Electromagnetic Nanofield and Planck Frequency

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Abstract

Planck's relation isn't quantum in intrinsic manner because of frequency that changes with continuity into a largest range of frequencies that includes classic electromagnetic waves, microwaves and nanowaves. These last are placed inside spectrum after microwaves and they are associated with electromagnetic nanofield. The distinction between micro and nanowaves enables to define Planck's frequency that is the threshold frequency between the two types of wave and it is located where microwaves end and the infrared band begins (300GHz). Planck's frequency enables to complete the effective quantization of Planck's relation because for energy quanta frequency cannot be smaller than Planck's frequency.

1. Introduction

The relation E=hf was theorized by Planck in order to explain the emission spectrum of black body whose experimental survey diverged rather from Rayleigh-Jeans' theoretical formula. Planck solved the problem introducing the hypothesis, after proved exact, that energy emitted by a black body, and in general by any body, happened in discrete way by any emitting oscillator inside body and matter. Planck called "quantum" that discrete and discontinuous quantity of energy emitted in every event of emission. In actuality it could seem in contradiction with continuous spectrum of emission of black body at any temperature but contradiction vanishes if we consider distribution of single levels of energy in each atom and in the molecular structure of body. In fact energy structure of single atoms is discontinuous and it is represented by single levels of energy while energy distribution of complex bodies and of condensed matter is represented by continuous bands of energy: it explains the continuous character of emission spectrum of a body while the single atom presents a discontinuous spectrum of emission composed of lines. So Planck's relation is quantum in regard to discrete levels of energy of single atoms and to the single act of emission in complex matter but it isn't quantum in regard to continuous levels of energy bands in complex solid matter. In that situation in fact frequency can change with continuity.
In general the exact quantization of Planck's relation can be obtained taking on frequency in the relation presents a limit of inferior threshold that we call "Planck's frequency".

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2. Energy levels and bands

Inside single atom orbiting electrons occupy defined and discrete levels of energy that produce known spectrums of line emission. Inside complex bodies of condensed matter intermolecular forces, that guarantee cohesion of matter at solid state, produce a redistribution of single discrete atom levels determining a structure with energy bands[1] (fig.1).

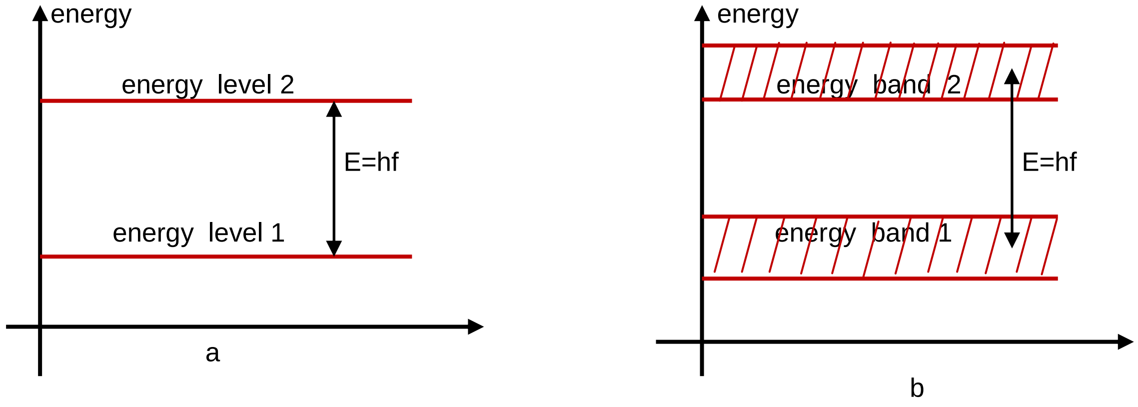

Figure 1. a. Atom energy levels
b. Energy bands of condensed matter

When an electron, that is at the energy level 2 of atom, jumps to the energy level 1 (fig.1.a), it emits an energy quantum E=hf that is discrete and quantized. Similarly in condensed matter an electron can be in any energy level of the band 2 and it can jump to an energy level of the band 1 emitting an energy quantum.
Fig.1.b represents the distribution of energy bands for non-conductors and semiconductors. It is known that conductors present energy bands that are partially overlapping. Like this in matter at solid state single quantum is discrete and quantized but the general process can generates a continuous distribution of energy for emission spectrums (fig.2).
Like this Planck explained the continuous trend of emitted energy by black body even if the single event of emission is quantum (fig.3). In figure graph of emission of black body is drawn for two different values of temperature. All energy quanta are characterized by a frequency f and by a wavelength λ with $f\lambda=c$ where c is the physical speed of light.
Energy quanta cover an energy largest band (3×10^{11}Hz , > 1.13×10^{23}Hz), that starts from infrared rays (3×10^{11}Hz, 4×10^{14}Hz) to delta-Y rays (>1.13×10^{23}Hz)[2][3].
Classic electromagnetic waves cover the energy band that goes from the inferior limit of ultra-long waves (≈0Hz) to the upper limit of microwaves (300GHz) that practically coincides with the inferior limit f_t of infrared nanowaves. This inferior limit $f_t=3\times10^{11}$Hz can be considered the threshold frequency (that we call Planck's frequency) between classic electromagnetic waves and quantum nanowaves. It is possible also to consider nanowaves like electromagnetic impulses characterized by a modulating frequency.

