Solution : Tutorial Sheet-7, Physics-2 (15B11PH211).

① Class Notes.

② (a) Energy of each photon, $E = nh\nu$, $n = E/h\nu = \frac{E\lambda}{hc}$

$$\Rightarrow n = \frac{1 \times 694 \times 10^{-9}\,m}{6.62 \times 10^{-34} \times 3 \times 10^{8}} = 3.5 \times 10^{18} \text{ ions}$$

(b) Energy of the laser pulse = total no. of ions (n) × energy of each photon

$$E = nh\nu = n\frac{hc}{\lambda}$$

$$E = 2.8 \times 10^{19} \times \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{7 \times 10^{-7}} = 7.94\,J.$$

③ Ratio of the population $\frac{N_2}{N_1} = e^{-(E_2-E_1)/kT}$, $E_2 - E_1 = \frac{hc}{\lambda} = 1.96\,eV$

So $\frac{N_2}{N_1} = \exp\left[\frac{-1.96\,eV}{8.61 \times 10^{-5} \times 300}\right] = e^{-75.88} = 1.1 \times 10^{-33}$.

④ Ratio of spontaneous to stimulated emission is given as.

$$R = [e^{h\nu/kT} - 1] = [e^{hc/\lambda kT} - 1], \text{ At } T = 50K, \lambda = 10^{-5}m$$

then $R = e^{28.78} - 1 = 3.16 \times 10^{12}$.

⑤ Efficiency of laser = 1% = 0.01, $\text{Efficiency} = \frac{P_{out}}{P_{in}}$

$$\text{So } P_{in} = \frac{P_{out}}{\text{Efficiency}} = 1 \text{ Watt} = 1\,J/sec$$

Number of atoms excited in one second $= \frac{1\,J}{20\,eV} = \frac{1\,J}{20 \times 1.6 \times 10^{-19} J}$

$= 3.12 \times 10^{17}$ Ans

⑥ (i) $\lambda = 5890\,\text{Å}$ so $\nu = \frac{c}{\lambda} = 5.09 \times 10^{14}\,Hz$

(ii) no. of oscillations $n = l_c/\lambda = \frac{2.945 \times 10^{-2}}{5.89 \times 10^{-7}} = 5 \times 10^{4}$.

(iii) Coherence time $\tau_c = l_c/c = \frac{2.945 \times 10^{-2}}{3 \times 10^{8}} = 9.82 \times 10^{-11}$ sec. Ans

⑦. Relative population $\frac{N_2}{N_1} = e^{-(E_2-E_1)/kT}$, $E_2 - E_1 = \frac{hc}{\lambda} = 1.77\,eV$

at $27^\circ C = 27 + 273 = 300K$, $\left(\frac{N_2}{N_1}\right)_{300K} = e^{-68.5}$

& at $227^\circ C = 227 + 273 = 500K$

$\left(\frac{N_2}{N_1}\right)_{500K} = e^{-41.1}$, Now Ration $\frac{(N_2/N_1)_{300K}}{(N_2/N_1)_{500K}} = 1.25 \times 10^{-12}$

Ans.