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A Scientific Review of Photon and Light

From: **Francisco Lopez <d005734c@dcfreenet.seflin.lib.fl.us>**
Date: Wed, 11 Dec 1996 13:01:12 -0500 (EST)
Fwd Date: Thu, 12 Dec 1996 10:44:10 -0500
Subject: A Scientific Review of Photon and Light

Taken from the Photon Belt Page at http://www.salemctr.com/photon.html

SCIENTIFIC REVIEW OF PHOTON & LIGHT
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Photon is not a new word, it has been around since the early part of this century....maybe earlier=85..just not recorded. The Cat Scan or PET is an example of Photon energy.

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Photon {foh'-tahn}

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A photon is a quantum of light, or the smallest possible packet of light at a given wavelength. It is emitted by an atom during a transition from one energy state to another.
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As FUNDAMENTAL PARTICLES, photons travel at the speed of light and have mass and momentum dependent on their frequencies. By classical reasoning a photon would have the apparent dualistic property of being either a particle or a wave disturbance. That is, such phenomena as INTERFERENCE and diffraction require an interpretation in terms of the wave characteristics of photons, but such phenomena as the PHOTOELECTRIC EFFECT require an interpretation in terms of the particle nature of the photon. Quantum mechanics is able to resolve this dilemma by assigning probabilistic characteristics to the motions of atoms and photons.
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The energy associated with an individual photon is quite minute. For instance, a photon in the visible spectrum would contain an energy of approximately 4 X (10 to the power of -19) joules. Thus, a perfectly efficient 100-watt light bulb would emit approximately 2.5 X (10 to the power of 20) photons per second. D. J. Lovell Bibliography: Goldin, E., Waves and Photons (1982). Copyright 1995 by Grolier Electronic Publishing, Inc.

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LIGHT

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Light is ELECTROMAGNETIC RADIATION in the wavelength range extending from about 0.4 micron to about 0.7 micron; or, perhaps more properly, the visual response to electromagnetic radiation in this range. By extension, the term is frequently applied to adjacent wavelength ranges that the eye cannot detect: ULTRAVIOLET LIGHT, infrared light (see INFRARED RADIATION), and black light. In addition to wavelength, FREQUENCY, in hertz, and wavenumber, in inverse units of length, are also used to specify and designate the character and quality of the radiation. Associated with wavelength or frequency is the visual response of COLOR. The term monochromatic is applied to the idealized situation in which the light in a beam is all of one wavelength.
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CHARACTERIZATION OF LIGHT Light is characterized not only by wavelength, essentially a temporal quality, but also by state and degree of polarization (see POLARIZED LIGHT), a geometric or directional quality, and by intensity, essentially a physical quality. The visual response to intensity is brightness. In the human visual system, at least, there is no counterpart response, to the state and degree of polarization, but ample evidence exists that certain arthropods--bees in particular--are sensitive to the state of polarization of sky light. There is some speculation that certain migrating birds may also respond to this quality of light.
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Light is further characterized by its degree of coherence (see COHERENT LIGHT). Coherence, closely related to the degree of polarization and to the degree of monochromaticity, refers to the ability of a beam of light to interfere (see INTERFERENCE) with itself. Coherence is therefore an interferometric property of light. By the use of a Michelson INTERFEROMETER, most light sources can be made to produce interference fringes. These are clearest when the length of the two arms of the interferometer are equal. As one arm is lengthened, however, the contrast of the fringes is seen to decrease until they are no longer visible. Unfiltered light from an incandescent source will barely produce fringes under any circumstances. Light from a mercury arc lamp will produce fringes over a range of one or two centimeters. On the other hand, light from a continuous-wave gas laser has produced fringes at a distance of over 100 meters. Therefore, light can be characterized by its degree of coherence or coherence length.
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Light is a transport of energy. It can be regarded both as a particulate flow and as a wave phenomenon. These two apparently diametrically opposed views have been brought together in a theory that combines the best features of each. The particulate unit is the PHOTON, which has associated with it a central frequency or wavelength that determines (or is determined by) the amount of energy it contains. In a so-called monochromatic beam, the photons are all of the same energy and therefore have the same frequency. They can be made to interfere, which indicates a high degree of coherence as well as a more or less uniform state of polarization. If the distribution of the energy in the photons is more random, however, the beam will be less coherent and will have a lower degree of polarization.
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It is also convenient to think of light as propagating as wavefronts (see HUYGENS's PRINCIPLE). These waves, like the crest of an ocean wave, are surfaces on which the phase relationship is constant. Unlike an ocean wave, a wavefront or surface of constant phase is unobservable and undetectable. Light may be considered as energy being transported in a train of wavefronts. The direction of propagation (except for anisotropic media) is in a direction perpendicular to the wavefront. Rays can be conceived as trajectories of photons.
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LIGHT PRODUCTION Light, like any other electromagnetic radiation, results from either an accelerating electric charge or a nuclear fusion or fission reaction. In nuclear reactions, a PHOTON is created in the same manner as other elemental partial products of the reaction. With the exception of sunlight and starlight, however, light usually is the result of changes in the electronic structure of atoms and molecules as they absorb and readmit energy.
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The incandescent electric light has as its light source the heat that results from the ohmic resistance of the filament to the electric current. A red-hot poker absorbs heat directly from the fire resulting from the liberation of chemical energy. As the material in the filament or poker heats up, the atoms and molecules gain kinetic energy, which is realized by an increase in the number of collisions among the particles. Boiling off of some of the material is one mechanism that can be used to maintain an equilibrium temperature.

