History of Optics

Based on:
“A short history of Optics” by B. Vihnsen,
&
Various articles on the Internet

Optical Engineering
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~ 400 B.C. **Democritus**: developed the concept of atoms; attempted to explain perception and color.

~ 350 B.C. **Aristotle**: questions of perception; rejected the Euclidian theory that vision was solely due to rays emanating from the eyes and "touching" the object.

~ 300 B.C. **Euclid**: In his *Optica* he noted that light travels in straight lines and described law of reflection. He believed that vision involves rays going from the eyes to the object seen.

~ 250 B.C. **Archimedes**: setup of optical weapons/defense machines for the king of Syracuse (Sicily) to defend the city against the Romans; very much involved in *catoptrics* (reflection on surfaces).

~ 30 A.D. **Seneca**: wrote about magnifying effect of liquids in transparent vessels.
~ 60 A.D. **Hero of Alexandria**: Light follows the shortest path, law of refraction.

~ 120 A.D. **Ptolemy**: wrote a five volume textbook on optics; observed the small angle approximation of Snell’s law (i.e. the ratio of the angle of incidence vs. angle of refracted light is constant).

~1000 A.D. **Alhazan (Abu Ali Hasan Ibn al-Haitham)**: investigated reflections from spherical & parabolic mirrors, disproved Ptolemy’s refraction law; disagreed with Euclidian theory of vision; discussed atmospheric refraction; explained the increase in apparent size of the sun and moon near the horizon; attempted to measure the height of the atmosphere.
~ 1220 A.D. **Robert Grosseteste:** University of Oxford: Theory should be combined with experimental observations as basic scientific method; He believed colors are related to light intensity. Share view with earlier Greeks that vision involves emanations from the eye.

~ 1250 A.D. **Roger Bacon:** insisted on experimental observations as basic scientific method; carried out experiments with lenses and mirrors; described principles of reflection and refraction. Finite speed of light. He attributed rainbow to sunlight reflection by raindrops.

~ 1270 A.D. **Witelo (or Vitelo) of Silesia:** completed *Perspectiva* which was a standard text on optics for several centuries. Parabolic mirrors construction, refraction (angle of refraction non proportional to angle of incidence)
~ *1600 Galileo Galilei*: learned in 1609 of the invention of the telescope (by a Dutch eye glass manufacturer-Hans Lippershey); build his own devices with magnification up to 30 times, i.e. the most powerful instruments of his time; thus enabled the discoveries that established the Copernican system.

~ *1600 Johannes Kepler*: was among the few to accept the Copernican heliocentric astronomy; discovered the laws of planetary motion; provided correct explanation of vision and functions of the pupil, cornea and retina; gave first correct explanation of how eyeglasses work; changed the setup of Galilei‘s telescope by concave lenses.

~ *1621 Willebrord van Royen Snell*: found experimentally the law of refraction; *Rene Descartes*: described Snell’s law for the first time involving sinus terms (i.e. the form we are used to).
~ 1657 *Pierre de Fermat*: postulated the principle of shortest propagation times; deduction of the refraction law from *Fermat’s principle.*

~ 1665 *Francesco Maria Grimaldi*: described diffraction of light.

~ 1665 *Robert Hooke*: investigated interference effects at thin films; his ideas triggered the wave theory of light.

~ 1666 *Isaac Newton*: (among many other achievements) investigated dispersion (e.g. at prisms) and the spectrum of white light; developed the particle theory of light; worked on the correction of lens errors (but did not believe in the possibility of achromats); developed mirror telescopes.

