

Photon diffraction

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Abstract

In this article two types of diffraction are considered: the macroscopic diffraction occurs whether with electromagnetic waves or with photon beams like light, the photon diffraction or nanoscopic diffraction occurs only with photons. The difference between the two diffractions depends on both the width of the slot and the wavelength of radiation. This consideration proves further that electromagnetism and optics, including in optics infrared, visible, ultraviolet and X radiation, have a different physical nature: electromagnetism is characterized by waves, optics by photon beams. The frequency band employed by infrared radiation represents the point of connection between the two diffractions and the two physical behaviours.

Introduction

We have proved in the article “ On the physical structure of radiant energy: waves and corpuscles “^[1] that electromagnetism and optics are substantially different physical branches, although they have some common specifics. Maxwell’ s equations describe electromagnetic phenomena but they cannot be applied also to light, to infrared, to ultraviolet radiation and to X-rays. Electromagnetic waves are continuous waves of energy while light and the other radiations are photon discrete beams made up of energy quanta. In the propagation of light and other radiations there isn’ t propagation of an electromagnetic field but only motion of photons. When the photon beam has a wave intensity its motion can be described by D’ Alembert’s equation. It is not correct therefore to include infrared, visible, ultraviolet and X radiation among electromagnetic waves.

We have also proved nevertheless that the single photon is an electromagnetic nanowave that can be described by Maxwell’ equations^[1] (photon equations). Electromagnetic waves include frequencies to microwaves and produce only one type of diffraction: the macroscopic diffraction. Light and other radiations are photon beams and are able to produce two types of diffraction: a macroscopic diffraction due to the photon beam (with constant or variable intensity) and a photon diffraction due to single photon of a photon collimated beam. The difference between the two diffractions depends on both the width of the slot and the wavelength of radiation. The infrared radiation employs the wavelength band (1mm – 0,8 μ m) and has an important role in this different physical behaviour because the transition from the continuous nature to the discontinuous nature of energy happens in this band.

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1. Macroscopic diffraction

From macroscopic viewpoint all radiations with greater frequency than microwaves (infrared, light, ultraviolet, X-radiation) are photon beams which can have a constant or variable intensity and in both the cases they produce diffraction when meet a slot or an obstacle with suitable width.

The same macroscopic diffraction is obtained also with electromagnetic waves. If the photon beam or the electromagnetic wave is plane in the vicinity of slot and has cosinusoidal intensity the diffraction on the screen is like in fig.1^[1]. In this case in order to have the best effect of diffraction it is necessary that

$$\begin{aligned}d &\geq X_0 \\ X_0 &\approx \lambda_0\end{aligned}\quad (1)$$

where d is the part of surface hit by radiation, X_0 is the width of slot and λ_0 is the wavelength of radiation. The macroscopic diffraction is well observed when $X_0 \approx \lambda_0 \geq 0,1\text{mm}$; electromagnetic waves have generally greater wavelength than 1mm but with special techniques it is possible to obtain microwaves to 0,1mm inside the infrared band. There is therefore a wavelength band (1mm – 0,1mm) common whether to electromagnetic microwaves or to infrared radiation.

A similar diffraction is obtained also with photon beams that have a constant intensity^[1], this isn't possible with electromagnetic waves which are always characterized by a variable intensity.

