Chapter 1
Origins and Development of Photon Science

1.1 Light in the Ancient and Modern Era

In the beginning, God said, "Let there be light," and there was light. God saw that the light was good. However, ever since the sixth day of the heavens and the earth, the human understanding of the nature of light has been keenly contested. The very earliest ideas are lost to history, no doubt influenced by natural phenomena such as sunlight, starlight, lightning, and fire. The first recorded thoughts on light were offered by the ancient Greeks. In the sixth century BCE, Pythagoras (570–495 BCE) reasoned that sight required visual rays to leave our eyes and shine upon an object. Expanding on this notion, the philosopher Empedocles (490–430 BCE) believed the eye to be composed of the four basic elements (water, earth, air, and fire), with the fire of the eye facilitating vision. An outcome of this notion is the ability to see in the dark; to counter this difficulty, Plato (428–348 BCE) supposed that the fire of the eye mixes with daylight to enable a link between man and the external world. Around 300 BCE, the mathematician Euclid (325–265 BCE) provided a geometric description of visual rays and proclaimed that "light travels in a straight line."[7] Much later, in 499 CE, the Indian astronomer Aryabhata (476–550) recognized that objects are seen by reflected light. In his virtually unknown work, he wrote that celestial objects do not shine through their own intrinsic effulgence but through the light from the Sun that they reflect.[8] The Arab mathematician and physicist Ibn Al-Haytham (965–1039) noted that extremely bright light injures the eye, and he concluded that "[…] light comes to the surface of the eye from the light of the visible object."[9]

In the early modern period, the philosopher and mathematician René Descartes (1596–1650) postulated the idea of luminiferous (light-bearing) aether, i.e., a medium for the propagation of light that is imperceptible by human senses. He suggested that the speed of light is infinite, traveling from one place to another in an instant;[10] however, in 1676, this idea was dispelled by the astronomer Ole Rømer (1644–1710), who estimated a finite speed of light by observing the eclipses of Jupiter's moon Io. Christiaan Huygens (1629–1695) and Robert Hooke (1635–1703) supported the idea of light as a vibratory motion of the aether, much like ripples propagating on the surface of water. However, most scientists around that time accepted the corpuscular theory of light advocated by Isaac Newton (1643–1727), primarily owing to the great reverence placed on Newton's accomplishments and the deficiencies of experimental apparatus in the 18th century. According to the theory of corpuscles, luminous objects eject tiny

particles of light that are governed by Newton's laws of motion. The color was thought to vary with its size, where red is the largest particle and violet the smallest. Although Newton accepted the concept of an aether, he did not believe that it acted as a medium for propagating light.

In 1801, the late modern period, Thomas Young (1773–1829) seemingly disproved the corpuscular theory of light with his two-slit experiment. As shown in Fig. 1, following the passage of a light beam through two parallel slits, the interference pattern (a series of light and dark patches) predicted by Huygens' principle is observed on the screen—not the two bands expected from the particle theory of light. Despite the importance of this experiment to modern physics, Young's contemporaries showed little interest in his work. However, within 50 years, the wave theory of light was generally accepted, mainly due to the extension of the theory by Augustine-Jean Fresnel (1788–1827).[11] He overturned the prevailing idea that light is a longitudinal wave, which greatly troubled Newton, by suggesting that the vibrations of light (in the aether) were transverse to the direction of propagation; a universally acceptable explanation of light polarization followed. Following the discovery of electromagnetic induction by Michael Faraday (1791–1867), it was realized by James Clerk Maxwell (1831–1879) that the propagation speed of electromagnetic waves and the speed of light—at the time, measured by the Fizeau–Foucault apparatus with reasonable accuracy—are very similar. He concluded in 1865 that "the agreement of the results seems to show that light and magnetism are affections of the same substance, and that light is an electromagnetic disturbance propagated through the field according to electromagnetic laws."[12] Identical to every major scientific figure that followed Descartes, Maxwell believed in an aether. However, the existence of such a "substance" was irrevocably dispelled by the experiment conducted by Albert Michelson (1852–1931) and Edward Morley (1838–1923) in 1887.

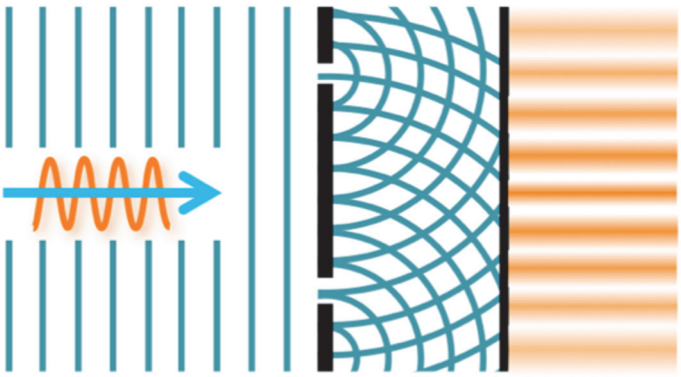

Figure 1 When light, in the form of a plane electromagnetic wave, passes through two slits in a screen, it diffracts and creates bright and dark fringes on a detector screen (screen and pattern shown on the right-hand side). The effect is commonly explained in terms of constructive and destructive interference of the diffracted wave at different positions.