LASER

1. Introduction

The word laser is an acronym for the expression "Light Amplification By Stimulated Emission of Radiation."

As a result of the rapid scientific and technological development witnessed in different areas of human life, which led to the emergence of new challenges and problems as a result of this development, it became necessary to find advanced scientific and practical solutions to solve those problems and challenges.

One of the most successful solutions is laser, its known as " a solution seeking a problem". At present, the laser is an essential application in various civilian and military fields. Where, it uses in the medicine, industry, fiber optic communication, information technology, and consumer electronics.

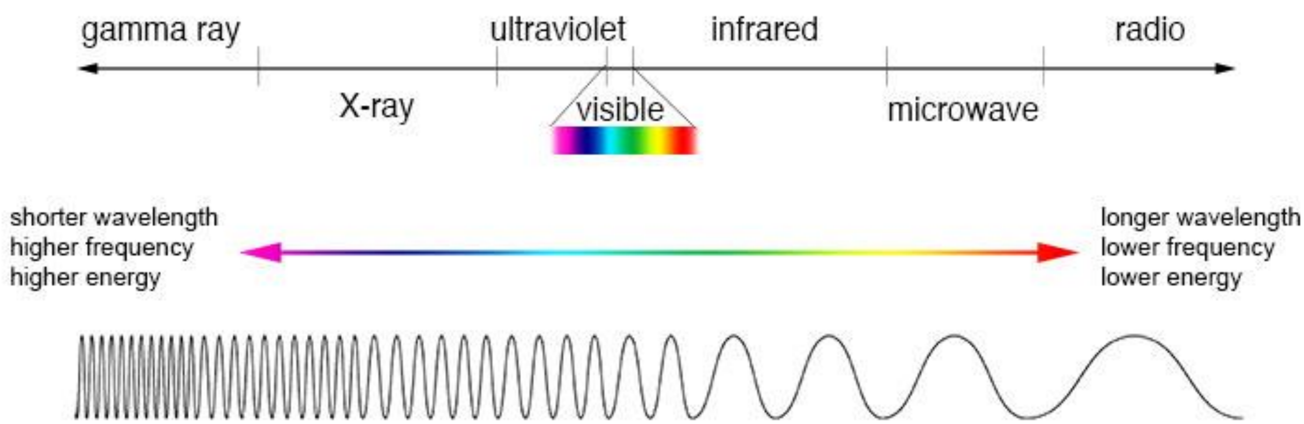
Theodore Maiman made the first laser operate on 16 May 1960 at the Hughes Research Laboratory in California, by shining a high-power flash lamp on a ruby rod with silver-coated surfaces.

The laser is an electromagnetic radiation whose photons are equal in frequency and matched in the waveform, Where the photons waves overlap constructively into a high-energy beam with a temporal and spatial coherence and a very small divergence angle. This output laser beam can be arranged in continuous waves or pulses with high frequency and very short pulse duration.

The spot sizes of laser beam ranging from approximately one-tenth the diameter of a human hair to that of a very large building. Lasers produce powers ranging from Nano watts to a billion trillion watts (10^{21} W) for very short bursts.

2. The laser spectrum and wavelengths

The color of the laser beam depends on its wavelength, which can be changed accurately. The wavelengths that can be obtained range from microwave ray (1.25 cm called maser), infrared, visible light, ultraviolet ray and then x-ray (about 21 nm)), as shown in Fig(1-1).



Fig(1-1): The Spectrum of electromagnetic radiation

Table (1-1): The wavelength and energy for several spectrum regions

Region	Wavelentgh λ nm $1nm = 10^{-9}\ m$	Frequency $f = c/\lambda$ Hz	Energy $1\ ev = 1.6 \times 10^{-19}\ J$ ev(per photon)
Radio	$> 10^8$	$< 3 \times 10^9$	$< 10^{-5}$
Microwave	$10^8 - 10^5$	$3 \times 10^9 - 3 \times 10^{12}$	$10^{-5} - 0.01$
Infrared	$10^5 - 700$	$3 \times 10^{12} - 4.3 \times 10^{14}$	0.01 – 2
Visible	700 - 400	$4.3 \times 10^{14} - 7.5 \times 10^{14}$	2 – 3
Ultraviolet	400 - 1	$7.5 \times 10^{14} - 3 \times 10^{17}$	$3 - 10^3$
X ray	1 – 0.01	$3 \times 10^{17} - 3 \times 10^{19}$	$10^3 - 10^5$
Gamma (γ) ray	< 0.01	$> 3 \times 10^{19}$	$> 10^5$

Violet	Indigo	Blue	Green	Yellow	Orange	Red
400 nm	440 nm	470 nm	530 nm	580 nm	620 nm	700 nm

3. Black Body Radiation

The black body is a cavity filled with a homogenous insulating medium, whose walls (at a certain temperature) will emit electromagnetic radiation continuously and receive electromagnetic radiation. If the emission rate is equal to the absorption rate, the thermal equilibrium condition will be achieved at any position within the cavity or at its walls. The Absorption coefficient is given by

Absorption coefficient (A) = absorption rate (a) / emission rate (e)

For black body A=1 because a = e

A blackbody is a surface that

- completely absorbs all incident radiation
- emits radiation at the maximum possible monochromatic intensity in all directions and at all wavelengths.