Another mechanism is for the electrons associated with the various atoms in the metal to move to higher ENERGY LEVELS. When they drop back to lower energy levels they emit a PHOTON, keeping the temperature of the material more or less constant despite the fact that energy is continually supplied. The excess energy is emitted as light.
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Thermal production of light is essentially random and is idealized as BLACKBODY RADIATION. The light produced contains a mixture of wavelengths skewed around a central maximum, which is related to the temperature T of the material in degrees Kelvin. This relation, is known as the Wien displacement law. The spectrum produced by the light from such a source is continuous. Although there is a dominant wavelength, this light is not monochromatic. It is generally unpolarized and has a relatively short coherence length.
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Another type of light source is energized plasma such as a flame or the gas in a discharge tube such as a neon bulb. Although light is produced by a mechanism similar to thermal emission, the atoms are in a gaseous phase and less random. The energy levels reached by the electrons depend more on the electronic structure of the atoms themselves, and therefore the photons emitted tend to be clustered around specific wavelengths. The spectrum produced by such a source is not at all continuous but consists of lines or bands that are characteristic of the atoms or molecules in the gas. Highly monochromatic light can be obtained from this type of source, particularly if the light is filtered. The light has a much longer coherence length but is generally unpolarized.
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A third type of source is the LASER. Two principles are involved in laser operation. First, the lasing material is composed of atoms, or mixtures of atoms, that have a peculiar energy level structure. As they absorb energy, their electrons move up to higher energy levels, tending to accumulate at certain metastable levels. This is called population inversion. There they remain until stimulated by a PHOTON of the proper frequency. Then the electrons drop to a lower energy level, emitting a photon of the same frequency and traveling in the same direction as the incident, stimulating photon. Because a single photon may stimulate the release of a large number of additional photons, the total number of photons is increased, thus increasing the intensity of the light within the medium. The process is referred to as gain.
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The second principle is the geometry of the laser itself. The laser can be regarded as a hollow tube, much like an organ pipe, which is tuned to the wavelength of the emitted photons. The process can be visualized as a wavefront being reflected back and forth between the two ends of the laser, picking up more photons with each reflection. The portion of the light that is permitted to escape from the cavity is highly monochromatic, with a long coherence length. In some circumstances the laser output is highly polarized. DUALISTIC NATURE OF LIGHT The historical development of a theory of light, at least from the 17th century on, involved two apparently contradictory descriptions. One concept was the corpuscular theory, which envisioned light as a stream, or flow, of small particles. Rene DESCARTES modified this concept. He viewed light more as a pressure than as a flow--not as motion but as a tendency to motion. And since light was not motion it was not limited by a finite velocity. In other words, a beam of light required no time of transit. Pierre FERMAT held a different view. He believed not only that light propagated at a finite velocity, but also that its particles described trajectories or rays. Christiaan HUYGENS, on the other hand, was a believer that light was a wave phenomenon. Light propagated at a finite velocity in the form of a moving disturbance, just as a water wave moves as a ripple on a smooth pond.
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As a ray of light passes across a surface from one medium to another (for example, from air to glass), its direction is changed--a phenomenon known as REFRACTION. The law of refraction, discovered first empirically by Willebrord SNELL, then subsequently derived formally by Descartes and Fermat, states that sin r =3D K sin i, where i is called the angle of incidence, the angle between the incident ray and the normal (perpendicular) to the refracting surface. The angle of refraction, r, is the angle between the refracted ray and the surface normal.
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Fermat and Descartes agreed on the form of the refraction law, but they disagreed violently on the meaning of the constant K. Fermat saw K as being proportional to the reciprocal of the velocity of propagation. Descartes, even though he believed that the velocity of propagation was infinite, concluded, on a different level of logic,

