PH 201

OPTICS & LASERS

Lecture_Lasers_1

LASER

L: LIGHT

A: AMPLIFICATION by

S: STIMULATED

E: EMISSION of

R: RADIATION

Laser is a device that amplifies light and produces a high direction, high-intensity beam that most often has a very pure frequency or wavelength.

LASER

Power : 10^{-9} to 10^{20} W

Wavelengths : Microwave to soft X-rays (10^{11} to 10^{17} Hz)

Pulse duration : As short as 5×10^{-15} s

Applications : Drill holes in most durable of materials

Weld detached retinas within human eye

Photograph needle (CD/DVD)

Treatment of high-strength materials

Special surgical knife for medical procedures

Target designators for military weapons

Supermarket

Laser Inventors

Invention: 1960

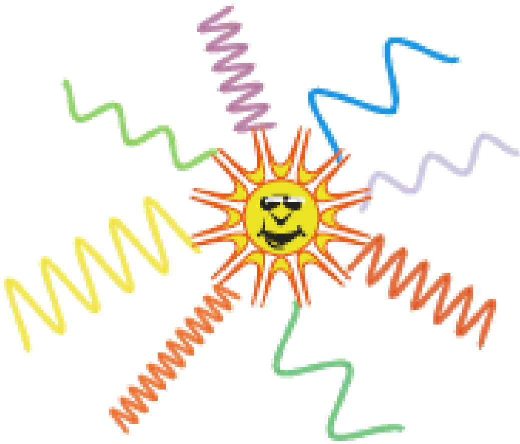
Nobel Prize: 1964

Charles Hard Townes
July 28, 1915
USA

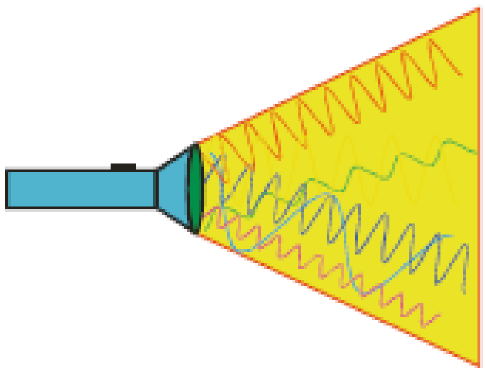
Nicolay Gennadiyevich Basov
14.12.1922 – 01.07.2001
Russia

Alexander Prokhorov
11.07.1916 – 08.01.2000
Russia

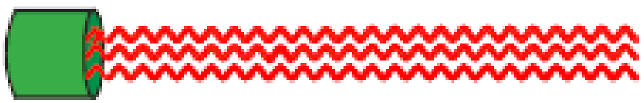
Light sources



Sun



Flashlight



L.A.S.E.R.

Light source	Light Power	Power density
Sun	10^{26} Watt	5×10^{2} W/cm²
100 W Filament-lamp	3 Watt	10^{-2} W/cm²
He-Ne- Laser	1 mWatt	4×10^{4} W/cm²
CO_2 Laser	60 Watt	5×10^{6} W/cm²
Pulsed Laser	1 GWatt	10^{14} W/cm²

LASER: Properties

Lasers generally have

- a narrower frequency distribution
- much high intensity
- much greater degree of collimation
- much shorter pulse duration

Properties of laser light

Laser light cannot:

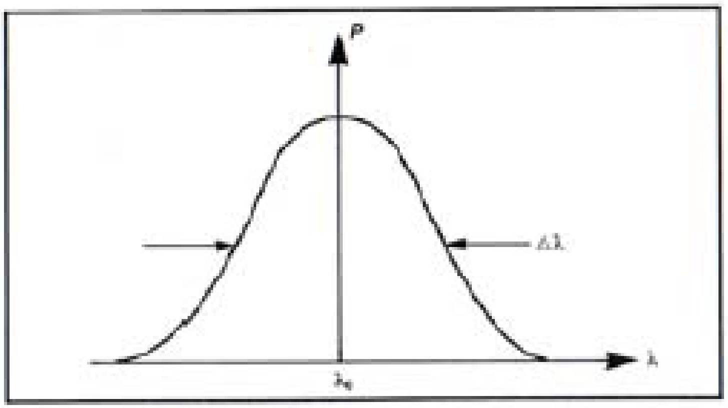
- be perfectly monochromatic
- be perfectly directional
- have perfect coherence