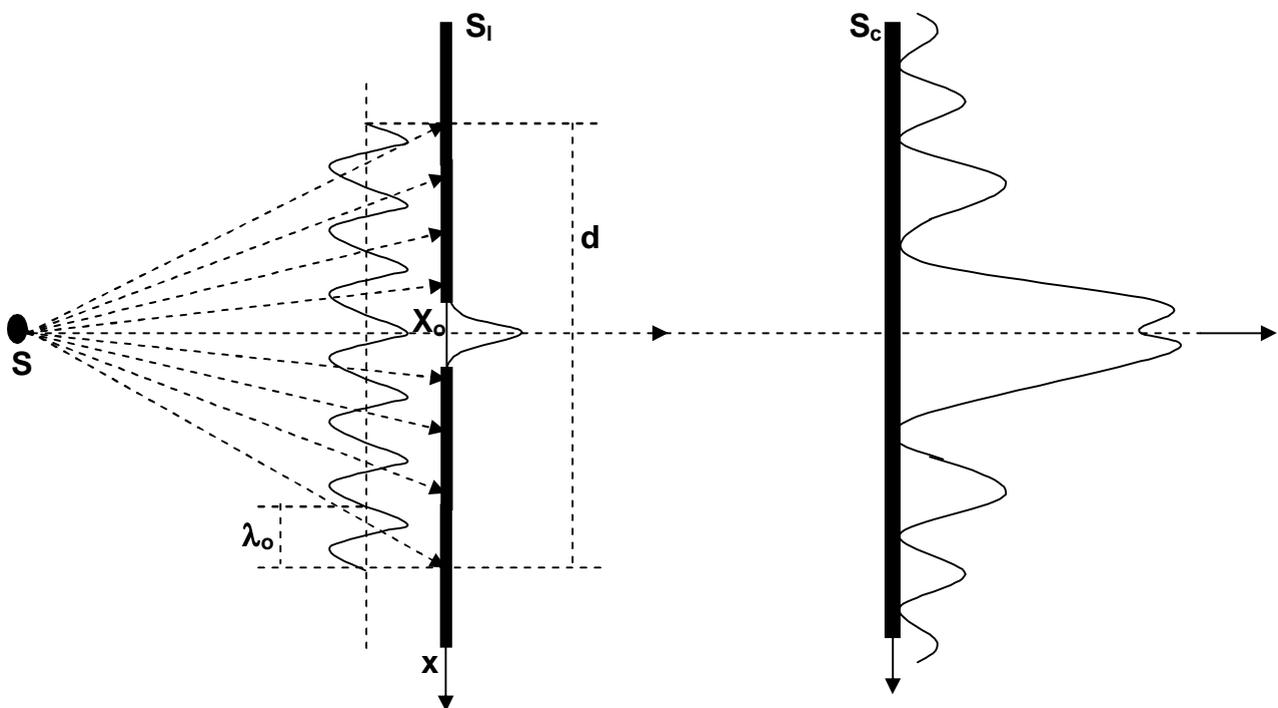


Fig.1 Scheme of diffraction for photon beams and electromagnetic waves which have cosinusoidal intensity and are plane in the vicinity of slot.

2. Photon diffraction

Photon is an electromagnetic nanowave defined by following photon equations^[1] which describe the beginning and the propagation of the electromagnetic nanofield connected with photon

$$\operatorname{rot} \mathbf{B} = \frac{v}{c^2} \frac{\delta \mathbf{E}}{\delta r} \quad (2)$$

$$\operatorname{rot} \mathbf{E} = - \frac{\delta \mathbf{B}}{\delta t} \quad (3)$$

$$\operatorname{rot} \mathbf{B} = \frac{1}{c^2} \frac{\delta \mathbf{E}}{\delta t} \quad (4)$$

Photon can be represented by a cosinusoidal nanowave function with wavelength λ_o . The photon diffraction or nanoscopic diffraction is obtained using a photon collimated beam like in fig.2. In order to have the nanoscopic diffraction it is necessary that

$$\begin{aligned} \lambda_o &\approx X_o \\ X_o &< 0,1\text{mm} \end{aligned} \quad (5)$$

In fact this wavelength ($\lambda_o = 0,1\text{mm}$) represents the full transition from microwaves to infrared radiation, from electromagnetic waves to photons. X_o is the width of the slot. Microwaves are electromagnetic waves; infrared, visible, ultraviolet and X-rays are photon discrete beams; photons are electromagnetic nanowaves.

