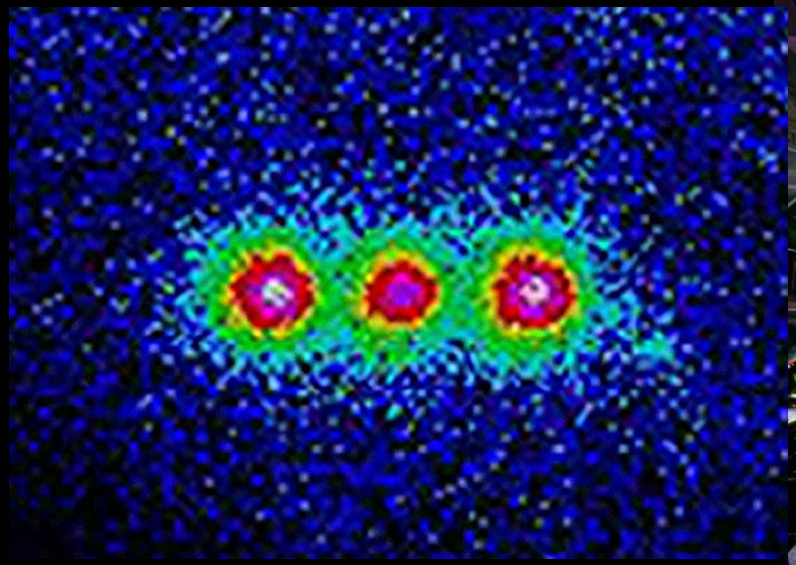
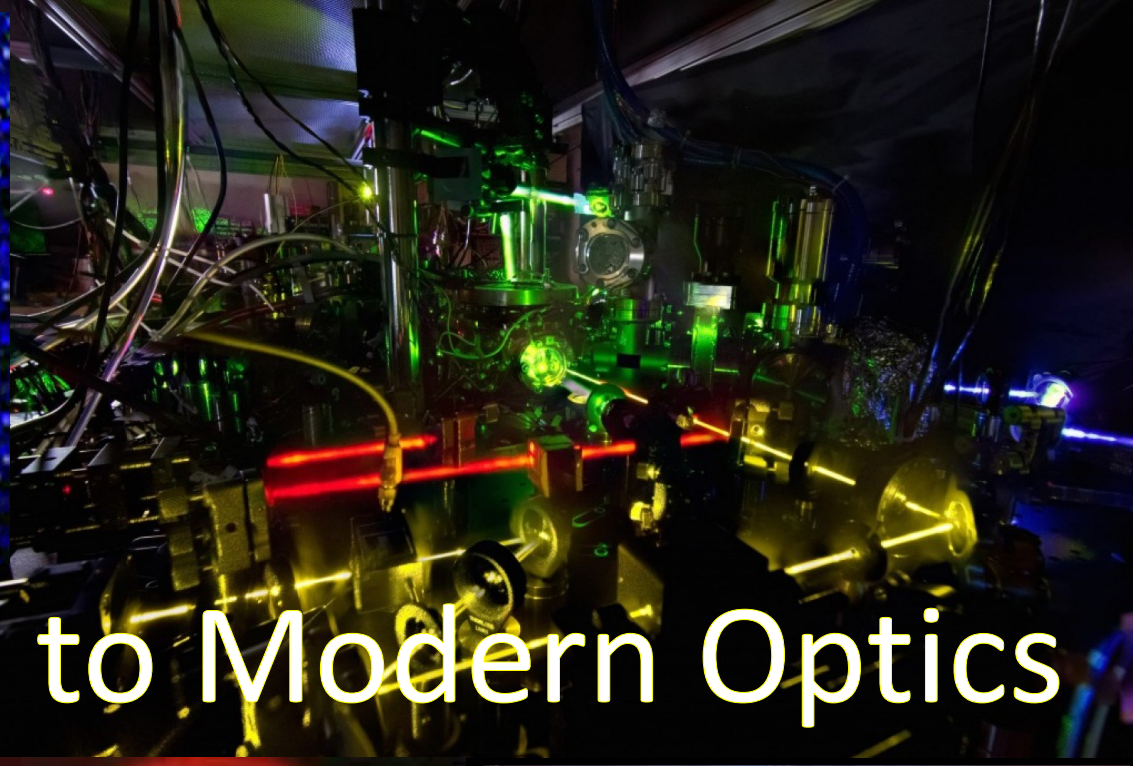
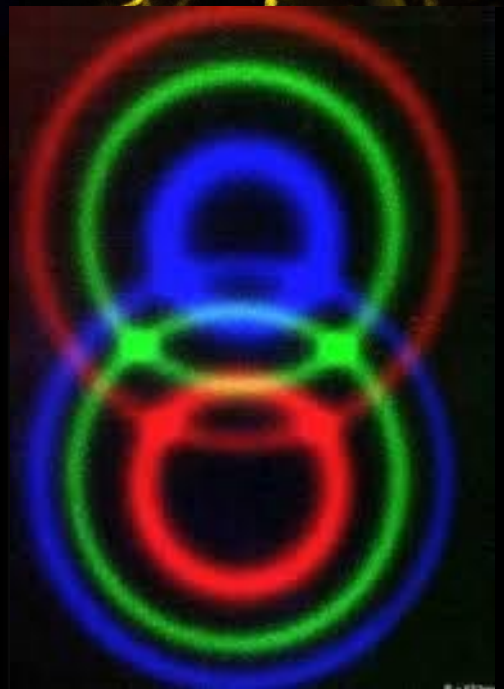
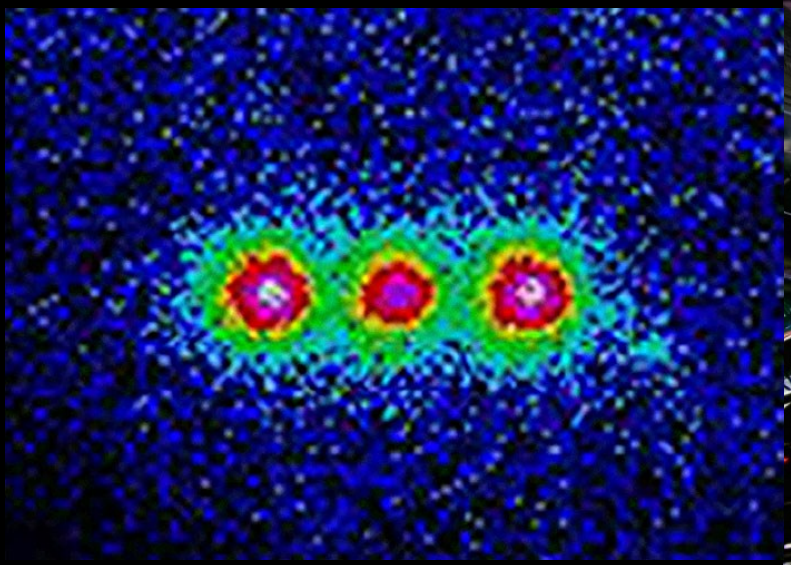