The theory of the energy distribution of blackbody radiation was developed by Planck and first appeared in 1901. Planck postulated that energy can be absorbed or emitted only in discrete units or photons with energy:

$$E = h\nu$$

The constant of proportionality is $h = 6.625 \times 10^{-34}$ J s. Planck showed that the intensity of radiation emitted by a black body is given by Planck function B_λ

$$B_\lambda = \frac{c_1 \ \lambda^{-5}}{\exp\left(\frac{c_2}{\lambda T}\right) - 1}$$

where c_1 and c_2 are constants

$$c_1 = 2\pi hc^2 = 3.74 \times 10^{-16}\, Wm^{-2} \qquad and \qquad c_2 = hc/k = 1.44 \times 10^{-2}\, mK$$

When B_λ is plotted as a function of wavelength on a linear scale the resulting spectrum of monochromatic intensity exhibits the shape illustrated as shown in Fig 1-2.

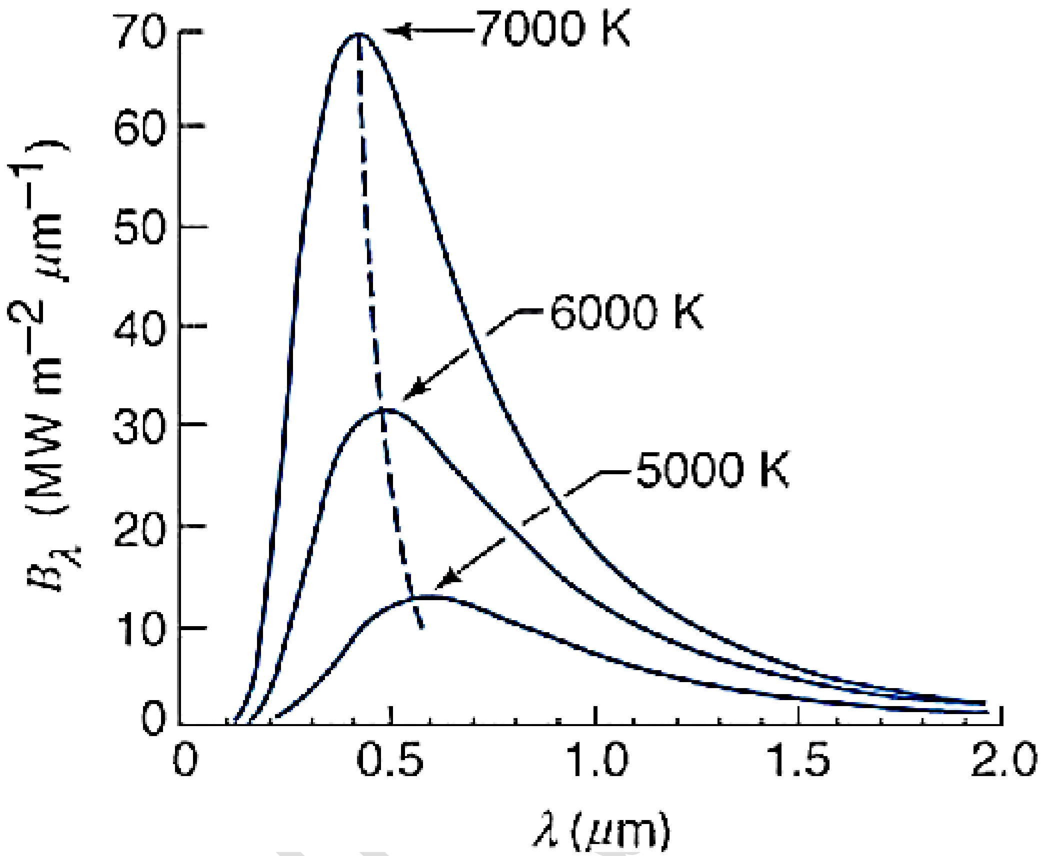


Fig 1-2: Blackbody emission (the Planck function) for absolute temperatures as indicated, plotted as a function of wavelength on a linear scale.

The Wien's Displacement Law

Differentiating Planck's function and setting the derivative equal to zero yields the wavelength of peak emission for a blackbody at temperature T

$$\lambda_m = \frac{0.0029}{T}$$

Where λ_m is expressed in meter and T in degrees kelvin.

Example 1 : Use Wien's displacement to compute the "color temperature" of the sun, if the wavelength of maximum solar emission is observed to be approximately 0.475 µm.

Solution:

$$\lambda_m = \frac{0.0029}{T} \qquad T = \frac{0.0029}{\lambda_m} = \frac{0.0029}{0.475\times10^{-6}} = 6105\ K$$

The Stefan-Boltzmann Law

The blackbody flux density (intensity) obtained by integrating the Planck function B_λ over all wavelengths, is given by

$$I = P/A = \sigma T^4$$

where σ is a constant equal to $5.67 \times 10^{-8} \mathrm{Wm^{-2}K^{-4}}$, P power and A area

Example 2:

A heater filament has a radius of 2 mm and a length of 200 mm. If its surface temperature is 2000 K what is the net radiated power??

Solution:

Radiated heat from object of temperature T into surroundings with temperature T_0 is given by

$$F = I = P/A = \sigma T^4$$

• Surface area of cylinder is given by

$A = 2 \pi r l = 2 \times 3.14 \times (2 \times 10^{-3}\ \mathrm{m}) \times 0.2\mathrm{m} = 2.51 \times 10^{-3}\ \mathrm{m}^2$

$P = (5.67 \times 10^{-})(2.5 \times 10^{-3})(2000)^4 = 2.27\ \mathrm{kW}$
