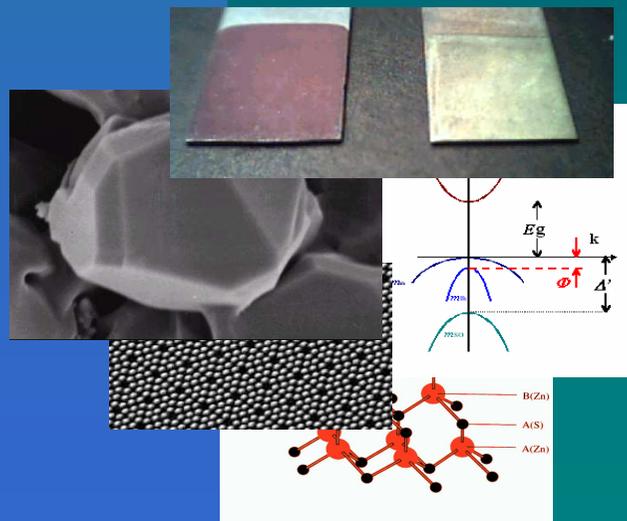


# *Propiedades Ópticas de Materiales: Introducción*



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# Motivación

APPLIED PHYSICS REVIEWS 1, 010402 (2014)



## Editorial: Some reflections on applied physics

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### I. INTRODUCTION

On the occasion of the *Applied Physics Reviews* (APR) as a stand-alone journal, I would like to look back on the history of the discipline and as an organizing principle and scholarly publication. When the term for centuries, an *Anglo-Saxon* corpus of English texts shows that it appears around 1830. The equivalent French (*angewandte Physik*, physics) at least to the beginning of the 19th century, the evolution of the ratio of the p

### III. INTERDISCIPLINARITY

As remarked above, when physics moves beyond its conventional boundaries, and gets used in other fields of science, it is often considered "applied." The obvious examples are the wealth of tools for visualization or spectroscopy physics has provided for other sciences, but just as important are new applications of physical concepts. The field of materials science is an excellent illustration. As a field, materials science is intrinsically interdisciplinary.<sup>3</sup> Its roots are in physics, chemistry, many of the engineering disciplines (mechanical, mining, metallurgical, chemical), and, increasingly, biology.

# Aplicación de Conceptos

Table 14.2. Practical relevance of the subjects considered in this book

Subject in this book	Section	Relation to thin film practice
Drude's formula	3.1	Free electron contribution to the linear optical constants (for example metal films, highly doped semiconductor films)
Lorentzian oscillator model	3.2	Bound electron contribution to the linear optical constants in the vicinity of a single absorption line, or lattice vibrations
Multioscillator model	4.3	Complicated absorption structures, caused by bound electrons or lattice vibrations Inhomogeneous line broadening
Sellmeier- and Cauchy formulae	4.4	Refractive index dispersion in transparency regions
Mixtures	4.5	Role of film contaminations (extrinsic absorption) Surface roughness with high spatial frequency Columnar film structure, large voids in evaporated coatings Simple treatment of optical anisotropy in terms of depolarisation factors Thermal shifts Subnanometer voids in coatings, produced by ion-assisted methods Properties of composite film materials

O. Stenzel,  
*The Physics of Thin Film Spectra, An introduction*  
Cap. 14

Kramers-Kronig-Relations	5	Sum rules for quantitative spectroscopy
Fresnel's equations	6	Interface reflections Polarization effects at oblique incidence Propagating surface plasmon polaritons at metal surfaces
$T$ and $R$ for thick slabs	7.1; 7.4.4	Optical properties of possibly absorbing substrates at any angle of incidence
$T$ and $R$ for thin films	7.2-7.4	Forward and reverse search for a single film on a surface or substrate
Mathematical treatment of refractive index gradients	8.1	Gradient index layers Rugate filters
Matrix formalism	8.2; 9.1	Multilayer coatings
Selection rules	10.4	Interpretation of optical spectra
Semiclassical treatment of the dielectric function	11; 12	Intrinsic thermal shifts Shape of the absorption edge in crystalline films (evaporation) Size effects Shape of the absorption edge in amorphous films (ion-assisted deposition)
Nonlinear susceptibilities	13	Nonlinear refraction at high laser intensities Nonlinear absorption at high laser intensities

# *Motivación*

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## **Preface to the First Edition**

This book is about the way light interacts with solids. The beautiful colours of gemstones have been valued in all societies, and metals have been used for making mirrors for thousands of years. However, the scientific explanations for these phenomena have only been given in relatively recent times. Nowadays, we build on this understanding and make use of rubies and sapphires in high power solid-state lasers. Meanwhile, the arrival of inorganic and organic semiconductors has created the modern opto-electronics industry. The onward march of science and technology therefore keeps this perennial subject alive and active.