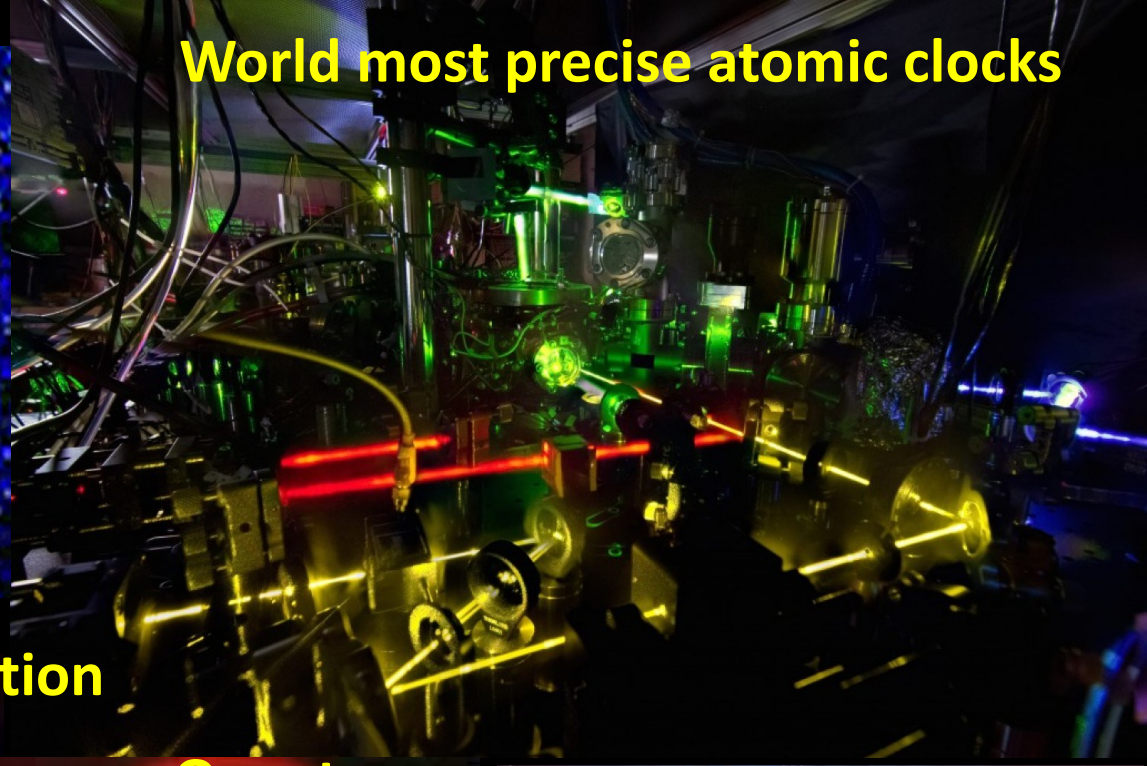


Introduction to Modern Optics



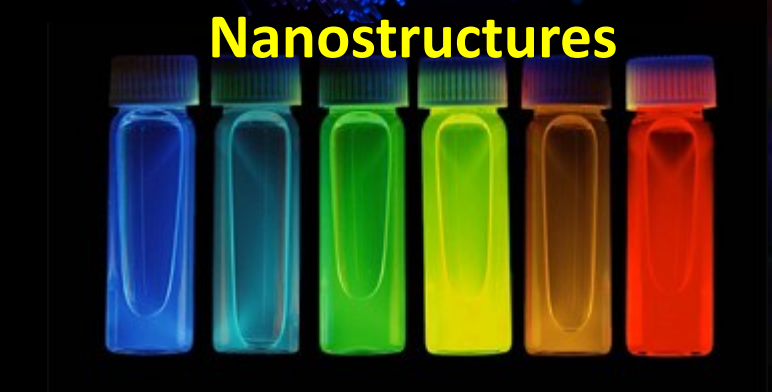


World most precise atomic clocks



Optical fiber telecommunication

Nanostructures



Quantum information

Astronomy

It is good to see you! But can you explain how vision works?

How would you explain to Rocky how human see things?

