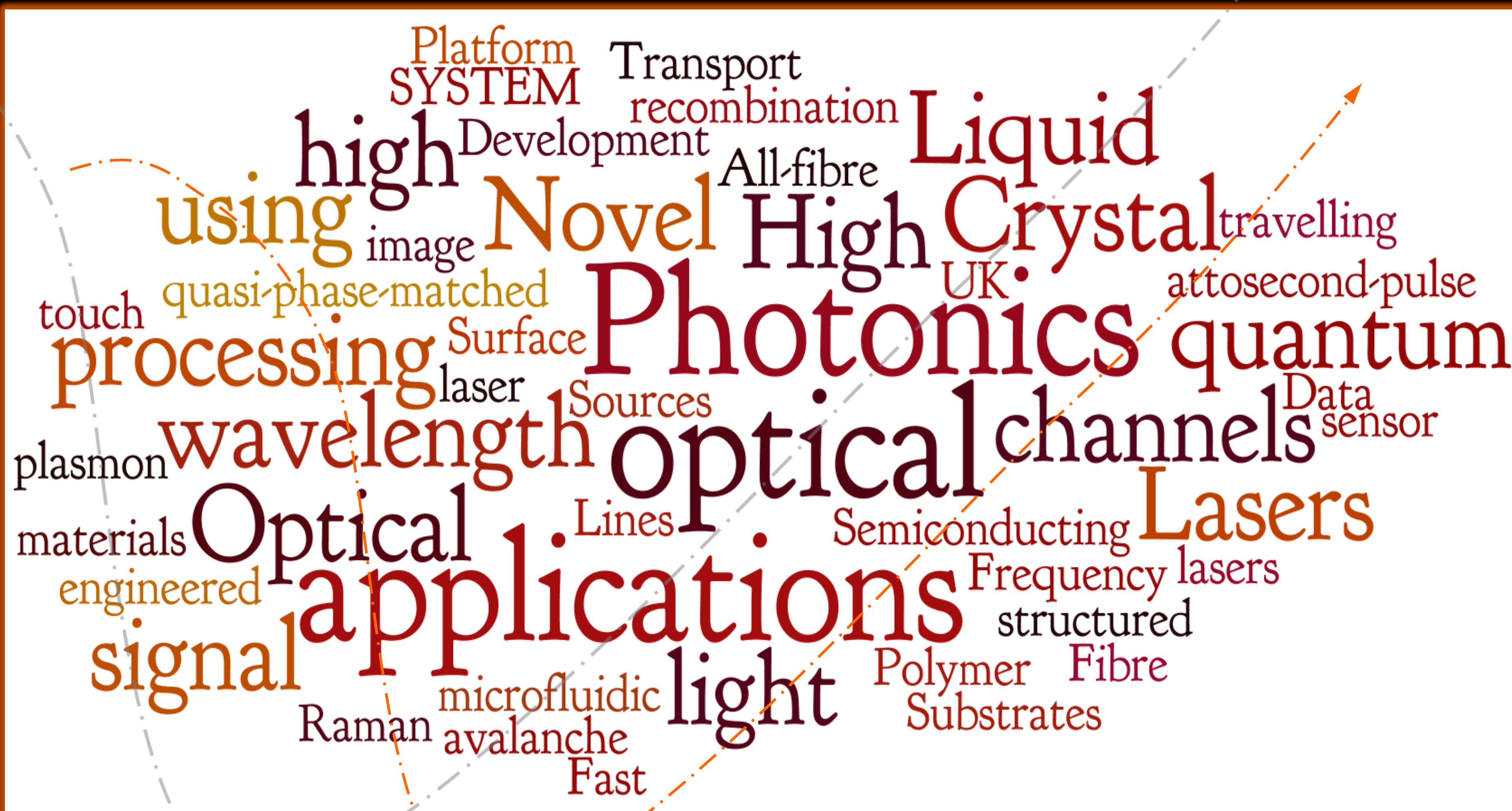
ODYSSEY of LIGHT

Maazam@unisa.ac.za, Maaza@tlabs.ac.za
UNESCO Africa Nano-CHAIR

OUTLINE



Platform
SYSTEM
Transport
recombination
high
Development
Liquid
All-fibre
using
Novel
High
Crystal
travelling
image
UK
quasi-phase-matched
attosecond-pulse
touch
Photonics
quantum
processing
Surface
laser
Sources
Data
sensor
wavelength
optical
channels
plasmon
Optical
Lines
Semiconducting
Lasers
materials
applications
Frequency
lasers
engineered
structured
signal
Polymer
Fibre
microfluidic
light
Substrates
Raman
avalanche
Fast

LIGHT:GENESIS

Birth of Humanity

LIGHT:GENESIS

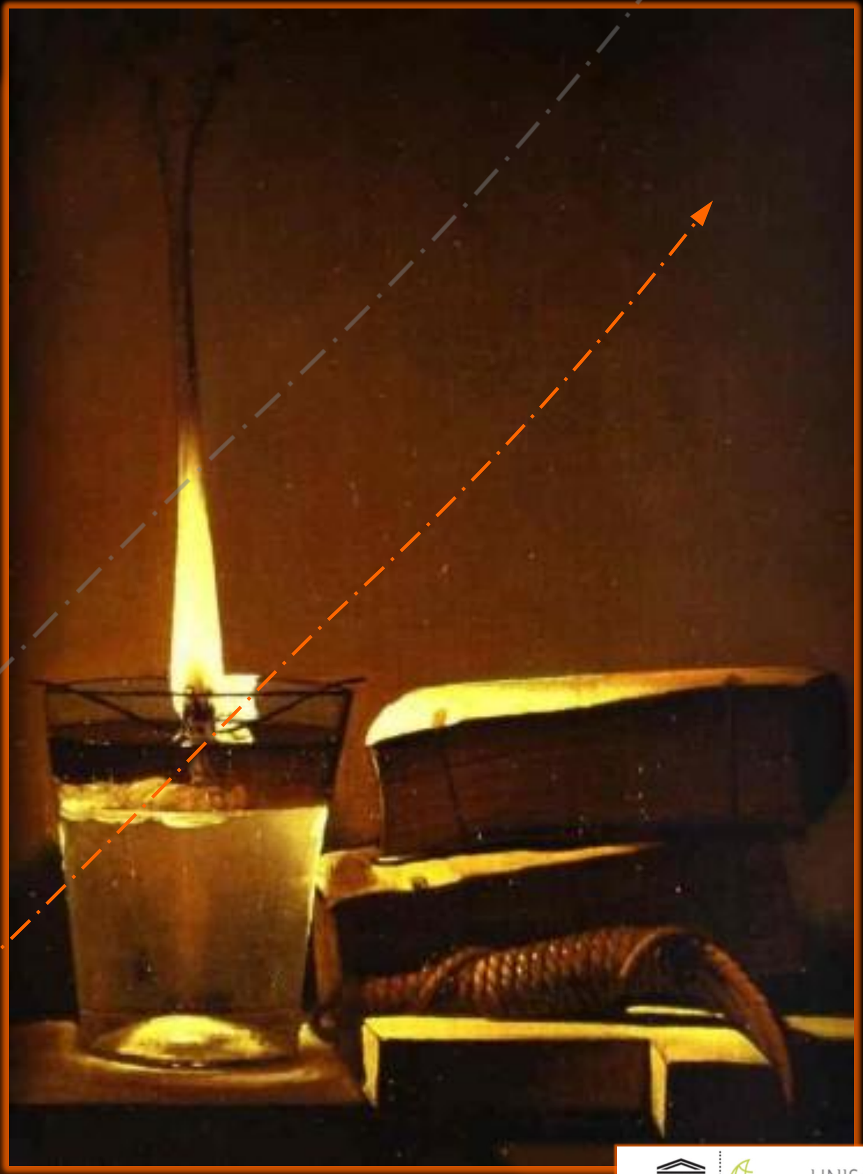
DIRECT CITATIONS

47 in Torah

71 in Bible

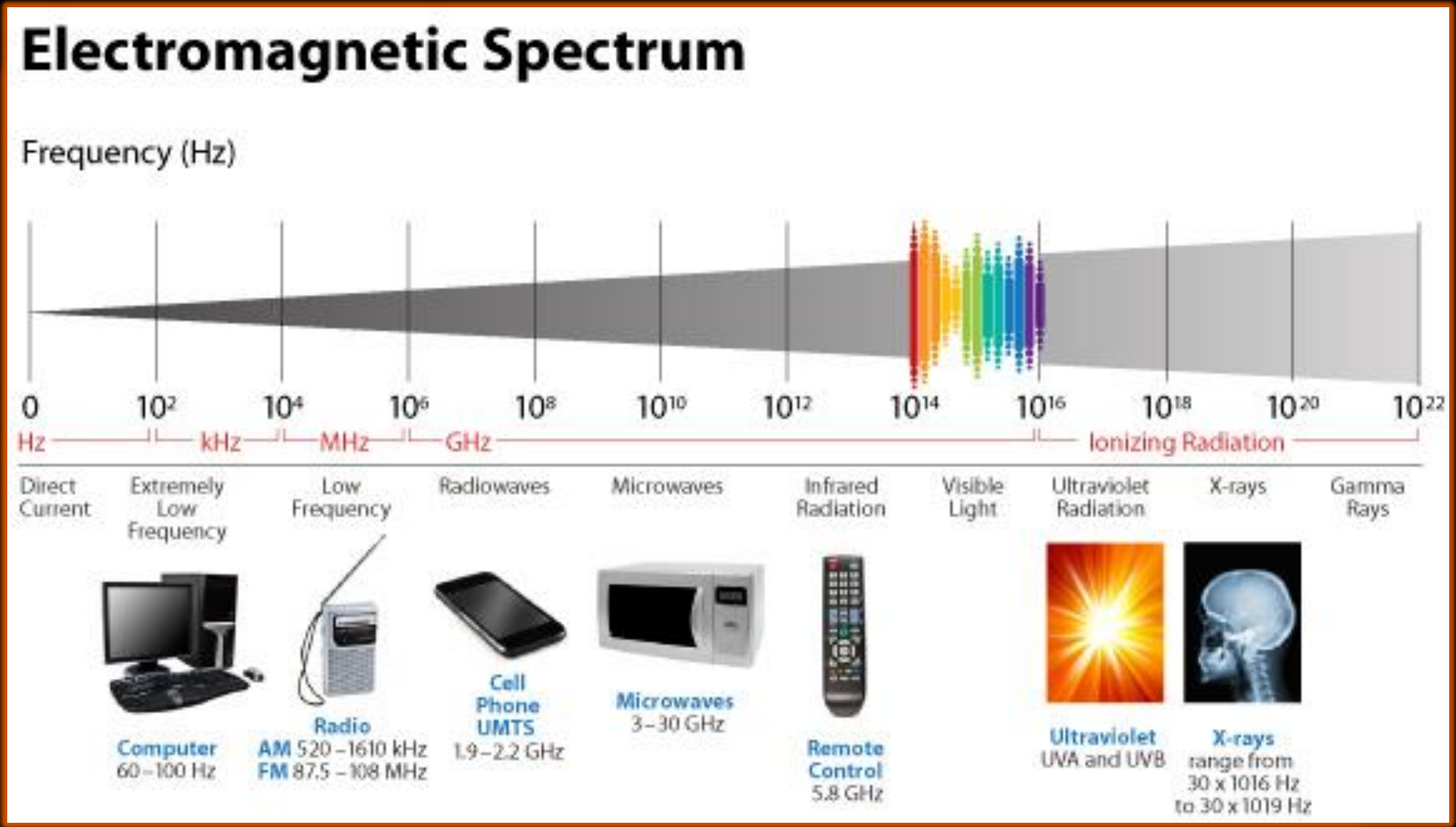
42 Coran

Several in other holy philosophies



LIGHT:GENESIS

What is light ?: It is not the VISIBLE part of the solar emission but includes the broader photonics spectrum