M, Fox

*Optical Properties of Solids*

# Ondas Electromagnéticas (en el vacío: $n = 1$ )

$$\left| \vec{E} \right| \propto \exp[\pm i(kz - \omega t)]$$

Unidades :

$$[\nu] \rightarrow \text{Hz}, \text{kHz}, \text{MHz}, \text{GHz}, \text{THz};$$

$$[\lambda] \rightarrow \text{\AA}, \text{nm}, \mu\text{m}, \text{m}; \lambda = \frac{c}{\nu} \Rightarrow \lambda[\text{nm}] = 3 \times 10^{17} / \nu[\text{Hz}];$$

$$\text{Energía del Fotón} \rightarrow E = h\nu = \frac{hc}{\lambda}$$

$$\text{Constante de Planck : } h = 6.626 \times 10^{-34} \text{ Js}$$

$$h\nu[\text{eV}] = \frac{hc}{e \lambda} = \frac{1240}{\lambda[\text{nm}]}; e = 1.602 \times 10^{-19} \text{ As}$$

$$\text{Número de Onda : } \tilde{\nu}[\text{cm}^{-1}] \equiv \frac{1}{\lambda[\text{cm}]} = \frac{1}{100\lambda[\text{m}]} = \frac{10^7}{\lambda[\text{nm}]}$$

$$c = \frac{\omega}{k} = \nu\lambda = \frac{\lambda}{T}$$

$c \cong 3 \times 10^8 \text{ m/s}$  → velocidad de la luz en el vacío.

$k = \frac{2\pi}{\lambda}$  → "Vector" de Onda;  $\lambda$  → Longitud de Onda.

$$\omega = 2\pi\nu = \frac{2\pi}{T}; \nu \rightarrow \text{Frecuencia Óptica}$$

# Ondas Electromagnéticas (en el vacío: $n = 1$ )

$$\vec{E} \propto \exp[\pm i(kz - \omega t)]$$

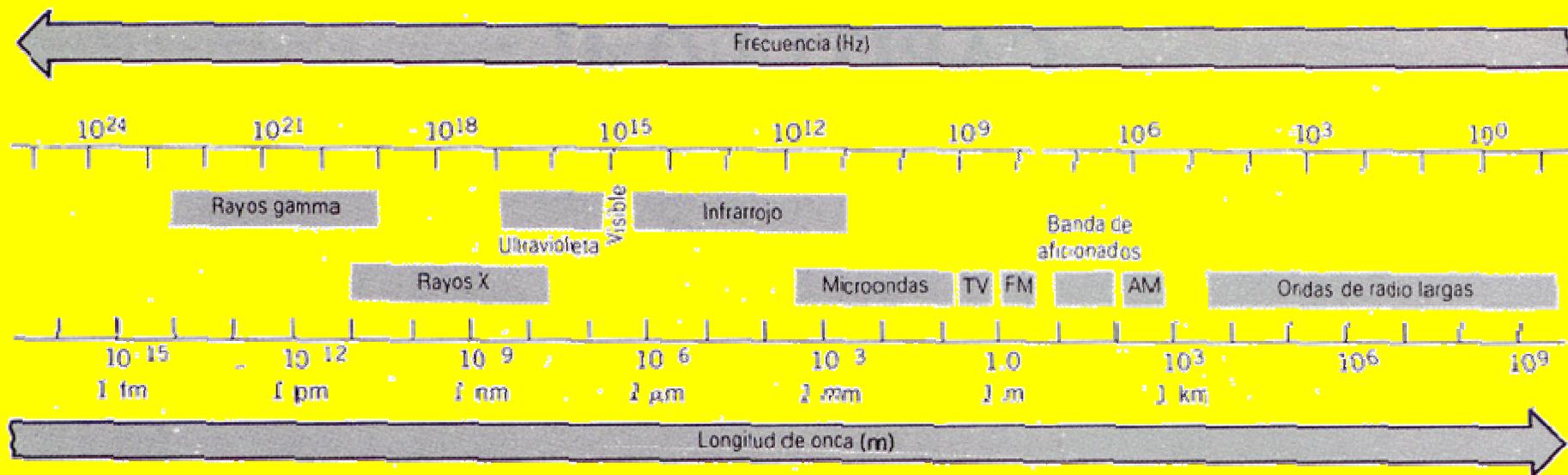
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# Origen Interacción Radiación - Materia