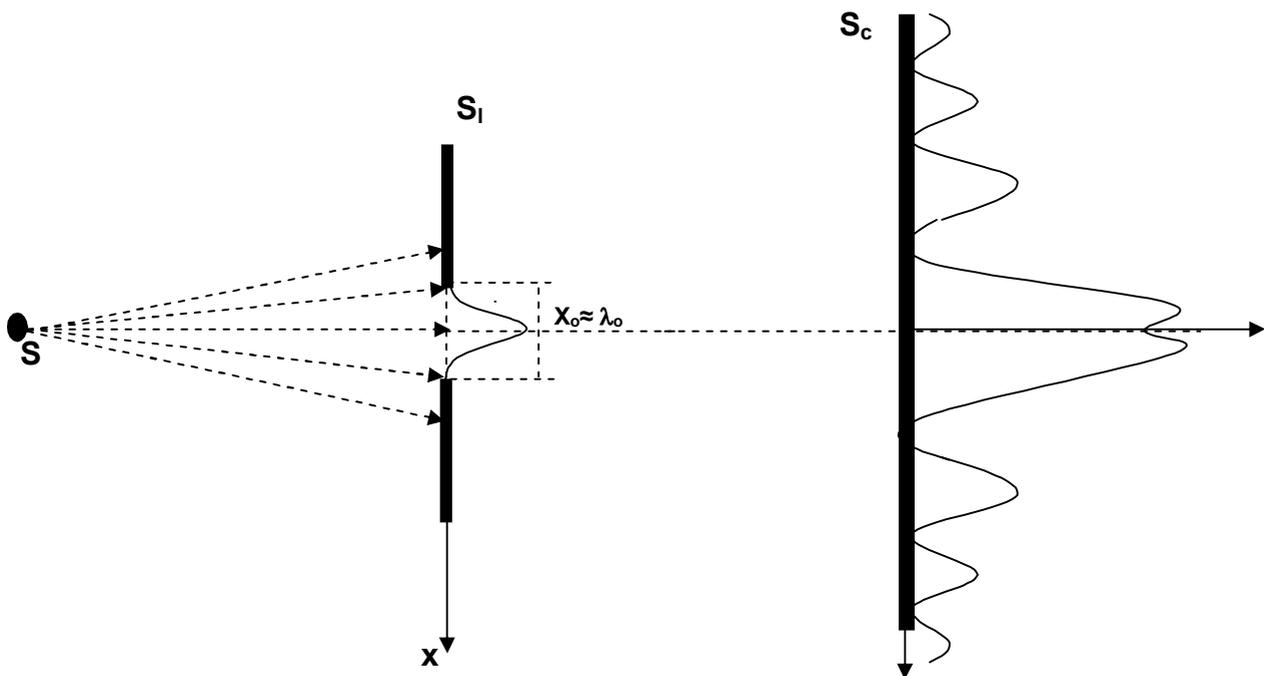


Fig. 2 Scheme of diffraction for the single photon belonging to a photon collimated beam.

This scheme of diffraction happens specifically also for X-rays with

$$X_0 \approx 1 \text{ Angstrom} = 10^{-10} \text{ m} \quad (6)$$

In this case in order to have so little slots it is necessary to use a crystal lattice.

3. Transition from waves to nanowaves

The difference between waves and nanowaves is defined only by wavelength, microwaves belong to electromagnetic waves. Photons are nanowaves, photon beams aren't electromagnetic waves and can have constant or variable intensity. Microwaves utilize the frequency band ($3\text{GHz} - 3 \times 10^3 \text{ GHz}$) and the wavelength band ($100\text{mm} - 0,1\text{mm}$), infrared radiation utilizes the frequency band ($3 \times 10^2 \text{GHz} - 4 \times 10^5 \text{GHz}$) and the wavelength band ($1\text{mm} - 0,8\mu\text{m}$). In the little band ($1\text{mm} - 0,1\text{mm}$) there is the full transition from electromagnetic waves to photons, from microwaves to nanowaves, from microwaves to infrared radiation, from the continuous structure of energy to the discontinuous structure. In this little band it is possible to have whether electromagnetic microwaves or quantum photons. According to our theory microwaves are electromagnetic waves with typical wavelength ($100\text{mm} - 0,1\text{mm}$), infrared radiation is a photon beam where photons are nanowaves with wavelength ($1\text{mm} - 0,8 \mu\text{m}$), visible radiation is a photon beam with photon wavelength ($0,8\mu\text{m} - 0,4\mu\text{m}$), ultraviolet radiation is a photon beam with photon wavelength ($0,4\mu\text{m} - 10^{-2}\mu\text{m}$) and X-radiation is a photon beam with photon wavelength ($10^{-2}\mu\text{m} - 10^{-2}\text{nm}$); gamma radiation is made up of rays of nuclear origin. The infrared radiation is also peculiar to the heat radiation and studying the emission spectrum of the black body M. Planck in the 1899 year understood that it was necessary to introduce the concept of energy quantum ($E=hf$) in order to explain experimental results. Planck saw that the typical continuous spectrum of the black body (fig.3) was explainable only introducing the discontinuous concept of energy. It can appear a paradox but paradox isn't.

