History of Optics

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

Optical Engineering
*Prof. Elias N. Glytsis*

*School of Electrical & Computer Engineering*
*National Technical University of Athens*
Light in Ancient Years

**Ra:** Egyptian God of the Sun (~5000BC)

Bible:
“Let there be Light” (day) (~1500-1060BC)

**Ancient Greeks:**
Pythagoras’ (569-475BC) Followers,
Democritus’ (460-370BC) Followers,
Empedocles’ (494-434BC) Followers

Prof. Elias N. Glytsis, School of ECE, NTUA
~ **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 reflection.

~ **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 Galileo's telescope by concave lenses (telephoto lens).

~ **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. Wrote Micrographia (used microscopes) – Contributions to Astronomy

~ 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 Janssen), 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 an 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.
~ 1891/1892 *Ludwig Mach and Ludwig Zehnder:* described (separately) what is known as a Mach-Zehnder interferometer (find changes in refractive index – density changes is gas flows).

~ 1896 *Wilhelm Wien:* described how the spectral distribution of radiation of a blackbody varies with temperature.

~ 1899 *Lord Rayleigh (John William Strutt):* Explained blue color of the sky and red sunsets due to preferential scattering in the earth’s atmosphere.

~ 1899 *Marie P A C Fabry and Jean B G G A Perot:* Described the Fabry-Perot interferometer which enabled high resolution observation of spectral features.
~ **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 $h$.

~ **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 Jönsson demonstrated the interference of an electron beam in a double-slit experiment (1961).

~ **1923** Arthur H. Compton
Scattering of a photon by a particle and the subsequent increase in wavelength of the scattered photon. (Nobel prize 1927)

~ **1931** Ernst Ruska and Max Knoll
build the first (transmission) electron microscope, 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

**Particles**

De Broglie (1924):

\[
\lambda = \frac{h}{p},
\]

\( h = 6.626 \times 10^{-34} \) J sec, \( p = \) momentum

**Waves**