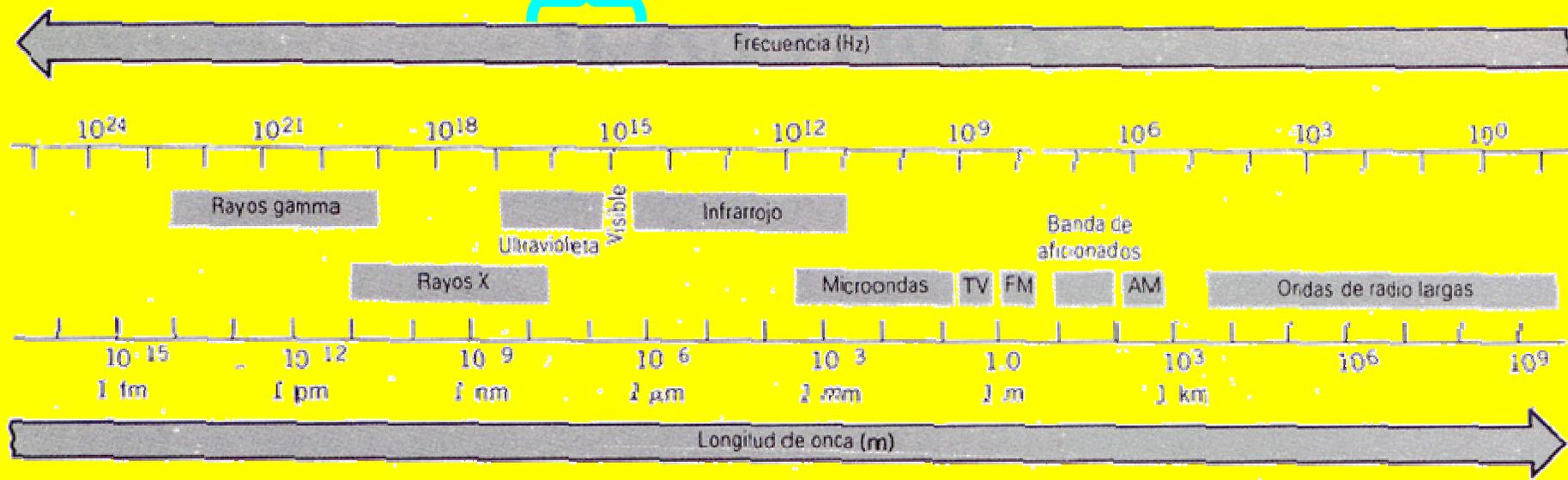
Excitación  
Electrones  
“Core”

Excitación Electrones  
“Valencia”