However…

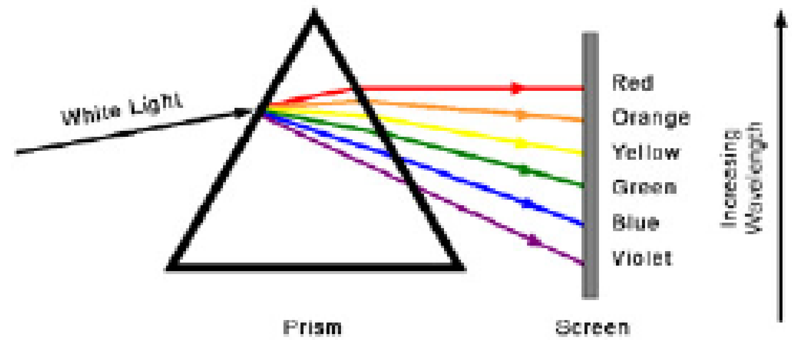
Laser light is far more coherent than light from any other source.

Properties of LASER light

Monochromaticity:

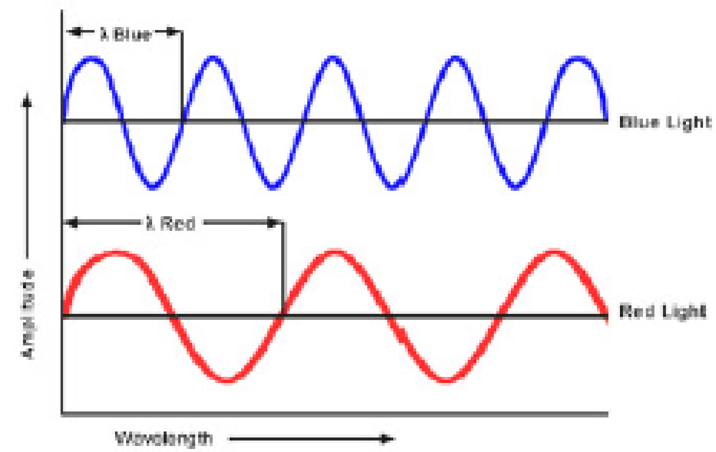


Nearly monochromatic light



Example:

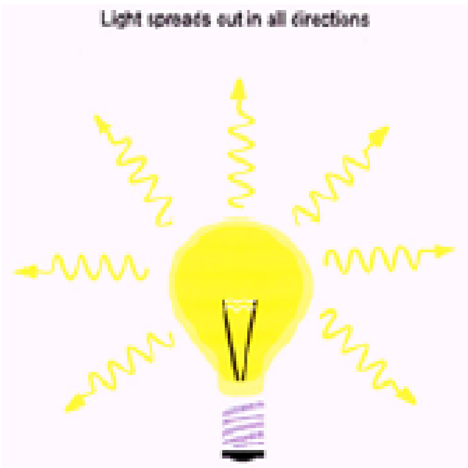
He-Ne Laser	Diode Laser
$\lambda_0 = 632.5$ nm	$\lambda_0 = 900$ nm
$\Delta\lambda = 0.2$ nm	$\Delta\lambda = 10$ nm



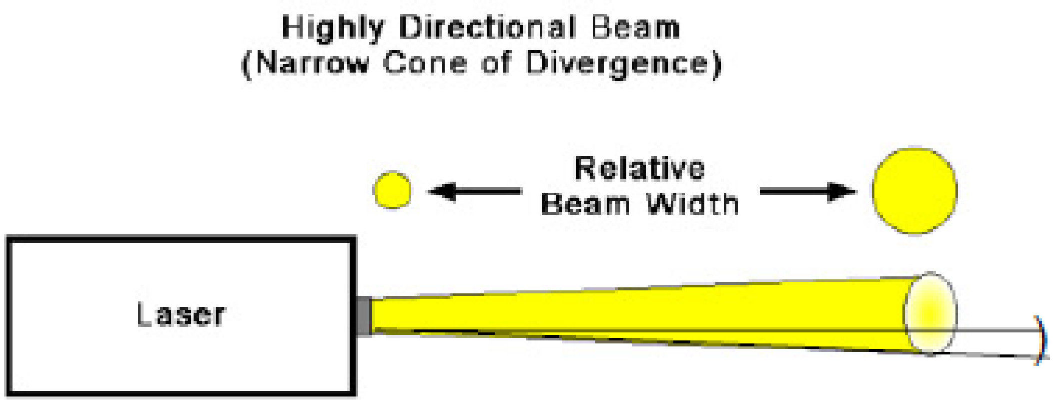
Comparison of the wavelengths of red and blue light

Properties of LASER light

Directionality:



