



ENGINEERING PHYSICS

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Department of Science and Humanities

Class #34

- Matter and Radiation
- Black body radiation spectrum
- Population of states and the Boltzmann equation
- Absorption and Emission processes

Unit IV : Review of concepts leading to Quantum Mechanics: LASERS

➤ *Suggested Reading*

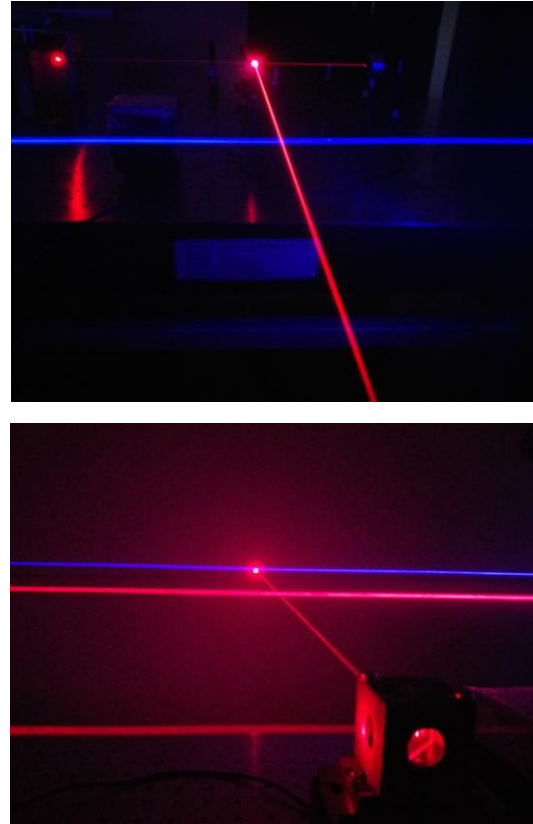
1. *Concepts of Modern Physics, Arthur Beiser, Chapter 9.6*
2. *Optical Electronics, A. Yariv*
3. *Course material developed by the department*

➤ *Reference Videos*

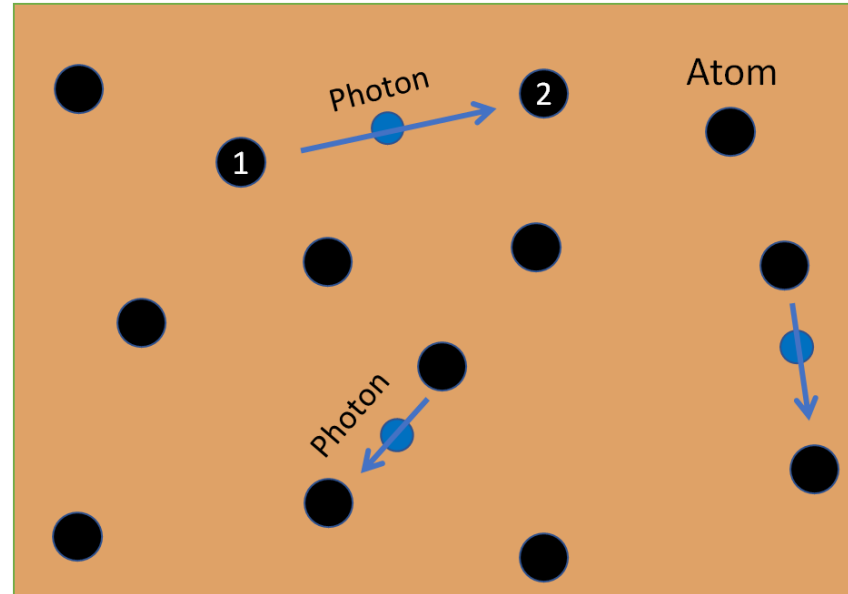
1. <https://ocw.mit.edu/resources/res-6-005-understanding-lasers-and-fiberoptics-spring-2008/laser-fundamentals-i/1>.
2. *Unit I Class # 4 Video*