LIGHT: GENESIS

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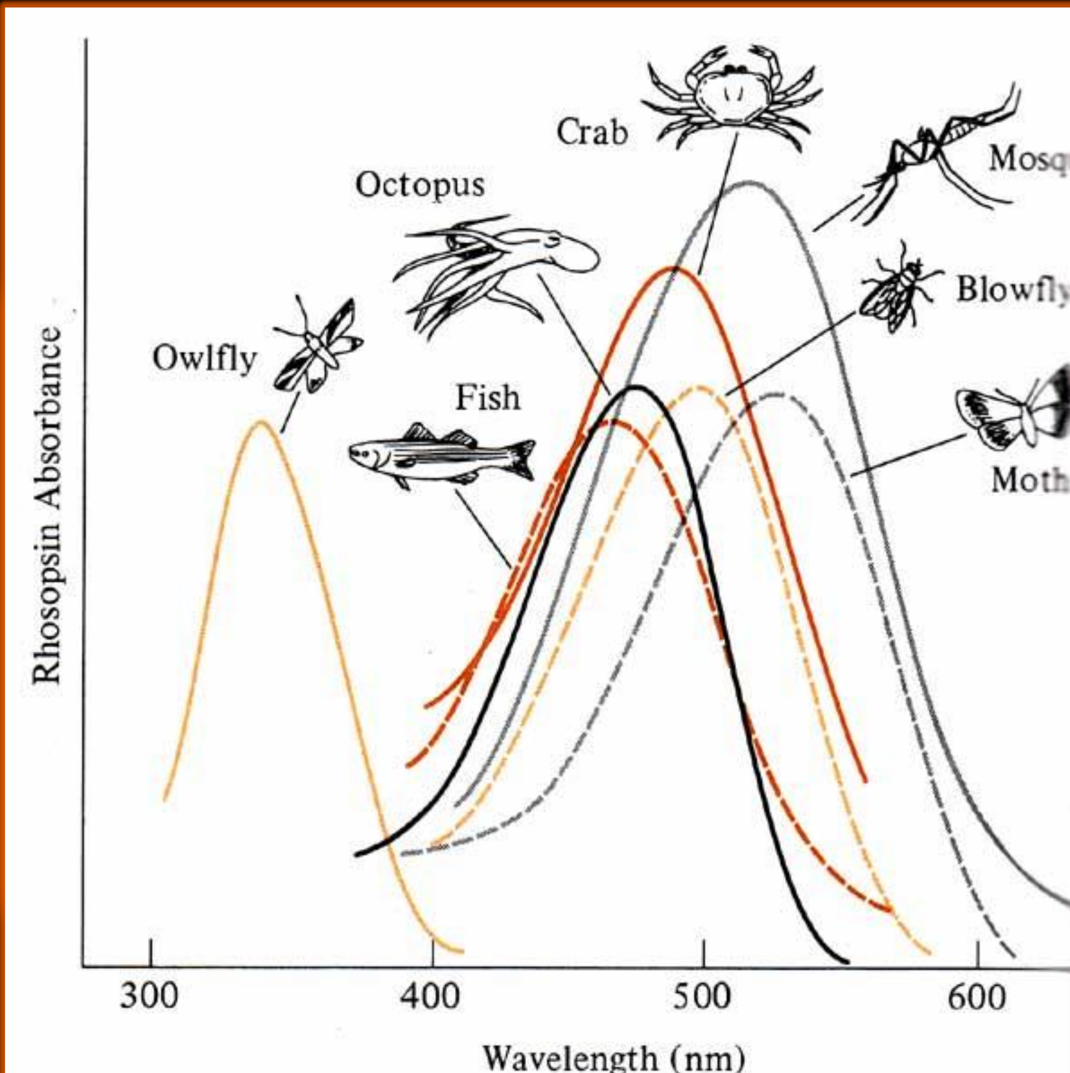
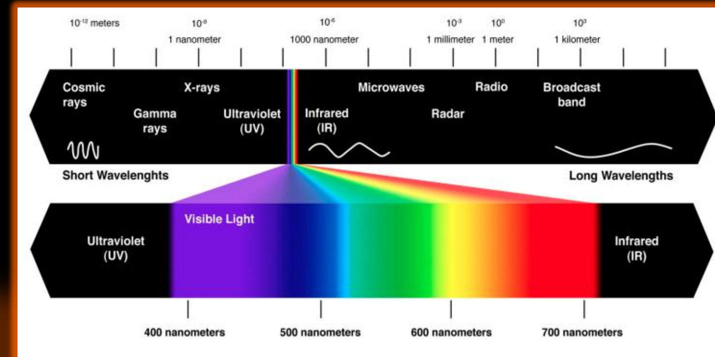




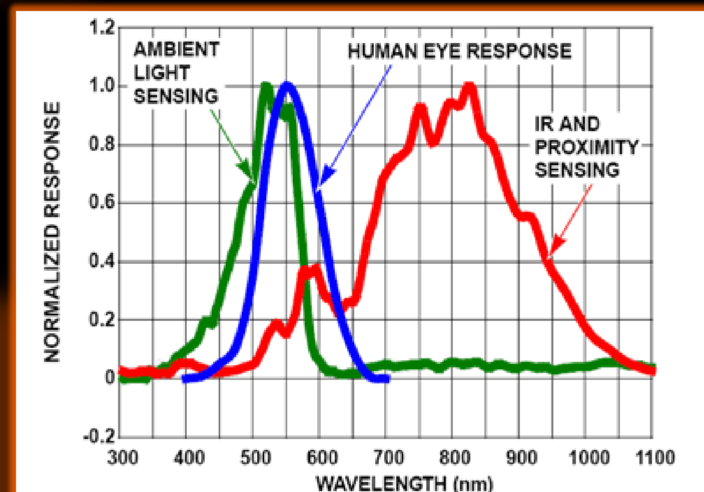
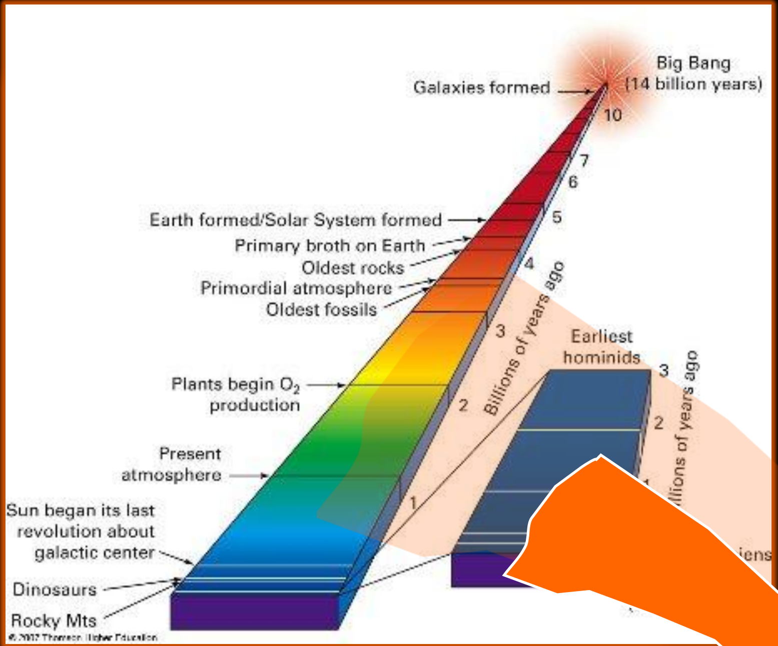
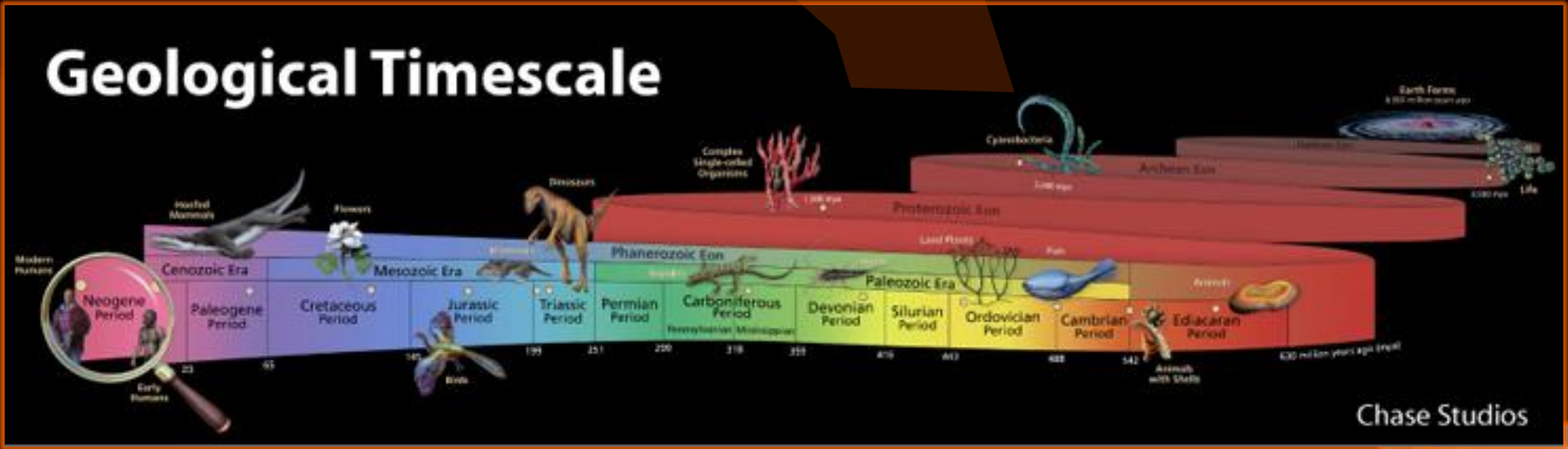