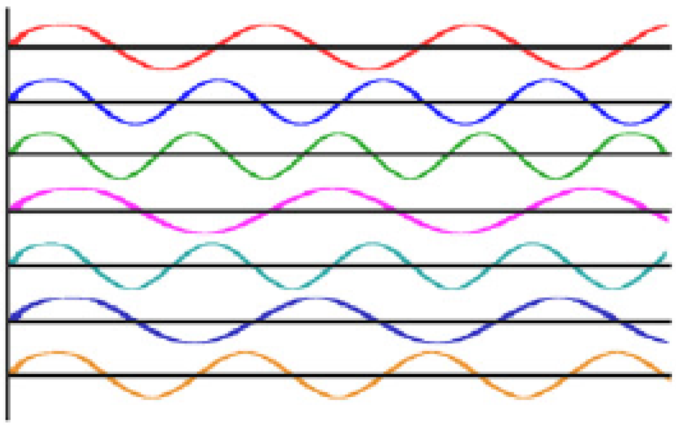
Conventional light source



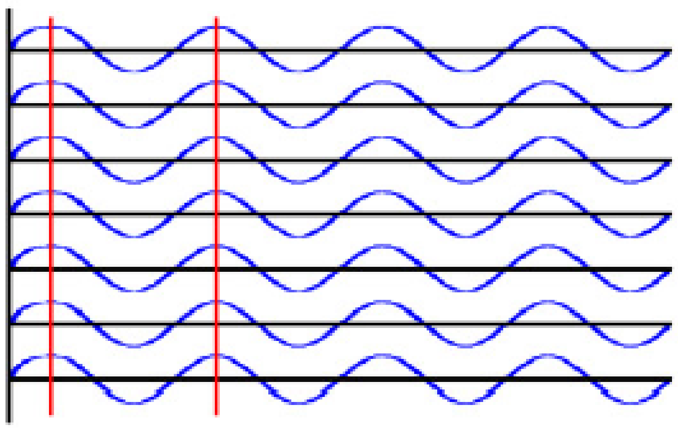
Divergence angle (θ_d)

Properties of LASER light

Coherence:



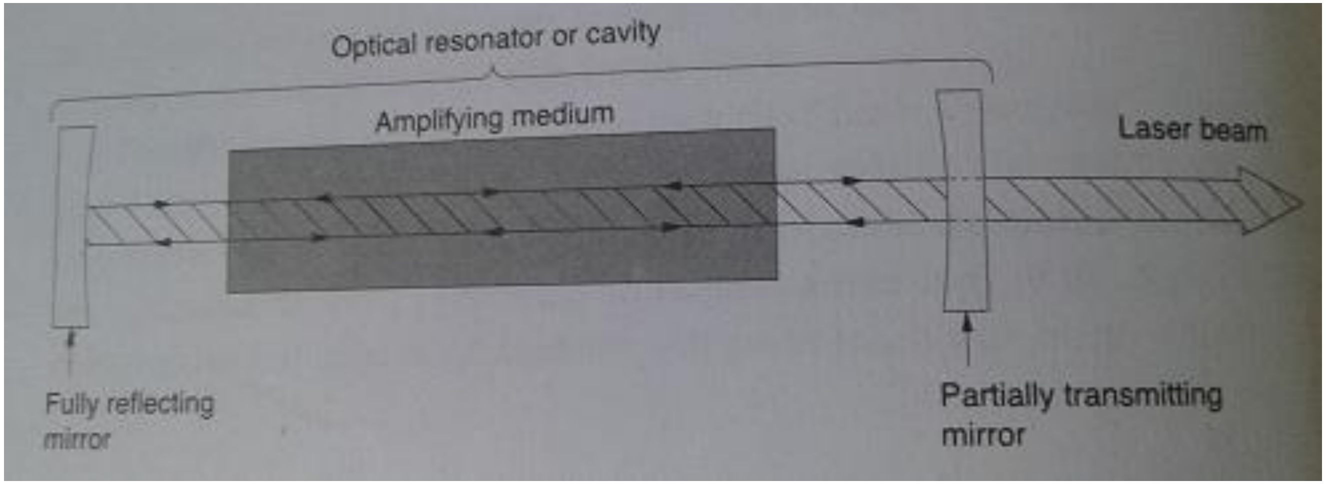
Incoherent light waves



Coherent light waves

Laser emitting process include:

- **Stimulated emission (natural effect) &**
- **Optical feedback (provided by mirrors)**