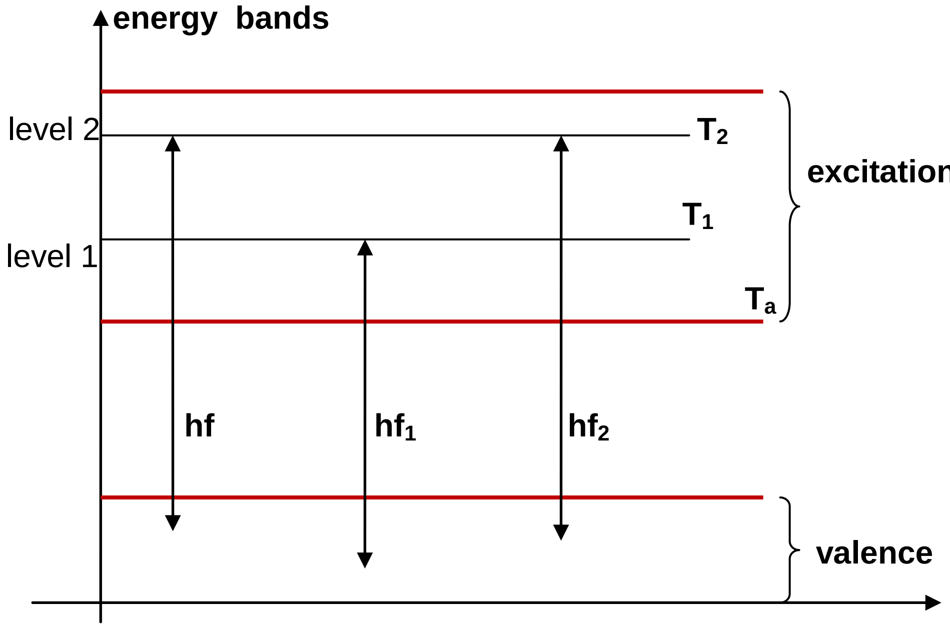

Fig. 2 Energy bands and energy quanta in the condensed matter

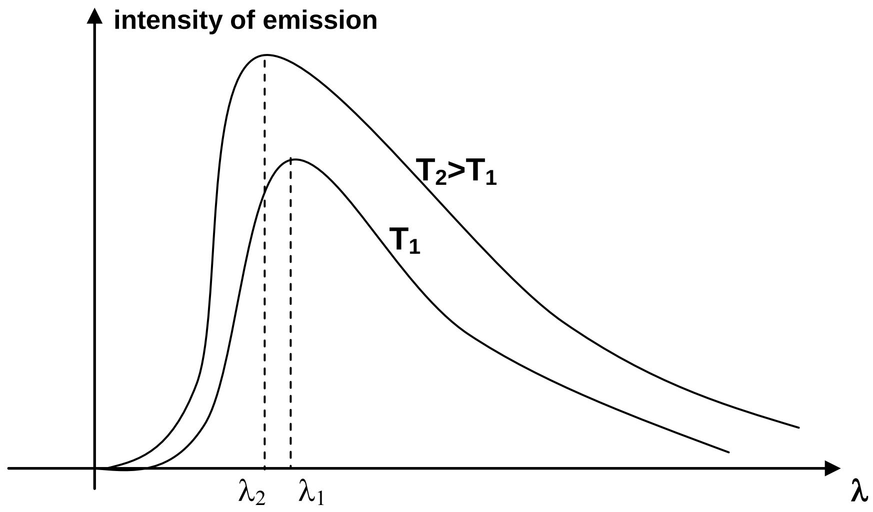

Fig. 3 Emission spectrum of black body for two different temperatures in function of wavelength

Quantum energy corresponding with this threshold frequency is $E_t=hf_t=1.24 \times 10^{-3}$eV.
In actuality Planck's relation has a well defined physical meaning only in the order of e.m. nanowaves (with greater frequency than Plank's frequency) where frequencies are great and wavelengths are small. Therefore for the effective quantization of Planck's relation it is not sufficient that the constant h has a finite value but it is necessary to assume a lower limit of frequency, equal to Plank's frequency, so that frequency of quanta cannot assume smaller values that the threshold frequency. In fact for smaller frequencies than Planck's frequency there is the spectrum of classic e.m. waves (to microwaves) in which the continuous nature of event is determined by continuous variation of current density or of electric charge density.

