Spectrum of epola waves (electromagnetic waves)

Revised Oct 2009; Jan 2013 Jan 2017 rgg

from: *"The Electron-Positron Lattice Space", (Fig. 4, page 64)*, M. Simhony (1990)

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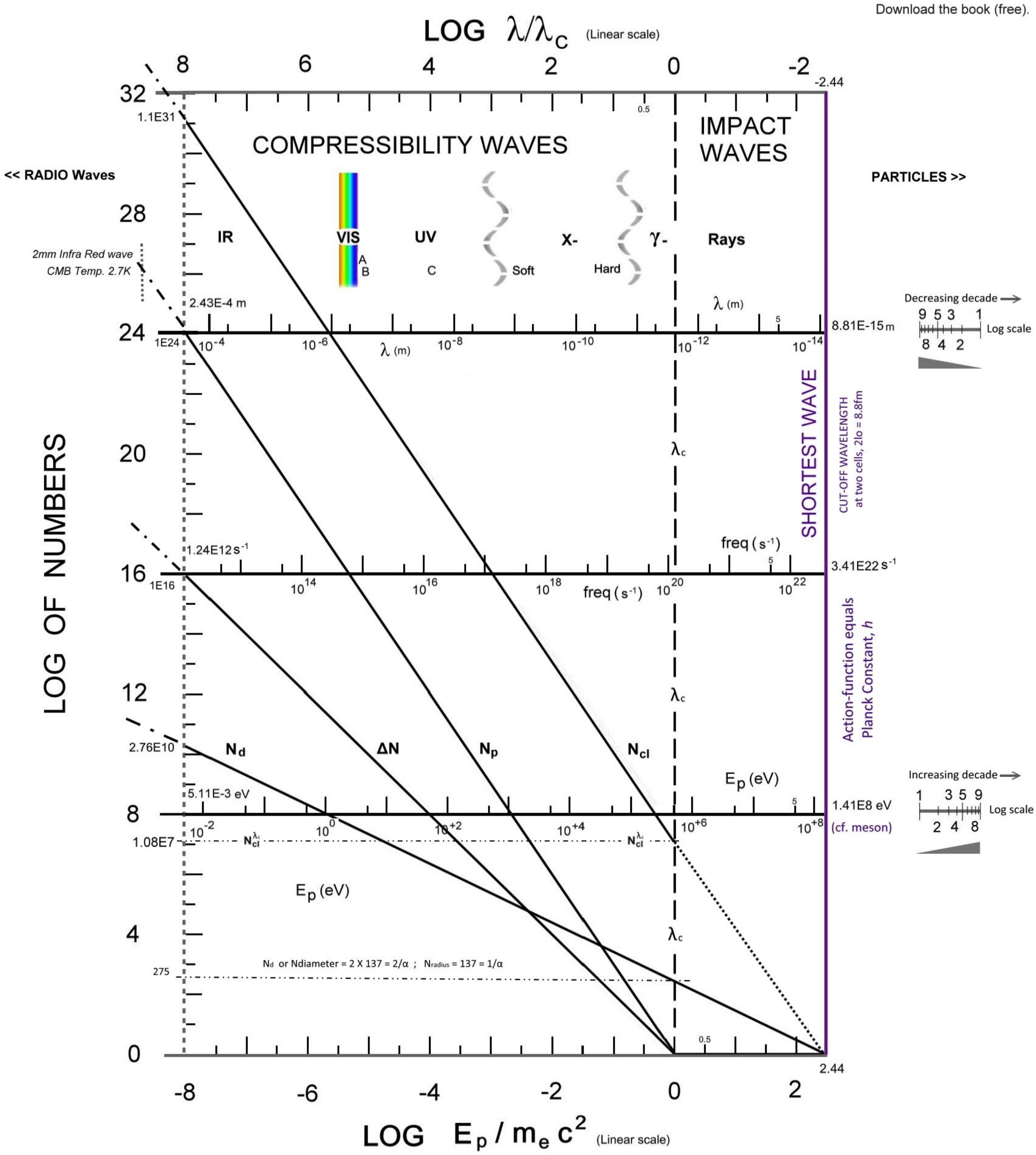

epola half-wave cluster characteristics

N_d epola particles on diameter

ΔN excess particles in cluster (max)

N_p photons in cluster(max)

N_{cl} epola particles in cluster

λ_c Compton Wave of electron, positron

The energy, Ep, of each photon in a wave of freq. 1Hz = $h\nu$ = h/1s = 4.136E-15 eV where h = Planck Constant.
and λ = 3E8m; Log(λ /λc) = 20.09; Ncl = 2.05E20; Nd = 2.05E67; Np = 1.9E60; ΔN = 1.53E40; Nd = 3.4E22

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Chapter 6. Epola Waves and Electromagnetic Radiation

6.1. Half-wave clusters of bulk deformation waves in elastic media

In uniform elastic media, such as gases or bulks of liquids far (deep) from their surfaces, the only propagating waves are the bulk deformation waves. They consist of half-wave clusters of increased density, thus increased pressure, which are followed by half-wave clusters of reduced density, thus reduced pressure. In other words, in some half-wave clusters, there is an excess number ΔN of molecules, $\Delta N > 0$, while in the neighboring half-wave clusters, the number of molecules is less than the normal number N, and ΔN is negative. With the tremendous number of molecules in any half-wave cluster, usually $N >> \Delta N$, and $\Delta N >> 1$ (except in shock-waves; see also Section 7.7).

In each half-wave cluster, the molecules of the substance vibrate (in addition to the random thermal vibrations) with the frequency of the wave in all possible directions. Relative to any chosen direction of wave propagation, there are molecules vibrating along this direction, as well as molecules vibrating in directions perpendicular to the direction of wave propagation. Therefore, bulk deformation waves may show effects of longitudinal and transversal waves, depending on the means of detection.

