



## 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

# ENGINEERING PHYSICS

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

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### ➤ *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*  $R_{Ab} = BN_1E(\nu)$

*Rate of Stimulated Emission*  $R_{StEm} = BN_2E(\nu)$

*Under thermal equilibrium,  $N_1 \gg N_2$*

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

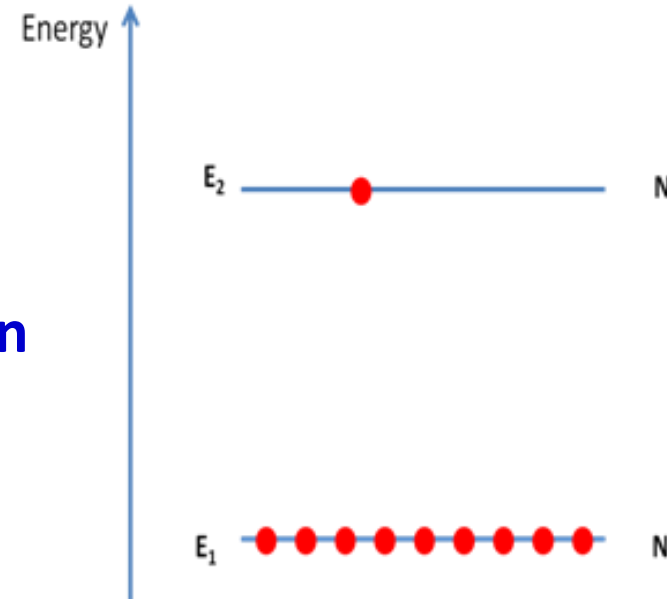
*If the rate of stimulated emission  
is lesser than the rate of absorption,  
then the laser emission is impossible.*

- 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

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## Two level system

- Initially:  $N_1 > N_2$
- Goal : Achieve  $N_2 > N_1$
- In the presence of  $E(\nu)$  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  $E(\nu)$  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



