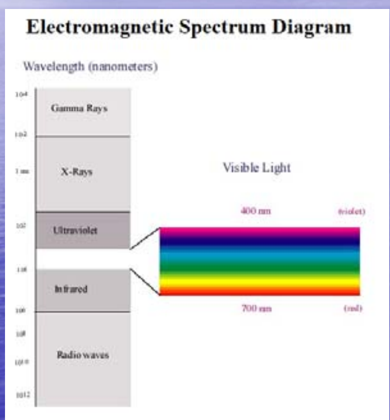
History

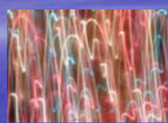
- 1917 '*Emission by Stimulation*' Einstein
- 1954 MASER
- 1960 'Red Ruby Laser' Theodore Maiman
- 1965 Ruby Laser used in the inner ear of Pigeons
- 1967 Nd:YAG used on otosclerotic foot plate
- 1972 Argon laser used on otic capsule
- 1980 CO_2 Laser

LASER

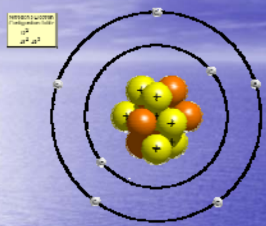
- Light
- Amplification
- Stimulated
- Emission
- Radiation

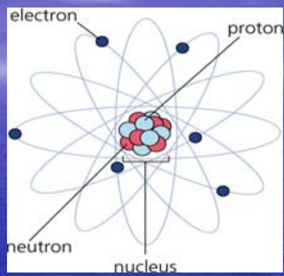
Light



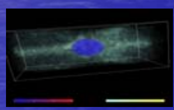


Atom





- Particle
- Cloud



Uncertainty Principle

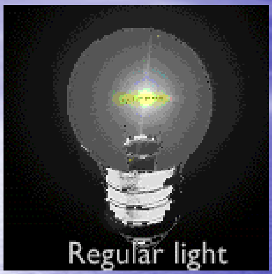
- String

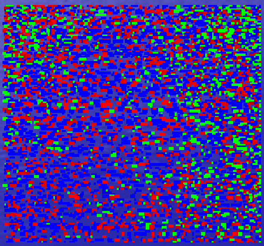
Heisenberg, Werner

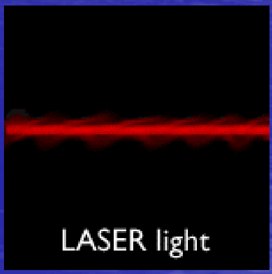
Generation of Photon

A quantum of electromagnetic energy having both particle and wave properties. A photon has no electric charge or mass but possesses momentum, energy, and spin

