Optics – The physics of light

Light is a complex phenomenon and there are essentially four models that can be used to describe and explain it and to predict its behavior.

- Light as rays (ray optics or geometrical optics)
- Light as waves (electromagnetic radiation)
- Light as particles (energy particles or photons)
- Light as radiant energy

The different light models are not contradictory, but complement each other perfectly

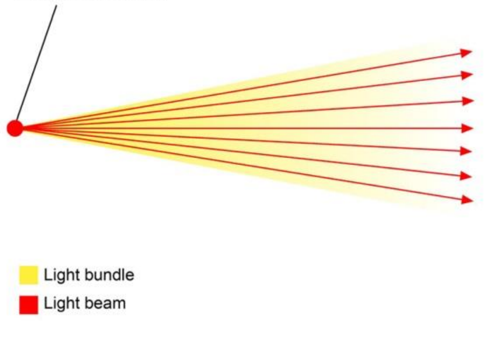
These four models describe the physical properties of light as exact laws of nature and are by no means self-contradictory. Which model or which theory is given preference depends on the conditions under which the properties of light are considered or on phenomena that are of particular interest to the observer.

Optical lenses for cameras, for instance, can be designed using precise calculations based on the laws of geometrical optics (light as rays). However, to achieve the sharpest image, the wave character of light must also be taken into account. This is because even though the bulk of the light passes through the lens in a straight line as a bundle of rays, diffraction phenomena occur additionally at the edges of the lens diaphragm, producing a fuzzy supplementary image. The lens maker will therefore base design calculations on the laws of geometrical optics, but will optimize light intensity and aperture range by additionally applying the laws of wave optics.

It is a similar picture with the particle character of light. If, for example, you consider the propagation of light in solid bodies, this can be simply described in terms of the interaction between the electromagnetic wave and the electron shells of the atoms. However, the particle character of light provides a precise explanation if you want to know why a portion of the light is always “swallowed” in solid bodies. The light energy is ultimately converted into phonons, i.e., heat, through impacts of the photons with the lattice vibrations of the solid body.

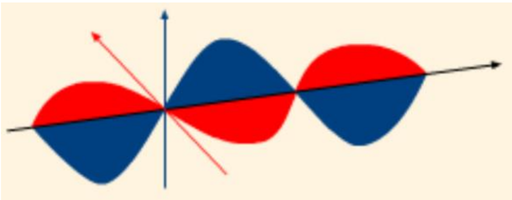
Ray optics

Ray optics is based on the assumption of the rectilinear propagation of light, i.e., in accordance with the laws of geometry. Changes in the direction of the light due to refraction are always at defined angles. This subbranch of optics is therefore also known as “geometrical optics”.



This model is well suited for describing phenomena such as the formation of shadows, reflection, scattering, and refraction of light. At a practical level, ray optics is concerned with the path of light in optical elements such as mirrors, lenses, and prisms and their application in optical devices (microscope, telescope, camera, etc.).

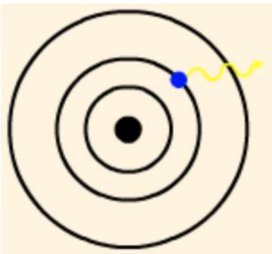
Wave optics



It can also be demonstrated on the basis of other physical investigations that light is made up of electromagnetic waves (transversal waves).

This property of light is apparent, for example, in wave optics according to Huygens' principle. This states that every point at which light impinges is the source of an elementary wave. The elementary waves advancing from each point are then superimposed to form new wave fronts. Phenomena such as the diffraction of light at narrow slits, interference, and polarization can be explained according to this wave model.

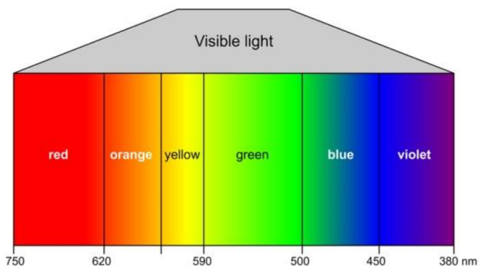
Quantum optics



This model makes it possible, for example, to interpret the light emanating from the sun as a constant flow of photons. The famous physicist Albert Einstein developed the idea of the particle nature of light in 1905.
According to the light quantum or photon model, light consists of a stream of portions of energy (photons) that behave like particles.

This particle behavior is manifested in the fact that in certain situations, light occurs only with particular wavelengths (= energy). The photo effect also demonstrates the energy particle character of light. Only light of a particular wavelength can release electrons from solid bodies. The particle and wave characters of light are not mutually exclusive, but complement each other. The term particle-wave dualism is therefore often used today to express this.

The energy character of light



Although light transports energy, it is not treated in physics as a separate energy form, but is classified as radiant energy and assigned to a subrange of the electromagnetic spectrum. Albert Einstein formulated the equation $E = h \cdot \nu$, whereby it is possible to determine exactly the energy possessed by photons of light with a particular frequency or wavelength.