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Illuminating Asia

The Science of Light Across Civilisations

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This ten-part series in VIGYAN 2047 traces the journey of light from Indian and Asian civilisational thought to modern scientific understanding, advanced technologies, and future possibilities. Bridging heritage with optics and photonics, it highlights light as a unifying force of knowledge and innovation. ***VIGYAN 2047*** *is honoured to present this series on the science of light and its vast applications.*

— Editor

The human quest to understand light is among the oldest and most universal scientific endeavours. Yet this quest has never progressed along a single, linear path, nor has it belonged to one civilisation alone. Instead, the science of light evolved through a long continuum of observation, experimentation, and conceptual refinement across Asia—shaped by land routes and maritime networks that connected distant cultures of the world, especially Egypt in Africa, Greece in Europe, and West Asia, Central Asia ana South-East Asia in the Asian continent. From the Indian subcontinent to Central Asia, China, Southeast Asia, and the Islamic world, light was studied as illumination, perception, energy, and cosmic regulator. Together, these traditions laid much of the intellectual and practical groundwork for modern optics.

In early Indian thought, light (*jyoti, tejas, prakāśa*) occupied a foundational position in understanding nature. The Vedic worldview placed light at the heart of *rta*, the cosmic order governing regularity and balance. The daily motion of the Sun structured time, while seasonal changes in solar illumination regulated agriculture, ritual calendars, and social rhythms. The Sun (*Sūrya*) was repeatedly described as the “eye of the universe,” an expression that fused symbolism with physiological insight—vision depends on illumination. Fire (*Agni*), the terrestrial form of light, revealed another crucial property: transformation. Through controlled fire, early observers encountered melting, combustion, and chemical change, making light inseparable from material processes. These experiences ensured that light was not merely revered but consistently observed and manipulated.

While similar solar-centred cosmologies existed in Mesopotamia and Egypt, Indian thought distinguished itself by encouraging inquiry. Light was not confined to divine agency; it became an object of questioning. This intellectual shift became clearer in the Upanishadic period, when reflection turned toward perception itself. Texts such as the *Brhadāraryaka Upanishad* ask what enables sight when external sources of illumination are absent. Though expressed philosophically, such questions reveal a proto-scientific concern with the conditions of visibility—an issue that would later lie at the heart of optical science.

As Indian philosophy matured, schools such as *Nyāya* and *Vaiśeṣika* approached vision analytically. They asked how the eye perceives distant objects, why reflection occurs, and why light is indispensable for sight. Some thinkers proposed that subtle rays emanate from the eye, while others stressed the necessity of external illumination. Comparable debates took place in ancient Greece, where Euclid and Plato supported emission theories and Aristotle favoured intromission. The significance of these Indian discussions lies not in their eventual resolution but in their framing of vision as a natural, law-governed process, subject to geometry and interaction rather than mysticism.

A decisive transition toward classical optics occurred with the rise of mathematical astronomy. Light now became central to explanation rather than metaphor. This shift is most clearly embodied in the work of Aryabhata (476–550 CE). In the *Āryabhatīya,* Aryabhata explained solar and lunar eclipses as shadow phenomena produced by precise geometric alignments of the Sun, Earth, and Moon. Such explanations presuppose rectilinear propagation of light, predictable shadow formation, and spatial geometry—principles fundamental to geometrical optics. His assertion that the apparent motion of celestial bodies arises from the Earth's rotation further refined the relationship between light, motion, and perception, anticipating later discussions in global astronomy.

Simultaneously, Central Asia—particularly regions such as Bactria, Sogdia, and Transoxiana—emerged as dynamic intellectual crossroads. These areas synthesised Indian astronomical models, Greek geometry, and Persian observational traditions. Scholars refined calendrical calculations, observational instruments, and eclipse predictions, transforming inherited ideas into more precise tools. The Silk Road thus functioned not only as a commercial artery but also as a scientific corridor, transmitting optical concepts across continents.

Parallel developments unfolded in China, where light was understood through the complementary forces of *yin* and *yang*. Unlike purely speculative cosmologies, Chinese science emphasised long-term empirical observation. Chinese scholars maintained some of the world's longest continuous astronomical records, documenting eclipses, comets, halos, and atmospheric optical effects over millennia. Light in the sky was measured, dated, and correlated with seasonal and terrestrial changes, forming a systematic observational science.