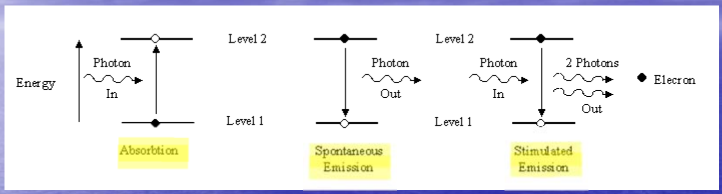
Light and Laser

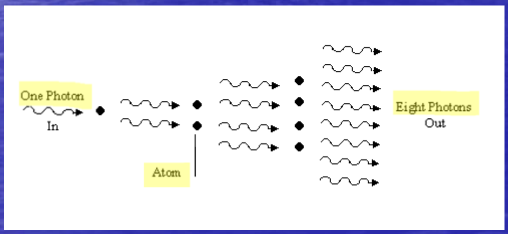




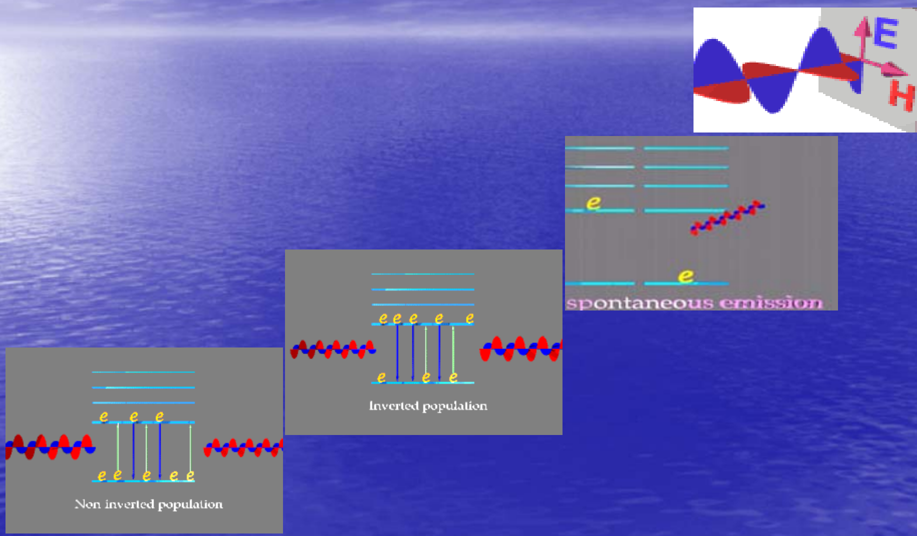


Laser Generation

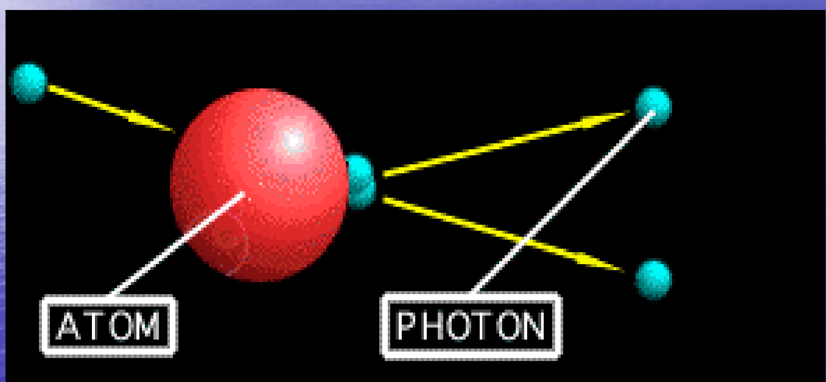




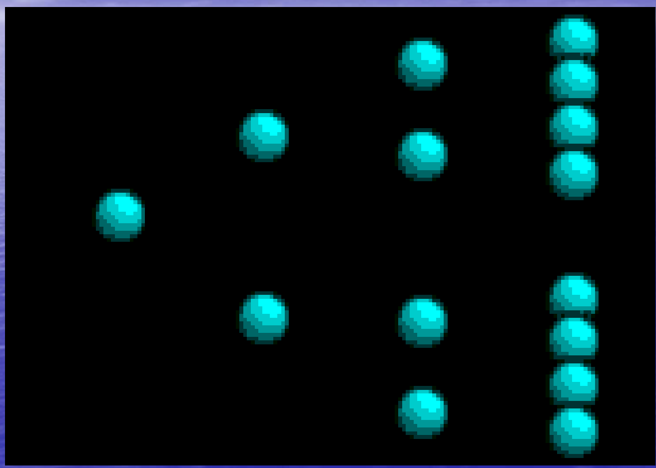
Laser generation



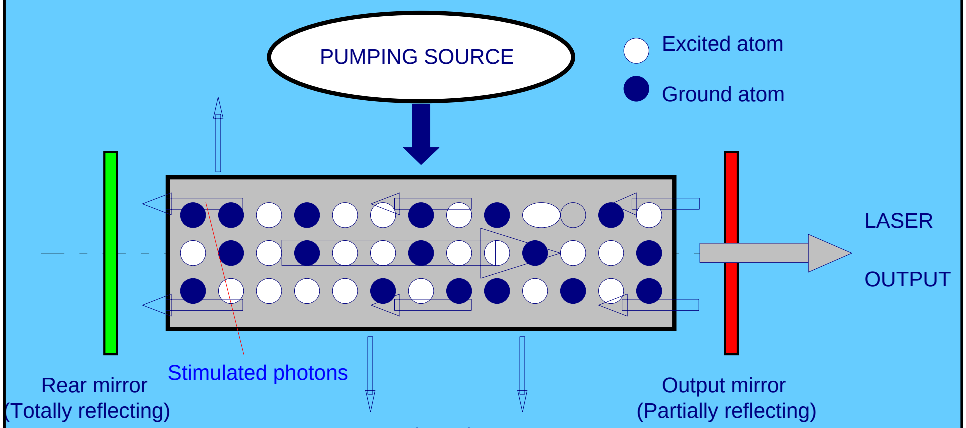
Stimulated Emission



Amplification

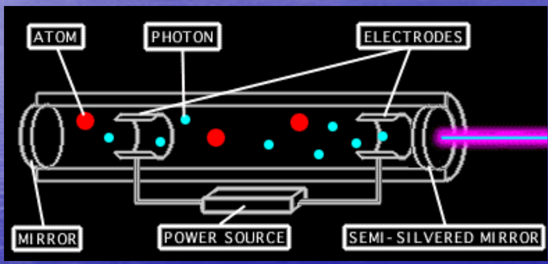


Laser Machine



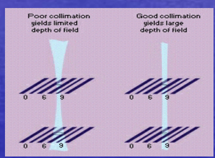
A LASER SYSTEM

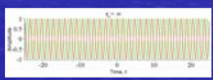
Laser Machine



Properties of Laser

- Monochromatic : EM radiation of same wavelength
- Collimated: Parallel waveform
- Coherence: Waves in phase; both time and Space
- Beam size