FIGURE 6. SPECTRAL RESPONSE FOR AMBIENT LIGHT SENSING AND PROXIMITY SENSING

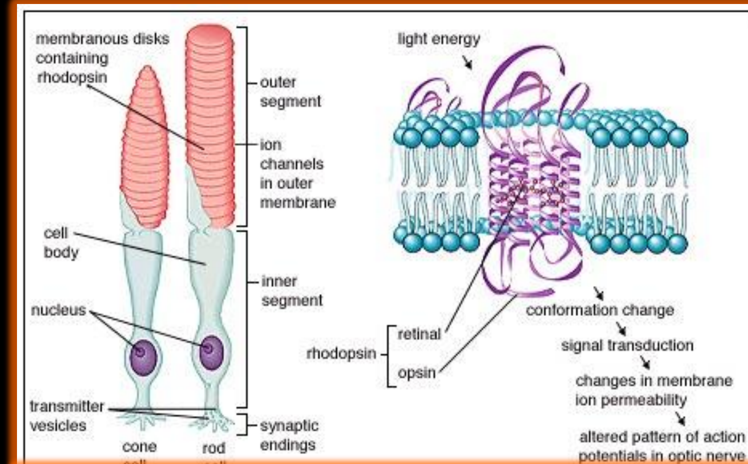
LIGHT: GENESIS

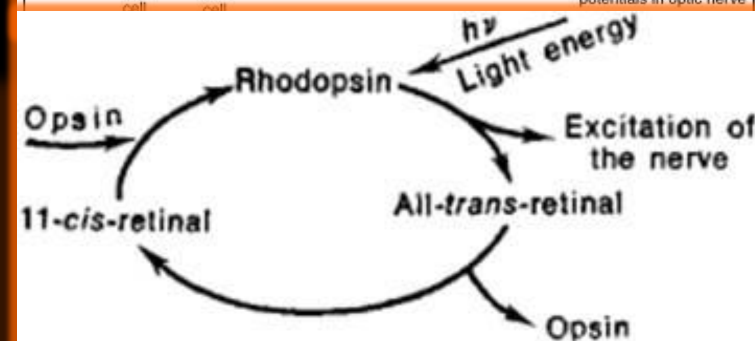


5 Billions years ago



LIGHT: GENESIS

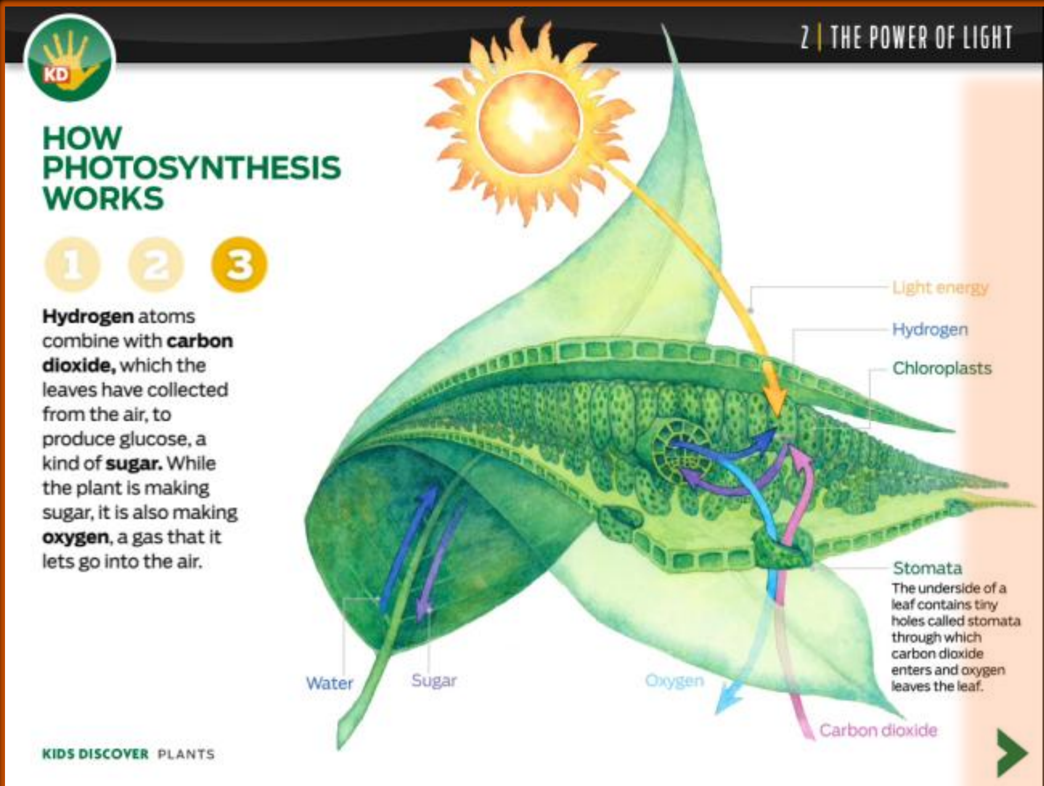


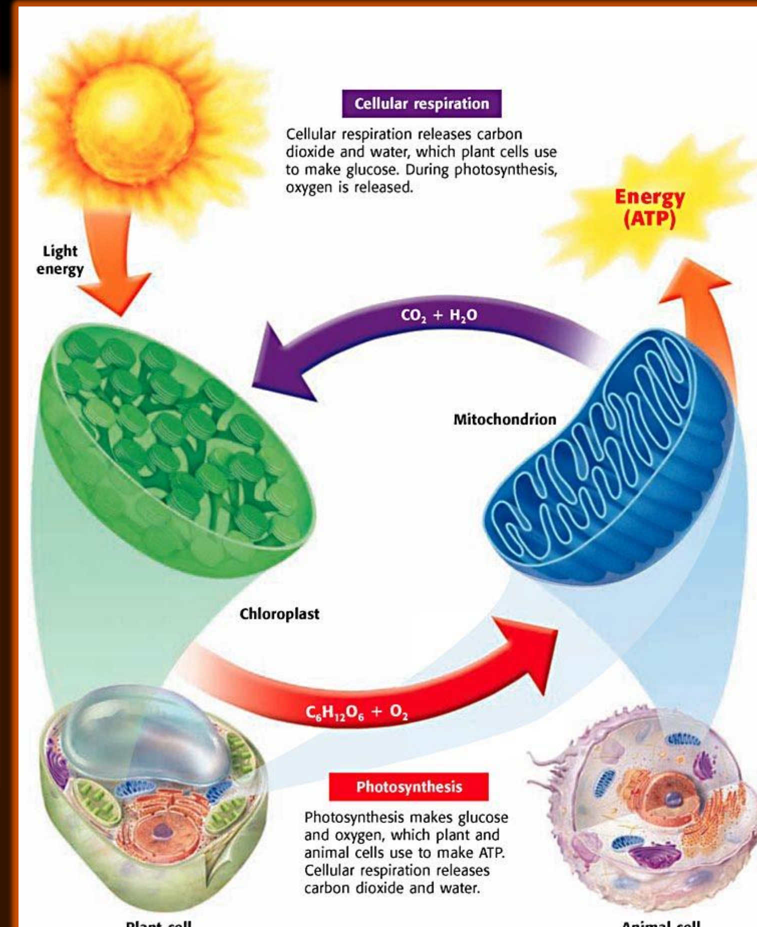


EYE:

- **Rod photoreceptor cell,** responsible for dim-light vision.
- **Rod cell:** stack of disk membranes containing visual pigment rhodopsin.
- **Rhodopsin:** G protein-coupled receptor (GPCR)
- Mutations in the gene for rhodopsin are responsible for autosomal dominant retinitis pigmentosa, causing night blindnes/peripheral vision defects.

LIGHT: GENESIS





PHOTOSYNTHESIS:

- CO2+H2O+ hv: C6H12O^ + O2
- Calvin cycle: hv + ATP +NADPH2/ ADP + NADP$^+$
- Chlorophyl: An effective porphyrin chemical cycle

LIGHT: GENESIS

300 BC: Reflection of light from smooth surfaces: Euclid (325-265 BC), Ancient Greek mathematician (*Optica*).

1021: Theory of Vision: vision takes place by light entering the eye and not vice versa: Alhazen (965 - 1040 AD), Persian scientist & polymath, (*Book of Optics*).

1284: Eyeglasses (disputed): Salvino D'Armate (1258–1312), Italian.
1550: Camera obscura with bi-convex lens: G. Cardano (1501-1576), Italian mathematician and physician.
1590: Compound Microscope: Hans and Zacharias Janssen, Dutch spectacle-makers.
1608: Telescope: Hans Lippershey (1570-1619), Dutch eyeglass maker.
1621: Refractive index: Willebrord Snell (1580-1626), Dutch mathematician.
1668: Reflecting telescope: Isaac Newton (1642 - 1727), English physicist and mathematician.
1676: Single lens microscope: Antonie van Leeuwenhoek (1632-1723), Dutch tradesman and scientist.
1704: Spectrum of light prism experiments: Isaac Newton (1642 - 1727), English physicist, mathematician.
1729: Achromatic Lens: Chester Moore Hall (1703 - 1771), British lawyer and inventor.
1750: Lighthouse lenses: Georges de Buffon (1707-1788), French naturalist and mathematician.

1804: Wave nature of light: double slit exp.: Thomas Young (1773 - 1829), English polymath.

1816: Kaleidoscope: David Brewster (1781-1868), Scottish physicist.
1823: Fresnel lens: Augustin-Jean Fresnel (1788-1827), French engineer.

LIGHT: GENESIS

1825: Astigmatism: correcting eyeglasses using cylindrical lens: G. Biddell Airy (1801-1892), English mathematician astronomer.
1839: Photovoltaic effect: Alexandre Becquerel (1820 - 1891), French physicist.

1840s: Lens production: Carl Zeiss (1816-1888), German maker of optical instruments.

1850: Speed of light measurement and demonstration that the velocity of light is a constant: Armand Hippolyte Fizeau (1819-1896), French physicist.

1861: Light as electromagnetic radiation: Maxwell's equations: James Clerk Maxwell (1831 - 1879), Scottish physicist and mathematician.

1874: Refractometer: Ernst Abbe (1840 - 1905), German mathematician and physicist.
1884: Mechanical Television (Nipkow scanning disk): Paul Nipkow (1860-1940), German inventor.
1887: Photoelectric effect: Heinrich Hertz (1857 - 1894), German physicist.
1888: Hand-Held Camera: George Eastman (1854-1932), American inventor.

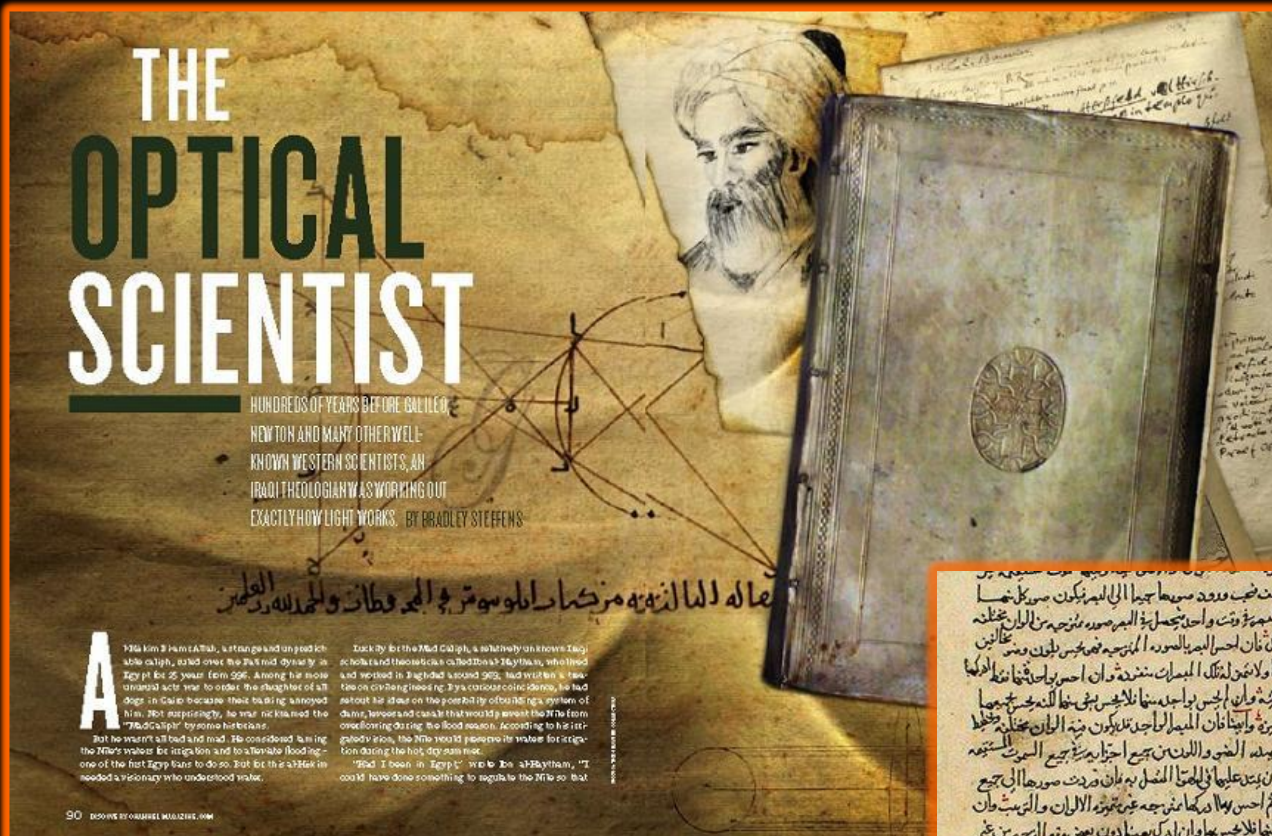
1899: Quantum theory of energy: exchange of energy between light and matter only occurs in discrete amounts – *quanta*: Max Planck (1858-1947), German physicist.

1925: Leica camera lens: Max Berek (1886-1949), German physicist and mathematician.
1938: Electron microscope: Ernst Ruska (1906-1988), German physician and biologist.

LIGHT: GENESIS

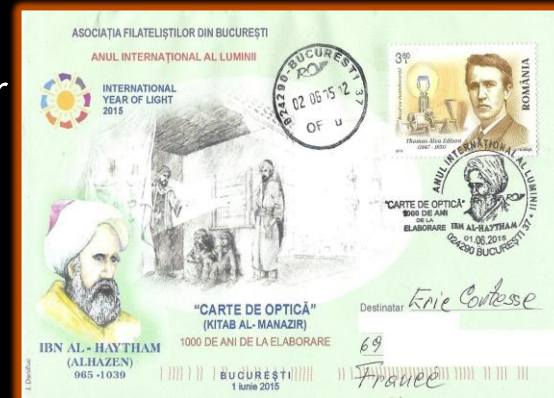
1021: Theory of Vision: vision takes place by light entering the eye and not vice versa: Alhazen (965 - 1040 AD), Persian scientist & polymath, (*Book of Optics*).

