



ENGINEERING PHYSICS

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Class #37

Two, Three and Four level systems

- 1. Condition for laser emission**
- 2. Two level system**
- 3. Three level system**
- 4. Four level system**

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

➤ *Suggested Reading*

1. Lasers: Fundamentals and Applications

K Thyagarajan, A Ghatak

2. Course material developed by the department

➤ *Reference Videos*

<https://ocw.mit.edu/resources/res-6-005-understanding-lasers-and-fiberoptics-spring-2008/laser-fundamentals-i/>

$$B_{12} = B_{21} \quad (\text{say } = B)$$

Rate of Absorption $R_{Ab} = BN_1 E(v)$

Rate of Stimulated Emission $R_{StEm} = BN_2 E(v)$

Under thermal equilibrium, $N_1 \gg N_2$

Which leads to $R_{Ab} > R_{StEm}$

If the rate of stimulated emission

is lesser than the rate of absorption,

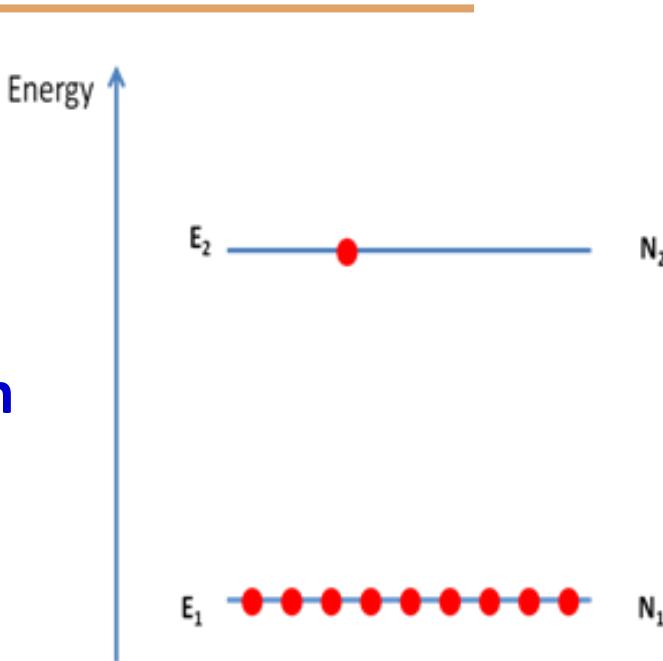
then the laser emission is impossible.

LASERS: Condition for laser emission

- Stimulated Emission is crucial for laser emission
- Only Stimulated Emission can ensure same wavelength and phase (Coherence)
- Stimulated Emission has to dominate over spontaneous Emission and absorption during emission
- For this to happen, we must have Population Inversion ($N_2 > N_1$)
- To achieve population inversion we need an external energy source called energy pump
- Thermal equilibrium is disrupted

Two level system

- Initially: $N_1 > N_2$
- Goal : Achieve $N_2 > N_1$
- In the presence of $E(v)$ initially the absorption will increase as N_1 is greater. This will cause increase in N_2 . Eventually we will reach $N_1 = N_2$
- From here increasing $E(v)$ will cause both absorption rate and stimulated emission rate to increase.
- So Population inversion $N_2 > N_1$ is not practically achievable in a two level system