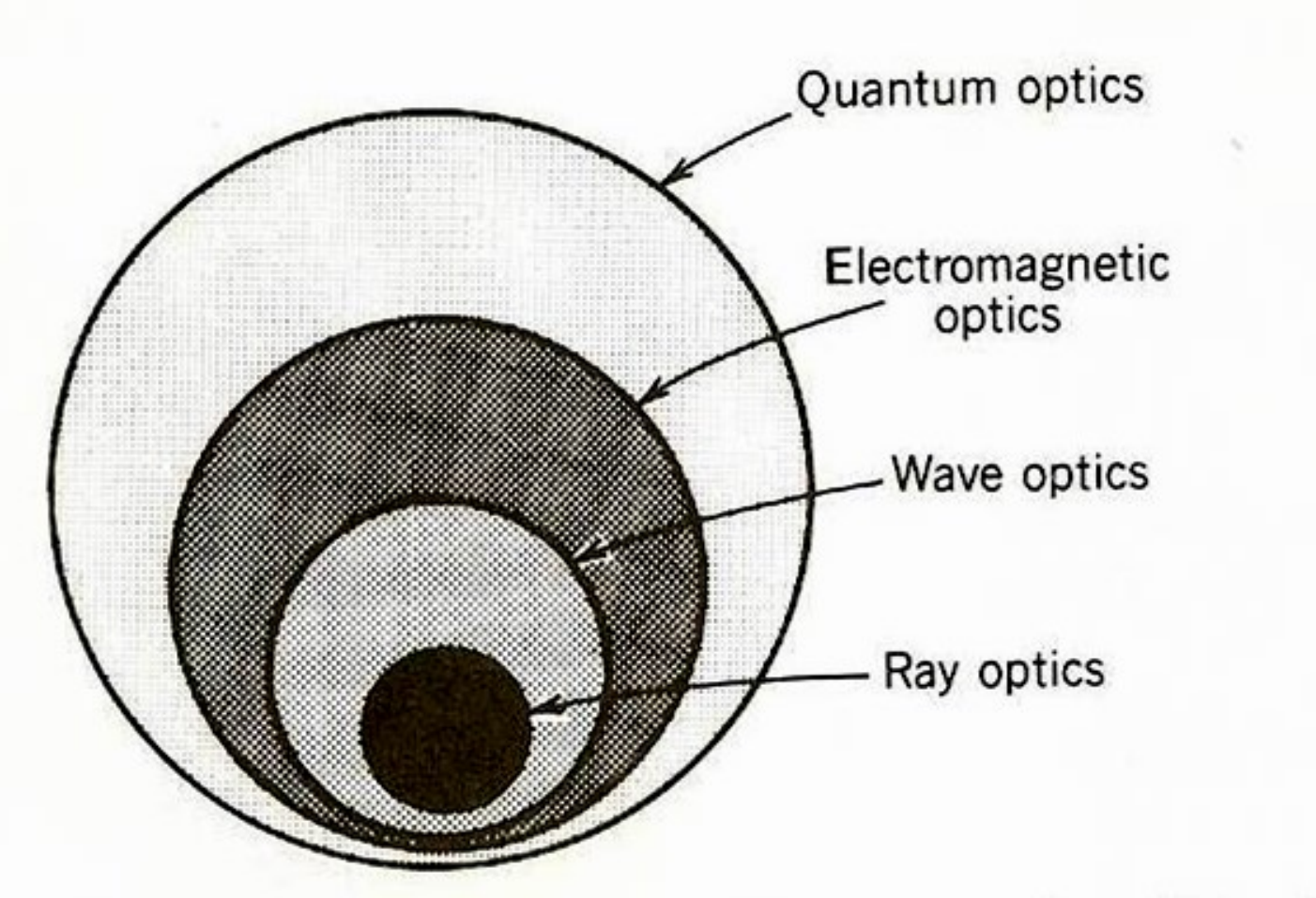
It is good to see you! But can you explain how vision works?

How would you explain to Rocky how human see things?

Consider how do we…

- Recognize shapes and distances
- Distinguish colors
- Distinguish textures

Many layers of understanding optics



How old is optics?

The earliest known lenses were made from ground crystal, often quartz, and have been dated as early as 700 BC. They are found in Assyria, Egypt, Greece and Babylon.

A mirror was discovered in workers' quarters near the tomb of Pharaoh Sesostris II (1900 BCE).

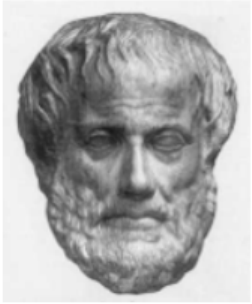
Burning glass mentioned by Aristophanes (424 BCE)

SOLO

Optics History

c. 490-430 B.C.
Empedocles
Sicily

Light constitute of small particles that were presumed to enter the eyes and then returned to visible bodies



c. 384-332 B.C.
Aristotel
Greece

Light is the activity of "transparent" (i.e. visible) bodies.

c. 300 B.C.
Euclid
Greece

"Optica" 280 B.C.
Rectilinear propagation of Light. Law of Reflection.
Light originate in the eye, illuminates the object seen, and then returns to the eye.

c. 100 B.C-150 A.C.
Heron
Alexandria

"Catoptrics"
The Light travels the shortest path between two points.

100-170 A.D.
Claudius Ptolemey
Alexandria

"Optics" 130 A.D.
Tabulated angle of incidence and refraction for several media.

Optics History 984

Ibn-Sahl
c 940-1000

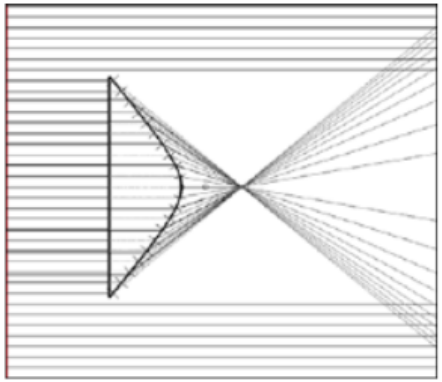
Ibn Sahl (Abu Sa`d al-`Ala' ibn Sahl) (c. 940-1000) was an Arabian mathematician, physicist and optics engineer associated with the Abbasid court of Baghdad.

About 984 he wrote a treatise On Burning Mirrors and Lenses in which he set out his understanding of how curved mirrors and lenses bend and focus light.

Ibn Sahl is credited with first discovering the law of refraction, usually called Snell's law.

