

History Of Optics

HIMANSHU MALL

B.Sc. Physics Honours

27 Apr 2026

- Motivation
- Ancient World(Euclid and Ptolmey)
- Medieval Islamic Optics (Alhazen)
- Early Modern Europe
- 19th Century Breakthroughs
- Quantum Optics (20th Century Onward)

- By tracing the journey of optics from Euclid to quantum discoveries, I confirm that knowing the past is essential to understanding the future. Each milestone connects the dots across centuries, revealing how science grows through patience and vision. The dedication of countless scientists, who questioned, experimented, and persevered, inspires deep respect within me. Their hard work reminds us that progress is built on collective effort, not sudden leaps.

- / **Euclid's Optics (c. 300 BCE)** was the first systematic mathematical treatment of vision, introducing geometric principles to explain how we see. He proposed that straight visual rays emanate from the eye, forming a cone, and that the apparent size and position of objects depend on the angles of these rays. His work laid the foundation for perspective in art and influenced later scientists like Ptolemy, Alhazen, and Renaissance thinkers.
- Perspective: His propositions explain why distant objects look smaller, why parallel lines seem to converge, and why planes above or below the eye shift in appearance.
- **Ptolemy's Optics (2nd century CE)** was a landmark work that combined geometry with physical theories of light, addressing reflection, refraction, and vision. It built on Euclid's geometric optics but added experimental tables of refraction, making it one of the earliest systematic studies of how light behaves.

- Alhazen (Ibn al-Haytham, 965–1040 CE) revolutionized optics with his Book of Optics, rejecting the ancient idea that vision comes from rays emitted by the eye and proving instead that light enters the eye. His experimental approach, use of the camera obscura, and theories of reflection, refraction, and color laid the foundation for modern physics and influenced European science for centuries.
- The Book of Optics (Kitāb al-Manāir)
- Written between 1011–1021 CE in seven volumes.
- Main achievement: Established the intromission theory of vision—objects emit rays of light from every point on their surface, which enter the eye.
- Refutation of extramission theory: He argued against Euclid and Ptolemy's idea of rays leaving the eye, noting phenomena like eye damage from sunlight.

- Camera obscura: Described how light through a small aperture projects an inverted image, a precursor to modern photography.
- Alhazen's problem: A geometric challenge of determining the point on a spherical mirror where light reflects to the eye, later influencing Renaissance mathematics.

- **Galileo's** main contribution to optics was the improvement and use of the telescope(1609) for astronomical observation. He refined lens grinding, built telescopes with magnifications up to $30\times$, and used them to discover the moons of Jupiter, the phases of Venus, and the rough surface of the Moon — transforming both optics and astronomy.
- **Johannes Kepler (1571–1630)**
- Major Work: *Astronomiae Pars Optica* (1604).
- Retinal Imaging: First to explain that the eye forms a real, inverted image on the retina, like a camera obscura. This overturned medieval “species” theories of vision.
- Lens & Telescope Theory: Analyzed how convex and concave lenses form images, improving telescope design.
- Astronomical Applications: Applied optics to solar eclipses, planetary observations, and the geometry of light rays.

- Major Work: Opticks (1704).
- Prism Experiments: Demonstrated that white light is composed of seven spectral colors (red to violet). Showed colors could be recombined into white light.
- Corpuscular Theory: Proposed that light consists of particles (“corpuscles”), explaining reflection and refraction by forces acting on them.
- Diffraction (“Inflexion”): Studied how light bends around edges, though his particle model struggled to explain it fully.
- Queries: Speculative essays at the end of Opticks explored electricity, magnetism, and matter, influencing later science.

- Major Work: *Traité de la Lumière* (1690).
- Wave Theory of Light: Proposed that light propagates as waves through an ether, with each point on a wavefront acting as a source of secondary spherical waves (Huygens' Principle).
- Polarization & Double Refraction: Studied birefringence in Iceland spar, showing light had directional properties.
- Lens Design: Developed mathematical methods for reducing aberrations in telescopes, including the Huygenian eyepiece.

- Double-Slit Experiment (1801): Demonstrated interference of light, proving its wave nature against Newton's particle theory.
- Thin Film Colors: Explained soap bubble colors using interference.
- Wavelengths of Light: Estimated wavelengths of visible colors.
- Polarization: Proposed that light waves are transverse, not longitudinal.
- Vision & Color Theory: Introduced the three-color theory of vision (basis of RGB), later refined by Helmholtz.

- Diffraction: Gave the first satisfactory wave-based explanation of diffraction, confirming rectilinear propagation of light.
- Polarization: Showed light is a transverse wave, explaining polarization phenomena.
- Interference Devices: Invented the Fresnel biprism to produce interference fringes.
- Fresnel Lens (1820s): Designed stepped lenses for lighthouses, dramatically increasing visibility and saving lives at sea.
- Poisson's Spot: His theory predicted a bright spot in a shadow, experimentally confirmed by Arago, cementing wave optics.

- Electromagnetic Theory (1865): Showed that light is an electromagnetic wave traveling at the speed of light.
- Maxwell's Equations: Unified electricity, magnetism, and optics into one framework.
- Prediction of Radio Waves: His equations implied other electromagnetic waves beyond visible light.
- Color Vision & Photography: Demonstrated additive color mixing (RGB) and produced the first color photograph (1861).
- Legacy: Einstein later said, "One scientific epoch ended and another began with Maxwell."

Michelson–Morley Experiment (1887) Theoretical Nexus

- Goal: Detect Earth's motion through the “luminiferous ether,” thought to be the medium for light waves.
- Method: Used a Michelson interferometer to compare light speed in perpendicular directions.
- Result: Found no difference — a “null result.”
- Impact: Disproved ether theories, leading directly to Einstein's special relativity (1905), which established the constancy of light speed in all frames of reference.

- Blackbody Radiation Problem: Classical physics predicted the “ultraviolet catastrophe.”
- Solution: Planck proposed that energy is emitted in discrete packets (quanta), $E=h\nu$
- Impact: This radical idea introduced the concept of quantization, laying the foundation for quantum theory.

- Photoelectric Effect (1905): Showed that light consists of particles (photons), each carrying energy $E=h\nu$
- Wave-Particle Duality: Demonstrated that light behaves both as a wave and a particle.
- Stimulated Emission (1917): Predicted that atoms could be induced to emit photons coherently — the principle behind lasers.
- Legacy: Einstein's work transformed Planck's quantum hypothesis into a full theory of light quanta.

- Heisenberg, Schrödinger, Dirac: Developed the mathematical framework of quantum mechanics.
- Light-Matter Interaction: Quantum mechanics explained absorption, emission, and scattering of photons.
- Quantum Electrodynamics (QED): Dirac and later Feynman unified quantum mechanics with electromagnetism, describing photons and electrons with unprecedented accuracy.

- Theodore Maiman: Built the first working laser using a ruby crystal.
- Principle: Based on Einstein's stimulated emission, lasers produce coherent, monochromatic, and highly directional light.
- Applications: Medicine (surgery, eye correction), communication (fiber optics), industry (cutting, welding), entertainment (CD/DVD, holography).

- Quantum Coherence & Entanglement: Study of how photons can be correlated across space and time.
- Squeezed Light: Reducing quantum noise in one property of light at the expense of another, useful in precision measurements (like LIGO detecting gravitational waves).
- Quantum Communication: Using entangled photons for secure communication (quantum cryptography).
- Quantum Computing: Photons as qubits in optical quantum computers.
- Quantum Metrology: Ultra-precise measurements using quantum states of light.



Thank you for your attention

Himanshu Mall
mallhimanshu051@gmail.com