1011-21: Camera Obscura: Basis of the modern camera/ Object-Image concept/Indirectly law of refraction



LIGHT: GENESIS

- Under house arrest in Cairo, Egypt (1011-1021), Iraqi Muslim scientist Ibn al-Haytham (Latinized as Alhacen or Alhazen) wrote *The Book of Optics* (Arabic: *Kitab al-Manazir*; Latin: *De aspectibus or Opticae Thesaurus*: *Alhazeni Arabis,*), 7 volumes treatise on optics, physics, mathematics, anatomy and psychology.



- Foundations for modern physical optics after drastically transforming the way in which light and vision had been understood,

- The Book of Optics has been ranked alongside Isaac Newton's *Philosophiae Naturalis Principia Mathematica*

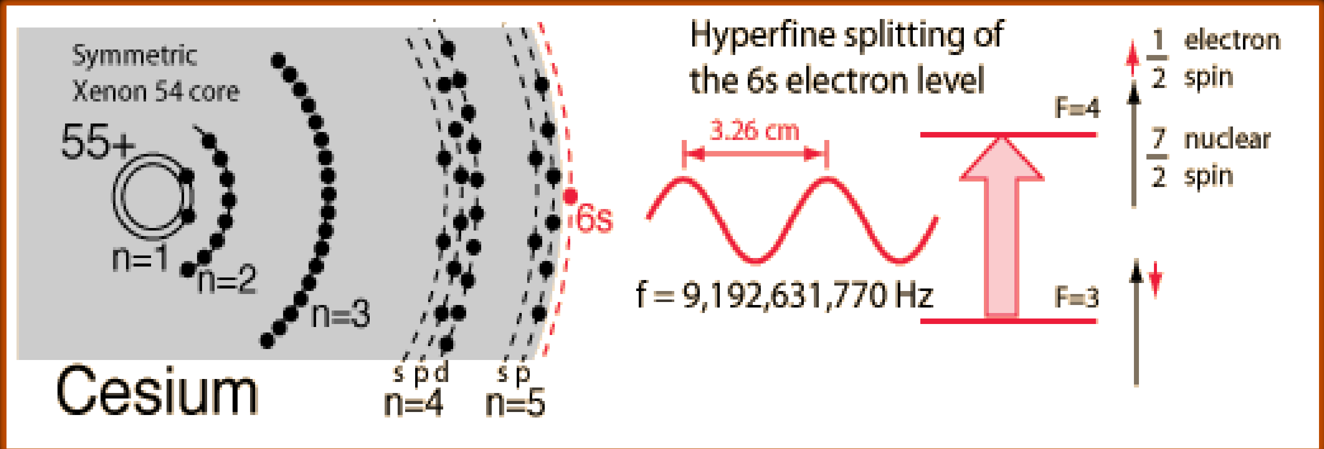
- Ophthalmology: correctly explained the process of sight for the first time

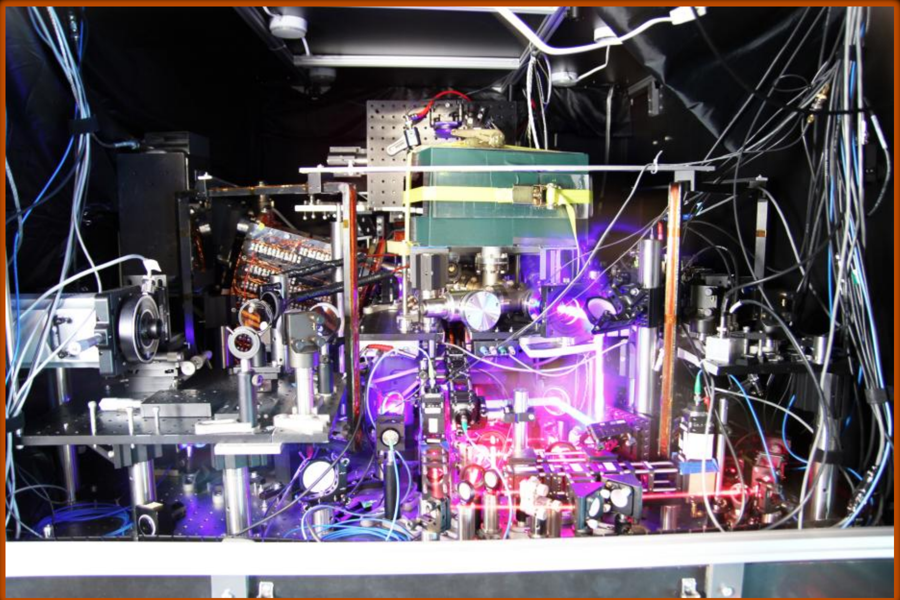
- Edited for print publication by the German mathematician Friedrich Risner and issued as *Opticae thesaurus. . . libri septem, nunc primum editi . . . item Vitellonis Thuringopoloni libri X* in Basel by Episcopus in 1572.

LIGHT: GENESIS

DEFINITION OF TIME: What is 1 second?

LIGHT: GENESIS



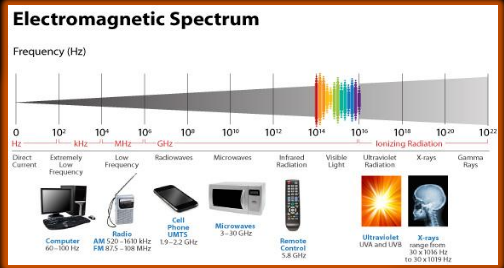


DEFINITION OF TIME

- 1s = 9. 192, 631, 770 periods

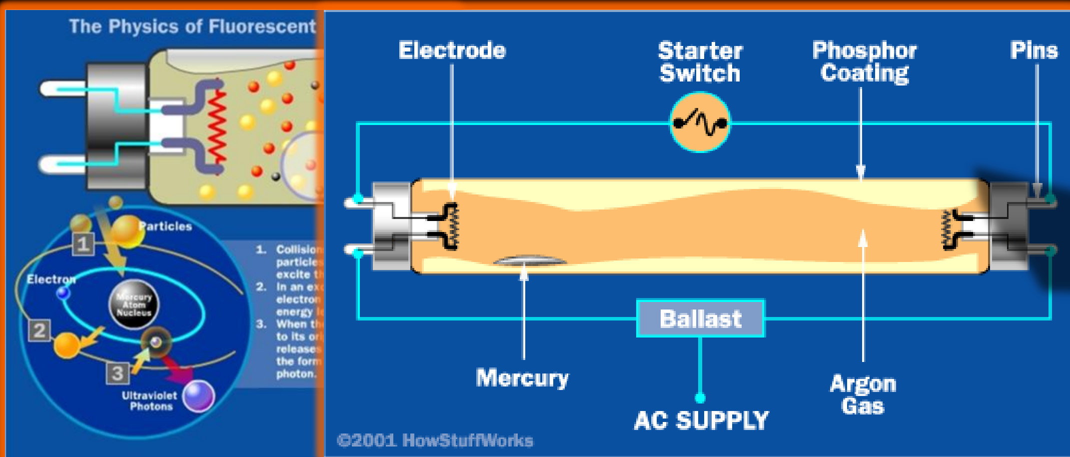
of transition between 2 hyperfine levels of ^{133}Cs ground state
it measured the second with an uncertainty of 0.53 x 10-15

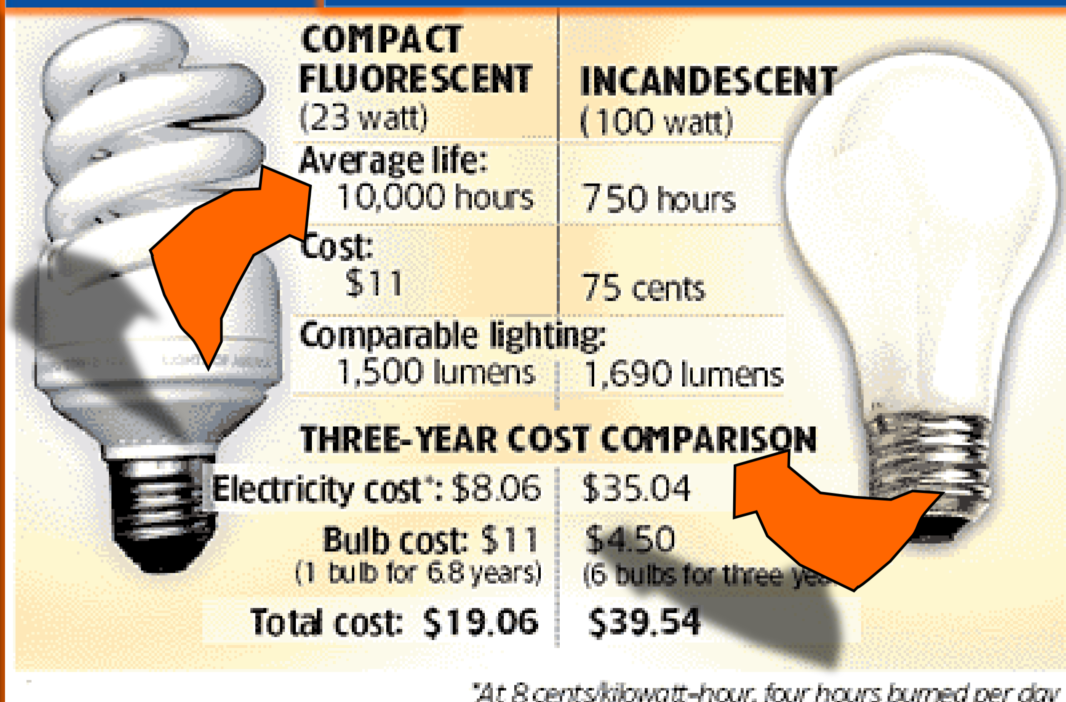
LIGHT: MAJOR IMPACT



- 1879: Thomas Edison's first successful light bulb model, used in public demonstration at Menlo Park-USA.
- First with carbon filaments and then with platinum and other metals. With C filament: 13.5 hours.
- 1st commercially practical incandescent light.

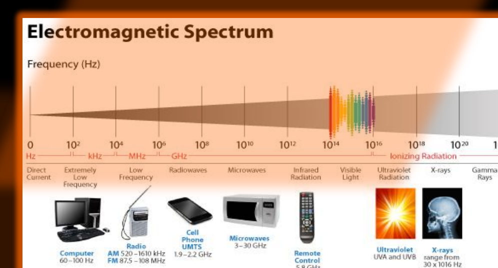
LIGHT: MAJOR IMPACT



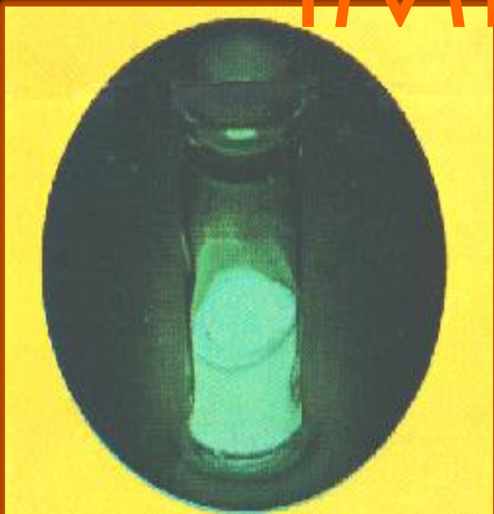


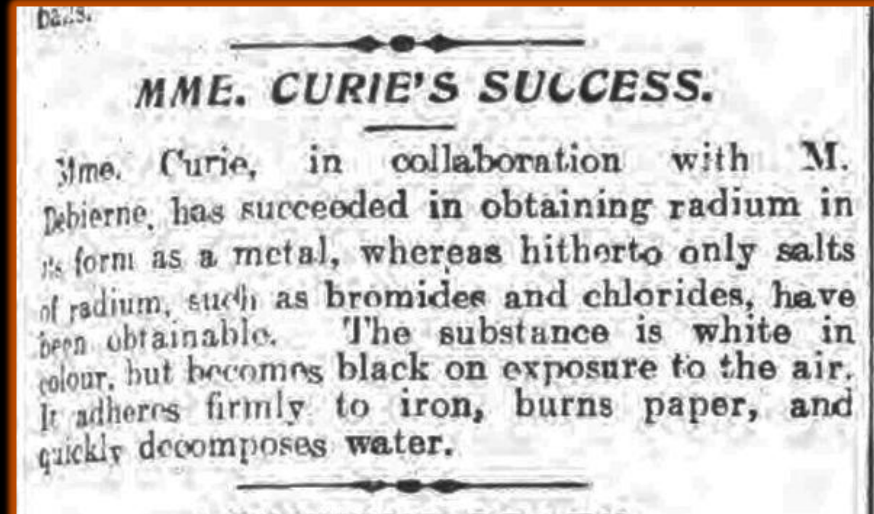
	COMPACT FLUORESCENT (23 watt)	INCANDESCENT (100 watt)
Average life:	10,000 hours	750 hours
Cost:	$11	75 cents
Comparable lighting:	1,500 lumens	1,690 lumens
THREE-YEAR COST COMPARISON		
Electricity cost*:	$8.06	$35.04
Bulb cost:	$11 (1 bulb for 6.8 years)	$4.50 (6 bulbs for three years)
Total cost:	$19.06	$39.54

*At 8 cents/kilowatt-hour, four hours burned per day



LIGHT: MAJOR IMPACT





MME. CURIE'S SUCCESS.

