LASER

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DEPARTMENT OF PHYSICS

GOVERNMENT GIRLS' GENERAL DEGREE COLLEGE

SEM-V-DSE-A1(b): LASER AND FIBER OPTICS (PHSA-A-DSE-A1-TH)

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LASER : Light Amplification by Stimulated Emission of radiation

Historical background of LASER

- 1917: Einstein's treatment of stimulated emission.
- 1951: Development of the MASER by C.H. Townes. (MASER: The MASER is similar to LASER but produced only microwaves)
- 1958: Proposal by C.H. Townes and A.L. Schawlow that the maser concept could be extended to optical frequencies.
- 1960: T.H. Maiman at Hughes Laboratories reports the first laser: the pulsed ruby laser.
- 1961: The first continuous wave laser is reported: the helium neon laser.
- 1962: Invention of the semiconductor laser.
- 1964: Nicolay Basov, Charlie Townes and Aleksandr Prokhorov are awarded the Nobel prize for "fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser-laser principle."
- 1981: Arthur Schalow and Nicolaas Bloembergen are awarded the Nobel Prize for "their contribution to the development of laser spectroscopy."
- 1997: Steven Chu, Claude Cohen-Tannoudji and William D. Phillips are awarded the Nobel Prize for the "development of methods to cool and trap atoms with laser light."
- 2005: John Hall and Theodor H¨ansch receive the Nobel Prize for "their contributions to the development

  of laser-based precision spectroscopy, including the optical frequency comb technique".
- 2010: 50th anniversary of the laser

LASER : Light Amplification by Stimulated Emission of radiation (Light amplification + positive optical feedback)

How to make a LASER

- A medium that has the potential for optical gain

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an amplifying medium.

- A means of putting energy into that medium

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an excitation system.

- Construct an optical feedback system for stimulating further emission

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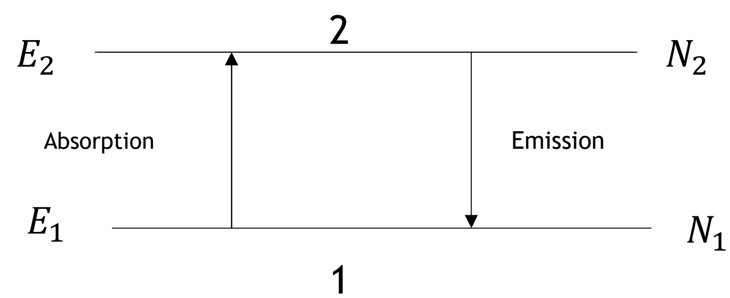
an optical resonator.

Einstein coefficients

- Einstein A and B coefficients :
- Radiative transition from excited state to ground state

  1. Spontaneous emission
  2. Stimulated Emission
- Figure description: 1, 2 Energy states:
- Energy values E_1 and E_2 in states 1 and 2

  N_1 and N_2: Population in energy states 1 and 2



- Rate of excitation for the absorption process:(1 → 2)
- $\frac{dN_2}{dt}|_{abs} = B_{12}N_1U(\nu)$

$U(\nu)$: spectral energy density of light at frequency ν

- Rate of spontaneous emission: (2 → 1)
- $\frac{dN_2}{dt}|_{spt.emission} = -A_{21}N_2$

B_{12}, B_{21} , A_{21}: Constants

- Rate of stimulated emission: (2 → 1)
- $\frac{dN_2}{dt}|_{sti.emission} = -B_{21}N_2U(\nu)$

Einstein coefficients

- Imagine a gas of atoms inside a box at temperature T with black walls. If we leave the atoms for long enough, they will come to equilibrium with the black-body radiation that fills the cavity.
- $B_{12}N_1U(\nu) = A_{21}N_2 + B_{21}N_2U(\nu)$ [Rate of upward transitions balance the rate of downward transitions.]
- Therefore $U(\nu) = \frac{A_{21}N_2}{B_{12}N_1 - B_{21}N_2} = \frac{A_{21}}{\boldsymbol{B}_{12}\frac{N_1}{N_2} - B_{21}}$.
- If ν be the frequency of the radiation corresponding to transition from the level 2 to the level 1, we have $h\nu = E_2 - E_1$.
- Furthermore if the gas is in thermal equilibrium at temperature T°K, the ratio of N_2 to N_1 must satisfy Boltzmann's law
- $\frac{N_2}{N_1} = e^{-\frac{(E_2 - E_1)}{kT}}$, where k is the Boltzmann's constant.
- $\frac{N_1}{N_2} = e^{\frac{h\nu}{kT}}$
- $U(\nu) = \frac{A_{21}}{\boldsymbol{B}_{12}e^{\frac{h\nu}{kT}} - B_{21}} = \frac{A_{21}/B_{12}}{e^{\frac{h\nu}{kT}} - \frac{B_{21}}{B_{12}}}$
- From Planck's Law $U(\nu) = \frac{8\pi h\nu^3}{c^3}\frac{1}{e^{\frac{h\nu}{kT}} - 1}$
- Comparing equations, we find that

$$\boldsymbol{B_{12} = B_{21}}$$
$$\boldsymbol{A_{21} = \frac{8\pi h\nu^3}{c^3} B_{21}}$$

- **These A & B known as Einstein Coefficients.**