Laser Energy and Irradiance

Power (Watts) = Energy (Joules) / Time (Sec)

Power Density

Irradiance = Power / Unit area

I = Watts / cm^2

Laser Classifications

- **Class 1** Inherently safe
- **Class 2** Low power, within the visible band. Safety by aversion response
- **Class 3A** Hazardous to eye if viewed through microscope
- **Class 3B** Direct viewing is hazardous. Viewing reflection is safe
- **Class 4** High powered hazardous laser

General Concepts

- All lasers consist of
  - A medium with suitable set of energy levels
  - A pumping (energy) source
  - An optical cavity
- Classified by active medium
  - Solid state lasers
  - Gas lasers
  - Liquid lasers
  - Semiconductor lasers
- Compared by output characteristics
  - Wavelength
  - Coherence
  - Beam divergence
  - Irradiance or power

Types of Lasers

- Gas
- Liquid
- Solid
- Semiconductors

Types of Lasers

- CO_2 Laser
- Nd:YAG Laser
- KTP laser
- Argon laser
- Holmium : YAG laser
- Erbium : YAG laser
- Diode laser
- Ruby laser

Gas Laser

Gas Lasers

Nitrogen	(UV)	337 nm	Spectroscopy, Non-destructive Testing
Helium Cadmium	(UV)	325 nm	Spectroscopy, Non-destructive Testing
	(Violet)	441 nm	Spectroscopy, Non-destructive Testing
Argon	(Blue)	488 nm	Displays, Lightshows, Opthalmology, Surgery
	(Green)	514 nm	Displays, Lightshows, Opthalmology, Surgery
Krypton	(Blue)	476 nm	Displays, Lightshows
	(Green)	528 nm	Displays, Lightshows
	(Yellow)	568 nm	Displays, Lightshows
	(Red)	647 nm	Displays, Lightshows, Opthalmology
Xenon	(White)	multiple	Invasive Surgery
Helium Neon	(Green)	543 nm	Industrial Alignment, Dynamic Balancing
	(Yellow)	594 nm	Industrial Alignment
	(Orange)	612 nm	Industrial Alignment
	(Red)	633 nm	Industrial Alignment, Dynamic Balancing, Printing, Copiers
	(NIR)	1,152 nm	Spectoscopy
	(MIR)	3,390 nm	Spectoscopy
Hydrogen Fluoride	(MIR)	2,700 nm	Non-Destructive Testing
Carbon Dioxide	(FIR)	10,600 nm	Industrial Cutting, Soldering/Welding, Materials Processing, surgery

Solid State Lasers

Solid State Lasers

Doubled Nd:YAG (Green)532 nm Invasive Surgery, Light Shows, Military Ranging

Neodymium:YAG (NIR)1,064 nm Industrial Sealing, Soldering, Lithography, Invasive Surgery
Erbium:Glass (MIR)1,540 nm Spectoscopy
Erbium:YAG (MIR)2,940 nmInvasive Surgery, Dentistry
Holmium:YLF (MIR)2,060 nm Spectoscopy
Holmium:YAG (MIR)2,100 nm Invasive Surgery, Dentistry
Chromium Sapphire (Ruby) (Red) 694 nm Invasive Surgery, Cosmetic Surgery
Titanium Sapphire (NIR)840-1,100 nm Spectoscopy
Alexandrite (NIR)700-815 nm Spectoscopy

Excimers

Excimer Gas Lasers

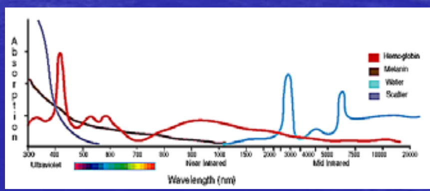
- Argon Fluoride (UV)193 nm Opthalmology, Industrial Cutting/Drilling,
  Krypton Chloride (UV)222 nm
  Krypton Fluoride (UV)248 nm
- Xenon Chloride (UV)308 nm Invasive Surgery, Industrial Cutting
  Xenon Fluoride (UV)351 nm

Wave length and Absorption

Characteristics of Surgical Lasers.