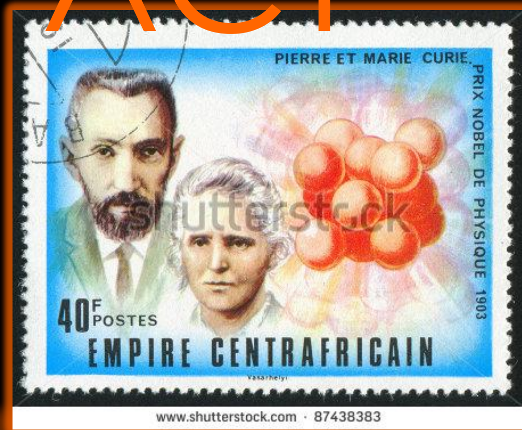
Mme. Curie, in collaboration with M. Debierne, has succeeded in obtaining radium in its form as a metal, whereas hitherto only salts of radium, such as bromides and chlorides, have been obtainable. The substance is white in colour, but becomes black on exposure to the air. It adheres firmly to iron, burns paper, and quickly decomposes water.

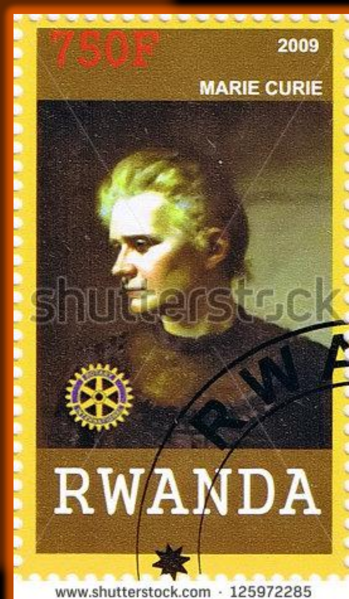
- 1898: Due to luminescence of Zinc salt, Marie Curie discovered that 2 common uranium ores, *pitchblende* and *chalcolite* were more radioactive than refined uranium. This was the indication that there must be another element, one even more radioactive than uranium, mixed with these ores: radium & polonium.

- 1899-1902: She continued to dissolve, filter, and repeatedly crystallized nearly 3 tons of *pitchblende*/production of 1/10 of a gram of high grade radium chloride. This was enough to confirm her discovery spectroscopically and determine the exact atomic mass of radium.

- 1902-1910: Detection of the nuclear decay of radium, as indicated by the emanation of alpha, beta, and gamma radiation,

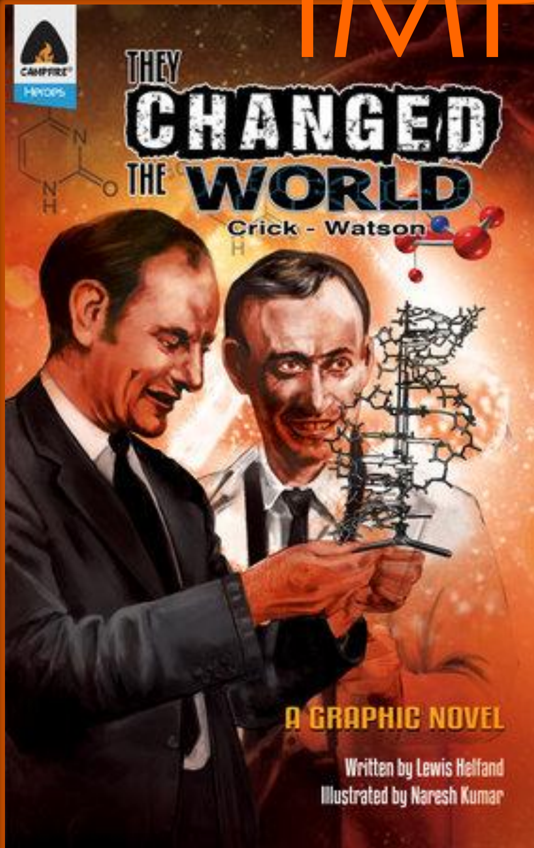
LIGHT: MAJOR IMPACT

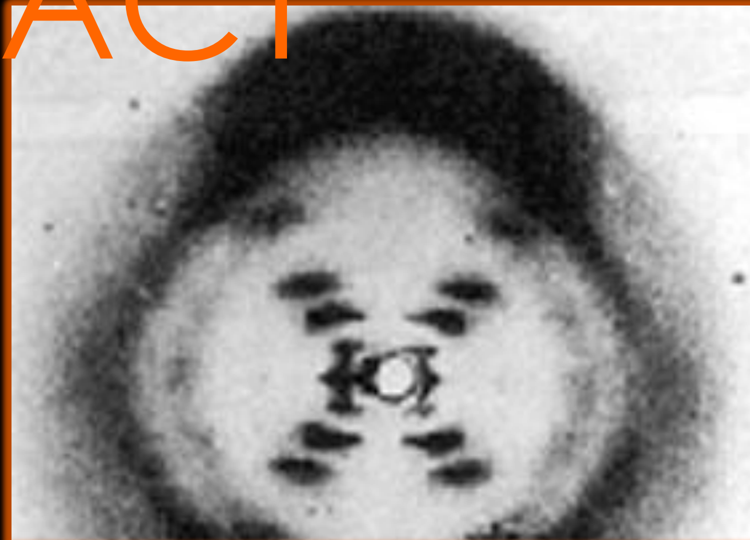


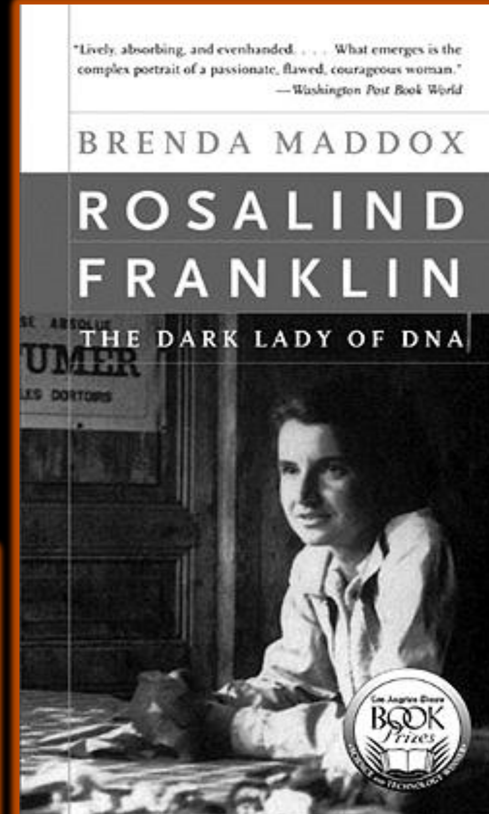


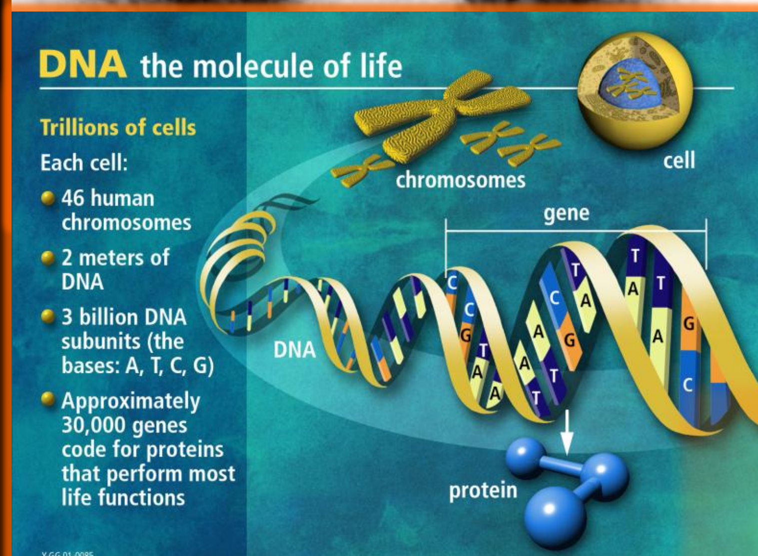
1902-1910: Detection of the nuclear decay of radium, as indicated by the emanation of alpha, beta, and gamma radiation,

