy levels. Photon are emitted when electron jump from higher energy level to lower energy level.

The reactions that appear most promising for a fusion power reactor involve deuterium and tritium [17]:

$$^2_1H + {}^2_1H \rightarrow {}^3_2He + {}^1_0n \quad Q = 3.27\ MeV \qquad \ldots (3)$$

$$^2_1H + {}^2_1H \rightarrow {}^3_1H + {}^1_1H \quad Q = 4.03\ MeV \qquad \ldots (4)$$

$$^2_1H + {}^3_1H \rightarrow {}^4_2He + {}^1_1H \quad Q = 3.27\ MeV \qquad \ldots (5)$$

One major problem in obtaining energy from nuclear fusion is that the Coulomb repulsive force between two nuclei, which carry positive charges, must be overcome before they can fuse. This problem can be overcome by giving enough kinetic energy to two nuclei. This requirement can be accomplished by raising the fuel to extremely high temperatures (to approximately 10^{8}°K). At these high temperatures, the atoms are ionized and the system consists of a collection of electrons and nuclei, commonly referred to as plasma.

For same mass, number of deuterium atoms is 100 times more than the uranium atoms and thus, the energy obtained in fusion is more than the energy obtained from fission.

As high temperature is required for fusion, acceleration of charged particle is increased with temperature hence the excess energy is released in the form electromagnetic radiation, from which we can state that the excess energy is not due to reduction in mass of the Helium atom formed during fusion process.

5. Conclusion

The theoretical analysis done in this paper clearly states that electromagnetic waves are produced only when there is an acceleration of charged particle. In contradiction to this, in nuclear fission and nuclear fusion it is stated that the mass deficit that is observed during both the reactions is converted into energy which is in the form of electromagnetic waves. Therefore concluding our paper we propose that electromagnetic waves cannot be a conversion of mass and thus the energy obtained during nuclear fission and fusion is solely due to acceleration of charged particles available during the reaction.

References

[1] Daniel J. Kevles. "Robert A. Millikan". In: Scientific American 240.1 (1979), pp. 142–151. ISSN: 00368733, 19467087.
[2] Otto Hahn and Fritz Strassmann. "Evidence of the formation of active barium isotopes from uranium and thorium by neutron irradiation; Detection of further active fragments in uranium fission". In: science 27.6 (1939), pp. 89–95.
[3] Lise Meitner and Otto R Frisch. "Products of the fission of the uranium nucleus". In: Nature 143.3620 (1939), p. 471.
[4] James Clerk Maxwell. A dynamical theory of the electromagnetic field. The Society, 1856.
[5] Denis Smith et al. "The Electromagnetic Spectrum: Using light and color to search for astronomical origins". In: Science Scope 26.8 (2003), pp. 40–42. ISSN: 08872376, 19434901. URL: http://www.jstor.org/stable/43183537.
[6] Heinrich Hertz. "The Discovery of Radio Waves Repeat Hertz's Experiments that Confirmed the Existence of Electromagnetic Radiation". In: (). URL: https://www.juliantrubin.com/bigten/hertzexperiment.html.
[7] E. L. Ginzton. "Microwaves". In: Science 127.3303 (1958), pp. 841–851. ISSN: 00368075, 10959203. URL: http://www.jstor.org/stable/1754828.
[8] N. C. Beese. "Infrared Radiation". In: Science 95.2477 (1942), pp. 614–617. ISSN: 00368075, 10959203. URL: http://www.jstor.org/stable/1668847.
[9] David K Lynch, William Charles Livingston, and William Livingston. Color and light in nature. Cambridge University Press, 2001.
[10] Massimo Altarelli, Fred Schlachter, and Jane Cross. "Making Ultrabright X-rays". In: Scientific American 279.6 (1998), pp. 66–73. ISSN: 00368733, 19467087. URL: http://www.jstor.org/stable/26058237.
[11] Umran Inan. "Gamma Rays Made on Earth". In: Science 307.5712 (2005), pp. 1054–1055. ISSN: 00368075, 10959203. URL: http://www.jstor.org/stable/3840146.
[12] Niels Bohr and John Archibald Wheeler. "The mechanism of nuclear fission". In: Physical Review 56.5 (1939), p. 426.
[13] Resnick Halliday. Fundamentals of Physics. Jearl Walker.
[14] Arthur Beiser. Concepts of Modern Physics. 2003.
[15] J. M. Irvine. "Nuclear fission". In: Science Progress (1933-) 62.248 (1975), pp. 501–522. ISSN: 00368504, 20477163. URL: http://www.jstor.org/stable/43420329.

[16] Robert L. Hirsch and William L. R. Rice. "Nuclear Fusion Power and the Environment". In: Environmental Conservation 1.4 (1974), pp. 251–262. ISSN: 03768929, 14694387. URL: http://www.jstor.org/stable/44516311.
[17] Jewett Serway. Physics for scientists and Engineers with Modern Physics. 2014.