- Pump and laser frequency Decoupling**

$$R_{Ab} = BN_1 E(v_{13})$$

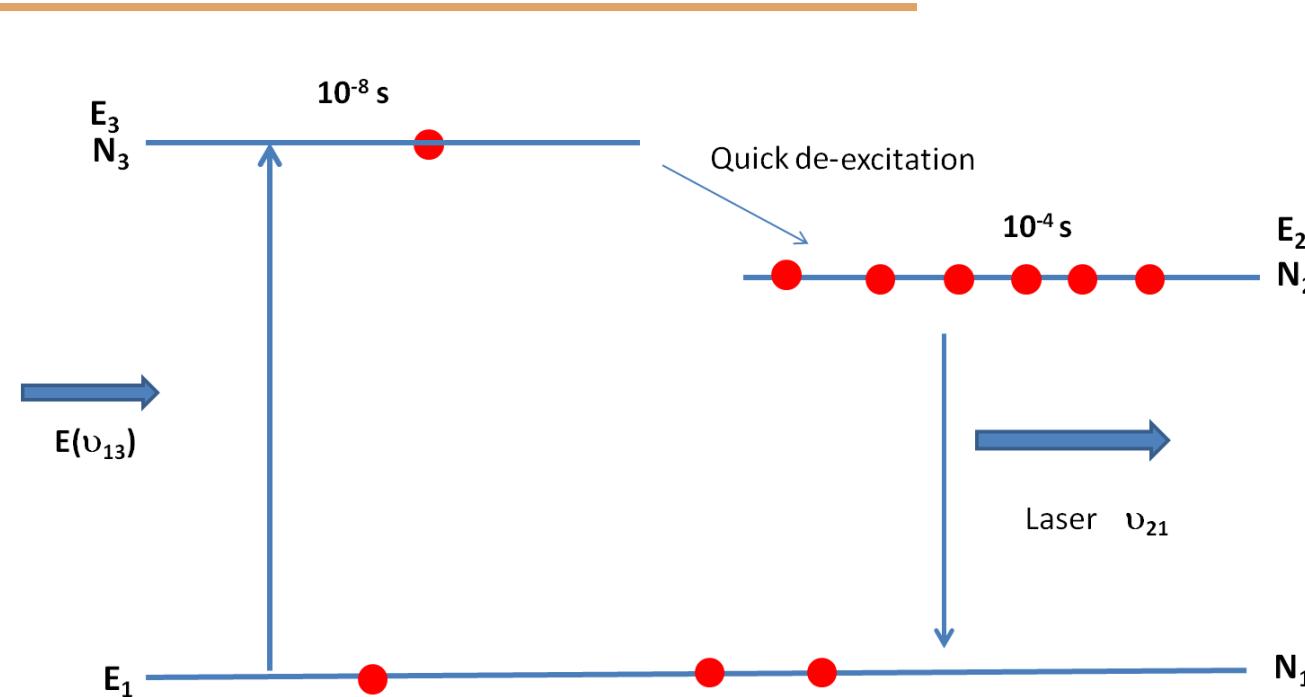
$$R_{StEm} = BN_2 E(v_{12})$$

By increasing $E(v_{13}) R_{Ab}$ can be increased without affecting R_{StEm}

This causes high population in E_3 .

E_3 is a short lived state.

Quick and Nonradiative decay to E_2 (Meta stable state)

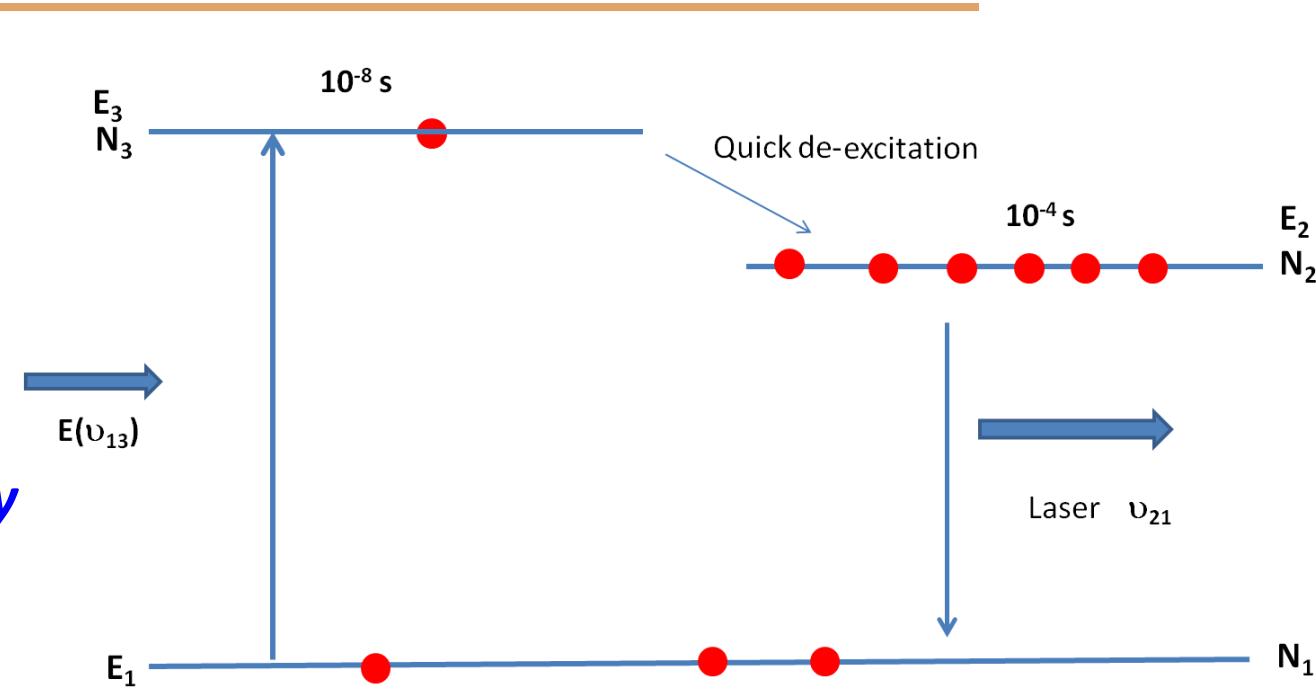


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Three level laser system

**Population Inversion
between E_2 and E_1**

Population Inversion is energy demanding as we work against the heavily populated ground state