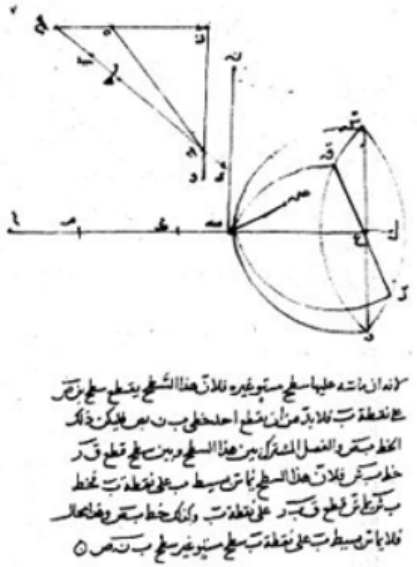
He used the law of refraction to work out the shapes of lenses that focus light with no geometric aberrations, known as anaclastic lenses.

http://en.wikipedia.org/wiki/Ibn_Sahl



Ibn-Sahl anaclastic lens (hyperbolic lens that focus light with no geometric aberrations)

http://www.brayebrookobservatory.org/



Reproduction of a page of Ibn Sahl's manuscript showing his discovery of the law of refraction (from Rashed, 1990).

In the remaining parts of the treatise, Ibn Sahl dealt with parabolic mirrors, ellipsoidal mirrors , biconvex lenses, and techniques for drawing .

Ibn Sahl's treatise was used by Ibn al-Haitham (965–1039), one of the greatest Arabic scholars of optics.

Ibn al-Haytham
or Alhazen
(965 - 1039)
Born in Basra

The “Father of Optics”
“Book of Optics” (1021)

Intromission Theory of Vision

Describes the optical system of eye and believes that light consists of rays which originate in the object seen, and not in the eye.

Alhazen pioneered the modern scientific method (hypothesis rejected or not rejected by experimentation).

Glass Production

~ 3000 BCE	First evidence of glass production
~ 700 BCE	First lenses appear (crystal)
~ 250 BCE	Glass blowpipe appears
~ 1000 CE	Commercial glass production
~ 1050	"Reading Stones"
~ 1250	Glass lenses manufactured


Medieval spectacles

Roger Bacon (1214-1294)
Initiated the idea of using lens to correct vision
Insisted on application of geometry to optics.


Roger Bacon
(1214-1294)

Witelo Erazmus (1230-1275)
Wrote “Perspectiva”, a standard text in optics for several centuries (covers Geometrical optics, reflection and refraction)

Albertus Magnus (1230-1275)
Proposed finite (even if very fast) speed of light, patron saint of natural sciences.

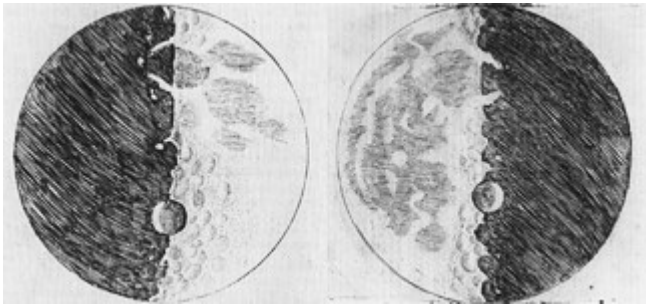

Albertus Magnus
(1193-1280)

Optics in early 17th-century Europe

Hans Lippershey applied for a patent on what now is known as the Galilean telescope in 1608.

Galileo (1564-1642) improved Lippershey design in 1609, and used one to look at our moon, Jupiter and its moons, and the sun.

Two of Galileo's telescopes



Galileo's drawings of the moon

Johannes Kepler

"*Dioptics*" 1611

Presented principles of convergent and divergent lens

Proposed "new" telescope design

Discovered total internal reflection

Developed a first-order theory of geometrical optics

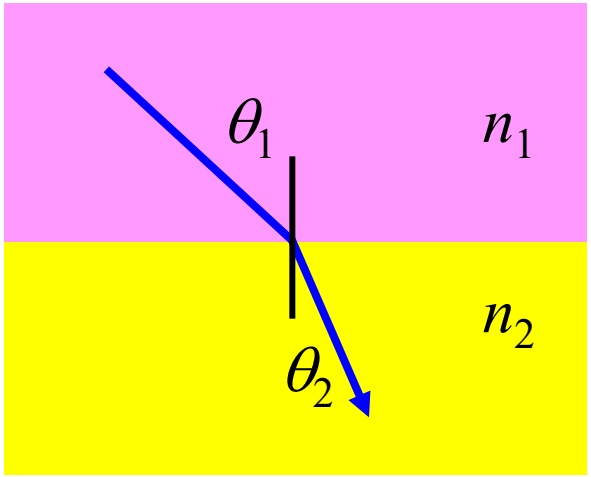
Discovered the small-angle approximation to the law of refraction

Johannes Kepler
(1571–1630)

Willibrord Snell

Willibrord Snell experimentally discovered the Law of Refraction (now named after him) in 1621

Willibrord Snell (1591-1626)



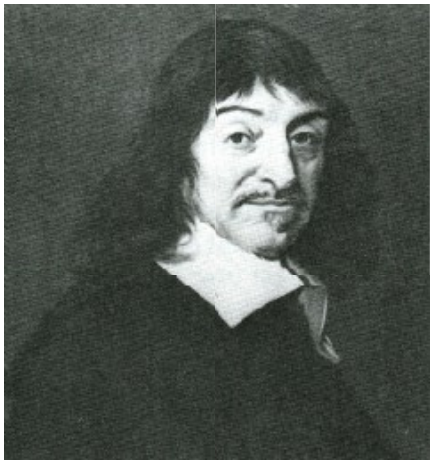
n_i is the refractive index of each medium.

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$

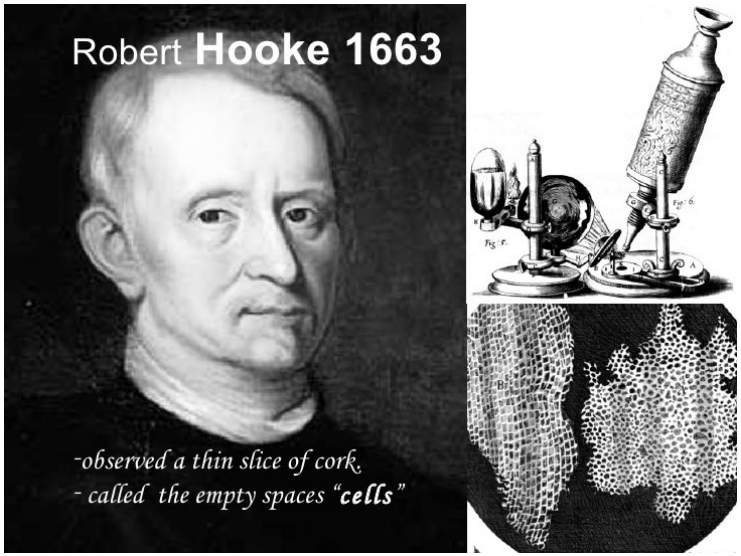
This law was first published by Rene Descartes (without credit to Snell) in 1637.