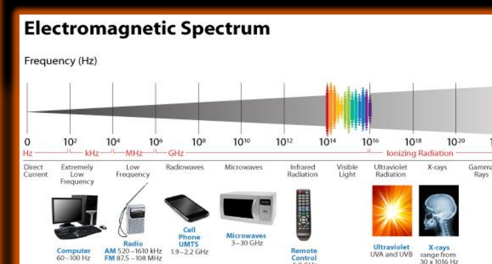
LIGHT: MAJOR IMPACT





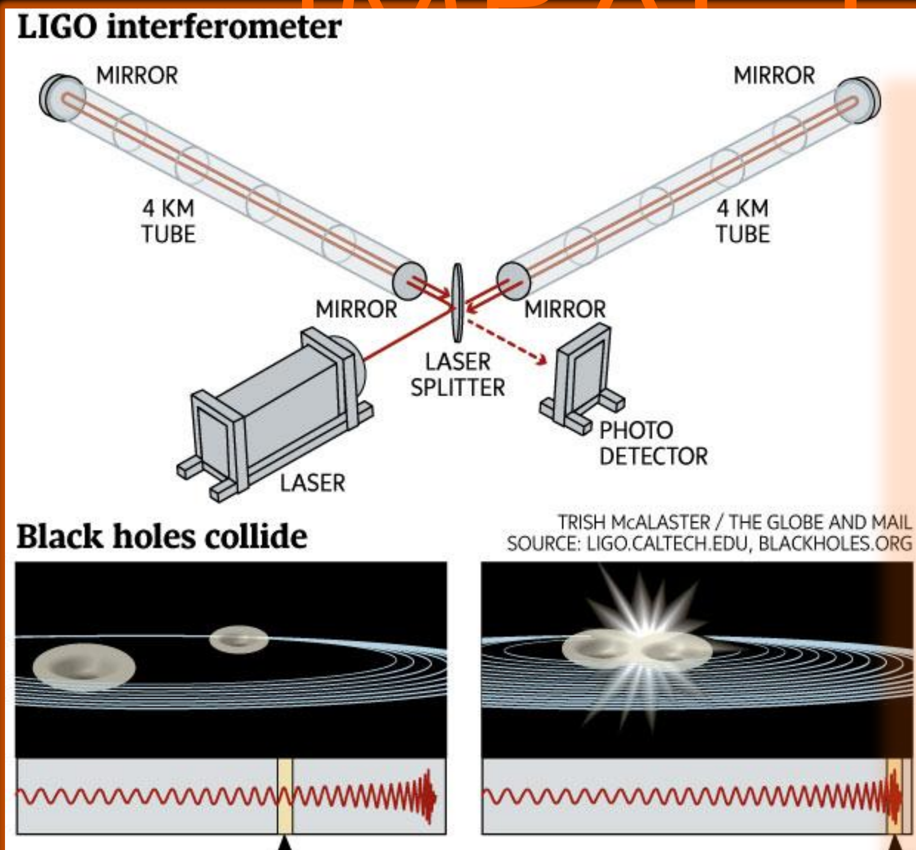


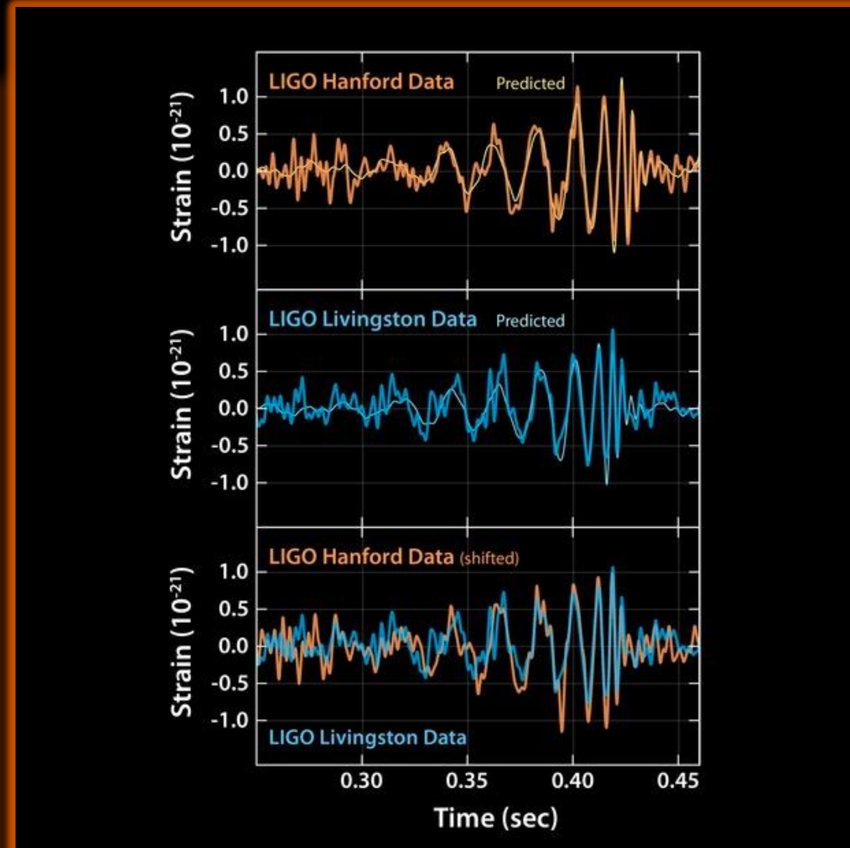




- 1953: Watson & Crick created their model of DNA based on X-ray fiber diffraction gathered by Rosalind Franklin actually

LIGHT: MAJOR IMPACT





- 2015: LIGO sensed a wave that stretched space by one part in 10^{21}, making the entire Earth expand and contract by 1/100,000 nm: width of an atomic nucleus.
- Einstein's theory of gravity, the general theory of relativity, with unprecedented rigor and provides proof positive that black holes exist.

LIGHT: MAJOR IMPACT

From prediction to reality: a history of the search for gravitational waves

1915 - Albert Einstein publishes general theory of relativity, explains gravity as the warping of spacetime by mass or energy

1916 - Einstein predicts massive objects whirling in certain ways will cause spacetime ripples—gravitational waves

1936 - Einstein has second thoughts and argues in a manuscript that the waves don't exist—until reviewer points out a mistake

1962 - Russian physicists M. E. Gertsenshtein and V. I. Pustovoit publish paper sketch optical method for detecting gravitational waves

1969 - Physicist Joseph Weber claims gravitational wave detection using massive aluminum cylinders—replication efforts fail

1972 - Rainer Weiss of MIT in Cambridge independently proposes optical method for detecting waves

1974 - Astronomers discover pulsar orbiting a neutron star that appears to be slowing down due to gravitational radiation—work that later earns them a Nobel Prize

1979 – NSF funds Caltech and MIT to develop design for LIGO

1990 - NSF agrees to fund $250 million LIGO experiment

1992 - Sites in Washington & Louisiana selected for LIGO; construction starts 2 years later

1995 – Construction GEO600 detector in Germany, partners with LIGO and starts taking data

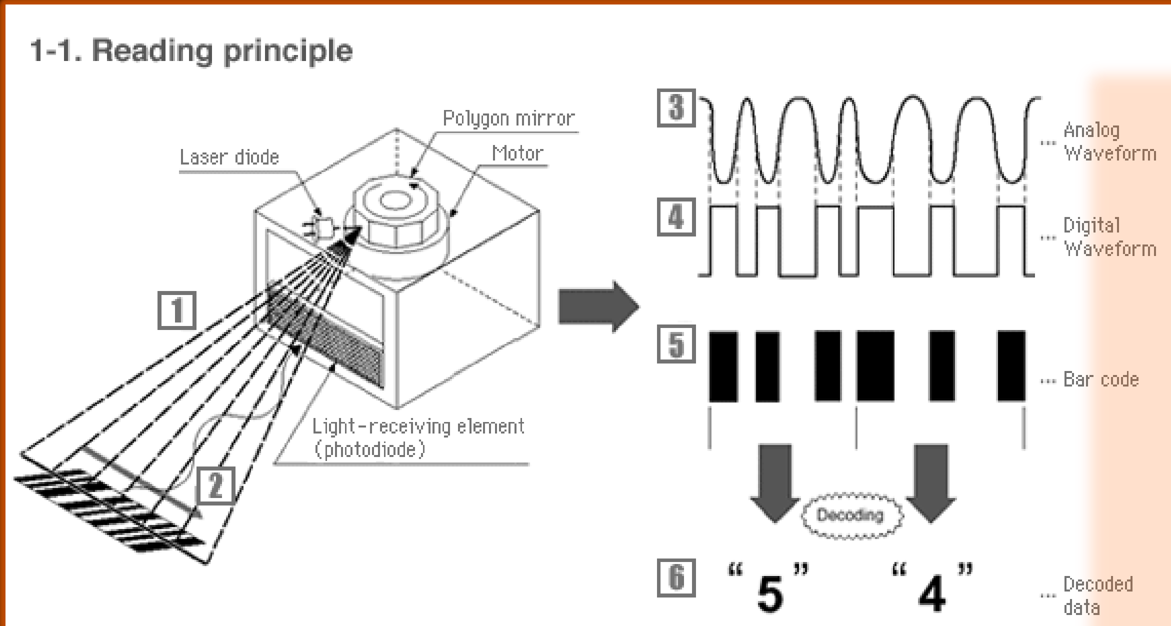
1996 - Construction starts on VIRGO detector in Italy, which starts taking data in 2007

2010–2015 - $205 million upgrade of LIGO detectors

2015 - Advanced LIGO begins initial detection runs in September

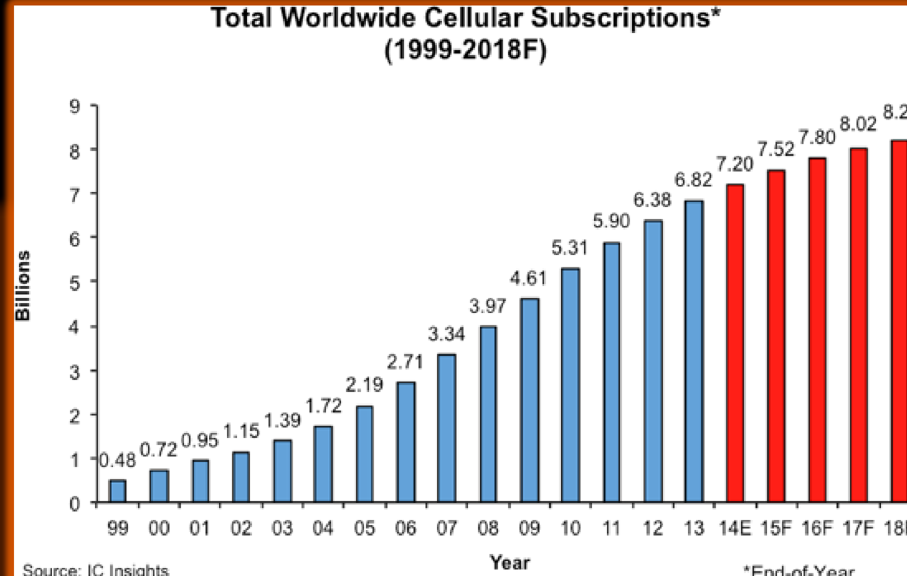
2016 - On 11 February, NSF and LIGO team announce successful detection of gravitational waves

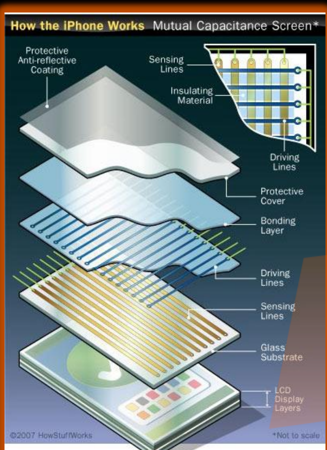
LIGHT: A DAILY USAGE



BARCODE: He-Ne Laser Beam reflcted on a polygonal rotating mirror/ Photodiode signal is Analog transformed

LIGHT: A DAILY USAGE





CELLPHONES: Phosphors & optoelectronic based component/ 7.13B Subscriptions (China/Nigeria)

LIGHT: A DAILY USAGE

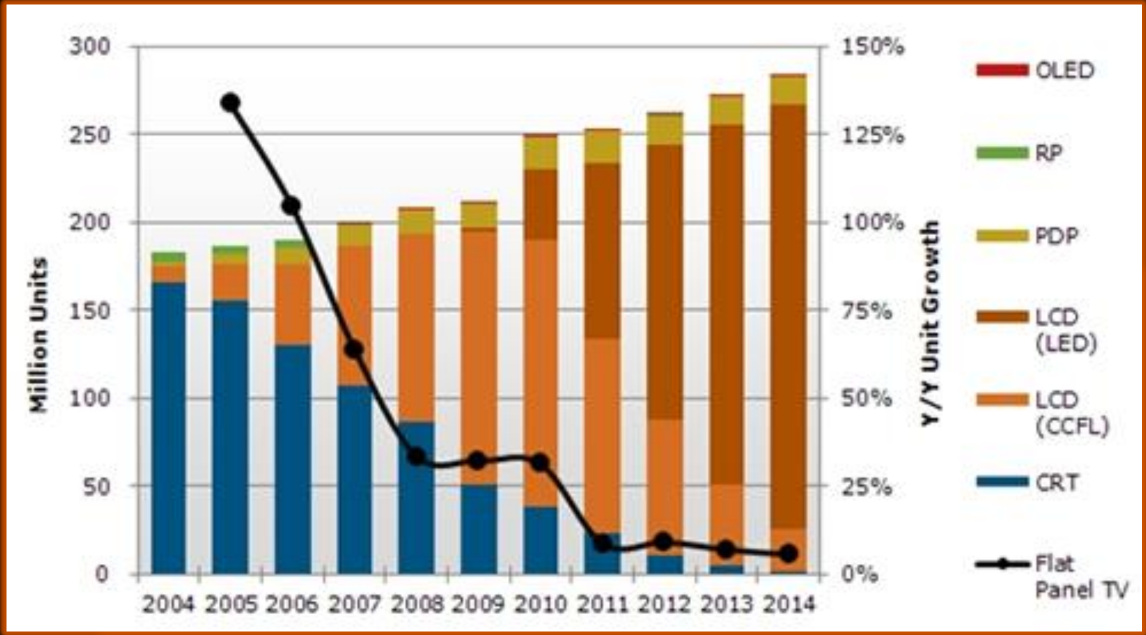
Rankings	Country or regions	Number of mobile phones	Population	Connections/100 citizens	Date of evaluation
	World	6,800,000,000+	7,012,000,000[1]	97	2013[2][3]
01	China	1,276,660,000[4]	1,364,270,000[5]	93.2	October 2014[6]
02	India	1,003,490,000[6]	1,295,291,543[5]	79.39	31 October 2015[6]
03	United States	327,577,529	317,874,628[7]	103.1	April 2014[8]
04	Brazil	284,200,000	201,032,714[9]	141.3	May 2015[10]
05	Russia	256,116,000	142,905,200[9]	155.5	July 2013[11]
06	Indonesia	236,800,000	237,556,363	99.68	September 2013[9]
07	Nigeria	167,371,945	177,155,754	94.5	Feb 2014[12]
08	Pakistan	140,000,000[13]	180,854,781[14]	77[15][16]	July 2014[17]
09	Bangladesh	133,720,000[18]	157,497,000[19]	84.95	April 2015[20]
10	Japan	121,246,700	127,628,095	95.1	
11	Germany	107,000,000	81,882,342	130.1	2013[22]
12	Philippines	106,987,098	94,013,200	113.8	October 2013[23]
13	Mexico	101,339,000	112,322,757	90.2	Jul. 2013[24]
14	Iran	96,165,000	73,973,630	130	February 2013[25]
15	Italy	88,580,000	60,790,400	147.4	Dec. 2013[26]
16	United Kingdom	83,100,000	64,100,000	129.6	Q4 2013[27]
17	Vietnam	72,300,000	90,549,390	79	October 2013[28]
18	Turkey	72,200,000	81,619,392	92.5	2016[29]
19	France	72,180,000	63,573,842	114.2	Dec. 2013[30]
20	Egypt	92,640,000	82,120,000	112.81	Egypt Ministry of Communications & IT, August 2013[31]
21	Thailand	69,000,000	67,480,000	105	2015[32]