~ 1678 *Christiaan Huygens*: developed the wave theory of light; introduced the concept of elementary waves; applied the theory to explain the lower speed of light in a dense medium, refraction and birefringence; he also observed polarization in birefringent crystals.
~ 1676 **Ole Christensen Römer**, proposed an experiment (by astronomic observation of a total eclipse of the sun, and of Jupiter satellite Io eclipses) to prove and determine the finite speed of light

~ 1670 after the invention of the microscope in 1595 (by **Zacharias Jansen**), **Antonie van Leeuwenhoek** improved the concepts and developed powerful devices (magnification up to 300 times)

~ 1730 **Chester Moore Hall**, developed an achromatic lens by trying different combinations of flint and crown glass; **John Dollond** copied and patented Hall‘s concept to start commercial production

~ 1800 **Carl Friedrich Gauss**: (among many other achievements) directed an astronomical observatory, developed a mathematical description of lenses (“Gaussian optics”), i.e. provided the mathematical basis for optical imaging theory; made contributions to the theory of electromagnetism
~ 1802 **Thomas Young**: supported the wave theory of light and postulated the interference principle, i.e. two light fields show constructive or destructive interference when coherently superimposed; introduced the idea of light as a *transversal* wave (so far understood as *longitudinal*, e.g. as sound waves)

~ 1815 **Augustine Jean Fresnel**: supported the wave theory of light; explained the straight propagation of light in homogeneous, isotropic media; calculated diffraction patterns at apertures; deduced eqns. for the amplitudes of reflection and refraction (Fresnel eqns.)

~ 1814 **Joseph von Fraunhofer**: developed telescopes, invented the spectroscope, investigated diffraction at optical gratings (Fraunhofer diffraction), and detected absorption lines in the solar spectrum (Fraunhofer lines)
~ 1845 **Gustav Kirchhoff:** *(among other achievements)* developed the (Kirchhoff) radiation law, and contributed to spectroscopy (e.g. investigation of Fraunhofer lines).

~ 1849 **Michael Faraday:** *(among other achievements)* demonstrated the rotation of the polarization of light in a medium, manipulated by a magnetic field (Faraday effect).

~ 1849 **Hippolyte Fizeau & Leon Foucault:** measured the speed of light, for the first time in a earth-bound experiment (also proposed by F. Arago).

~ 1864 **James Clerk Maxwell:** *(among other achievements)* developed the electromagnetic (classical wave) theory of light; deduced the transversal character of light and the speed of light.
~ 1881 Albert Abraham Michelson: determined experimentally the speed of light with large accuracy; invented the Michelson interferometer; disproved the existence of an ether (i.e. a medium, which was supposed to work as a carrier for light) light travels through vacuum without the need for a carrier medium.

~ 1887 Ernst Abbe: developed the theory of optical images in a microscope, design and production of optical instruments based on scientific theory rather than try-and-error; investigated lens errors.

~ 1888 Heinrich Hertz: designed a detector and an oscillator (Hertz dipole) for EM waves, to demonstrate reflection and refraction in the laboratory; EM wave properties are the same as those of light; light is an EM wave; Hertz also discovered the photo-electric effect.
~ 1900 *Max Planck:* quantum theory of light (beginning of quantum optics); Planck’s black-body radiation law; deduction of the values for Planck’s constant $h$, the Boltzmann constant $k$, Avogadro’s number $N_A$, and the charge of the electron.

~ 1905 *Albert Einstein:* (among other achievements) explained the photo-electric effect; introduced the concept of light quanta (later called “photons”); postulated a constant speed of light (special theory of relativity); contributed to the quantum theory of light (and matter).

~ 1912 *Max von Laue:* discovered the diffraction of X-rays at crystals; conducted optical experiments to support Einstein’s special theory of relativity.
~ 1924 Louis de Broglie, postulated the existence of matter waves (i.e. defining the beginning of matter wave optics); the wave character of matter was demonstrated by Clinton Davisson and Lester Germer (1926), observing the interference of an electron beam on a Nickel crystal; Claus Jöhnson demonstrated the interference of an electron beam in a double-slit experiment (1961).

~ 1931 Ernst Ruska and Max Knoll build the first (transmission) electron microscopy, based on the concepts of matter waves and electron optics (e.g. implemented with electro-static and magnetic lenses).

~ 1957 till today: the invention of the laser pushed a huge amount of research and developments in modern applied optics & optical technologies.
Wave-Particle Duality of Light

De Broglie (1924):
\[ \lambda = \frac{h}{p}, \]

\[ h = 6.626 \times 10^{-34} \text{ J sec}, \quad p = \text{momentum} \]