A polarizer screen, with a slit in the way of the waves, lets out, in addition to longitudinal waves, the transverse waves in which molecules vibrate parallel to the slit. However, the polarizer screen also changes conditions in the wave. First, due to the increased pressure at the screen, part of the molecules are forced to change the direction of their vibrations, so that more wave energy is "squeezed" through the slit. The slit also inducesdiffraction and interference, affecting not only the space-distribution of wave-energy, but also the energy distribution between the different transverse modes and the longitudinal mode of vibration. These effects will be further enhanced by the analyzer screen, placed in the way of waves, which passed the polarizer. Hence, the energy distribution among the various modes of vibration in the waves which passed the slits does not depict this distribution in the natural bulk deformation wave.

Bulk deformation waves are usually traveling waves, in which during each half period, the phase of vibrations, e.g., the phase of maximum positive deflection, and the vibrational energy of each molecule, are transferred a distance of half a wavelength in any chosen direction of propagation, with a singular velocity v_d of the bulk deformation waves.

6.2. Half-wave clusters in standing waves

Bulk deformation waves can also be standing waves. These result from the superposition of two waves of identical frequencies and amplitudes traveling in opposite directions, as, e.g., a direct wave and the reflected wave. In a standing bulk deformation wave, every molecule vibrates with a constant amplitude, thus keeping its vibrational energy constant (in addition to the energy of random vibrations). In the standing half-wave deformation cluster, the molecules on the boundary of the cluster have zero amplitude and zero vibrational energy. These values increase towards the center of the cluster, where they reach maximum. Hence, while energy is flowing in a standing wave in both directions, there is no net energy transfer in it.

The pressure in each half-wave cluster of a standing wave is changing in each half period from maximum to minimum, in phases opposite to those in the neighboring half-wave standing cluster. Thus, there is a flow of pressure, i.e., of excess molecules between neighboring clusters. While one cluster has a more than normal number of molecules, $\Delta N > 0$, the other has slightly less than normal, $\Delta N < 0$, and on the boundaries of the clusters, the pressure is normal, $\Delta N = 0$. Because of this flow of pressure or of molecules between the half-wave clusters, energy can be drawn from a standing wave, though there is no net energy flow in the wave. This can be achieved, e.g., by inserting a tube or pipe into the center of a half-wave cluster. Then, energy will flow from the wave through the "contact" - the mouth of the pipe - right into the pipe.

6.3. Velocity calculation of bulk deformation waves in unbounded NaCl crystals

The propagation velocity v_d of bulk deformation waves in a uniform elastic medium of density d can be expressed through the bulk elastic modulus of the medium as

$$v_d = (2B / d)^{1/2} \ .$$

The bulk elastic modulus B is defined as

$$B = -V \cdot \partial p / \partial V \ ,$$

where V is the volume and p is the hydrostatic pressure. Thus, the bulk elastic modulus is the rate of change of pressure with the change of volume; it also represents the elastic energy-density in the medium.

Let us now consider an unbounded NaCl crystal so large, that as large as its single-crystal grains may be, the crystal as a whole is polycrystalline, identical in all directions, thus representing a uniform elastic medium. In such NaCl lattice, the bulk elastic modulus was found to be

$$B = {}_bE / 2 \times l_o^3 \; ,$$

where ${}_bE$ and l_0^3 *are the mean binding energy and volume per ion in the lattice. The velocity* v_d is, therefore,

$$v_d = ({}_bE / d \times l_o^3)^{1/2} \; .$$

With m_i as the mean ion mass, the density d is $d = m_i / l_o^3$, *thus*

$$v_d = ({}_bE / m_i)^{1/2} \; .$$

Substituting the NaCl data: ${}_bE = 4$ eV and $m_i = 29$ AMU, we find the velocity v_d of bulk deformation waves in the huge NaCl crystal, $v_d = 3600$ m/s.

6.4. Velocity of sound in NaCl crystals

The velocity of sound v_s in gases and in the bulk of liquids (far from their surface) is the velocity v_d of bulk deformation waves. In large NaCl crystals, in which the effects of the surfaces in all directions can be disregarded (i.e., in crystals not shaped as rods or plates), there are still six different values for the sound velocity, depending on the direction of propagation in relation to the directions in the unit cube of the NaCl lattice and on the mode of vibration of the sound. These values are presented in the table.*

Direction parallel to:		Velocity in km/s of longitudinal sound	transverse sound
cube edge,	100	4.74	2.41
face diagonal,	110	4.72	2.90
cube diagonal,	111	4.37	2.45
		average value 3.60	

* Data from N.F. Mott and R.W. Guerney, <u>Electronic Processes in Ionic Crystals</u>, Oxford Univ. Press, 1946.

[See ed. note p151]

In the unthinkably large NaCl crystal, which can be considered as a uniform elastic medium, the ions in every half-wave cluster are vibrating in all possible directions, as described in Section 6.1. Because of the unavoidable poly-crystallinity of the huge crystal, all directional differences are averaged out and the velocity of sound should be the average of all six values listed in the table. This average value really is 3.6 km/s, exactly equal to the velocity of bulk deformation waves, calculated in Section 6.3. Thus, the velocity of sound in an unbounded very large NaCl crystal has a unique value equal to the velocity of bulk deformation waves in this crystal, $v_s = v_d = ({}_bE/m_i)^{1/2} = 3600$ m/s. Therefore, sound waves in such NaCl crystals are due to bulk deformation waves in it.

6.5. Velocity calculation of epola deformation waves and of light

The directional differences in the epola may possibly be detected on distances of up to a billion lattice units, which is a few micrometers. On larger distances, the directional differences average out, and the epola is a perfectly uniform elastic medium. Hence, the velocity of bulk deformation waves in the epola can be calculated in the same way as it was done in the huge NaCl lattice. The derived formula for v_d, $v_d = ({}_bE/m_i)^{1/2}$, can therefore be used in the epola. Here, the per-particle binding energy ${}_bE$ is $m_ec^2 = 511$ keV, and the average ion mass m_i is the mass of the electron m_e. Substituting these values, we obtain

$$v_d = (m_ec^2/m_e)^{1/2}$$

or

$$v_d = c\,.$$

Thus, the velocity of bulk deformation waves in the epola is equal to the unique vacuum light velocity c. In other words, electromagnetic radiation propagates with the same unique velocity c, as do bulk deformation waves in the epola. Thus, electromagnetic waves and radiation are just as closely connected with bulk deformation waves in the electron-positron lattice, as sound waves are connected with bulk deformation waves in the unbounded NaCl crystal.