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    that K was proportional to a velocity. The distinction is important
    because whether light speeds up or slows down as it passes into a
    denser medium determines the meaning of K.
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    Two opposing points of view evolved. Descartes and Fermat were both
    proponents of a corpuscular theory; Huygens believed in a wave theory.
    He also obtained a proof of the refraction law in terms of the
    existence of wavefronts, a construction now called Huygens's
    principle.
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    If light is a wave phenomenon, then a medium is required. Sound waves
    travel through the air but not through a vacuum; ripples require a
    watery medium. At first it was thought that air would be the medium
    that would support the propagation of light. The simple experiment of
    shining light through an evacuated jar, however, showed clearly that
    this theory was not correct. Theorists chose to hypothesize the
    existence of a medium called the ETHER.
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    Experimental evidence to support the wave theory of light was
    particularly strong. DIFFRACTION, the ability of light to bend around
    a sharp edge, certainly gave credence to the idea that light was a
    form of wave motion. Further support came with the discovery of
    polarization, which indicated that the undulations of a light wave
    were transverse to the direction of propagation and were not
    longitudinal, as were sound and water waves. Thus, if light was to be
    a wave phenomenon, the ether was required, and if so, then certain
    effects should be observed when a massive body passed through the
    ether. To detect such effects, telescope tubes were filled with water
    to determine the effect on starlight. No effect was observed.
    Experiments to detect an ether "drag" also failed.
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    On the other hand, James BRADLEY discovered stellar aberration in 1729
    when he found that he had to aim his telescope a little in the
    direction of the Earth's motion ahead of the theoretical position of a
    star. This effect could be compared to a person in a rainstorm tilting
    his umbrella a little in front of him as he walks into the rain.
    Bradley's discovery supported a corpuscular theory, or at least it did
    not support the idea of an ether drag.
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    But, it was postulated, if ether exists, then another observable
    phenomenon, ether "drift," must also exist. If both the Earth and
    light are moving through the ether, then the velocity of light
    observed on the Earth would depend on the direction of observation.
    The ether was regarded as stationary; the Earth and other planets, the
    Sun and the stars, and light moved through it. By measuring the
    apparent velocity of light in various directions, one could determine
    the absolute velocity and direction of motion of the Earth.
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    In the late 19th century A. A. MICHELSON and E. W. Morley (1838-1923)
    attempted to measure the absolute motion of the Earth through the
    ether (see MICHELSON-MORLEY EXPERIMENT). No ether drift was observed.
    The conclusion was the inconceivable notion that the velocity of light
    was constant and independent of the motion of the observer. This
    paradox led to Einstein's special theory of RELATIVITY, a cosmological
    theory of major significance. O. N. Stavroudis Bibliography: Babbitt,
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