17th-century Optics

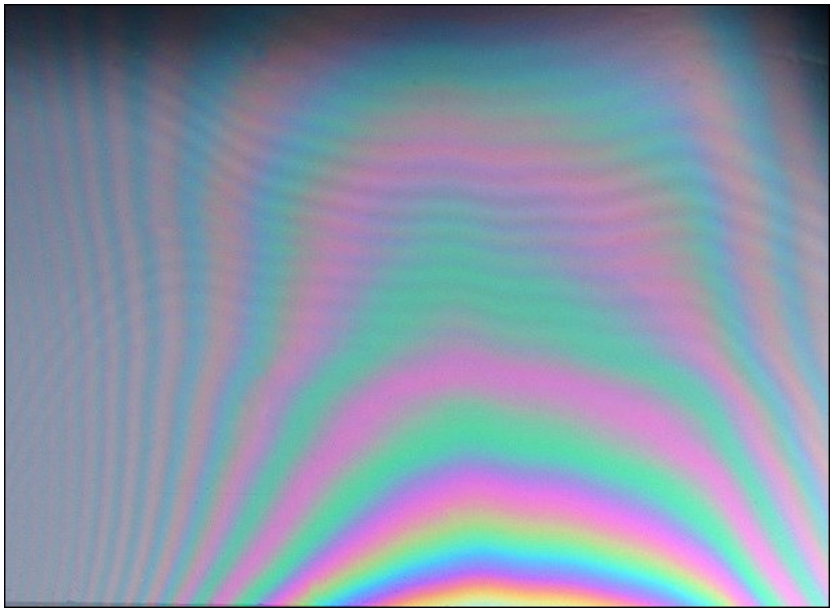
Descartes reasoned that light must be like sound. So he modeled light as pressure variations in a medium (aether).



Rene Descartes (1596-1659)



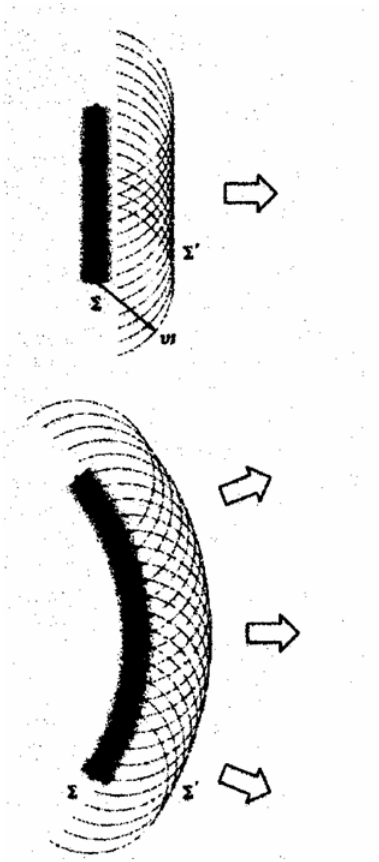
Robert Hooke (1635-1703) studied colored interference between thin films and developed the first wave theory of light.



Christiaan Huygens

Huygens extended the wave theory of optics.
He realized that light slowed down on entering dense media.

Christiaan Huygens
(1629-1695)



Huygens‘ principle says that a wave propagates as if the wave-front were composed of an array of point sources each emitting a spherical wave.

Isaac Newton

"I procured me a triangular glass prism to try therewith the celebrated phenomena of colours." (Newton, 1665)

Isaac Newton
(1642-1727)

After remaining ambivalent for many years, he eventually concluded that it was evidence for a particle theory of light.

18th and 19th century Optics: Euler, Young, and Fresnel

Leonhard Euler (1707-1783) further developed the wave theory and designed achromatic lenses by combining lenses of different materials.

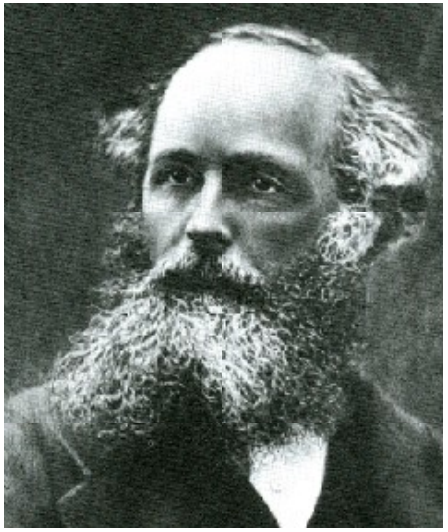
Thomas Young (1773-1829) explained interference and colored fringes and showed that light was a transverse wave.

Augustin Fresnel (1788-1827) did experiments to establish the wave theory and derived expressions for reflected and transmitted waves.

Augustin Fresnel

James Clerk Maxwell

Maxwell unified electricity and magnetism with his now famous equations and showed that light is an electromagnetic wave.