6.6. Epola bulk waves and the transverseness of electromagnetic waves

Electromagnetic waves and bulk deformation waves in the epola propagate with the same velocity c, but are not identical. In the epola waves, real particles are vibrating around their lattice sites with the frequency f of the wave motion. The waves are multi-faceted, and one of the ways to detect them is through their electric and magnetic fields, which are caused by the vibrations of the electrons and positrons in the waves.

The vibrations of the electric and magnetic fields spread throughout with the velocity and frequency of the bulk deformation waves, causing corresponding vibrations of electrically charged particles in all reached materials, susceptible to such vibrations. The vibrations of the electric and magnetic fields are described by the vibrations of the coupled electric and magnetic vectors $\vec{\mathcal{E}}$ and $\vec{H}$. These vectors are always found to be perpendicular to each other and to the direction of their propagation-velocity or the vector $\vec{c}$. This transverseness of the electromagnetic waves is seemingly opposed to the epola bulk deformation waves, in which electrons and positrons vibrate in *all* directions.

Clearly, the electrical charges of all electrons and positrons in equilibrium, positioned along any chosen direction in the epola, are equal and neutralize each other perfectly. When these electrons and positrons come into vibrations along *this* chosen direction, there is no violation of charge neutrality along this direction, because in longitudinal vibrations electrons or positrons do not cross the line of the chosen direction. Their numbers remain equal to each other and their charges neutralize each other as perfectly as in equilibrium. Therefore, the longitudinal component $\mathcal{E}_l$ of the electric vector along any chosen direction of wave propagation in the epola, caused by the vibrations of epola particles along this direction, is always zero, $\mathcal{E}_l = 0$.

Electrons and positrons of the epola, vibrating in directions perpendicular to the chosen direction of propagation, cross the lines of this direction in equal numbers, i.e., the negative charge above the lines is always equal to the positive charge below them. Therefore, these vibrations, too, do not cause any deviations from charge neutrality *along* the chosen direction. Hence, they do not contribute to the longitudinal component $\mathcal{E}_l$ of the electric vector, which remains zero. However, these vibrations change the amounts of electrical charge in directions perpendicular to the direction of wave propagation. This results in a vibrating transverse component $\mathcal{E}_t$ of the electric vector. In points where the *positive* charge of the perpendicularly deflected epola particles to one side of the chosen direction is maximal, the transverse component $\mathcal{E}_t$ of the electric vector has maximum, $\mathcal{E}_t = max$. In points where the *negative* charge of the perpendicularly deflected epola particles has maximum, the transverse component of the electric vector has maximum in the opposite direction, $\mathcal{E}_t = -max$.

Epola electrons and positrons vibrating in directions other than *along* the chosen direction or *perpendicular* to it contribute to the transverse component of the electric vector only with their deflection-component which is perpendicular to the chosen direction. The component of their deflection *along* the chosen direction does not contribute to the longitudinal component of the electric vector, which is always zero.

The zero value of the longitudinal electric vector also yields a zero value of its coupled magnetic vector. The non-zero value of the transverse electric vector produces a non-zero coupled magnetic vector. To summarize,

the transverseness of the electromagnetic waves is due to the fact that, for any deflection of an electron or positron of the epola, the deviation from charge neutrality is largest perpendicular to the deflection, while along the deflection charge neutrality is not violated.

Therefore,

the oscillations of the epola particles along any direction of propagation of the electromagnetic wave (or the maternal bulk deformation wave) do not contribute to $\vec{\varepsilon}$ *and* $\vec{H}$; hence, the longitudinal components of $\vec{\varepsilon}$ *and* $\vec{H}$ are always zero.

We may conclude that electromagnetic radiation is an observable result of epola bulk deformation waves. It is also right to say that electromagnetic radiation causes bulk deformation waves in the epola, or that

electromagnetic radiation is both the observed result and the observed cause of bulk deformation waves in the epola.

6.7. The epola as carrier of electromagnetic radiation

The fact that electromagnetic radiation is caused by and also causes bulk deformation waves in the epola, suggests that the epola *is* the carrier of electromagnetic radiation. As such, the epola is not an ether. The density of the epola, calculated as

$$d = m_e / l_e^{\,3} = 10^{13}\ kg/m^3$$

is 10^5 times smaller than that of 'dense' particles, electrons, atomic nuclei and nuclear matter. However, the epola is almost a billion times denser than the densest solids on Earth and has a binding energy 10^5 times larger than these solids.

From the epola viewpoint, atoms and atomic bodies (including ourselves) are conglomerates of loosely connected particles, separated from each other by 10^4 epola lattice constants. The bodies may move undisturbedly through the epola, sweeping their atomic electrons and nuclei in channels between the epola particles. This, provided that the epola particles move apart when their lattice unit is entered by an electron or nucleus of the atomic body. Such 'opening of gates' in the epola units in front of the moving particles and closing of the gates behind them is a wave motion in the epola. It will be shown later that this wave motion has the de Broglie wavelength of the moving particle and is responsible for making the epola vacuum-transparent for the motion of the particle and of the whole atomic body, to which the particle belongs (Section 8.1).