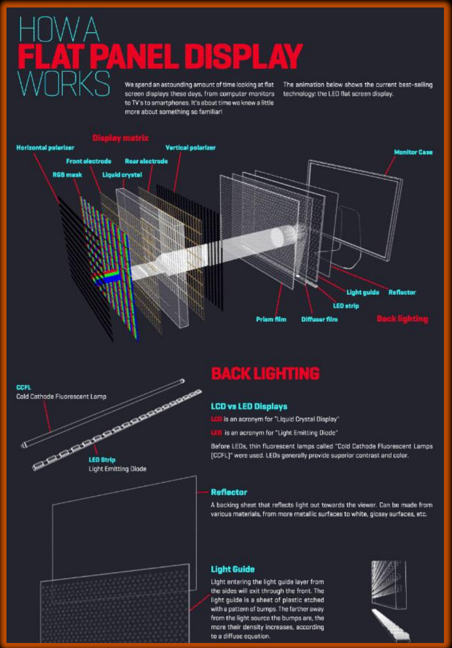
R[illegible]	Country or regions	Number of mobile phones	Population	Connections/100 citizens	Date of evaluation
[illegible]	Ukraine	57,505,555	45,579,904	126.0	Dec. 2013[33]
[illegible]	South Korea	56,004,887	50,219,669	111.5	2014[34]
[illegible]	Spain	55,740,000	47,265,321	118.0	Feb. 2013[35]
25	Argentina	56,725,200	40,134,425	141.34	2013[36]
26	Poland	47,153,200	38,186,860[37]	123.48	2013[38]
27	Colombia	49,066,359	47,000,000	104.4	2013[39]
28	South Africa	59,474,500	50,586,757	117.6	2013 GSM African Mobile Observatory report [40]
29	Morocco	44,450,000	33,818,662	131	2015[41]
30	Algeria	33,000,000	35,000,000	94.2	2013[42]
31	Taiwan	28,610,000	23,197,947	123.33	September 2013[43]
32	Kenya	28,080,000	42,000,000	71.3	2013[44]
33	Venezuela	32,019,086	30,163,157	106.15	2014[45]
34	Peru	33,000,000	30,000,000	110.0	Oct. 2013[46]
35	Romania	26,000,000	21,438,000	123.45	December 16, 2010 [47]
36	Canada	28,217,707	35,675,834	79.1	Q3 2014[48]
37	Netherlands	20,000,000	16,515,057	121.1	Nov. 2013[49]
38	Australia	20,570,000[50]	23,490,700[51]	132.0	– November 2014
39	Saudi Arabia	46,000,000	27,137,000	169.5	Jun 2013[52]
40	Malaysia	30,379,000	28,250,000	143.8	Apr 2014[53]
41	Sri Lanka	22,123,000	20,771,000	107	Dec. 2014[54]
42	Chile	21,000,000	17,094,270	122.9	Dec. 2013[55]
43	Nepal	18,240,670	26,620,020	86.82	Apr. 2014[56]

Rankings	Country or regions	Number of mobile phones	Population	Connections/100 citizens	Date of evaluation
44	Ethiopia	18,000,000	85,000,020	21.8	Dec. 2013[57]
45	Guatemala	17,571,895	14,713,763	119.4	Jan. 2013[58]
46	Ecuador	15,900,000	14,300,000	111.18	Jan. 2013[59]
47	Portugal	13,400,000	10,562,178	126.87	November 2013
48	Hong Kong	17,445,581	7,264,100[60]	240.2	March 2015[61]
49	Belgium	11,822,000	10,414,000	113.6	2013
49	Hungary	11,561,890	9,908,798	116.7	Nov. 2013[62]
50	United Arab Emirates	17,132,724	8,410,763	203.7	Nov 2014[63]
51	Sweden	11,194,000	9,103,788	122.9	(July 2012 est.)
52	Bulgaria	10,655,000	7,600,000	140.2	2008[64]
53	Israel	9,319,000	7,310,000	127.5	2008[64]
54	Finland	9,310,000	5,457,429	170.4	2H 2013[65]
55	Singapore	8,106,700	5,399,000	150.1	Jan 2015[66]
56	Denmark	7,000,000	5,543,819	126.2	February 2008[67]
57	Azerbaijan	7,000,000	8,900,000	78.7	November 2009
58	Jordan	6,010,000	5,950,000	101.0	March 2010[68]
59	New Zealand	4,922,000	4,430,000	111.1	2012[69]
60	Mongolia	3,500,000	2,980,000	117.4	2013[70]
61	Estonia	2,070,000	1,294,486	159.9	2012[71]
62	Lebanon	2,720,000	4,224,000	64.4	Oct 2010[72]
63	Lithuania	4,940,000	2,955,986[73]	167.1	End of Q2 2013 (Tentative)[74]

CELLPHONES: Phosphors & optoelectronic based component/ 7.13B Subscriptions (China/Nigeria)

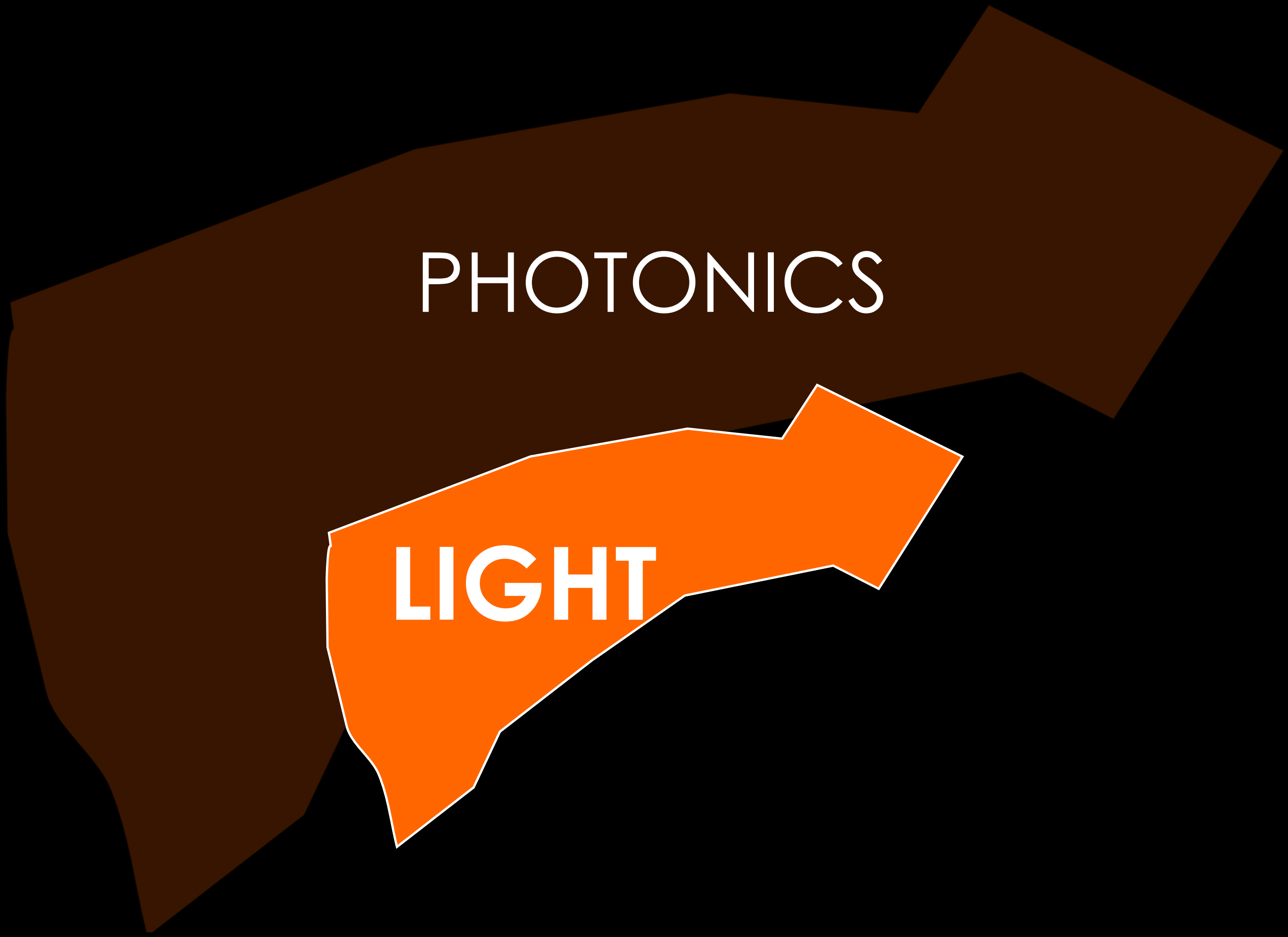
LIGHT: A DAILY USAGE





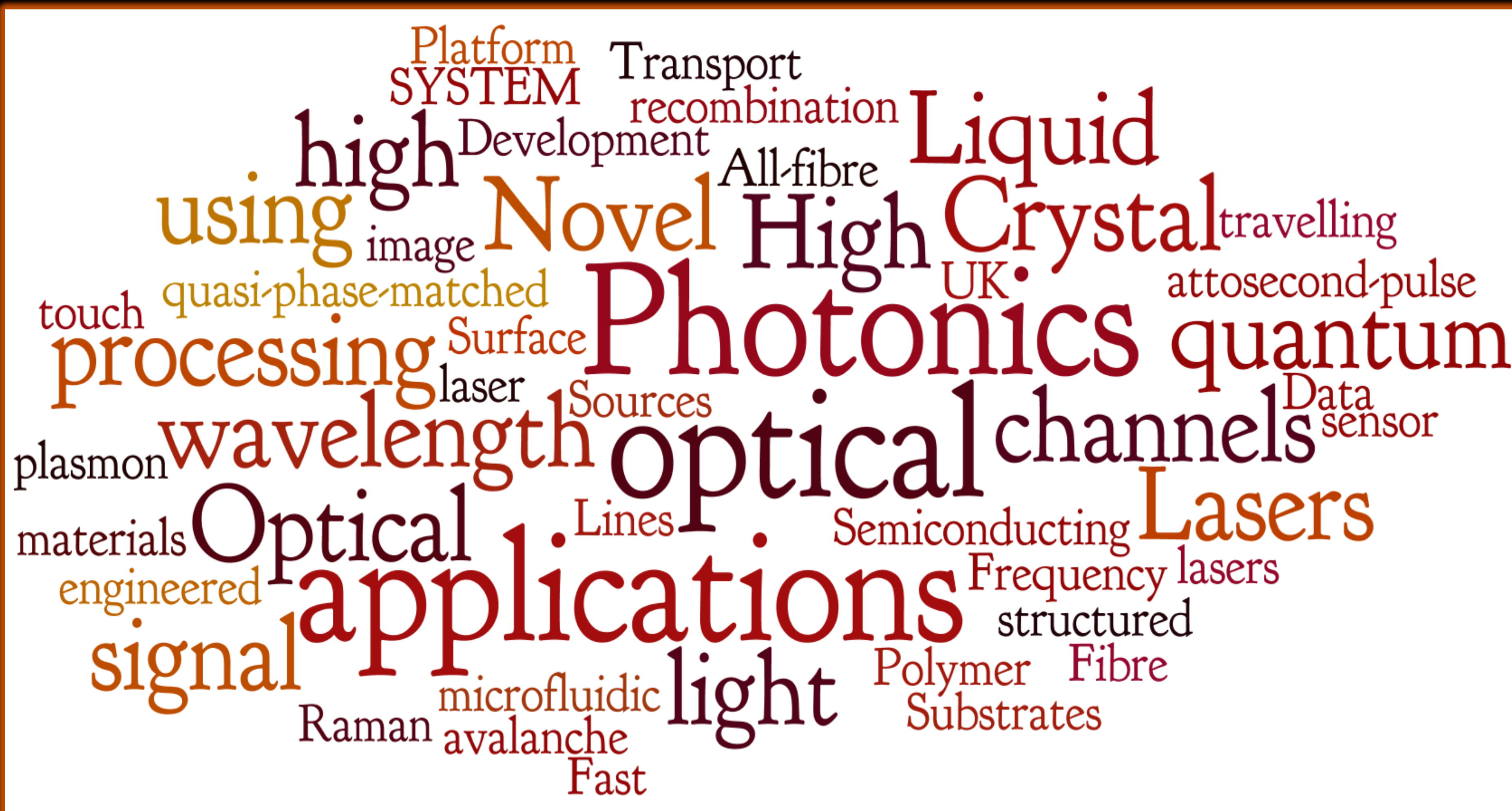
GLOBAL DISPLAY MARKET: Phosphors & Liquid crystals based component/ 300M units in 2016

LIGHT:PHOTONICS TREND



LIGHT:PHOTONICS TREND

LIGHT:PHOTONICS TREND



LIGHT:PHOTONICS TREND

Definition: photonics refers to the development of technologies based around the application, manipulation, and use of light.