James Clerk Maxwell
(1831-1879)

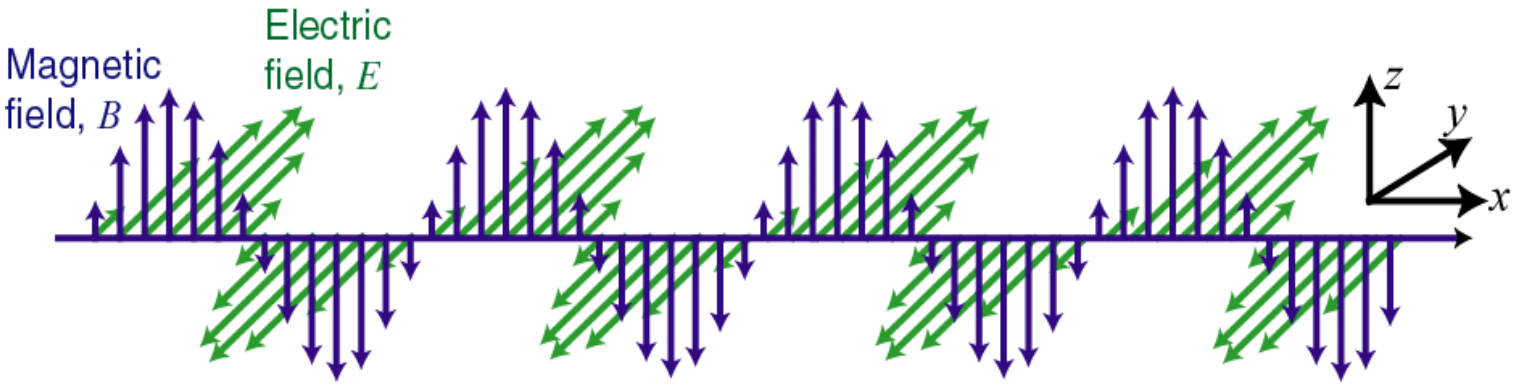
$$\vec{\nabla} \cdot \vec{E} = 0 \qquad \vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\vec{\nabla} \cdot \vec{B} = 0 \qquad \vec{\nabla} \times \vec{B} = \frac{1}{c^2}\frac{\partial \vec{E}}{\partial t}$$

where $\vec{E}$ is the electric field, $\vec{B}$ is the magnetic field, and c is the velocity of light.

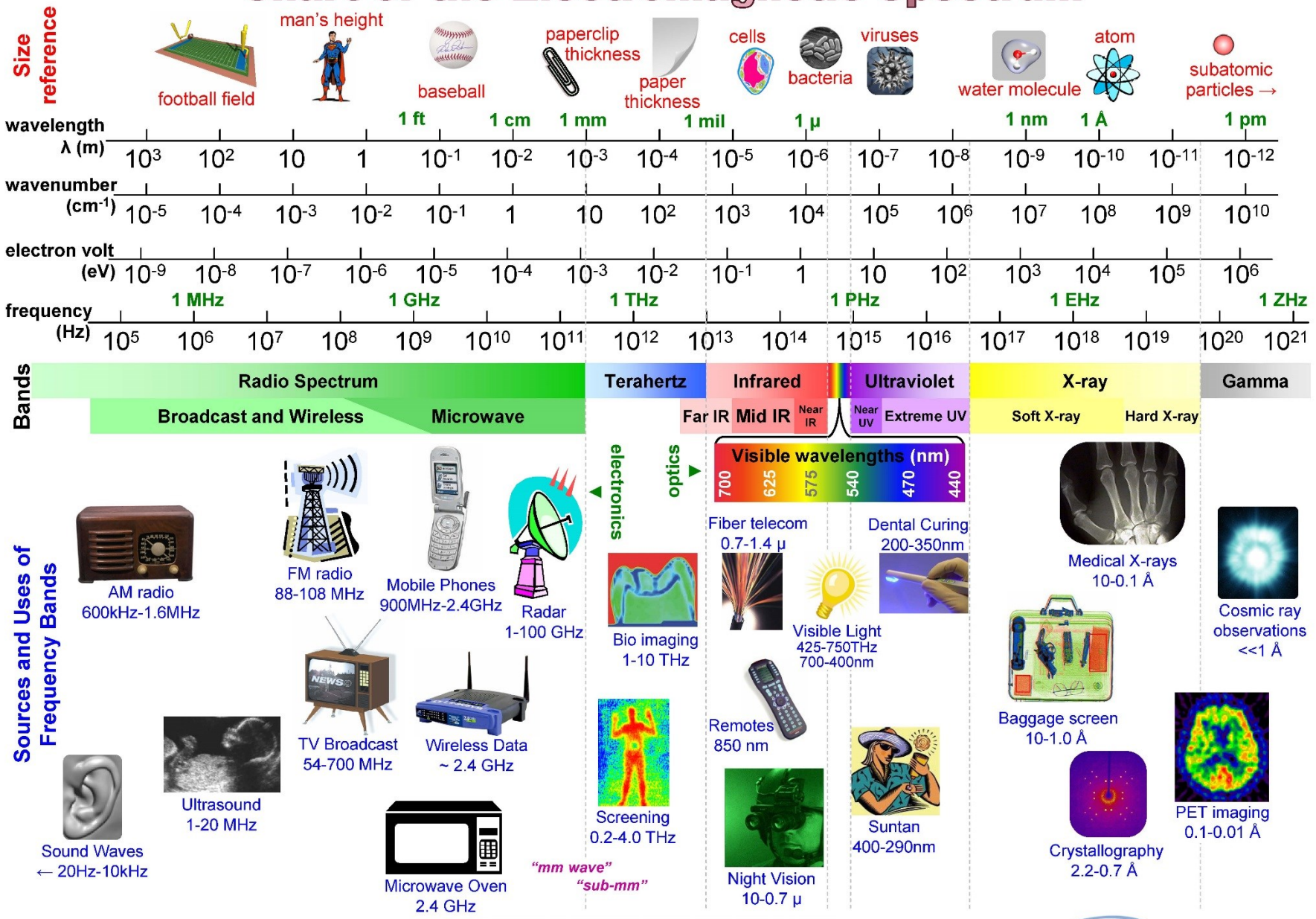
Light is an electromagnetic wave.

The electric (E) and magnetic (B) fields are in phase.