Our conclusion is that in the motion of Earth around the Sun, the production of epola waves with the corresponding de Broglie wavelengths is the only effect on the epola. Obviously, the motion cannot drag the epola, nor can it cause in it the wind, expected of an ether in Michelson-Morley's experiment. Only bodies of nuclear matter can cause such effects. Compared with the density of the epola, it is the Earth and earthy bodies which are the etherous ones. This contradicts our natural perception of the emptiness or etherosity of space, which we proved false, based on Anderson's experiments (Chapter 4). It also contradicts the natural perception of earthy objects and ourselves as bodies of continuous dense matter, proven false by Rutherford.

Except for contradicting our mentioned natural perceptions, the epola as carrier of electromagnetic radiation is in full agreement with all observed phenomena and experimental results. With the epola as such carrier, all these phenomena and experiments are given a full physical explanation without hiding behind complicated mathematical derivations and *ad hoc* invented postulates and principles.

6.8. Derivation of mass-energy equivalence

With the energy $m_ec^2 = 0.51$ MeV proven to be the binding energy $_bE$ of the epola particle (Section 4.5) we have calculated the velocity v_d of epola bulk deformation waves, $v_d = (_bE/m_e)^{1/2}$ and shown that it is equal to the vacuum light velocity c (Section 6.5). Let us rewrite the formulas for the velocity v_d of bulk deformation waves (Sections 6.3, 6.5), to read

$_bE = m_i \times v_d^2$, for the NaCl lattice, and

$_bE = m_ec^2$, for the epola.

The binding energy $_bE$ is the mean energy of freeing an ion or particle of its bonds in these lattices. Therefore, the formulas say that

> to free ions or particles of their bonds in a (fcc) lattice, one must supply to them energy, equal to their mass, multiplied by the velocity-squared of bulk deformation waves in the lattice. This energy is released in the lattice when an ion or particle is caught or entrapped into the lattice.

Multiplying the formula $_bE = m_ec^2$ by an arbitrary integer n, so that $n \times {_bE} = E$, and $n \times m_e = m$, we obtain

$$E = m c^2 .$$

This is Einstein's equation for the equivalence of mass and energy. The equivalence is therefore a direct consequence of the epola structure of space. In the epola here and in it only, 0.51 MeV is *equivalent* to the electron mass m_e

because 0.51 MeV is half the energy of freeing an electron-positron pair from its bonds. However, as is known, 0.51 MeV is much less than the not-yet-known energy, which might really create or destroy an electron.

We must point out that in the $E = mc^2$ formula, E is a radiative energy, i.e., energy of epola waves, emitted or absorbed in the epola when the mass m of electrons and positrons or of similar dense particles is caught into the epola or freed from it. Thus, E and m are not just any energy and any mass. So it also was in Einstein's derivation; his extrapolation onto any energy and any ponderable mass was unjustifiable (see Sections 2.3, 2.6).

6.9. Mass-energy equivalence in the NaCl crystal

In the NaCl lattice, with $v_d = v_s$, the velocity of sound, we have

$$_bE = m_i \times v_s^2 .$$

Multiplying by the arbitrary integer n, so that $n \times {}_bE = E$, and $n \times m_i = m$, we have

$$E = m \times v_s^2 .$$

This is the mass-energy equivalence formula for the unbound huge NaCl crystal. In it and in it only, 8 eV is equivalent to 58 AMU (or to 110,000 m_e), because 8 eV is sufficient to free an Na^+ Cl^- ion pair of its bonds, making the 58 AMU mass appear in the lattice. Obviously, 8 eV cannot *create* 58 AMU.

By virtue of the above, we may conclude that in both the epola and the NaCl lattice,

> *the mass-energy "equivalence" formulas result from the lattice structure of the media and express energy relations for the freeing of masses or for their entrapment, not for their real creation or destruction.*

6.10. The rocksalters' mass-energy saga.

Let us conceive a tremendously huge rocksalt crystal with imaginary intelligent creatures floating in it. Being unable to detect the Na^+ and Cl^- ions bound to the lattice sites in the crystal, the rocksalters have no indication on the existence of the crystal. Therefore, they consider themselves living in an emptiness, a rocksalters' vacuum. As their scientific knowledge developed, they observed some strange limitations, enforced on positions and motions in this vacuum. However, by introducing no less strange postulates, principles and exclusions, they somehow found ways to account for the observed limitations. Thereafter, each time when calculations did not fit new facts, they would make them fit by adding new postulates, space-dimensions or exotic particles. In such a manner, through a complete denial of physical causality, they could keep the idea of the emptiness of their space. This success made the rocksalters believe that the ability to calculate is the only thing which matters and the only proof of truth, that physical understanding is not only impossible but also meaningless, and that the natural desire for such understanding is a sign of ignorance, if not a sin.

Having developed 'high-energy' techniques, the rocksalt creatures observed, that when 8 eV of energy are absorbed in their vacuum, out of it a sodium and a chlorine ion may appear, and that when such a pair of ions disappears, 8 eV of energy emerge. The appearance of the ion pair is then interpreted as its creation out of nothing by the 8 eV of energy; the reverse disappearance of the ion pair is its 'obvious' annihilation into nothing, by emitting 8 eV of energy. This interpretation necessarily leads to a conclusion that 8 eV must be equivalent to the mass of the ion pair, i.e., to 58 AMU, otherwise it would not be able to create the pair. With the use of very complicated mathematics, the rocksalters had previously derived their formula for the equivalence of mass and energy,

$$E = mv_s^2 \ ,$$

where v_s is the rocksalt-vacuum sound velocity, proclaimed as a universal constant. Substituting the value of m_i,

$$m_i = 58\,AMU \times 1.66 \times 10^{-27} kg / AMU = 9.6 \times 10^{-26} kg \ ,$$

and the value of v_s,

$$v_s = 3600\ m/s,$$

they obtained

$$E = 1.25 \times 10^{-18} j \times 6.25 \times 10^{18}\ eV / j = 8eV \ .$$

This result represented a triumph for the rocksalters' interpretations of their vacuum space, of ion creation out of it and of ion annihilation into it, as well as for the genius of their mathematicians. A rocksalter was trying to spoil the jubilation by reiterating that the 8 eV are just the binding energy of the ion-pair to an undetected NaCl lattice, and that the celebrated mass-energy formula is just a formula for the velocity of sound in this lattice. However, his harm was minimal, because he was not allowed to publish his crazy ideas and nobody had the time and willingness to listen to him.