3. Quantum electromagnetic nanofield

From the value of the threshold frequency we derive the value of Planck's threshold wavelength

$$\lambda_t = \frac{c}{f_t} = 10^{-3}\text{m} = 1\text{mm} \qquad (1)$$

For greater values of wavelength the behaviour of electromagnetic field and of e.m. waves is continuous in classic sense, for smaller values we have electromagnetic nanofield and e.m. nanowaves that are quanta of energy and constitute shafts of radiant energy. Quantization doesn't change the physical behaviour of nanofield and of nanowaves with respect to classic field and waves, in fact whether field or nanofield are described substantially by Maxwell's same equations. We proposed a change with respect to Maxwell-Heaveside equations and we call new equations "rationalized equations"[3][4]: the change consists in the replacement of classic equation div**B**=0, that in actuality has small significance inside the group of equations because it defines an always verified identity rather than a true equation, with the Lorentz equation. Consequently "rationalized equations" for electromagnetic field can be written in the following differential shape:

$$\text{div}\,\mathbf{E} = \frac{\rho}{\varepsilon_o} \qquad \text{(Poisson-Gauss law)} \qquad (2)$$

$$\text{rot}\,\mathbf{B} = \mu_o\,\mathbf{J} + \frac{1}{c^2}\frac{\delta\,\mathbf{E}}{\delta\,t} \qquad \text{(Ampere-Maxwell law)} \qquad (3)$$

$$\text{rot}\,\mathbf{E} = -\frac{\delta\,\mathbf{B}}{\delta\,t} \qquad \text{(Faraday-Neumann-Lenz law)} \qquad (4)$$

$$\mathbf{E} = \mathbf{v}\Lambda\mathbf{B} \qquad \text{(Lorentz law)} \qquad (5)$$

Electromagnetic nanofield is generated by a variation of speed v of a charged massive elementary particle that, in determined physical conditions, produces a quantum elementary event of emission e.m. , in that case rationalized equations are defined more properly by three equations that are, making use of small letters for nanofield,

$$\text{rot}\,\mathbf{b} = \frac{1}{c^2}\frac{\delta\,\mathbf{e}}{\delta\,t} \qquad (6)$$

$$\text{rot}\,\mathbf{e} = -\frac{\delta\,\mathbf{b}}{\delta\,t} \qquad (7)$$

$$\mathbf{e} = \mathbf{v}\Lambda\mathbf{b} \qquad (8)$$

Equations (6) and (8) represent "nanowave equations" in phase of generation, in fact an elementary particle with speed **v** (for instance an electron) goes into the accelerating field of magnetic induction **b** and interaction generates for (8) the variable electric field **e**. For (6) the field **e** generates in its turn the magnetic field **b** and it generates nanowave. Equations (6) and (7) represent instead "nanowave equations" in phase of propagation like waves.
Fundamental difference between field equations and nanofield equations consists in the fact that waves and field regard a continuous electromagnetic process generally due to a continuous variation of current density or more rarely of charge density that generates a wavelike and propagating process. Nanowaves and nanofield regard an electromagnetic process due to acceleration of an elementary electric charge, for instance an electron, that can be whether at the free state or bound inside atomic matter, and this process e.m. is propagating and quantum in the meaning that it is discrete and located.

4. Physical meaning of quanization of Planck's relation

Planck's threshold frequency doesn't generate a discrimination with regard to the behaviour of field and of electromagnetic waves according to the value of frequency and wavelength. In fact field and nanofield are described practically by the same equations. The Planck frequency has an useful meaning instead if we consider Planck's threshold f_t for frequency (and λ_t for wavelength) allows to distinguish nanofield and nanowaves from field and waves. In fact the concept of quantum is related to a physical structure that has briefest duration and smallest space sizes with respect to a parameter that is taken like reference. The parameter of reference in that case is Planck's threshold frequency f_t or in equivalent way Planck's threshold wavelength λ_t. Like this e.m. processes characterized by greater frequencies $f>f_t$ (and smaller durations $T<1/f_t$) with respect to Planck's threshold frequency and by smaller wavelengths $\lambda< \lambda_t$ can be considered effectively quantum e.m. processes. Physical processes instead with smaller frequencies than Planck's frequency and with greater wavelengths than Planck's wavelength are typical continuous processes of classic electromagnetism.