Vibracionales

Orientación

Portadores Libres



# Origen Interacción Radiación - Materia

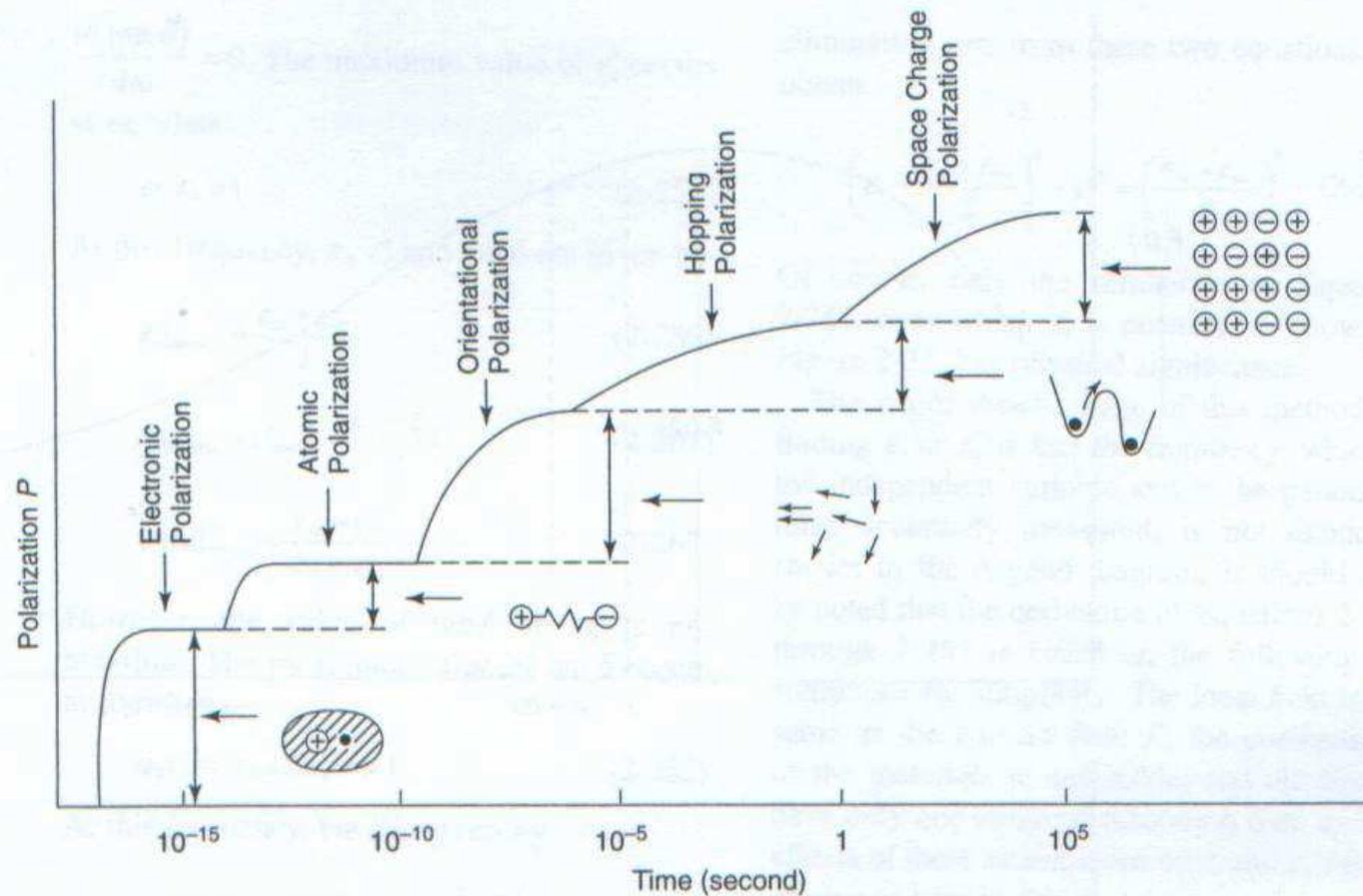


Figure 2-27 The variation of different types of polarization with time under a step-function electric field  $F$ .

# Origen Interacción Radiación - Materia

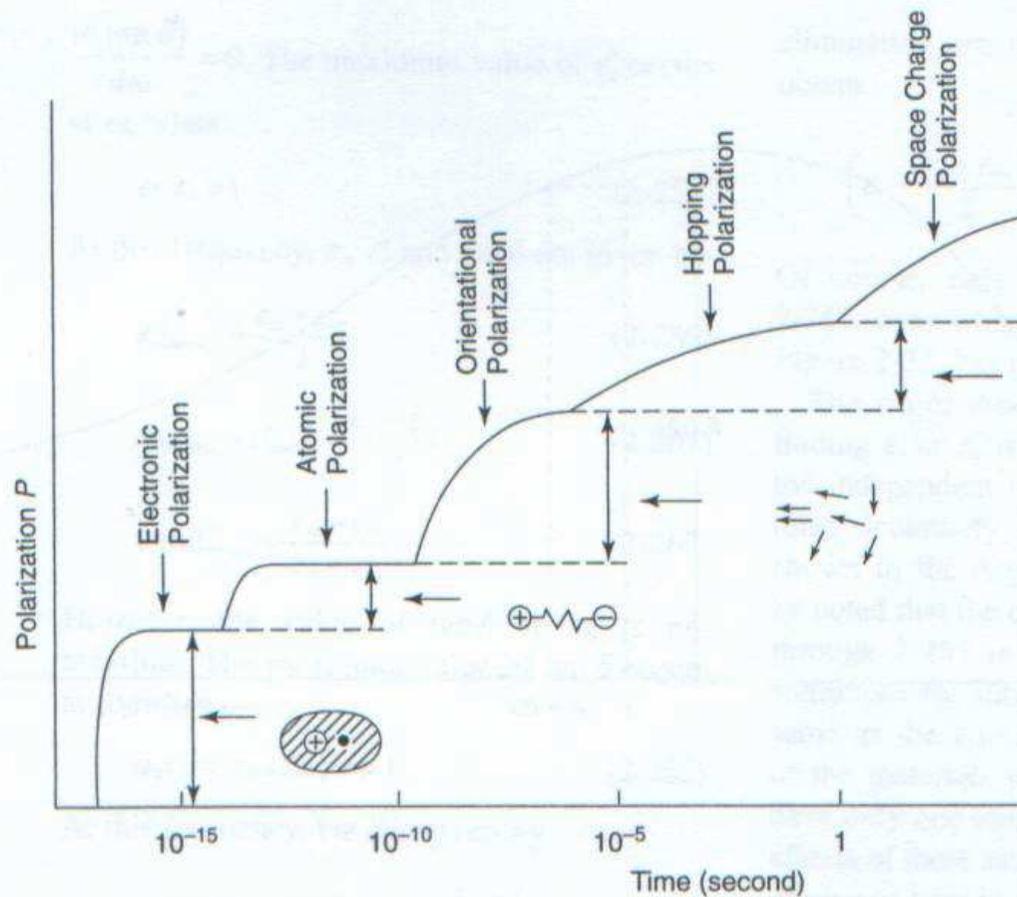


Figure 2-27 The variation of different types of polarization with time under a step-function

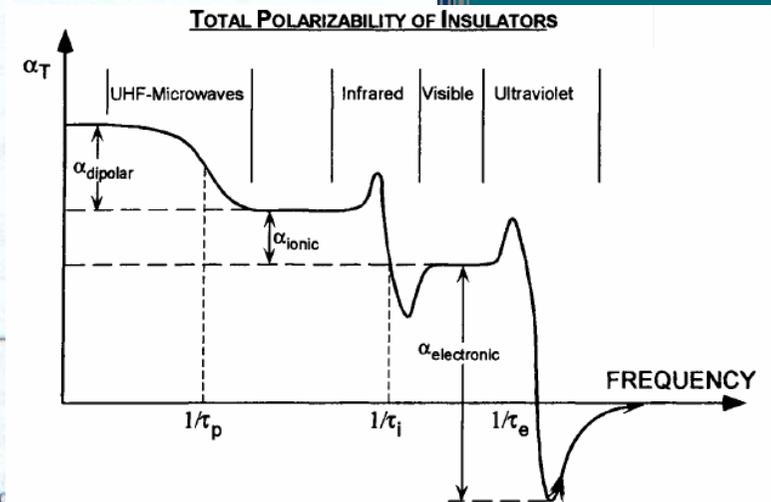


Figure 3.1: Components of the total polarizability of insulators (after Hecht 1998).