In figure it is possible to see that for greater temperatures the maximum of emission happens for smaller wavelengths and for greater frequencies. Heat energy supplied to body excites electrons moving them from the valence band to the excitation band; to that end it is necessary that heat energy provides electron with an energy $E \geq hf$. For every temperature there is an energy level in the excitation band with maximum number of excited electrons which generates the peak of intensity for a characteristic value of frequency and wavelength.

At ambient temperature molecular electrons are largely in the valence band and few electrons jump to level 'a' with subsequent emission of the photon hf (fig.4). Increasing temperature the number of excited electrons increases and at T_1 temperature most of electrons jumps to energy level 1 with subsequent preponderant emission of the photon hf_1 . This explains the peak of intensity in fig.3 at T_1 temperature for the wavelength $\lambda_1 = c/f_1$, however several electrons jump to greater or smaller energy levels than level 1 with subsequent emission of

photons with greater or smaller energy than hf_1 and this explains the graph next to λ_1 at temperature T_1 .

At $T_2 > T_1$ temperature most of electrons jumps to energy level 2 with subsequent preponderant emission of the photon hf_2 but photons with greater or smaller energy than hf_2 are also emitted. This explains perfectly the continuous spectrum of emission of the black body with a discontinuous structure of energy made up of energy quanta (photons).

Photon with the minimum value of energy is produced in the infrared radiation at the minimum frequency of infrared (3×10^{12} GHz) and it has an energy $E = 1,24 \times 10^{-3}$ eV. According to our theory there isn't an energy smaller quantum.

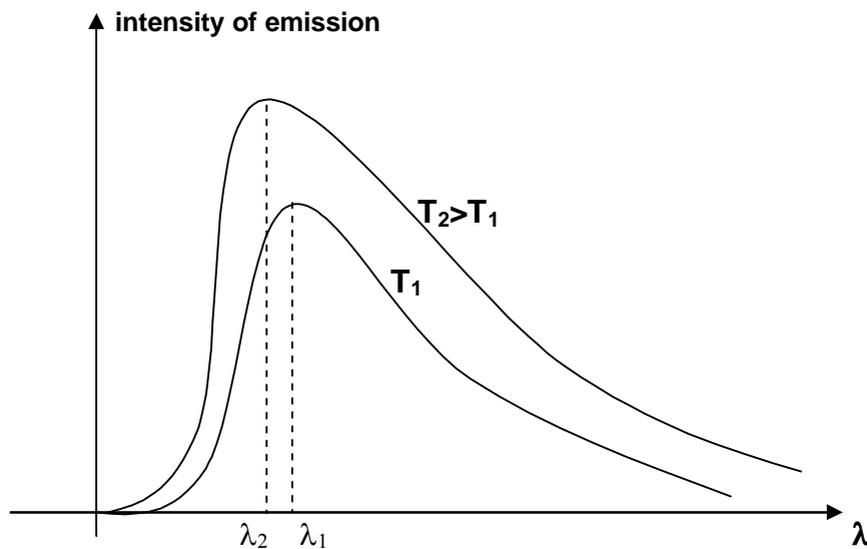


Fig. 3 Emission spectrum of the black body for two different temperatures in function of wavelength