LASER

Light
Amplification by
Stimulated
Emission of
Radiation



LASER beams from our Research Lab

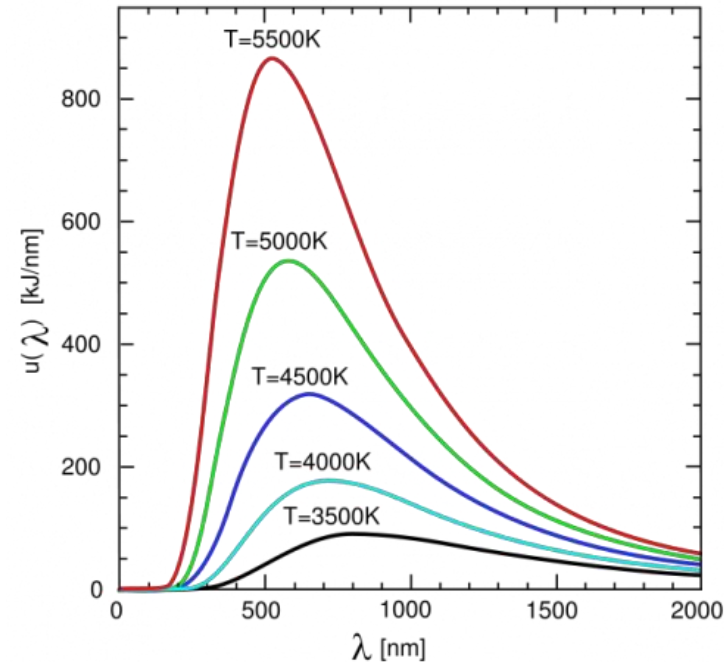


- Atoms emit and absorb electromagnetic radiation
- Electromagnetic energy is quantized in terms of photons
- Quantum of energy of a Photon, $E = h\nu$
- Equilibrium is achieved

Planck's expression for energy density

$$E(\lambda) d\lambda = \frac{8\pi hc}{e^{\frac{hc}{\lambda kT}} - 1} d\lambda$$

$$E(\nu) d\nu = \frac{8\pi h \nu^3}{e^{\frac{h\nu}{kT}} - 1} d\nu$$



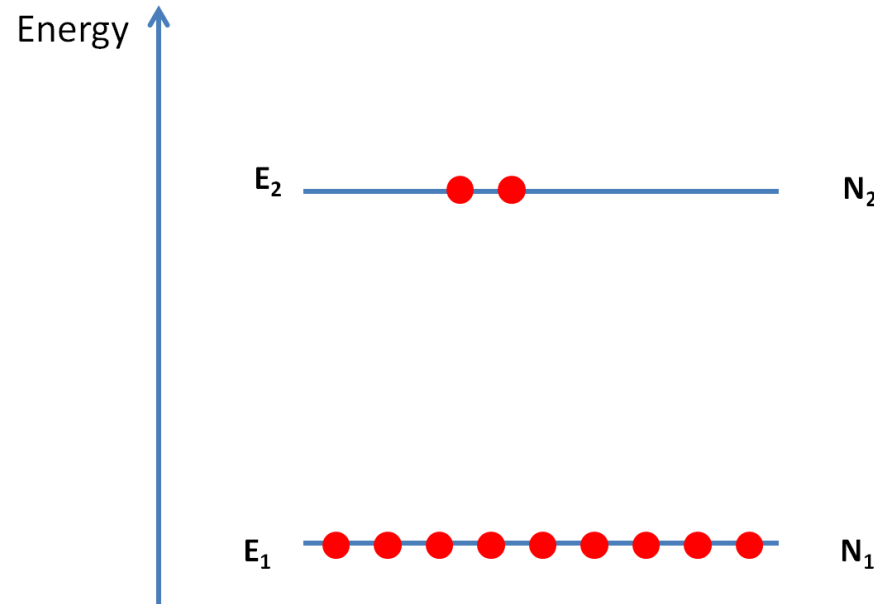
- Planck proved the particle nature of light and founded Quantum Mechanics