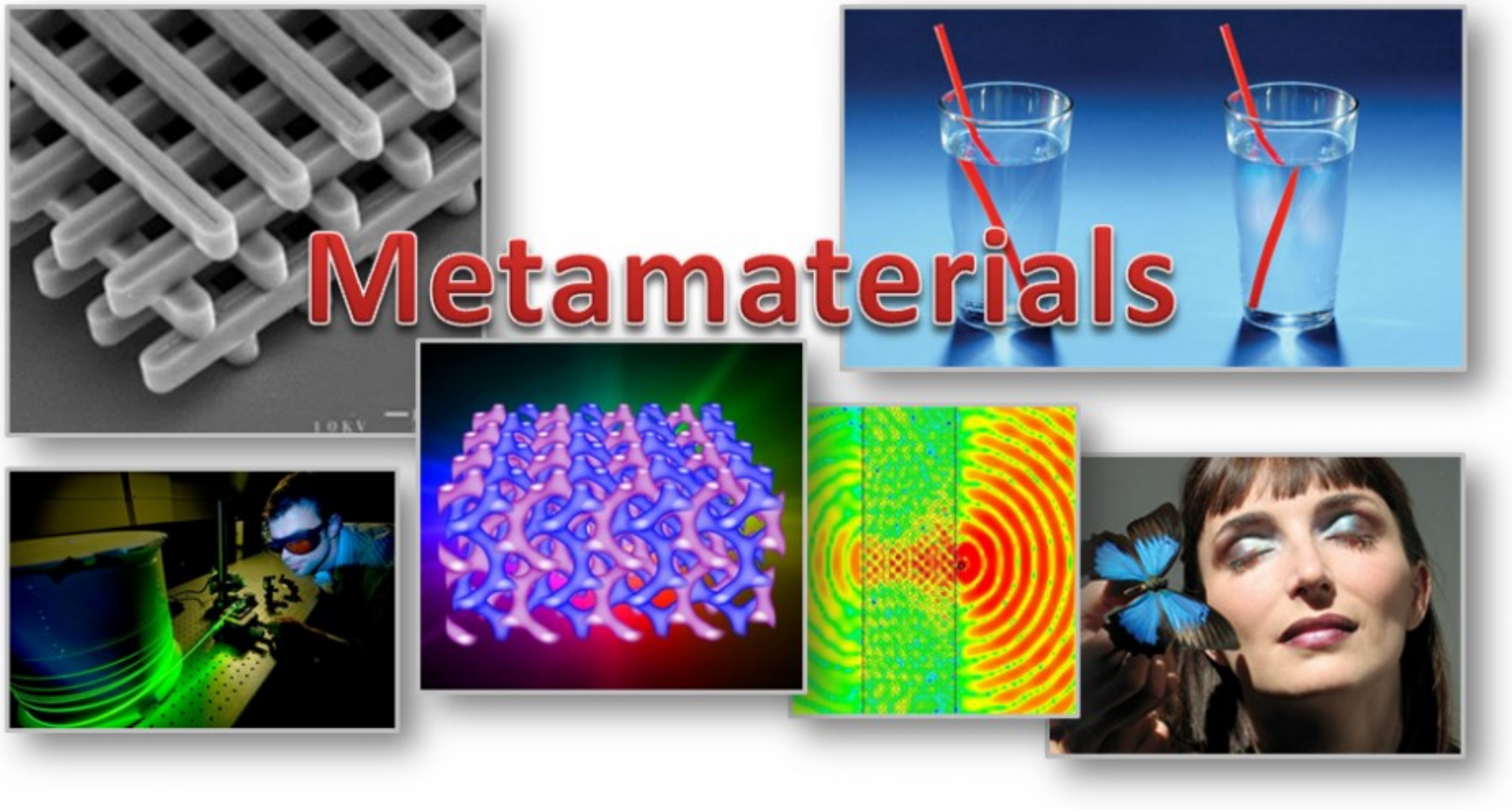
The electric field, the magnetic field, and the propagation direction are all perpendicular.