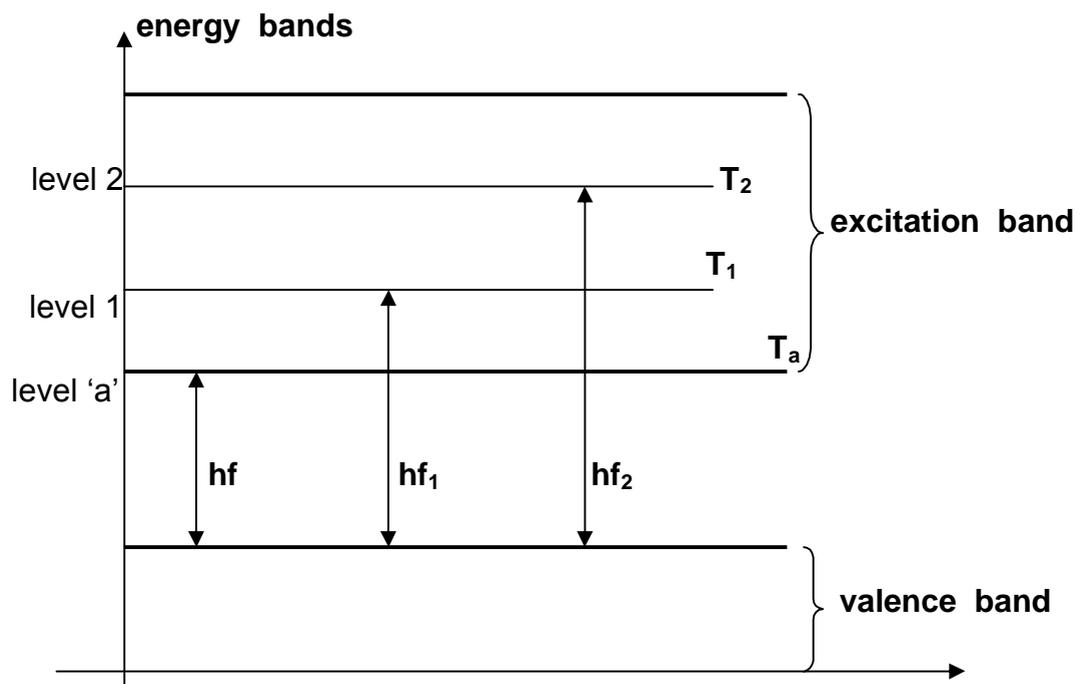


Fig. 4 Energy bands and excitation levels of the black body

4. Electron diffraction

Photon is a quantum of electromagnetic energy defined by Planck's relationship $E=hf$. We can fix an equivalence relation where an equivalent mass $m_p = hf/c^2 = h/\lambda c$ and an equivalent momentum $p_p = m_p c = h/\lambda$ are associated to photon. This equivalence doesn't change the nature of photon which is a quantum of electromagnetic energy and not a quantum of matter. Similarly electron is a quantum of electrodynamic matter^[2] with mass m_0 and momentum $p = m_0 v$ to which according to De Broglie's idea an equivalent photon with wavelength $\lambda = h/p = h/m_0 v$ can be associated. Also for electron this equivalence doesn't change the nature of electron which is a quantum of electrodynamic matter (leptonic particle) and not a energy quantum.

All photons have the same speed of light and their wavelength doesn't depend on speed but only on the nature of radiation: the wavelength of photons varies from the maximum value (1mm for infrared) to the minimum value (0,1-0,01 Angstroms for X-radiation). In De Broglie's equivalence the electron wavelength depends instead on the speed of electron: it is infinite at rest, is 0,024 Angstroms at the speed of light and 0,24 Angstroms at the speed $v=0,1c$: this proves that the wavelength isn't an intrinsic property of electron as it occurs for photon.

The discovery of electron diffraction in the 1927 year by Davisson-Germer in USA and by Thomson in England proved the wave nature of electron and the validity of De Broglie's idea only because at the time diffraction was supposed an exclusive property of waves. In our theory of diffraction based on the Fourier integral diffraction isn't an exclusive property of waves but also a corpuscle beam (photons, particles) can produce diffraction. In order to explain the electron diffraction it isn't necessary therefore to suppose that the electron has wave nature. Electron is a quantum of electrodynamic matter so photon is a quantum of electromagnetic energy and the two quanta are physically different but the formulation of an equivalence relation between the two quanta can be useful in some circumstances in order to explain better some physical situations.

References

- [1] D. Sasso, On the physical structure of radiant energy: waves and corpuscles, viXra.org, 1009.0073, 2010
- [2] D. Sasso, Dynamics and Electrodynamics of moving real systems in the theory of reference frames, arXiv.org, 1001.2382, 2010