# Origen Interacción Radiación - Mater

**Table 3.3.** Overview on spectral regions. The wavelength (and related) data may slightly differ in different sources

spectral re- gion	vacuum wave- length $\lambda$ nm	wavenumber $\nu$ $\nu = 1/\lambda$ $\text{cm}^{-1}$	angular frequency $\omega$ $\omega = 2\pi\nu c$ $\text{s}^{-1}$	origin of absorption (examples)
Far Infrared <b>FIR</b>	$10^6$ – $5 \times 10^4$	10–200	$1.9 \times 10^{12}$ – $3.8 \times 10^{13}$	free carriers; orientation
Middle Infrared <b>MIR</b>	$5 \times 10^4$ – $2.5 \times 10^3$	200–4000	$3.8 \times 10^{13}$ – $7.5 \times 10^{14}$	free carriers; vibrations
Near Infrared <b>NIR</b>	$2.5 \times 10^3$ – $8 \times 10^2$	4000–12500	$7.5 \times 10^{14}$ – $2.4 \times 10^{15}$	free carriers; vibrational overtones
Visible <b>VIS</b>	$8 \times 10^2$ – $4 \times 10^2$	12500–25000	$2.4 \times 10^{15}$ – $4.7 \times 10^{15}$	excitation of valence
Ultra-violet <b>UV</b>	$4 \times 10^2$ –10	25000– $10^6$	$4.7 \times 10^{15}$ – $1.9 \times 10^{17}$	electrons
X-ray <b>X</b>	10–0.005	$10^6$ – $2 \times 10^9$ (unusual)	$1.9 \times 10^{17}$ – $3.8 \times 10^{20}$	excitation of core electrons

**Table 10.2** Summary of Absorption Mechanisms

Spectral Region	Type of Absorption	References
Microwave > 1 mm	Debye relaxation in polar matter	Debye (1929)
	Electron energy splitting in rare earth ions	Hadni (1970a)
Far infrared ~ 1 mm (1000 $\mu\text{m}$ ) to ~ 100 $\mu\text{m}$	Phonon-difference processes	Hadni (1970b)
	Superconducting band gap	Tinkham (1970b)
	Defect-induced vibrations	Genzel (1969)
	Impurity-induced vibrations	McCombie (1970)
Infrared ~ 100 to ~ 2 $\mu\text{m}$	Intramolecular vibrations	Sherwood (1972)
	Intermolecular vibrations	Sherwood (1972)
	<i>Reststrahlen</i> absorption in ionic crystals	Mitra (1969); Plendl (1970)
	Two-phonon and multiphonon processes	Bendow (1978)
	Magnetic excitation in magnetic insulators	Tinkham (1970a)
	Intraband electron transitions in metals	Nilsson (1974); Glicksman (1971)
	Free carriers in semiconductors	Dixon (1969); Moss (1959)
	Electron states of impurities	McClure (1959b); Burns (1970)
	No-phonon lines and phonon sidebands	Silsbee (1969); Rebane (1974)
	No-magnon lines and magnon sidebands	McClure (1974)
Near visible ~ 2 $\mu\text{m}$ to ~ 3000 $\text{\AA}$	Electron defect states (color centers)	Markham (1966)
	Transition-metal-ion energy levels	DiBartolo (1974); Crosswhite and Moos (1967)
	Electron band gaps in semiconductors	Harbeke (1972)
	Electron band tailing in amorphous semiconductors	Tauc (1972)
Far ultraviolet ~ 3000 to ~ 500 $\text{\AA}$	Exciton bands (single and series)	Nikitine (1969); Reynolds (1969)
	Band-to-band transitions of electrons	Phillips (1966)
	Molecular electron transitions	McClure (1959a)
	Electron plasma oscillations in metals	Steinmann (1968); Glicksman (1971)
Extreme ultraviolet, soft x-ray ~ 500 to ~ 20 $\text{\AA}$	Core electron transitions	Brown (1974)