Chapter 7. Epola Waves and Photons

7.1. Stabilization of epola wave motions and frequency invariance

Let us follow the beginning of a harmonic oscillation with frequency f or period $T \equiv 1/f$, of a single epola particle in an otherwise undisturbed epola. At the moment $t = 0$ the particle, marked O, is in equilibrium position, having velocity $v_0 << c$. During the first quarter period, or the time T/4 of the amplitudinal deflection of particle O, the disturbance spreads throughout with the velocity v_d of epola bulk deformation waves, $v_d = ({}_bE/m_e)^{1/2}$, which is equal to the vacuum light velocity c (Sections 6.3, 6.5). At $t = T/4$, the surrounding particles, swept gradually into the motion, form a primary spherical deformation cluster with a radius $R_{cl} = cT/4$. During the second quarter period, or time from $t = T/4$ to $t = T/2$ the particle O returns to the equilibrium position, and a return signal travels through the cluster to move its particles in the opposite directions, while the first signal of the initial deflection is transferred with the velocity c further out to form the neighboring clusters, and so on.

The general principle of wave motion, discovered by Huygens and used ever since in all wave constructions, is that

> every point in space reached by a wave motion can be considered as a center of propagation of a new spherical wave.

To make Huygens's principle applicable for the epola we shall rephrase it as follows:

> *every lattice particle reached by an epola wave is forced to vibrate with the frequency of the wave; therefore, it acts as a center of a new spherical epola wave.*

Part of the energy of the new spherical waves, formed by each and every particle in the epola wave, returns to the 'initiating' particle O and to the 'primary' half-wave deformation cluster. Therefore, every epola particle in the wave is subject to an infinite number of signals or 'move!' orders, interfering with each other. An epola wave motion can be established if as a result of this interference in each particle, the vibrations of the primary cluster, as well as of any other half-wave deformation cluster of the wave motion, do come into compliance with the returning signals from clusters formed further and further away. Otherwise the primary vibration is damped and its energy is transferred to the random vibrations of epola particles around their lattice sites. Obviously, the interference conditions become much more complicated and severe in the presence of guest particles, atoms and bodies of atoms in the epola. This points out that not every or any vibration of epola particles or even systems of epola particles do establish a wave motion in the epola.

Once a wave motion is established in the epola, then the vibration of every epola particle in the wave is linked with quadrillions of particles, interconnected with each other and vibrating with the same compliant frequency. Therefore, if some factor would try to change the frequency of a particle or of a group of particles, the quadrillions of the other particles in the wave-motion will restore the compliant frequency. This explains the observed stability of the frequency or the principle of "frequency invariance". The frequency of wave motions in the epola is preserved even when the waves pass through regions containing bodies of atoms or through otherwise distorted zones.

7.2. Half-wave clusters in epola compressibility waves

Epola bulk deformation waves can be compressibility waves, which are waves of long and medium wavelengths, and shock or impact waves, of short and veryshort wavelengths.In the compressibility waves the half-wave deformation clusters have instantaneous spherical symmetry, so that the volume of the cluster and the equilibrium number N_{cl} of epola particles in it is proportional to the third power of the wavelength, $N_{cl} \propto \lambda^3$.

The deformation in the cluster is due to the excess epola particles, which entered the cluster or left it because of their vibrations in the wave motion. As long as the lattice remains intact, the excess particles, pushed into the half-wave cluster or pulled out of it can only be particles of the boundary layer of the cluster. Therefore, the number ΔN of the excess particles is proportional to the outer area of the half-wave cluster, or to the square of the wavelength, $\Delta N \propto \lambda^2$.

Every excess epola particle entering the cluster brings in an amount of energy equal to its binding energy $m_e c^2$, and every leaving particle takes this energy out. Therefore, the deformation energy E_{cl} of a half-wave epola deformation cluster is proportional to the number ΔN of excess particles in it, thus to the square of the wavelength, $E_{cl} \propto \Delta N \propto \lambda^2$.

The average deformation energy E_p per particle in the cluster, or the energy of the cluster, divided by the number of particles in it is, therefore, inversely proportional to the wavelength,

$$E_p = \Delta N / N_{cl} \propto 1 / \lambda .$$

7.3. Definition of photons in the epola and phonons in solids

The transfer of energy in the epola wave-motion can be represented by the motion of half-wave deformation clusters, or also by the transfer of the average per-particle energy E_p in the half-wave cluster from particle to particle along any direction in the wave motion. This transfer of energy E_p can be considered as the motion of a quasi-particle having this energy and moving with the velocity c of the wave motion. Our definition of the photon is, hence:

> *The photon is an imaginary quasi-particle depicting the transfer of energy in an electromagnetic wave. The photon energy or the quantum of energy in this wave is the average energy transferred from one epola particle to the next in line in the epola wave motion.*

The first sentence in this definition agrees with the original definition given by Einstein in 1905. The second part expresses the meaning of the photon in the epola. This meaning is in full agreement with all observed phenomena in which photons are involved. It releases the obscurity of the photon concept in quantum theory (Section 3.3).

In our definition the photon is not a real particle and does not represent a real particle. It does not even represent the vibrational energy of a real particle in the epola wave motion, because this energy is proportional to the square of the amplitude of the particle. It only represents the per-particle part of the energy, transferred in the wave motion.

Our definition of the photon can also be used to define the phonon in solids (or liquids) by inserting the appropriate terms. Thus,

> the phonon is an imaginary quasi-particle, depicting the transfer of energy in an elastic wave or sound wave in a solid (or liquid). The phonon energy or the quantum of energy in this wave is the average energy, transferred from one ion, atom or molecule of the body to the next in line in the wave motion.