One of the most remarkable early contributions to optics comes from Mozi (5th century BCE), whose writings describe the camera obscura. Mozi observed that light passing through a small aperture produces an inverted image—demonstrating an implicit understanding of rectilinear propagation. Similar ideas would later appear in Greek optics and, centuries afterward, in Ibn al-Haytham's experiments, suggesting independent yet convergent discovery of optical principles.

By the Han dynasty, Chinese scholars employed gnomons and shadow-measuring devices to determine solstices, equinoxes, and the length of the year. These methods closely parallel those used in India and the Mediterranean world, reflecting convergent evolution driven by shared practical needs—timekeeping, agriculture, and navigation. Chinese bronze mirrors further demonstrate mastery of reflective optics. Some were engineered to project patterns when sunlight reflected from them, revealing sophisticated control of surface geometry and light behaviour.

As Chinese knowledge moved southward, it encountered the maritime cultures of Southeast Asia. Here, light became central to navigation and environmental understanding. Seafarers relied on solar altitude, star paths, sky brightness, and water reflections to traverse open seas shaped by monsoons. Such practices demanded acute awareness of atmospheric optics—glare, scattering, and horizon illumination—acquired through cumulative experience rather than formal theory.

Monumental architecture across Southeast Asia reveals another applied dimension of optical knowledge. Structures such as Angkor Wat were designed with precise solar alignments, allowing sunlight to illuminate specific architectural features on solstices and equinoxes. Similar alignments appear in temples across Java and mainland Southeast Asia, embedding optical understanding into sacred space and ritual practice.

The maritime routes linking China, Southeast Asia, India, and the Middle East became powerful corridors of scientific exchange. Astronomical instruments, star charts, calendrical systems, and observational techniques travelled alongside spices, silk, and ceramics. These routes ensured continuity of optical knowledge even during periods when land routes were politically unstable.

This vast body of Asian knowledge entered a transformative phase in the medieval Islamic world during the 8th and 13th centuries during the Abbasid

Civilisation / Region	Time Period	Core View of Light	Understanding of Vision	Key Optical Phenomena Studied	Methods & Instruments	Notable Contributors / Texts
Early Egyptian Mythology	c. 2600 BCE	Light resulting from the eyes of the sun god "Ra".	Light due to opening of the eyes of sun god "Ra", and darkness when "Ra" closes its eyes	It is simply based on the Egyptian mythology	—	Egyptian Mythology books
Early Indian (Vedic–Upanishadic)	c. 1500–500 BCE	Light (*jyoti, tejas*) as cosmic order and life-giving energy	Vision dependent on illumination; early perception awareness	Day–night cycles, solar motion, fire, illumination	Naked-eye observation, fire, ritual instruments	Rigveda, Upanishads
Classical Indian (Astronomical–Philosophical)	c. 500 BCE–600 CE	Light as a physical phenomenon governed by geometry	Mixed emission–interaction ideas; vision requires light	Eclipses, shadows, reflection, atmospheric effects	Gnomons, shadow measurement, geometry	Aryabhata (*Āryabhatīya*), Varahamihira (*Brhat Samhitā*)
Ancient Greek	c. 500 BCE–300 CE	Light as rays or emanations	Strong emission theories (eye emits rays); later intromission	Reflection, perspective, basic geometry	Geometrical reasoning, mirrors	Euclid (*Optics*), Plato, Aristotle
Chinese (Early to Classical)	c. 500 BCE–1000 CE	Light–dark balance (*yin–yang*); natural process	Vision via light entering the eye (implicit)	Image inversion, shadows, atmospheric optics	Camera obscura, gnomons, mirrors	Mozi (*Mo Jing*), Han astronomers
Central Asian (Silk Road Regions)	c. 300 BCE–800 CE	Synthesis of Indian, Greek, Persian ideas	Practical vision models	Eclipse prediction, celestial illumination	Observatories, instruments, computation	Sogdian, Persian intermediaries
Southeast Asian (Maritime Cultures)	c. 500–1500 CE	Light as navigational and ritual guide	Practical perception-based understanding	Solar alignment, glare, sky brightness	Solar navigation, architecture	Angkor Wat planners, maritime traditions
Islamic Golden Age	c. 800–1300 CE	Light as a physical entity governed by laws	Vision occurs when light enters the eye	Reflection, refraction, lenses, image formation	Controlled experiments, camera obscura	Ibn al-Haytham (*Kitāb al-Manāzir*)
Early Modern Europe	c. 1300–1700 CE	Light as wave/ray phenomenon	Intromission fully accepted	Refraction, lenses, telescopes	Optics instruments, mathematics	Kepler, Descartes, Newton
Modern Europe	(17th – 19th Century CE)	Electromagnetic Spectrum; Blackbody Radiation Experiment; Photoelectric Effect	Failure of Wave Theory in explaining Blackbody Radiation Experiment and Photoelectric Effect	Emission Spectrum of Blackbody Radiation; Experiments on Photoelectric Effect	Sophisticated experimental observations	Heinrich Hertz and other scientists
Modern Europe	(1900 CE onwards)	Quantum Nature of Light; Development of Quantum Mechanics from 1925 CE onwards	Light having dual nature – wavelike and particle-like properties	Theoretical developments in Quantum Mechanics	—	Max Planck; Albert Einstein; Niels Bohr; Erwin Schrödinger; Werner Heisenberg; PAM Dirac; Richard Feynman
Modern India (Quantum Era)	20th century	Light as quantum (photon) + wave	Vision understood physically and biologically	Light–matter interaction, scattering	Spectroscopy, experiments	Bose, C. V. Raman