The Populations of the states E_1 and E_2 are given by the

The Boltzmann equation

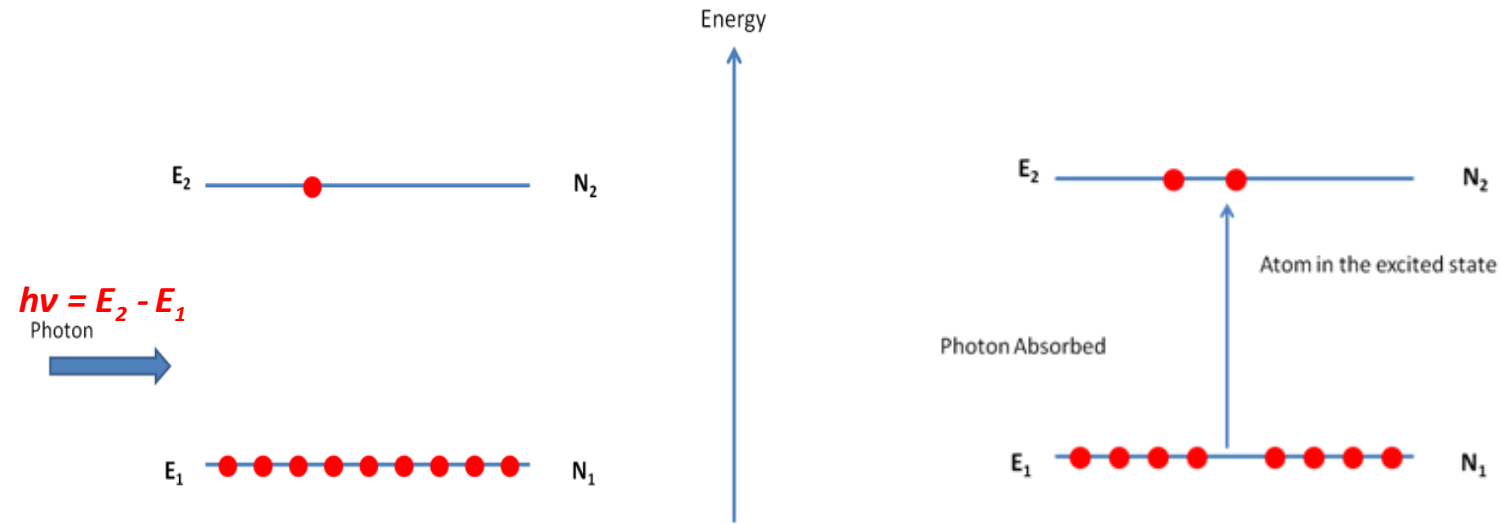
$$\frac{N_2}{N_1} = e^{\frac{-(E_2 - E_1)}{kT}}$$