Laser Type	Wavelength (nm)	Sprectral Region	Mode	Typical Maximum Power
CO_2	10,600	Mid infrared	CW and gated	100 W cw
Holmium	2,100	Near infrared	Pulsed	15 W avg.
Nd:YAG	1,064	Near infrared	CW and pulsed	100 W cw
Diode	800–890	Near infrared	CW	>4 W
KTP/KDP	532	Visible	Pulsed	20 W avg.
Argon	488/514	Visible	CW	20 W
Excimer ArF-XeCL	190	Ultraviolet	Pulsed	550 mJ
	308	Ultraviolet	Pulsed	250 mJ

CW = continuous wave.



Laser Tissue Interaction

- Laser absorption depends on the absorption coefficient of the tissue
- Photothermal Effect: Laser energy is converted into heat which in turn raises the temperature of the Cytosol and Extracellular fluid (water)
- 49°C Photocoagulation
- 55° C Irreversible Tissue damage
- 100° C Vaporisation
- 350° C Charring

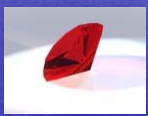
Ruby Laser

First working laser to be demonstrated

Cylindrical crystal of synthetic Sapphire (Al_2O_3)
doped with roughly 0.05%, by weight, of
Chromium ions (Cr^{3+}) = Ruby

Ruby Laser

Lasing medium Ruby Crystal



Wave Length 694 nm

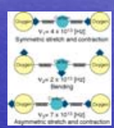
Power / Energy 3 J

Beam Delivery Fibre Optic

Ruby Laser

- Ruby absorbs pumping energy in blue-green region of the spectrum and emits laser energy at a wavelength of 694.3 nm
- The absorption of blue-green light raises the Cr^{3+} ions to a broad band of upper levels
- A population inversion is established between this state and the ground state

Carbon Dioxide Laser



- The important energy levels are provided not by the distribution of electrons
  - Instead from the vibration of the entire CO_2 molecule itself
- The CO_2 molecule can be pictured as
  - a linear arrangement of O-C-O atoms,
  - which vibrate in relation to each other
- Several different modes of vibration give rise to a set of energy levels with transitions far into the infra-red.
- The principal CO_2 wavelength is 10.6 μm
  - Far Infra-red

Carbon Dioxide Laser

- **Lasing medium** CO_2
- **Wave Length** 10.6 µm
- **Power / Energy** 10-60 W
- **Superpulse** 250 W
- **Beam Delivery** Articulated arm

Argon-ion Laser

- Lasing takes place in the plasma state
- An electric discharge is created in a narrow tube of gaseous argon.
- Argon atoms are first ionised and then excited by multiple collisions with electrons into their upper energy levels.

Argon-ion Laser

Lasing medium	Argon gas
Wave Length	488-514 nm
Power / Energy	3-10 W
Beam Delivery	Fibre optic
Light	Blue 488nm Green 514

Nd-YAG Laser

Lasing medium **Yttrium-Aluminium-Garnate** **($Y_3Al_5O_{12}$)**

Doped with 0.7% by weight of Neodymium (Nd3+) ions

Wave Length	1064 nm
Power / Energy	100 W
Beam Delivery	Fibre optic

Note: Q switched **Nd-YAG Laser**

KTP laser

Lasing medium Nd:YAG frequency doubled by passing it through

Potassium Titalyl Phosphate ($KTiOPO_4$)

Wave Length 532 nm

Power / Energy 15 W

Beam Delivery Fibre optic

Holmium:YAG laser

Wavelength: 2.1 micron

Pulse duration: 250 ms

Peak power: 11 KW

Aiming beam: 5mW HeNe

Delivery system: Fibreoptic

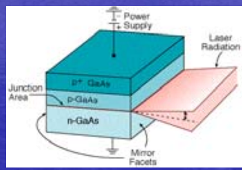
Diode Laser

Lasing medium Gallium-Arsenide / Semiconductors

Wave Length 810nm

Power / Energy > 4 W

Beam Delivery Fibre optic



Erbium Laser

- Lasing Medium: Erbium :YAG
- Wave Length:10.6
- Power / Energy: 0.5-1.0J
- Beam Delivery: Fibre optic

Recommended Reading

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3799025/pdf/islsm-20-095.pdf

http://www.sciencedirect.com/science/article/pii/S0001209212002578