Aryabhata (476–550 CE)

Geometry, Shadows, and the Birth of Classical Optical Reasoning

Aryabhata marks one of the earliest moments when light was treated as a geometrically predictable physical phenomenon. In his seminal work, the Āryabhatīya, he explained solar and lunar eclipses as shadow effects arising from precise alignments of the Sun, Earth, and Moon—rejecting mythological explanations.

This explanation implicitly assumes:

- Rectilinear propagation of light
- Predictable shadow formation
- Spatial geometry governing illumination

Aryabhata's assertion that the apparent motion of the heavens results from the rotation of the Earth further refined the relationship between light, motion, and perception. Though he did not write a formal treatise on optics, his eclipse theory represents one of the earliest correct applications of geometrical optics in global science.

(IUCAA, Pune)

Mozi (5th century BCE)

The Camera Obscura and Early Geometrical Optics in China

Mozi stands out as one of the earliest thinkers to describe a phenomenon central to modern optics—the camera obscura. In the Mo Jing (Canon of Mozi), he observed that light passing through a small aperture projects an inverted image of an external scene.

This observation demonstrates:

- Understanding of straight-line propagation of light
- Recognition of image formation without lenses
- Empirical reasoning grounded in everyday observation

Mozi's description predates similar accounts in Greek optics and anticipates later experimental work by Ibn al-Haytham. It shows that core principles of geometrical optics emerged independently in different civilisations through observation rather than abstract theory.

(Wikipedia)

Ibn al-Haytham (965–1040 CE)

(Father of Modern Optics; Father of Applied Psychology)

From Observation to Experimental Optics; Scientific Method

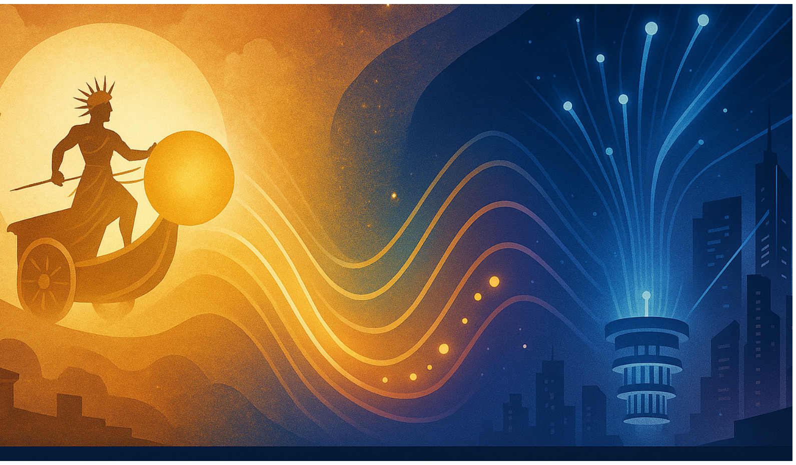
Ibn al-Haytham represents a decisive methodological shift in the history of light. In his Kitāb al-Manāzir (Book of Optics), he demonstrated experimentally that vision occurs when light travels from objects to the eye, decisively rejecting emission theories.