# Origen Interacción Radiación - Materia

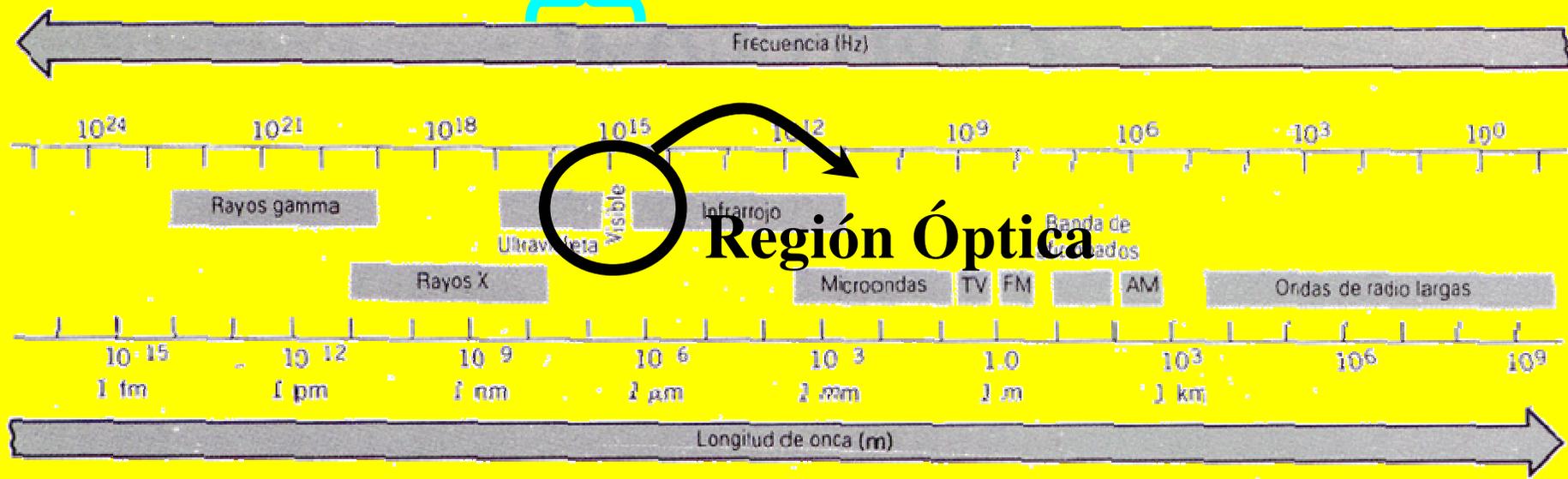
Excitación  
Electrones  
"Core"

Excitación Electrones  
"Valencia"

Vibracionales

Orientación

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# Regiones del Espectro “Óptico”

Región  
Espectro  
“Visible”

Color	Wavelength (nm)	Frequency (THz)	Energy (eV)
Ultraviolet*	10–400	750–30,000	3.1–12
UV-C*	10–280	1,000–30,000	4.4–12
UV-B*	280–320	940–1,000	3.9–4.4
UV-A*	320–400	750–940	3.1–3.9
Violet	390–455	660–770	2.7–3.2
Blue	455–492	610–660	2.5–2.7
Green	492–577	520–610	2.15–2.5
Yellow	577–597	500–520	2.08–2.15
Orange	597–622	480–500	2.00–2.08
Red	622–780	384–480	1.6–2.00
Infrared*	780–10,000	30–384	0.1–1.6