$$\frac{N_2}{N_1} = e^{\frac{-h\nu}{kT}} \quad \text{where } E_2 - E_1 = h\nu$$



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Absorption of Radiation



Before Absorption

After Absorption of the photon

The Rate of Absorption

$$R_{Ab} \propto N_1$$

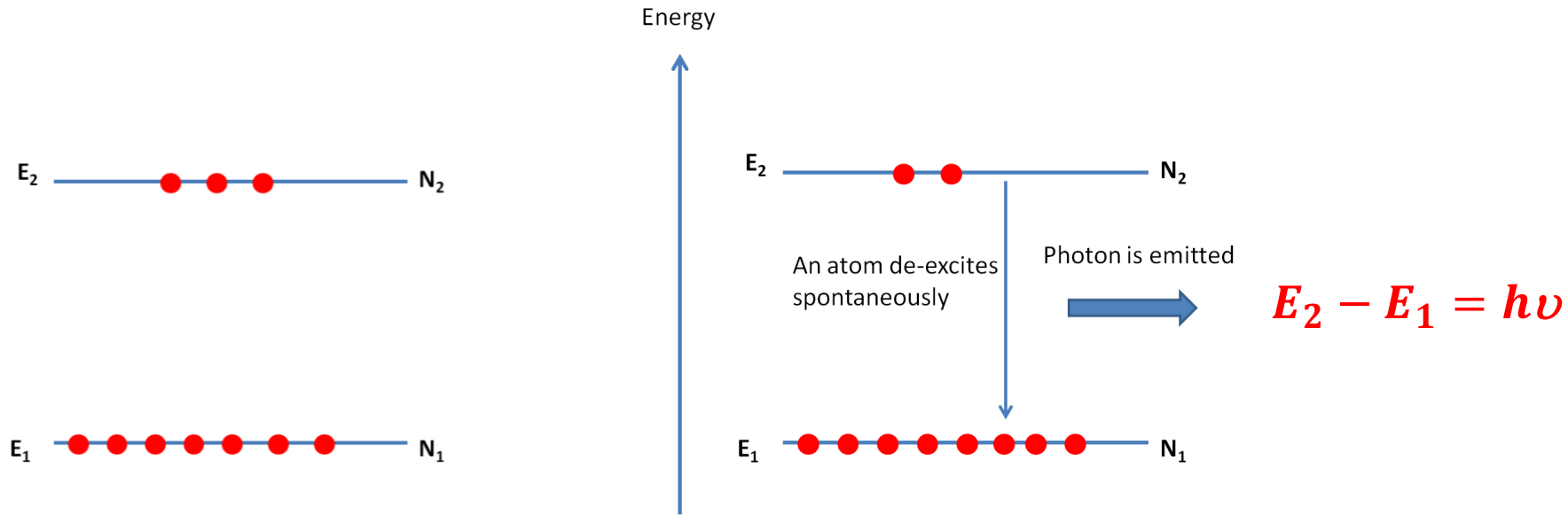
$$R_{Ab} \propto E(\nu)$$

$$R_{Ab} = B_{12} N_1 E(\nu)$$

B_{12} is the coefficient of Absorption

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Spontaneous emission



- Life time of excited states generally $\tau = 10^{-8} \text{ s}$
- Meta-stable states $\tau > 10^{-8} \text{ s}$

The Rate of Spontaneous Emission

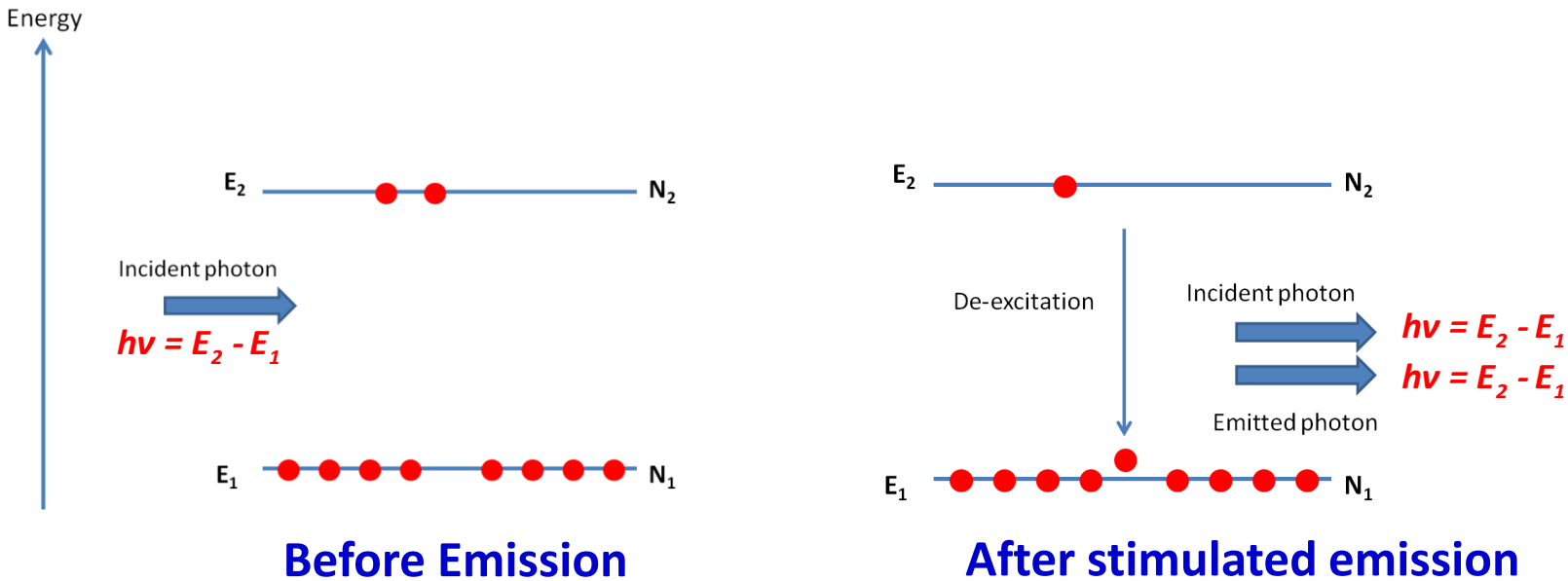
$$R_{SpEm} \propto N_2$$

$$R_{SpEm} = A_{21} N_2$$

A_{21} is the coefficient of Spontaneous Emission

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Stimulated Emission



The Rate of Stimulated Emission $R_{StEm} \propto N_2$ $R_{StEm} \propto E(\nu)$

$$R_{StEm} = B_{21} N_2 E(\nu)$$

B_{21} is the coefficient of Stimulated Emission

Check Your Understanding (Yes/No)

- 1. Light emission from a bulb is because of spontaneous emission*
- 2. The Boltzmann equation is applicable in a non equilibrium condition*
- 3. In equilibrium, the lower state is more populated compared to upper state*
- 4. In stimulated emission the photons are coherent and unidirectional*



THANK YOU

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