His contributions include:

- Systematic experiments on reflection and refraction
- Study of lenses and image formation
- Use of the camera obscura as an experimental device
- Introduction of controlled experimentation in optics

While revolutionary in method, Ibn al-Haytham's work synthesised earlier Indian geometrical reasoning, Central Asian instrumentation, Chinese observational insights, and Greek geometry—transforming optics into a rigorous experimental science.

(UNESCO)



Caliphate which covered the entire Arab & West Asian countries and Central Asia, with Baghdad as the Centre. Al-Mamun, the Caliph started a research university, "Bait-ul Hikma" in Baghdad, where philosophers and scientists from all enlightened nations of that time, namely Egypt, Greece, Europe, Persia, India etc. were invited to translate the books ion philosophy and science into Arabic. Such philosophers and scientists included included Christians, Jews, Muslims, Hindus and Buddhists. Thus the vast knowledge available throughout the world was made available in Arabic. The knowledge was not confined to mere translated work, but it was further expanded through research for almost six centuries. At the same time the Fatimid rulers in Egypt set up a "Dar-ul Hikma" in Egypt with the same objectives. This gave rise new centres of learning in Persia, Samarkand, and Bukhara. The period from 8th century CE to 13th century CE is referred to as the "Islamic Golden Age Science", during which the entire Europe was in the dark and hence call it as the "Dark Age". It was how all the available knowledge in philosophy and science available from the Indian astronomical computation, Central Asian instrumentation, Chinese observational traditions, and Greek geometry was synthesised. It was within this synthesis that Ibn al-Haytham, who was born in Basra (in the present day Iraq) moved to Cairo in Egypt on the invitation of its Fatimid Caliph, and transformed optics into an experimental science during 1011–1040 CE. During this period, he he wrote the famous book, "Kitab al-Manazir" (Book of Optics) in Arabic in six volumes. By systematically investigated reflection and refraction of light, lenses, and vision and demonstrated that light travels from objects to the eye—resolving centuries-old debates. He also for the first time gave the "Scientific Method" which is almost similar to the method that is adopted for scientific studies. Ibn al-Haytham is considered to be the greatest scientist in 2000 years in between Archimedes and Newton and is called the "Father of Modern Optics". He explained for the first time the large size of the rising moon (Moon Illusion"), explaining that that this is not due to refraction, but it causes due to psychological effect, where the human brain plays an important role. He is therefore also known as the "Father of Applied Psychology".

Through Latin translations, Islamic optics profoundly shaped European science, influencing figures such as Roger Bacon and Kepler. By the time optics entered early modern Europe, it had already passed through Indian, Central Asian, Chinese, Southeast Asian, and Middle Eastern intellectual traditions.

In India, the colonial period disrupted this continuity, marginalising indigenous scientific lineages. The early twentieth century therefore marked not merely India's entry into modern optics but its re-engagement with a long-standing tradition. Satyendra Nath Bose redefined radiation through quantum statistics, while C. V. Raman revealed new modes of light–matter interaction through optical scattering. Their work represents the culmination of a civilisational arc—from shadows and mirrors to photons and quanta.

The story of light is thus not a linear narrative of progress from East to West or ancient to modern. It is a shared human endeavour, sustained by observation, experimentation, and exchange across cultures. As Asia and the world move toward futures shaped by photonics, satellite navigation, and space-based observation, this history reminds us that scientific knowledge often travels quietly—reflected in mirrors, traced in shadows, and guided by the Sun across open seas. ◆

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