Laser; Brief History

- ❖ **1958:** **Charles Townes developed stimulated emission process to construct a microwave amplifier, MASER (coherent beam of microwave $\lambda \sim 1.25$ cm to be used for communications).**
- ❖ **1960:** **Theodore Maiman from Hughes Res. Lab. produced 1st laser using a Ruby crystal**
- ❖ **1961:** **A. Javan, W. Bennet, & D. Hariott from Bell Lab. Developed 1st Gas laser (He + Ne)**
- ❖ **1962:** **R. Hall from General Electric Res. Lab. demonstrated 1st semiconductor laser**
- ❖ **1963:** **C.K.N. Patel from Bell Lab. discovered infrared carbon dioxide laser**

Wave-Particle duality of light

- Evidence for Wave Nature of Light

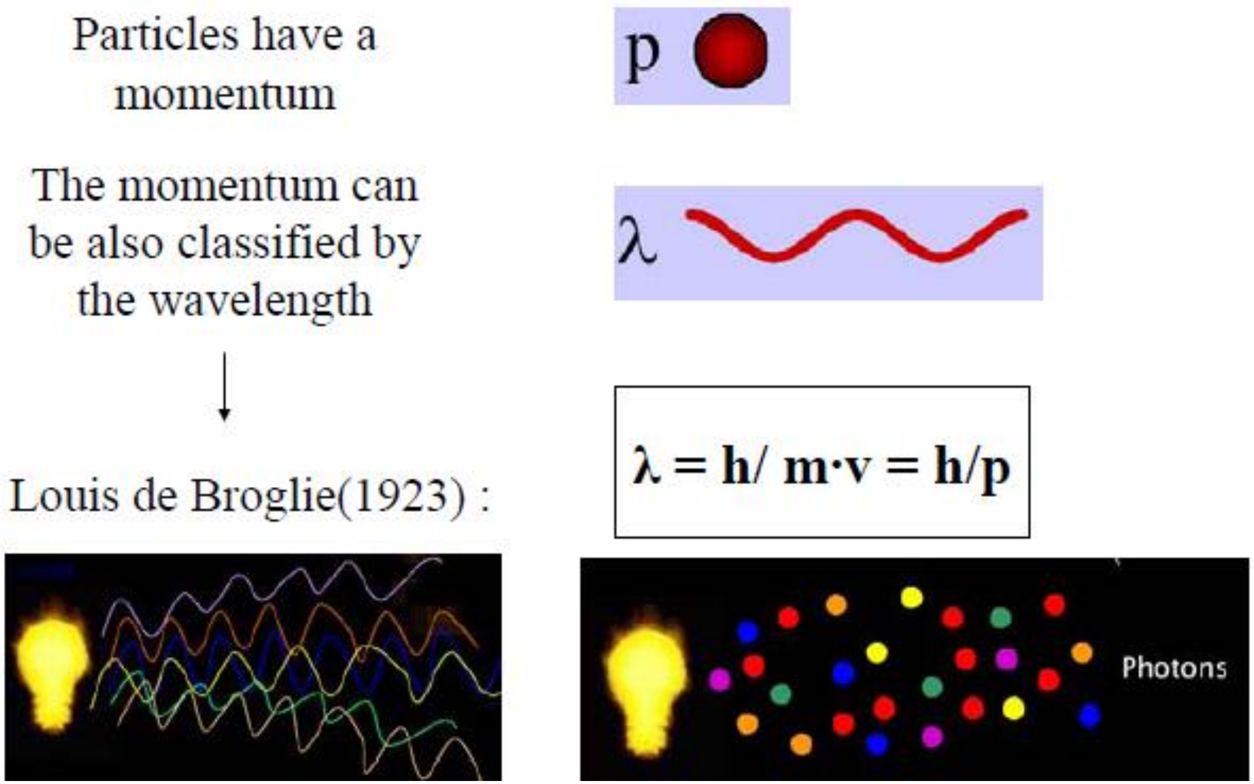
  Diffraction & Interference

- Evidence for Particle Nature of Light

  Photoelectric effect & Compton effect

When UV light is shone on a metal plate in a vacuum, it emits charged particles (Hertz 1887), which were later shown to be electrons by J.J. Thomson (1899).

- In 1923 Prince Louis de Broglie postulated that ordinary matter can have wave-like properties, with wavelength *λ* related to momentum *p* in same way as for light.

