Module 1 Unit 1

PRINCIPLES OF LASERS - NUMERICALS

(As per Revised Curriculum SVU R-2023)

Physical constants:

Planck's constant: 6.63 x 10^{-34} J-s
Speed of light c = 3 x 10^{8} m/s
Boltzmann constant k = 1.38 x 10^{-23} J/K
Elementary charge q = 1.6 x 10^{-19} C
1 eV = 1.6 x 10^{-19} J

Classwork:

1. The visible radiation emitted from He-Ne laser results from transition of electrons between $3S_2$ to $2P_4$ states. If energies of these states are 20.66 eV and 18.7 eV respectively, determine the wavelength of radiation emitted.
2. A pulsed laser emits photons of wavelength 780 nm with average power of 20 mW/pulse. Calculate the number of photons emitted per second. Further, if the pulse duration is 10 µs determine the number of photons emitted/pulse.
3. Nd:YAG laser emits a radiation of 100 W optical power. If its beam diameter is 500 µm, determine the pulse intensity. Assume the beam to be perfectly circular.
4. A diode laser operates at 3.6 V and 130 mA current. If its optical power is 10 mW, calculate its efficiency.
5. For He-Ne laser, the linewidth is 2 x 10^{-4} nm. Determine its coherent length if its peak emission wavelength is 632.8 nm.
6. A laser beam has a diameter of 1 mm at a distance of 10 m and 3.5 mm at a distance of 35 m from the source. Determine the beam divergence angle.
7. Find the ratio of population of two energy states of an active medium for radiation of wavelength 694.3 nm emitted at room temperature (27 °C). Comment on the result.
8. The wavelength of laser emission is 6000 Å and the coefficient of spontaneous emission is 10^{6}/s. Determine the coefficient for the stimulated emission.
9. At what temperature the rates of spontaneous and stimulated emission are equal at a peak emission wavelength of 5000 Å? Comment on the result.
10. Find the limiting value of the overall loss factor in the laser cavity if the mirrors have reflectivity of 100% and 98.9% and length of the cavity is 10 cm. Overall gain factor is 5.34 x 10^{-4}/cm.

Homework:

1. In CO_2 laser, the transition between its vibrational-rotational energy states leads to laser emission at 1.05 µm. Determine the difference between these energy states in electron-volts.
2. The energy band gap of the compound semiconductor aluminium gallium arsenide (AlGaAs) is given by the equation $E_g(Al_xGa_{1-x}As) = 1.422 + 1.2475x$. Find the wavelength of radiation emitted from AlGaAs laser diode for x = 40%. Will this radiation be visible to eyes?
3. The argon laser produces a visible blue-green beam with wavelengths of 488 nm and 514 nm at an optical power output of 160 mW. Find the number of photons emitted per sec by the laser. The optical power share between blue and green spectral radiation is around 3:5.
4. Intensity of a 2 mW laser beam is 500 W/m^2. Determine beam diameter assuming it to be perfectly circular.
5. Light from He-Ne laser has intensity of 25 mW/cm^2 with spot size of 5 mm diameter. If it is driven at 230 volt, determine its operating current if the laser efficiency is 2%.
6. For some security application in a society laser systems are required with an uninterrupted intensity of 5 x 10^{6} W/m^2 at the output. Two laser systems are quoted. System A has operational

cost of Rs. 5/- per W (input power) per month while system B costs at Rs. 4/- per W (input power) per month. System A consists of laser source of efficiency 5% and beam diameter 5 mm while system B has 3% efficient laser with 4 mm beam diameter over the required distance. Decide which system can be finalized.

7. Find the relative populations of the two states in a Ruby laser that produces a light beam of wavelength 6943 A at 1000 K.
8. Show numerically that it becomes increasingly difficult to achieve stimulated emission at shorter wavelengths.
9. Find the peak emission wavelength at which, rates of spontaneous and stimulated emission are equal at room temperature.
10. The length of a laser tube is 15 cm and the gain factor of the laser material is 0.0005/cm. If one of the cavity mirrors reflects 100% light, what is the required reflectance of the other cavity mirror to keep the loss factor to be at least 1% lower than the gain?

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