What was said about the nature of the photon relates also to the phonon. However, as in the case of the epola – NaCl lattice analogy (Section 5.1), the photon-phonon analogy cannot be driven too far. Material bodies are much more complex than the epola, so that the phonon concept is also more complex and diverse than the photon concept. However, our derivation of the photon energy, of Planck's law and of Planck's constant can be carried out on phonons in crystalline solids as well.

7.4. Derivation of Planck's Law

We found that the energy E_p transferred from particle to particle, thus the energy of the photon, is inversely proportional to the wavelength of the epola wave motion, $E_p \propto 1 / \lambda$. We may write this proportionality in the form $E_p \times \lambda =$ const, meaning that the photon energy in any epola wave motion, multiplied by the wavelength of this motion, is a constant. This can also be written in the form

$$E_p \cdot \lambda = E' \cdot \lambda'$$

where $E' \cdot \lambda'$ is the outcome of any experiment, in which the photon energy E' is measured together with the corresponding wavelength λ'. Such can be, e.g., the photon energy $E_c = m_e c^2$ of the electromagnetic wave with the Compton wavelength λ_c, $\lambda_c = 2426$ fm. Therefore,

$$E_p \cdot \lambda = E' \lambda' = E_c \lambda_c = 511\ keV \times 2426\ fm = 1.24\ eV \times \mu m.$$

Replacing λ by c / f, we have

$$E_p = (E' \lambda' / c) \cdot f = (1.24\ eV \times \mu m / 300\ Mm \times s^{-1}) \times f$$

or

$$E_p = hf,$$

which is Planck's Law. Here

$$h = E_c \lambda_c / c\ ,$$

or

$$h = 1.24\ \mathrm{eV} \times \mu\mathrm{m} / 300\ \mathrm{Mm} \times \mathrm{s}^{-1} = 4.14\ \mathrm{feV} \times \mathrm{s} = 6.63 \times 10^{-34}\ \mathrm{j} \times \mathrm{s}$$

is Planck's constant.

7.5. The Compton Wave in the epola

According to our description of epola compressibility waves, the shortest wave of this kind would be a wave with a single excess particle in the half-wave deformation cluster. The deformation energy of this cluster is then equal to the binding energy of this single particle, or to $m_e c^2$. However, the transfer of the energy of a single excess particle to the next particle of the cluster can only be described by a single photon having the energy of the excess particle. This means that the single excess particle which entered the cluster transfers the $m_e c^2$ energy to the nearest epola particle, this particle transfers it to the next in line and so on. Thus, for $\Delta N = 1$, the number of photons N_p in the half-wave cluster is $N_p = 1$ and the energy of the photon is equal to the energy of the cluster,

$$E_p = E_{cl} = \Delta N \times m_e c^2 = m_e c^2.$$

It was experimentally established and it also follows from Planck's law, that an electromagnetic wave with photon energy m_ec^2 has the Compton wavelength λ_c, $\lambda_c = h / m_ec = 2426$ fm,

We shall refer to such wave as to the Compton wave.

The diameter of the half-wave deformation cluster of the Compton wave is 1213 fm and the number N_d of epola particles across this diameter is

$$N_d = \lambda_c / 2l_0 = 1213\,fm / 4.4\,fm = 280.$$

If spherical symmetry can still be assumed, then the number of epola particles in this cluster is

$$N_{cl} = (4\pi / 3) \times (\lambda_c / 2\,l_o)^3 = 1.1 \times 10^7 .$$

7.6. Characteristic relations for epola compressibility waves

The characteristic values found for the Compton wave can be used as proportionality factors in the expressions for the half-wave deformation clusters of epola waves. We did it already in our derivation of Planck's law (Section 7.4) when we substituted for E' λ' the known values of the photon energy $E_c = m_ec^2$ and the wavelength $\lambda_c = 2426$ fm of the Compton wave. The derived standard expression for Planck's law may thus be replaced by

$$E_p = E_c \times \lambda_c / \lambda = m_ec^2 \times \lambda_c / \lambda = 1.24\,eV \times \mu m / \lambda.$$

The proportionality expression for the equilibrium number N_{cl} of epola particles in a half-wave cluster, $N_{cl} \propto \lambda^3$ can now be replaced by $N_{cl} / 1.1 \times 10^7 = \lambda^3 / \lambda_c^{\ 3}$, leading to

$$N_{cl} = 1.1 \times 10^7 (\lambda / \lambda_c)^3 \quad .$$

The number ΔN of excess particles, $\Delta N \propto \lambda^2$ is correctfor $\lambda > \lambda_c$. With the Compton-wave value of $\Delta N = 1$ we may rewrite the proportionality as $\Delta N/1 = \lambda^2/\lambda_c^2$, so that

$$\Delta N = (\lambda / \lambda_c)^2 .$$

The number N_d of epola particles along the diameter of the cluster is proportional to the wavelength, so that $N_d / 280 = \lambda / \lambda_c$, thus

$$N_d = 280\lambda / \lambda_c = \lambda / 2l_0 .$$

The energy E_{cl} *of the cluster,* $E_{cl} \propto \Delta N$, or $E_{cl} / E_c = \Delta N / 1$, is thus

$$E_{cl} = E_c \times \Delta N = m_ec^2 (\lambda / \lambda_c)^2 .$$

The number N_p of photons in the cluster, multiplied by the photon energy E_p *at any instant* must be equal, for energy conservation, to the energy E_{cl} of the cluster,

$$E_{cl} = N_p E_p$$

Therefore,

$$N_p = E_{cl} / E_p = m_e c^2 (\lambda / \lambda_c)^2 / m_e c^2 (\lambda_c / \lambda) = (\lambda / \lambda_c)^3$$

It is seen, that N_p is 1.1×10^7 times smaller than N_{cl}. This means that

in any half-wave deformation cluster of an epola compressibility wave there is at any instant one photon per every 11 million epola particles.