- **Generation**
- **Amplification**
- **Transmission of light**
- **Modulation**
- **Detection**

— Lighting (LEDs, displays)
— Manufacturing (high power lasers)
— Telecom (fibers, components, systems)
— Medicine (lasers, microscopes)
— Sensor technology (optical sensors)

“Photonics bears the same relationship to light and photons as electronics does to electricity and electron”

LIGHT:PHOTONICS TREND

1-Communication & IT-Infrastructure

— Cloud computing
— Internet
— Large data transfer, computation, and storage

World Wide Web continues its rapid expansion, with Internet traffic growth exceeding 60% pa.

2-Industrial Automation

— Optical quality checks
— Manufacturing with Laser-Technology
— Digital Technologies to network & transform manufacturing

3-Infrastructure & Cities

— Smart & efficient lighting solutions
— UV-Disinfection & Water treatment solutions
— Mobility & Safety

19% of electricity consumption worldwide
In 2020 LED share of the global lighting market will be 70%

4-Healthcare & Life-Sciences

— Genome sequencing
— Lasers for precise surgery
— Cosmetic treatments and therapy

~80% of the overall In-Vitro Diagnostic market is already based on optical technologies
Eye Cataract surgery restoring eyesight is already surgical intervention no.1 in the world (20 Mio/year)

LIGHT:PHOTONICS TREND

Core photonics components & materials

— $ 156 B Revenue

— 2750 Companies

— 700, 000 Jobs

- Materials, LEDs, lasers
Detectors, image sensors,
Lenses, prisms, optical filters,
gartings, solar cells, fibers

LIGHT:PHOTONICS TREND

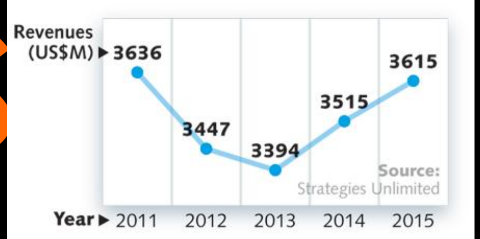
The Geography of Photonics Components Production:

2748 firms span more than 46 countries

LIGHT:PHOTONICS

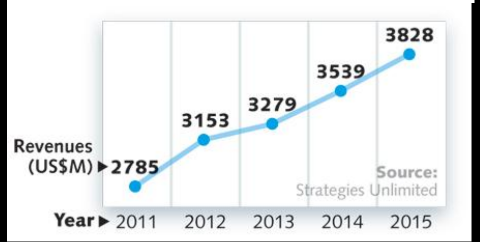
Communications & optical storage

Includes all laser diodes used in telecommunications, data communications, and optical storage applications, including pumps for optical amplifiers.



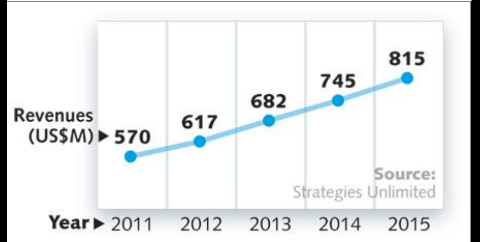
Materials processing & lithography

Includes lasers used for all types of metal processing (welding, cutting, annealing, drilling); semiconductor and microelectronics manufacturing (lithography, scribing, defect repair, via drilling); marking of all materials;



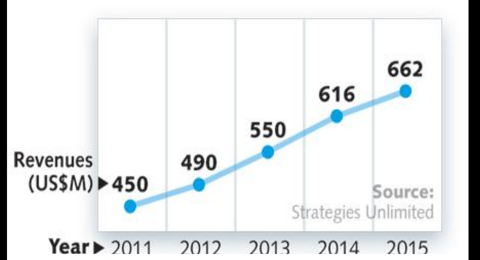
Medical & aesthetic

Includes all lasers used for ophthalmology (including refractive surgery and photocoagulation), surgical, dental, therapeutic, skin, hair, and other cosmetic applications.



Instrumentation & sensors

Includes lasers used within biomedical instruments; analytical instruments (such as spectroscopy); wafer and mask inspection, metrology, levelers, optical mice, gesture recognition, LIDAR, barcode readers, and other sensors.

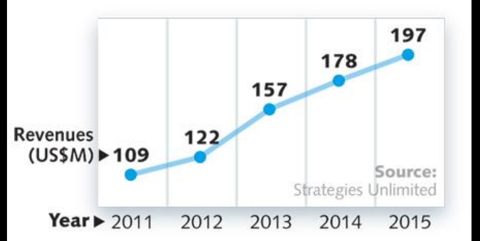


Scientific research and military

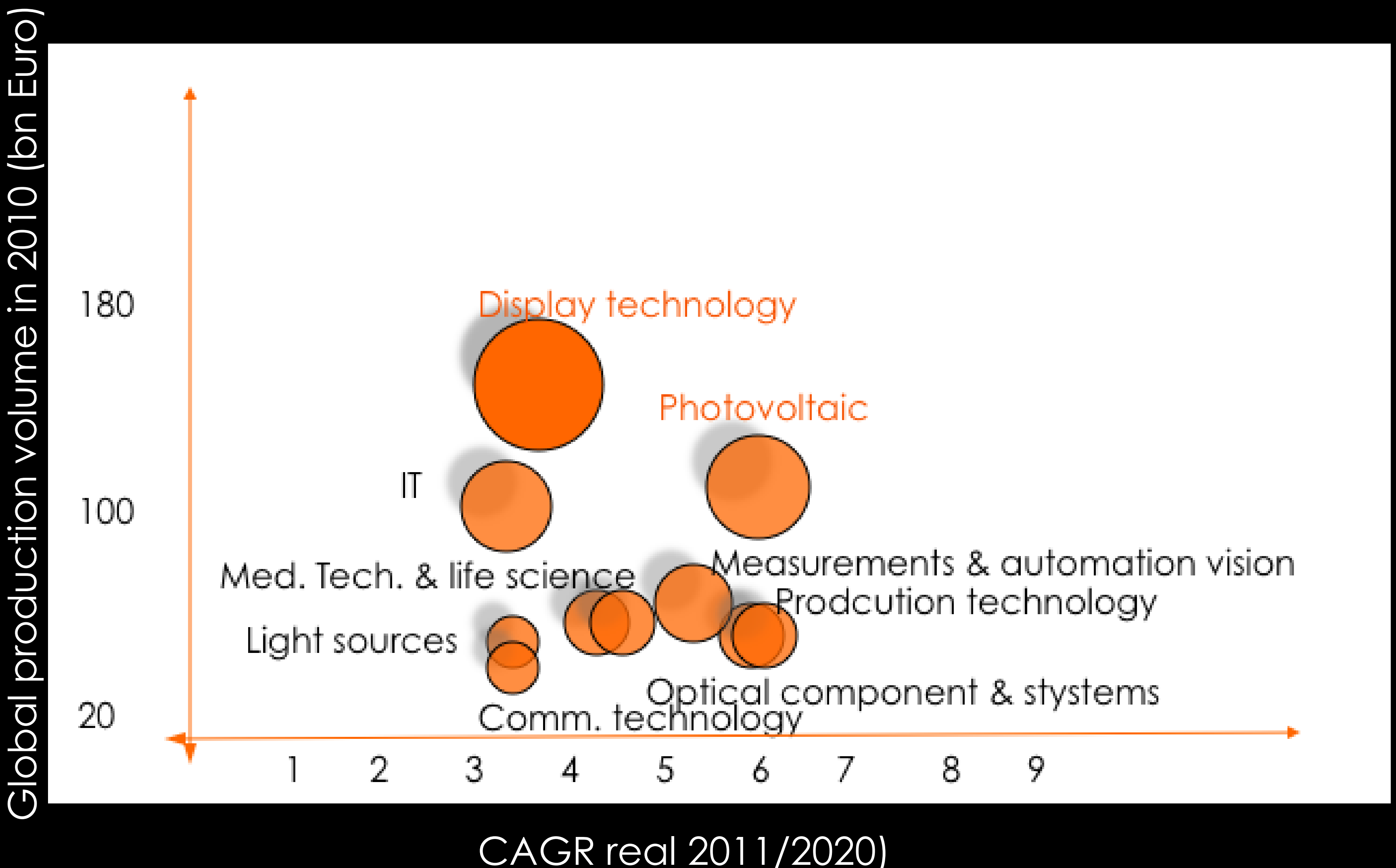
Includes lasers used for fundamental research and development, such as by universities and national laboratories, and new and existing military applications, such as rangefinders, illuminators, infrared countermeasures, and directed-energy weapons research.

Entertainment & displays

Includes lasers used for light shows, games, digital cinema, front and rear projectors, picoprojectors, and laser pointers.



LIGHT: A DAILY USAGE



GLOBAL GROWTH MARKET: Worldwide production volume in 2020

EXPECTED GROWTH OF GLOBAL PHOTONICS SEGMENTS-2020 compared to GDP

LIGHT: AFRICAN CONTRIB

KEA LEBOGA, THANK YOU
BAIE DANKIE, NDI LIVHUWA

United Nations
Educational, Scientific and
Cultural Organization

UNESCO-UNISA Africa Chair
in Nanosciences/Nanotechnology
(South Africa)

UNISA university of south africa

NRF National Research Foundation

iThemba LABS Laboratory for Accelerator Based Sciences

SPONSORS

UNISA university of south africa

ICSU International Council for Science

ICTP The Abdus Salam International Centre for Theoretical Physics

Ministero degli Affari Esteri

Université Pierre & Marie Curie — La science à Paris

Clark Atlanta University

Princeton University

African University of Science and Technology, Abuja — Knowledge is Freedom

AIMS South Africa

elettra

APS American Physical Society

twas

African Union

Department of Science and Technology

SOLEIL Synchrotron

NIMS 独立行政法人 物質・材料研究機構 National Institute for Materials Science

Organization of Women in Science for the Developing World

UNESCO

Liberté • Égalité • Fraternité — République Française — Ministère des Affaires Étrangères et Européennes

Université de Picardie Jules Verne

Université du Maine

IUPAP

cnrs

IAEA International Atomic Energy Agency — Atoms For Peace

CHPC Centre for High Performance Computing

LRI Laser Research Institute

中国科学院 Chinese Academy of Sciences

NSF

UNIDO

NRF National Research Foundation

MAScIR Moroccan Foundation for Advanced Science, Innovation and Research

CSIR our future through science

IOP Institute of Physics

AAS

The New York Academy of Sciences

For Women in Science — L'Oréal Fondation

iThemba LABS Laboratory for Accelerator Based Sciences — NRF National Research Foundation

Seventh Framework Programme

ICPCNANONET

cost

ANSOLE

Excellence in Science

BRICS Research Group

alc african laser centre — African Laser Centre