5. Question of spectral gap

In ResearchGate a researcher (E.M. Howard) has raised the question of the "spectral gap" that regards calculation of the difference between the smallest level of energy that electrons are able to occupy into a complex material and the subsequent level. The problem regards the fact that theoretical models of simulation not would be able to decide if calculation of gap can happen within a finite time and consequently it would generate undecidability for solution of the problem. This conclusion would be the outcome of a theoretical research[5] by T. Cubitt and others at the University College London and it would prove also in Quantum Mechanics problems of undecidability exist as it has been demonstrated in mathematics by Kurt Godel's Incompleteness Theorem.

For article's authors, with regard to a complex system, the problem of the spectral gap not would be a problem of hard mathematical solution but their conclusion is that it is logically impossible to say if the prospective presence of a spectral gap for a problem of quantum mechanics can be calculated in a finite time. This conclusion represents the question of the undecidability for the problem of the spectral gap relative to a complex system. The question of the spectral gap is connected with the question of quantization because the existence of a spectral gap involves the presence of a discontinuous distribution of energy inside complex system while the absence of a spectral gap involves a continuous distribution of energy.

If we consider a simple system, constituted for instance by only one atom, distribution of energy levels inside atom is discontinuous like in fig.4. It is known that in one atom each state with quantum number n embraces n levels of energy E_k represented by the quantum number k (k=1,2,3....n). Every level k of energy with quantum number n can embrace n electrons for a total of n^2 electrons for the state n and considering the spin, that for every electron can assume two opposite different values, the maximum number of electrons for the quantum state n is therefore $2n^2$. It follows that the quantum state n=1 embraces 2 electrons, the quantum state 2 embraces 8 electrons and so on.

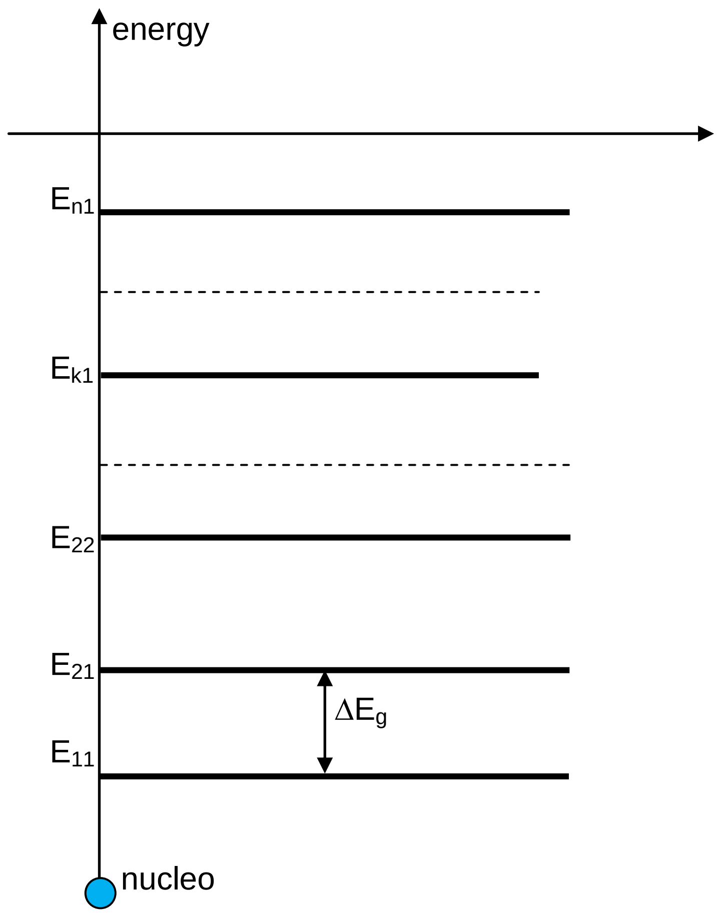

Fig.4 Discrete distribution of energy levels in one atom in which ΔE_g represents the spectral gap