The derived expressions for N_{cl}, ΔN, N_d and N_p are plotted against the photon energies, the frequency and wavelength of the epola (electromagnetic) waves in Figure 4, to the left of $\lambda = \lambda_c$

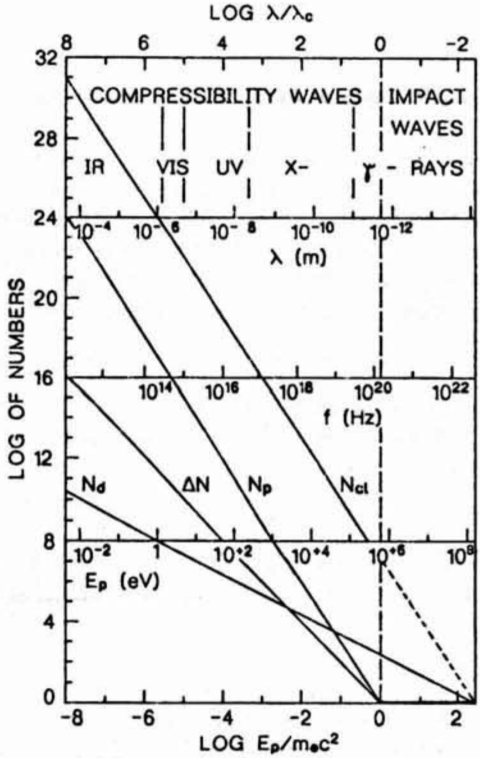

Figure 4. Spectrum of epola waves (of electromagnetic waves)

Abscissas are the photon energy, in units of m_ec^2 (lowest axis) and in eV, the frequency f in Hz, the wavelength in m and in units of the Compton wavelenth λ_c. N_d is the number of epola particles along the diameter of the $\lambda / 2$ deformation cluster, N_p is the number of photons, ΔN – the number of excess particles, and N_{cl} – of equilibrium particles in the $\lambda / 2$ cluster. The vertical dotted line connecting points $E = m_ec^2$, $\lambda = \lambda_c$, $\Delta N = N_p = 1$, divides between compressibility and impact waves. The right edge vertical line corresponds to the shortest epola wave, $\lambda = 2 l_o = 8.8$ fm $= \lambda_c / 280$, $f = 3.4 \times 10^{22}$ Hz, and $E_p = 280\ m_ec^2 = 140$ MeV. (Section 7.10)

[Editor's note: Ep axis scale corrected by x100 to range from 10^{-2} - 10^{8} eV. *Feb 2009. rgg*]

7.7. Epola impact waves

The half-wave deformation clusters in epola waves with wavelengths shorter than the Compton wavelength, $\lambda<\lambda_c$, are always invaded by *one* excess particle. The energy of the cluster, thus also the energy of the single photon, is $E_c = m_e c^2$, plus the kinetic energy $_kE$ of the invading (excess) particle. This energy defines the depth and the duration of the invasion, hence the subsequent deflection of the receiving host particle and, consequently, the energy transferred in the wave-motion, or the energy of the photon. The energy-transfer has the character of an impact and the waves in this case are epola impact waves. The characteristic relations for the impact waves are:

$$\Delta N = N_p = 1 \ ,$$
$$E_{cl} = E_p = m_e c^2 + {}_kE \ ,$$
$$E_p = m_e c^2 \lambda_c / \lambda = hf \ .$$

These relations are depicted in Figure 4 to the right of $\lambda=\lambda_c$.

As the wavelength becomes shorter and shorter, the impact or shock character of the wave strengthens. The half-wave clusters lose their spherical shape, becoming more and more prolate ellipsoids. The long axes of the elipsoids aim in the direction of propagation of the single photon. Their length is $\lambda / 2$ and the number N_d of epola particles along these axes is

$$N_d = 280\, \lambda / \lambda_c = \lambda / 2\, l_0$$

as in compressibility waves.

We assumed that in the Compton wave with $\lambda = \lambda_c$, the half-wave cluster is still spherical, which allowed us to find the number N_{cl} of particles in this cluster as 1.1×10^7. This number was then entered into the N_{cl} expression for compressibility waves. In impact waves we do not know how the short axis of the ellipsoidal half-wave clusters shortens with decreasing wavelength. For the shortest possible wavelength, where $N_d = 1$, $\lambda = 2l_0$, the short axis should be considered as just the effective diameter of the electron or the positron.

7.8. Directionality of epola impact waves

It is experimentally known that the impact or shock waves in elastic media do not spread energy evenly in all directions allowed by interference, as do compressibility waves. The energy of shock waves spreads mostly in the direction of the shock or the impact which created them, the more, the higher the power of the impact. Part of the energy of the impact waves is always dissipated throughout the medium by elastic waves, but this part is small, the smaller, the larger the impact power.

Electromagnetic radiation of wavelengths much longer than the Compton wavelength, identified by us as representing epola compressibility waves, spreads evenly in all directions (allowed by interference). In order to direct the radiation, i.e., to 'squeeze', say, 90 percent of it into a solid angle as small as possible, one has to build complicated systems based on reflection, refraction, as in wave guides, on interference and on increased coherence of the radiation, as in lasers. With all this, the result is still partial, the better, the shorter the wavelength of the radiation.

The ease with which long-wave electromagnetic radiation spreads in space is due to the ease with which epola particles can be deflected from their equilibrium positions at their lattice sites. This is shown by the flatness of the particle's energy minimum at $l = l_o$ in Figure 1 (Section 5.2). Therefore, in spite of the very high binding energy of the particle in the epola, even an infinitesimal energy is able to deflect the particle from its equilibrium position at $l = l_o$.