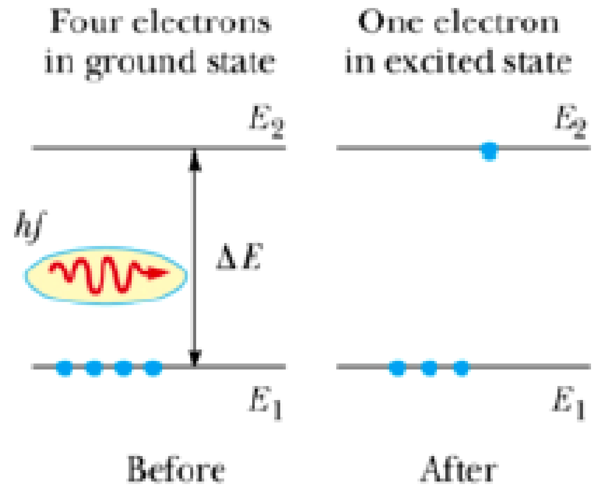


Atomic transitions

Almost all electronic transitions that occur in atoms that involve photons fall into one of three categories:

Stimulated absorption

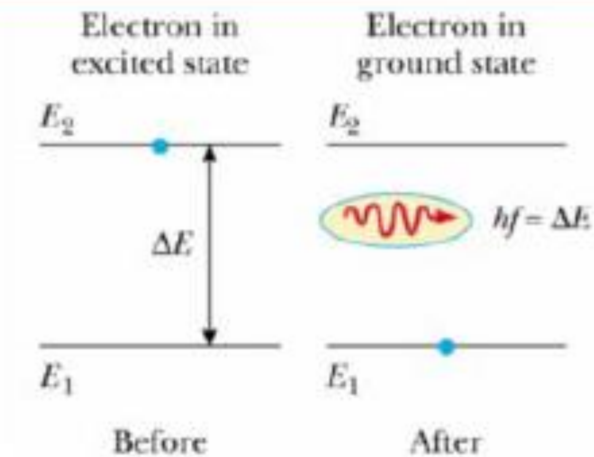
$\Delta E = hf$



Atomic transitions

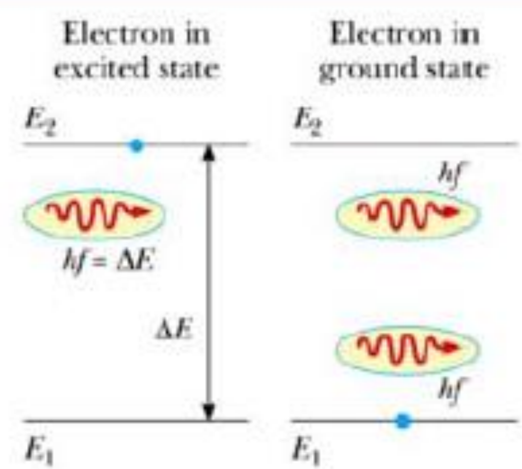
Spontaneous emission

Energy of the emitted photon = $hf = \Delta E$



Stimulated emission

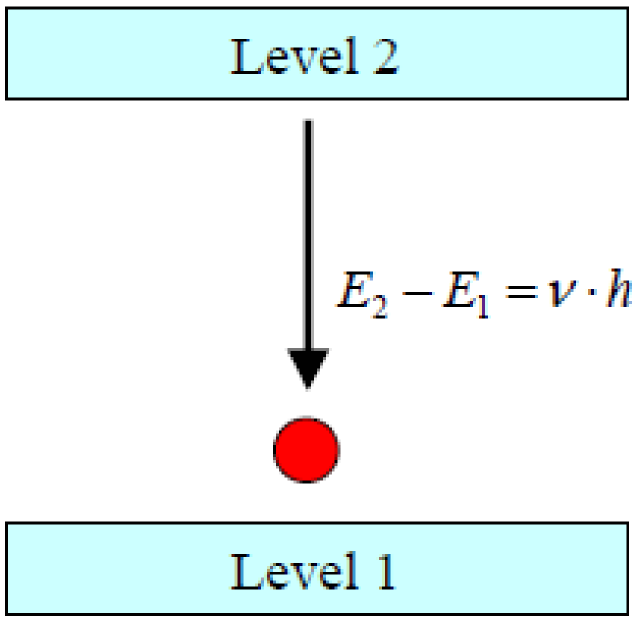
1 Photon with $\Delta E = hf$ produces two photons with the same energy



Atomic transitions

The frequency of the emitted photon going from Level 2 to 1 is given by:

$$\nu = \frac{E_2 - E_1}{h}$$



Defining *Ni* as the electron population of level *i* and considering the Boltzman equation which describes the relation between the electrons in level 1 and 2 at thermal equilibrium:

$$N_2 - N_1 = \exp\left(-\frac{E_2 - E_1}{k_B T}\right)$$

(k_B = Boltzman constant)

giving that $E_2 > E_1$ and $T>0$ => $N_1 > N_2$!