In figure E_{11} represents the minimum energy of the fundamental state (n=1, k=1), E_{21} represents the minimum energy of the subsequent state (n=2, k=1) for which

$$\Delta E_g = E_{21} - E_{11} \qquad (9)$$

represents the spectral gap of the considered atom.
If now we consider a complex system with non-interconnected more atoms, for instance more equal atoms of a gaseous system, it is predictable that energy spectrum of that system diverges little from the fig.4. In these physical conditions in fact there is practically no entanglement among atoms.
If instead we consider a complex system composed of very numerous atoms connected into a molecular structure at the solid state of condensed matter, that are bound by forces of reciprocal attraction, certainly energy spectrum is different from fig.4 and more precisely there is a change from a discrete distribution of energy levels to a continuous distribution constituted by energy bands[1][2][7] (fig.5). Continuous distribution of energy levels inside bands is given by the function N(E), that represents the state density (number of states for unit of volume) for unit of energy.
Accordingly the density D of states in the energy band ($E_2 - E_1$) for unit of volume is given by

$$D = \int_{E_1}^{E_2} N(E)dE \qquad (10)$$

Probability that these states are occupied is defined by Fermi-Dirac's statistics and it depends on absolute temperature.

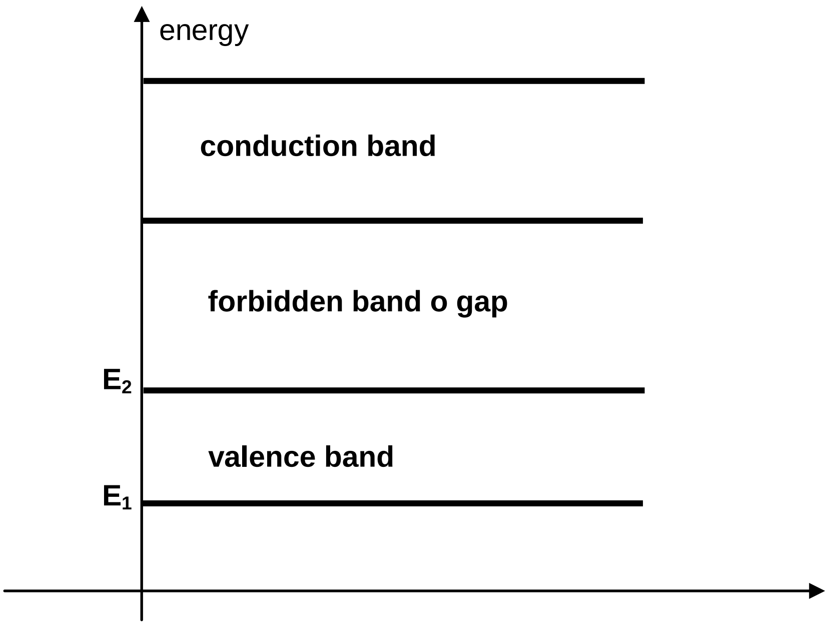

Fig.5 Energy bands in a non-conductor and in a semiconductor

Generally in matter at solid state there are two bands of energy: valence band and conduction band. In conductors the two bands are partially overlapping while in semiconductors and in non-conductors the two bands are separated by the forbidden band and in non-conductors the forbidden band is much larger than in semiconductors (fig.5).

The figure shows single bands have a continuous distribution of energy levels and therefore when the number N of atoms of complex system is greatest, we have

$$\lim_{N \to \infty} \Delta E_g = 0 \qquad (11)$$

It is manifest in that case there isn't spectral gap because of continuous distribution of energy levels and consequently the difference betwen the minimum level of energy and the subsequent level for each band is just zero. Undecidabilty would derive in that case from the fact that calculation of spectral gap for condensed matter at the solid state involves calculation of the limit practically for N that tends towards infinity and any algorithm of simulation isn't able to calculate that limit into a finite time.
Godel's Theorem of Incompleteness proves in a mathematical system, axiomatic for definition, exist a few propositions whose it isn't possible to demonstrate if they are true or false. Godel's Theorem is a theorem of fundamental logic from which A. Turin derived for a few algorithms it isn't possible to know if a computer will be able to complete calculations in a finite time: this is the problem of undecidability.
Cubitt and others would have proved this problem of undecidability would happen also in physics, in particular for the spectral gap of a complex material. Our study has proved mathematical models and algorithms that are used in order to achieve this conclusion are inappropriate. In fact in a simple quantum system, composed of one atom or little atoms, the distribution of energy levels is discontinuous and consequently a spectral gap exists between the minimum level of energy, that coincides with the fundamental level, and the subsequent level. In that case nevertheless energy levels can be calculated with great accuracy and consequently also the spectral gap can be calculated with great accuracy in acceptable times so that a problem of undecidability in this situation doesn't exist.
For complex systems of matter at the solid state, energy bands are composed of continuous levels of energy and therefore a problem of spectral gap doesn't exist because in this situation the spectral gap for each band is always zero and consequently there is no necessity to program an algorithm of simulation for calculation of gap.

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