On the other hand, even the smallest deflection of an epola particle is resisted by the surrounding quadrillions of particles and the terrific binding forces between them. But if energy is supplied to an epola particle slowly enough, then the slowly rising deflection of the particle is not resisted by its nearest neighbors, which have the needed time to deflect, too. Similarly, their deflections are not resisted by their neighbors, and so on. Hence, the energy is absorbed 'softly' and a compressibility wave is formed (see Section 7.1). If the energy is 'thrown' at the epola particle during a very short time, then the elastic deflections of connected epola particles have no time to develop. The deflecting power has against itself a super-solid wall of epola particles resisting the deflection. The energy cannot be accepted, the deflection cannot occur and the compressibility wave is not formed.

Electromagnetic radiation of wavelengths equal to and shorter than the Compton wavelength λ_c, $\lambda_c = 2426$ fm, or γ-rays, identified by us as epola impact waves, are known to have an explicit directionality. Gamma-rays propagate in rectilinear channels without significantly dissipating energy to the sides, just as if they were moving in wave-guides, created by themselves in space.

The wave-guide directionality of γ-rays can be explained, considering that they represent epola impact waves. The half-wave cluster of these waves contains a single excess particle. The energy of this particle is transferred as a single photon along the diameter of the cluster in the direction of motion of the excess particle. This direction is preserved when the single excess particle forms clusters further and further away, which is the physical basis for the propagation of the γ-ray photon.

The energy of the impact-wave cannot be spread sidewise when the frequency is high. Suppose that an epola particle, slightly outside a half-wave cluster, i.e., off the main direction of the impact wave, received from the wave a stray signal, ordering the particle to deflect in a certain sidewise direction. The signal persists only during one quarter-period of the wave, or a time $t = T/4$. Due to the high frequency of the impact wave, this time is too short for the particle to deflect against the opposing super-solid wall of neighboring epola particles, which did not receive the signal. During the next quarter-period, the signal commands the particle to deflect in the opposite direction, which the particle cannot do because of the wall of epola particles, opposing this deflection, and so on. The energy of the stray sidewise signal cannot therefore be accepted by this particle or by any other particles of the epola, adjacent to the propagating half-wave clusters of the impact waves. The super-solid walls of their surrounding quadrillions of epola particles serve as the walls of the "wave guide" of the impact wave, i.e., of the γ-ray.

7.9. Electrical polarity of epola impact waves

The electrical polarity of the half-wave clusters of impact epola waves is the stronger the shorter the wavelength. With only one excess particle in each cluster it is obvious that if in one cluster the excess particle is an electron, then in the next cluster the excess particle must be a positron. In the half-wave cluster of the Compton wave this means one electron or positron charge, $-e$ or $+e$, per 11 million epola particles. Though the wave as a whole is electrically neutral, on distances shorter than the wavelength strong electric fields should be experienced.

The electric field of a half-wave cluster in epola impact waves grows very fast with decreasing wavelength. Even if the cluster were spherical, its volume and the number of epola particles in it would be reduced proportionally to λ^{-3}. However, with the decrease of wavelength below λ_c, the half-wave clusters become more and more prolate ellipsoids. This is an additional factor reducing the volume of the cluster and the number N_{cl} of epola particles in it, thus the number of particles per the excess $+e$ or $-e$ charge of the cluster.

7.10. The shortest epola wave, the cutoff frequency and energy

The shortest possible wavelength λ_{min} of epola bulk deformation waves is twice the lattice constant l_o,

$$\lambda_{min} = 2 \times l_0 .$$

Such also are the shortest wavelengths of bulk deformation waves in any lattice. In the epola, the wave motion with the shortest wavelength has frequency f_{max}, sometimes referred to as the 'cutoff' frequency,

$$f_{max} = c / \lambda_{min} = 3.4 \times 10^{22}\, s^{-1} .$$

The photon energy E_{max} of this wave motion is

$$E_{max} = hf_{max} = 140\ MeV \ .$$

In the epola wave motion with the shortest possible wavelength the space-domain of each epola particle along the path of the photon is invaded by an excess particle during the entire period: half of the period by an electron, the other half - by a positron. This is somehow equivalent to tearing the lattice apart. Actually, as in the case of solid lattices, 'sublimation' in the epola, i.e., free electron-positron pair production, should occur, and occurs at wavelengths much longer than these.

It should be clear from the above that a 140 MeV photon is exactly a 140 MeV electron (or positron) and there is no way to distinguish between them. What is reported in the literature as γ-photons with energies exceeding 140 MeV could be electrons or positrons or other 'dense' particles (avotons, Section 8.14) which have these high energies. They create in the epola secondary, tertiary, etc., γ-rays, out of which the high energy of the primary particle is derived.

7.11. Action of photons, holding time and Planck's constant

The action (or action-function) was introduced to describe a dynamic system of particles. If the system passes from a position it had at time t_1 to a position reached at time t_2, then the action A is expressed by the integral

$$A = 2\int_{t_1}^{t_2} {}_kE \times dt$$

where ${}_kE$ is the total kinetic energy of the system.

Keeping the spirit of this definition, we introduce the action of a photon as twice its energy, multiplied by the time t_h which it takes to transfer this energy from one epola particle to the next in line. Obviously,

$$t_h = l_0 / c = 4.4\ \text{fm} / 300\ \text{Mm} \times s^{-1} = 1.5 \times 10^{-23}\ \text{s}.$$

We may also consider t_h as the time, during which an epola particle 'holds' the photon energy. Thus, t_h is the 'holding time' of the photon by an epola particle.

In our presentation, the action A_p of a photon is given by

$$A_p = 2\, hfl_0 / c = 2\, hl_0 / \lambda.$$

For the photon with the shortest possible wavelength $\lambda_{min} = 2 \cdot l_o$ we have

$$A_p = 2 \times hl_0 / 2l_0 = h.$$

Hence,

Planck's constant h is the action of the most energetic photon (or the cutoff-frequency photon).

If h is to be considered as Planck's 'quantum of physical action' then the actions of photons are proportional to the frequencies of the epola waves, just as the photon energies or energy quanta. Thus, they are smaller than h as many times, as the frequency of the photons is smaller than the cutoff frequency.