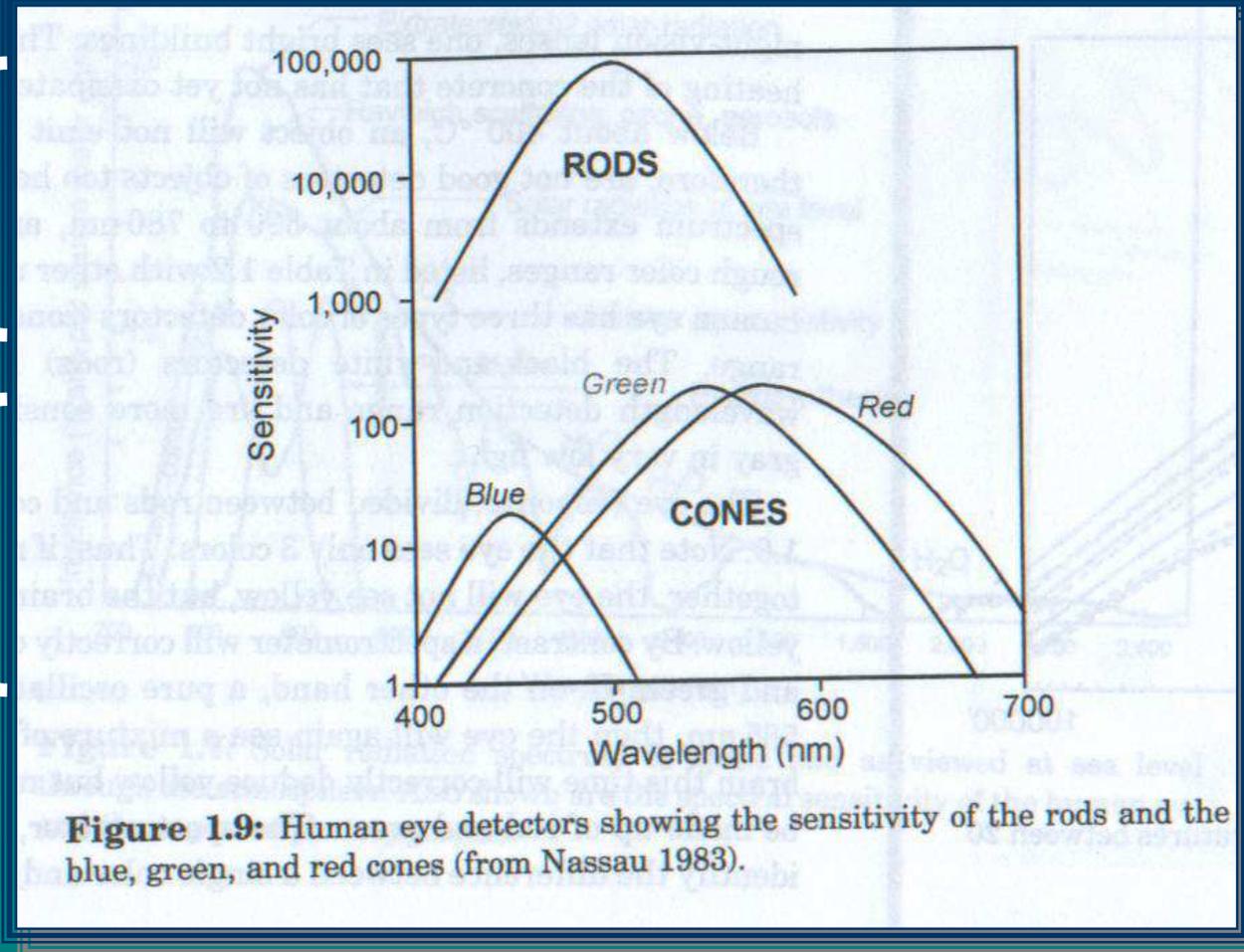
\* Outside the visible range.

**Table 1.2:** Approximate range of values for various colors.

# *Respuesta Espectral del Ojo (Primer Instrumento Óptico)*

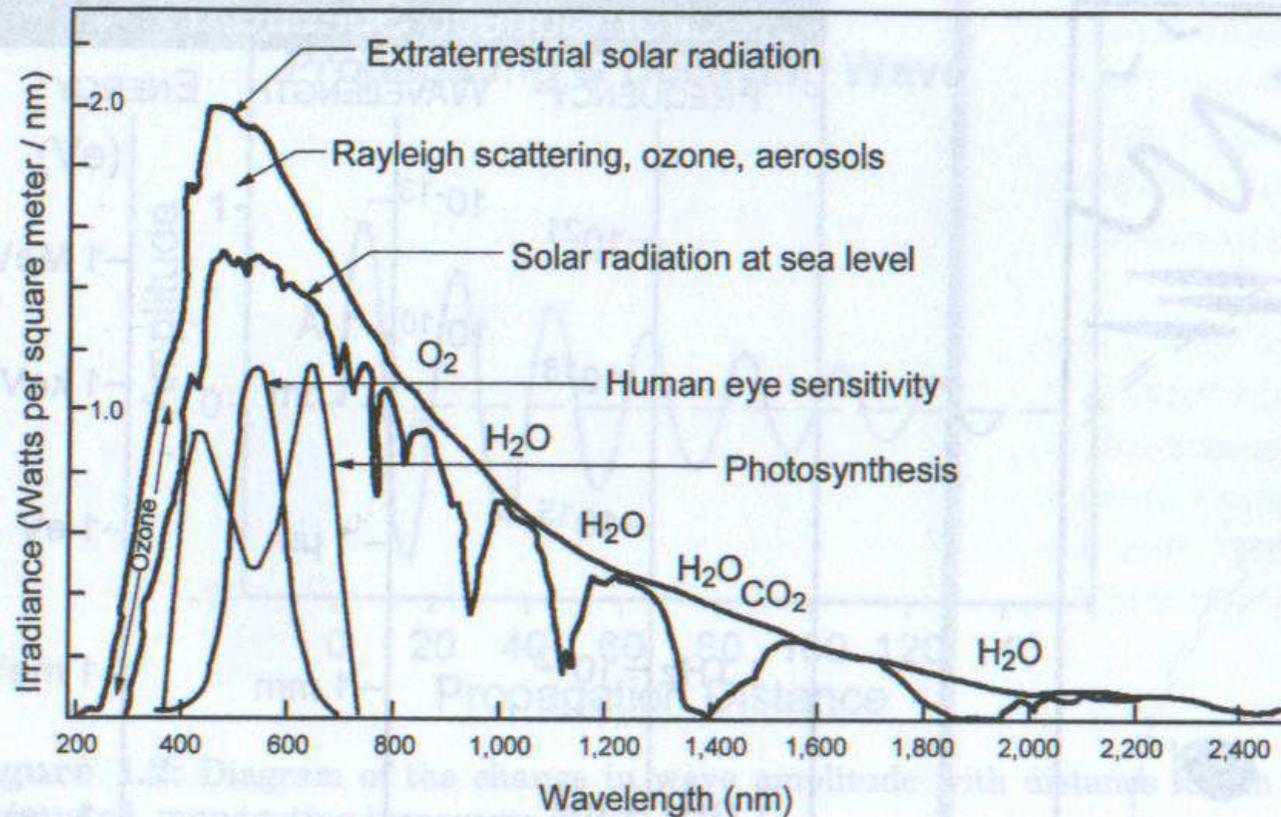
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Detector  
Óptico