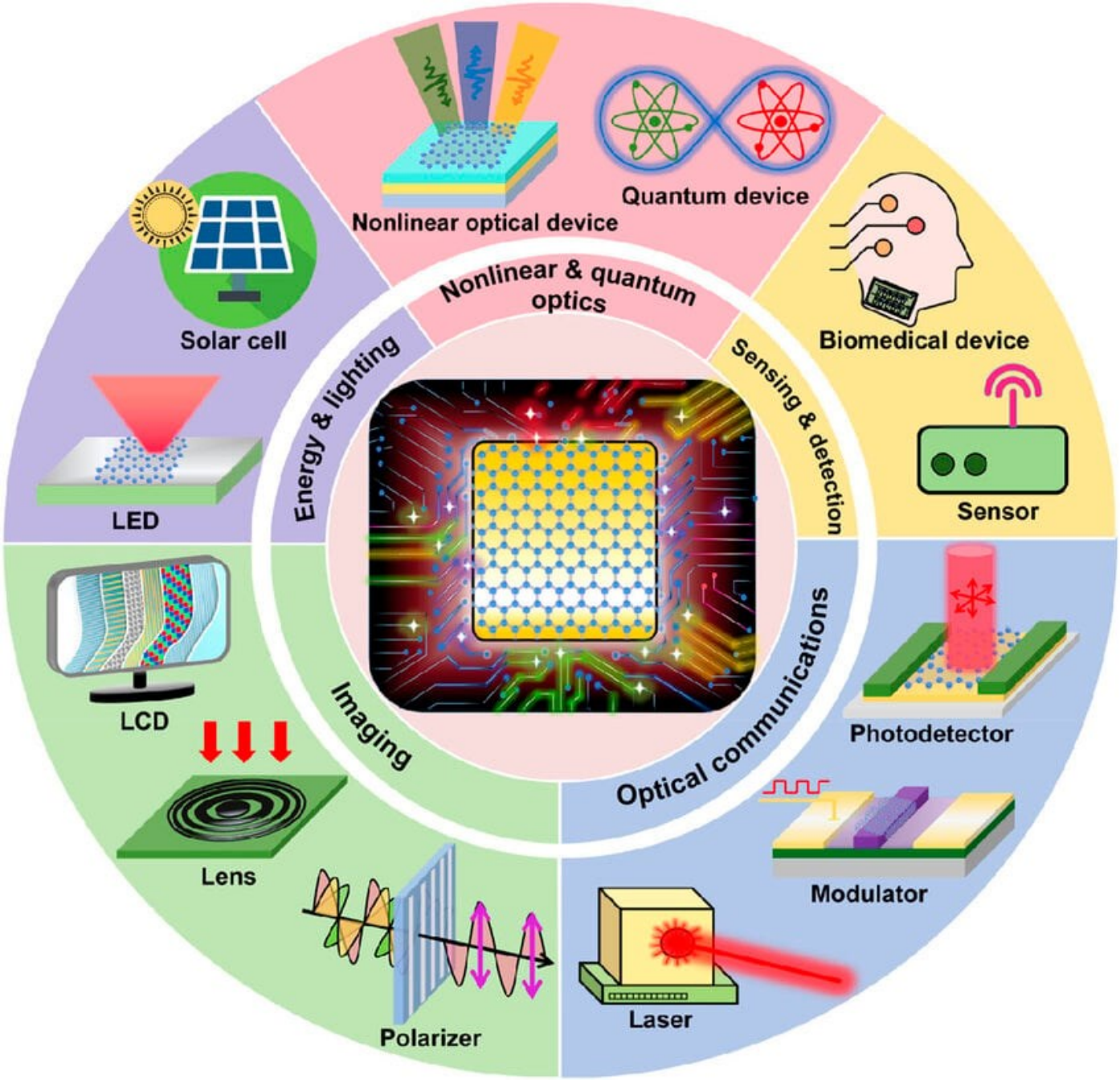
Chart of the Electromagnetic Spectrum



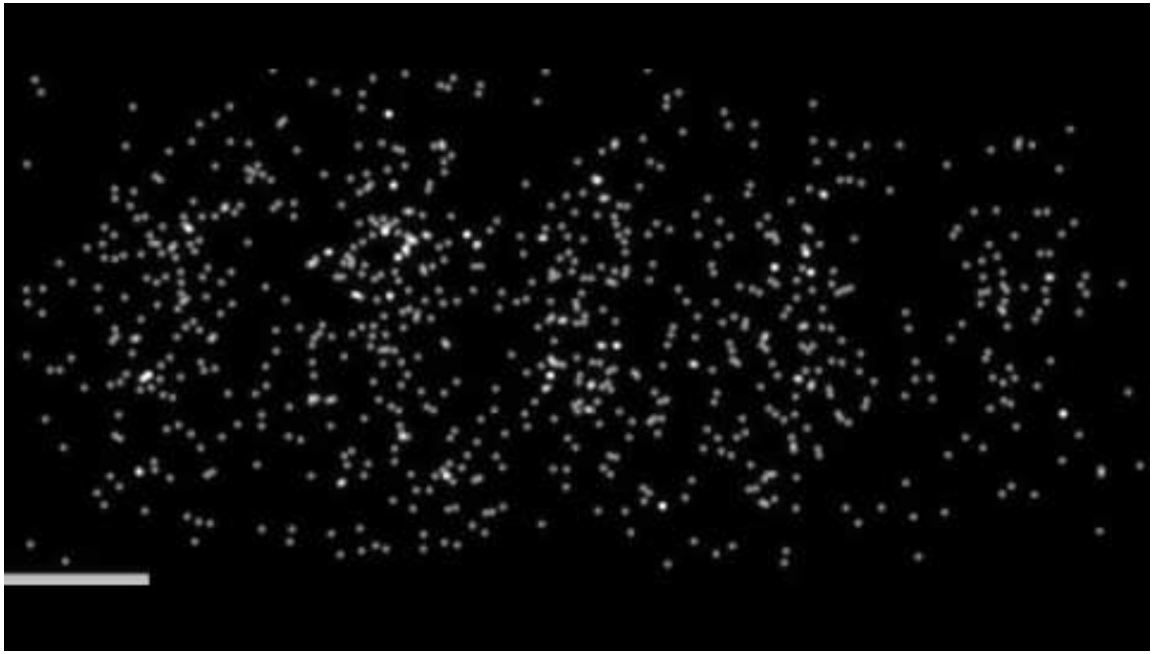
$\lambda = 3\times10^8/\text{freq} = 1/(\text{wn}*100) = 1.24\times10^{-6}/\text{eV}$

Metamaterials – artificially (and sometimes naturally) created sub-wavelength structures with pre-determined qualities

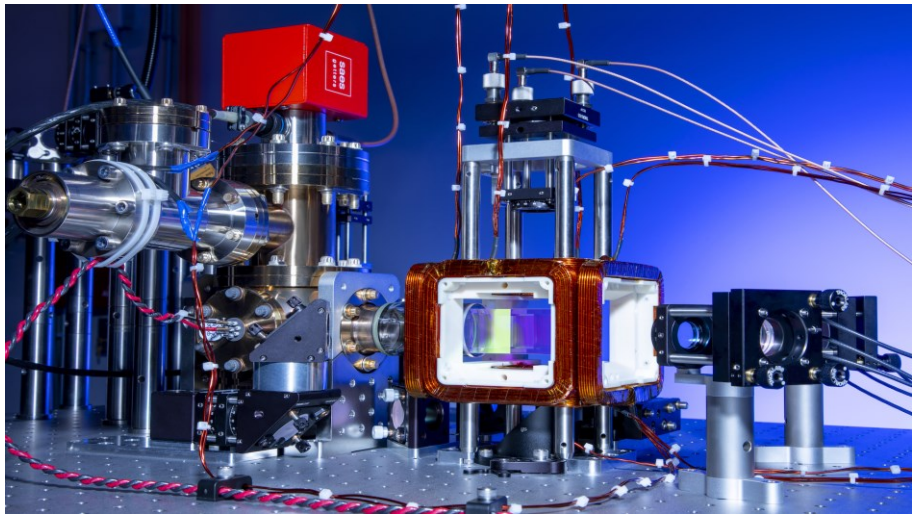



Nonlinear optical device
Quantum device
Biomedical device
Solar cell
Nonlinear & quantum optics
Energy & lighting
Sensing & detection
Sensor
LED
LCD
Photodetector
Imaging
Optical communications
Lens
Modulator
Polarizer
Laser

Quantum has arrived!



Quantum information



Quantum sensing