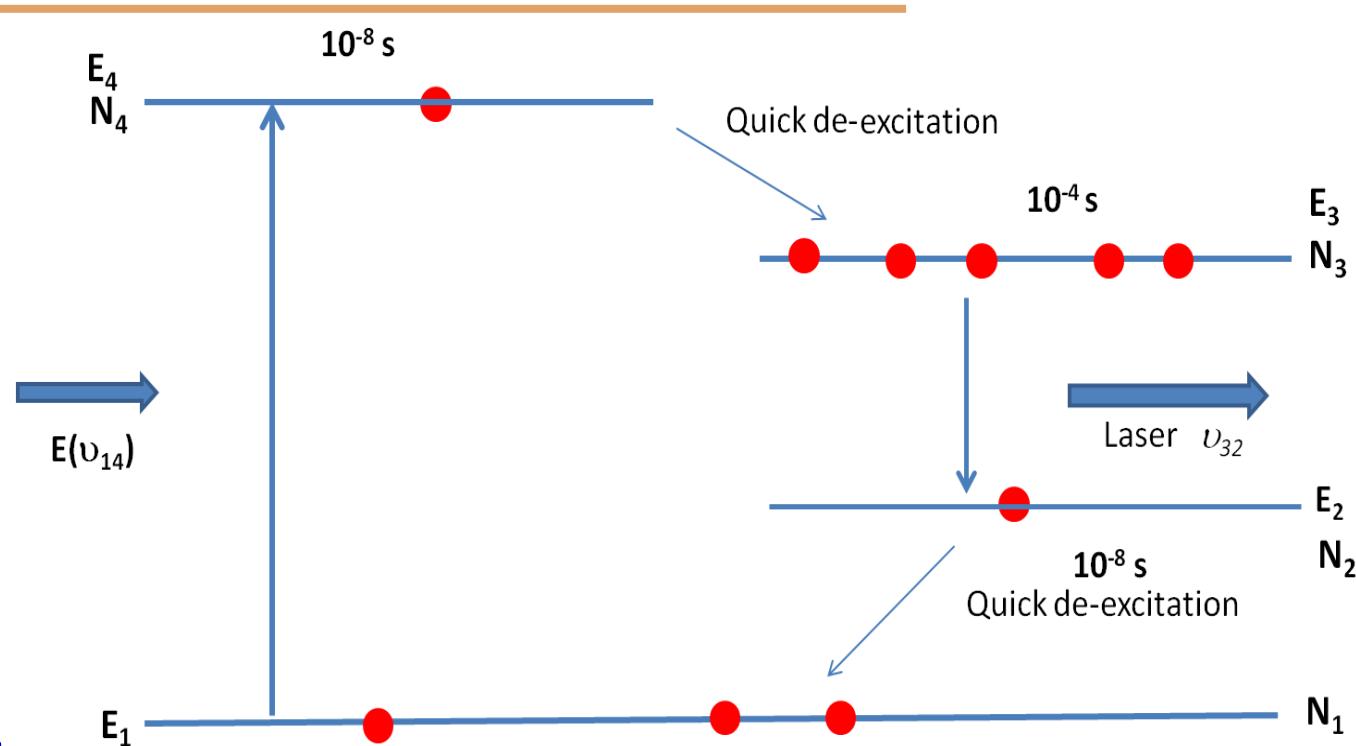


Pulsed laser

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Four level laser system

- Frequency Decoupled Pump $E(v_{14})$ and Laser $E(v_{32})$
- Quick decay E_4 to E_3
- Lasing states E_3 and E_2
- E_3 is meta-stable
- Ground state is not the lower Lasing state
- High energy pump not necessary
- Continuous laser



Check Your Understanding (Yes/No)

- 1. A two level laser is very efficient*
- 2. A three level laser produces a continuous laser*
- 3. A four level laser produces a pulsed beam*
- 4. A four level laser can produce very high intensity*



THANK YOU

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