Espectrómetro  
Rudimentario



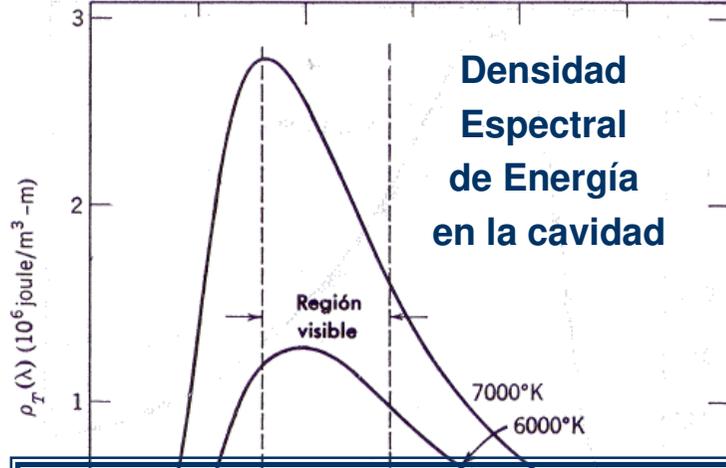
*Color ≠ Longitud de Onda*

# *Respuesta Espectral del Ojo (Ajustada a Espectro Solar)*



**Figure 1.7:** Solar radiation spectrum in space and as viewed at sea level through the atmosphere. Also shown are the spectral sensitivity of the human eye and the region of photosynthesis.

# Emisión de Cuerpo Negro o Radiación Térmica.



Temperature (°C)	Maximum-emission wavelength, $\lambda_m$	Perceived color
20,000–40,000	70–143 nm	Blue-white
6,000	462 nm	White (daylight)
5,700	485 nm	White
2,500	1.045 $\mu\text{m}$	Yellow (incandescent lamps)
1,600	1.547 $\mu\text{m}$	Orange
400	4.305 $\mu\text{m}$	Red
100	7.768 $\mu\text{m}$	IR (invisible)
37	9.348 $\mu\text{m}$	IR (invisible)
20	9.890 $\mu\text{m}$	IR (invisible)

Table 1.1: Equivalent temperatures for black-body radiation.

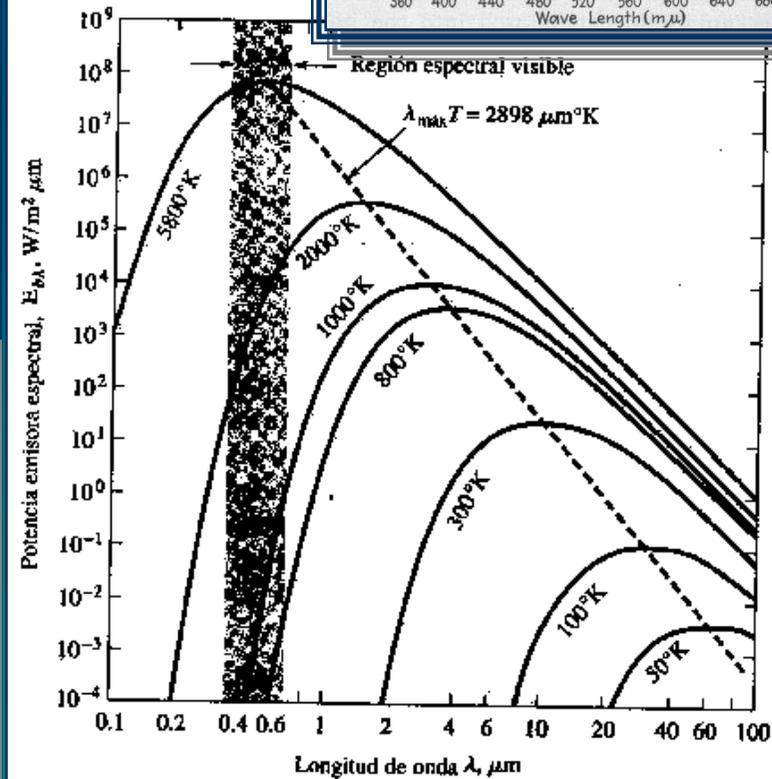


FIGURA 9 Potencia emisora monocromática de un cuerpo negro.