## Three level system

- Pump and laser frequency  
Decoupling

$$R_{Ab} = BN_1 E(\nu_{13})$$

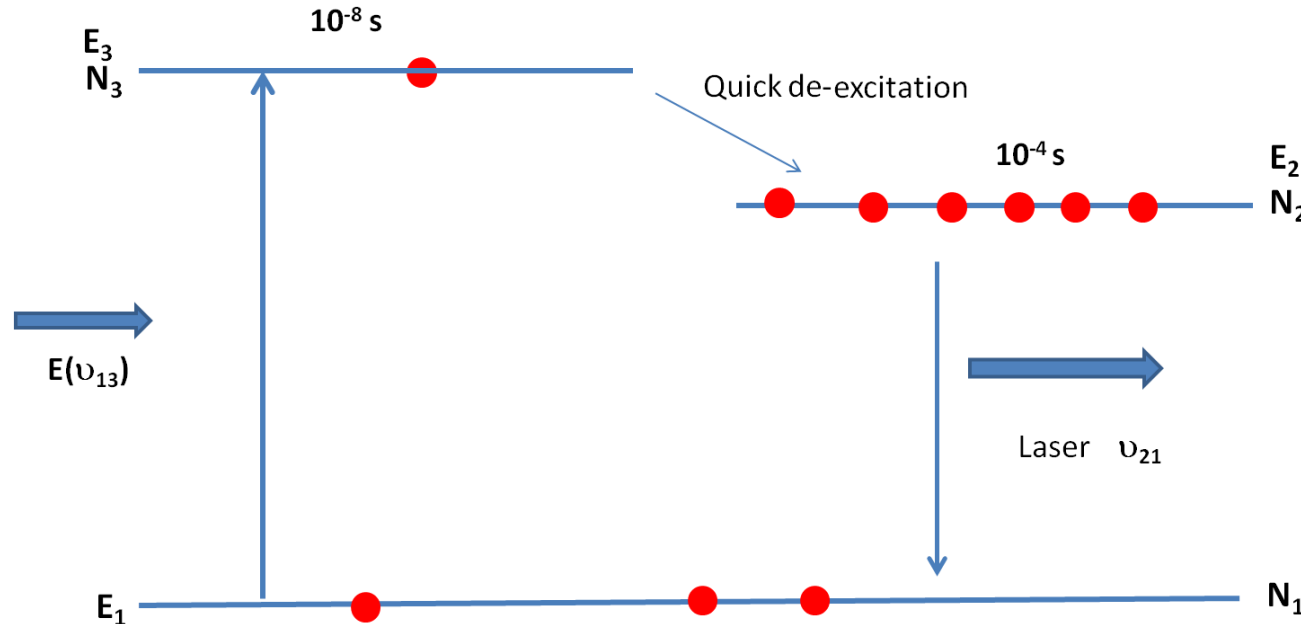
$$R_{StEm} = BN_2 E(\nu_{12})$$

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

*This causes high population in  $E_3$ .*

*$E_3$  is a short lived state.*

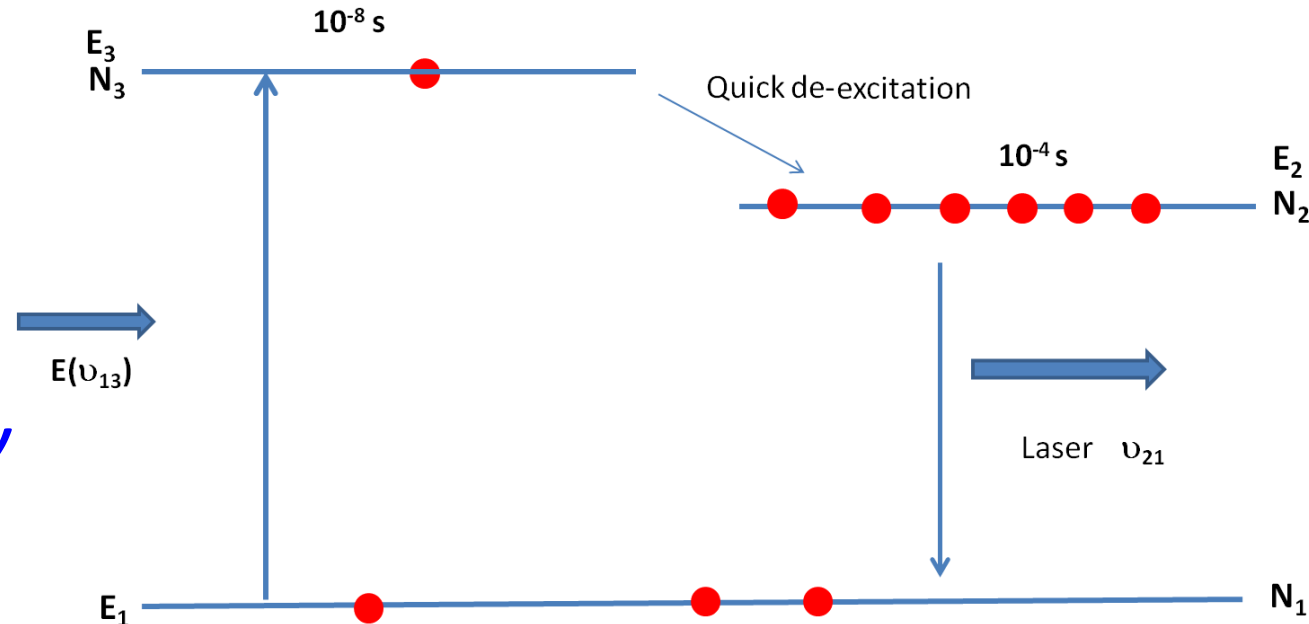
*Quick and Nonradiative decay to  $E_2$  (Meta stable state)*



# ENGINEERING PHYSICS

## Three level laser system

*Population Inversion  
between  $E_2$  and  $E_1$*

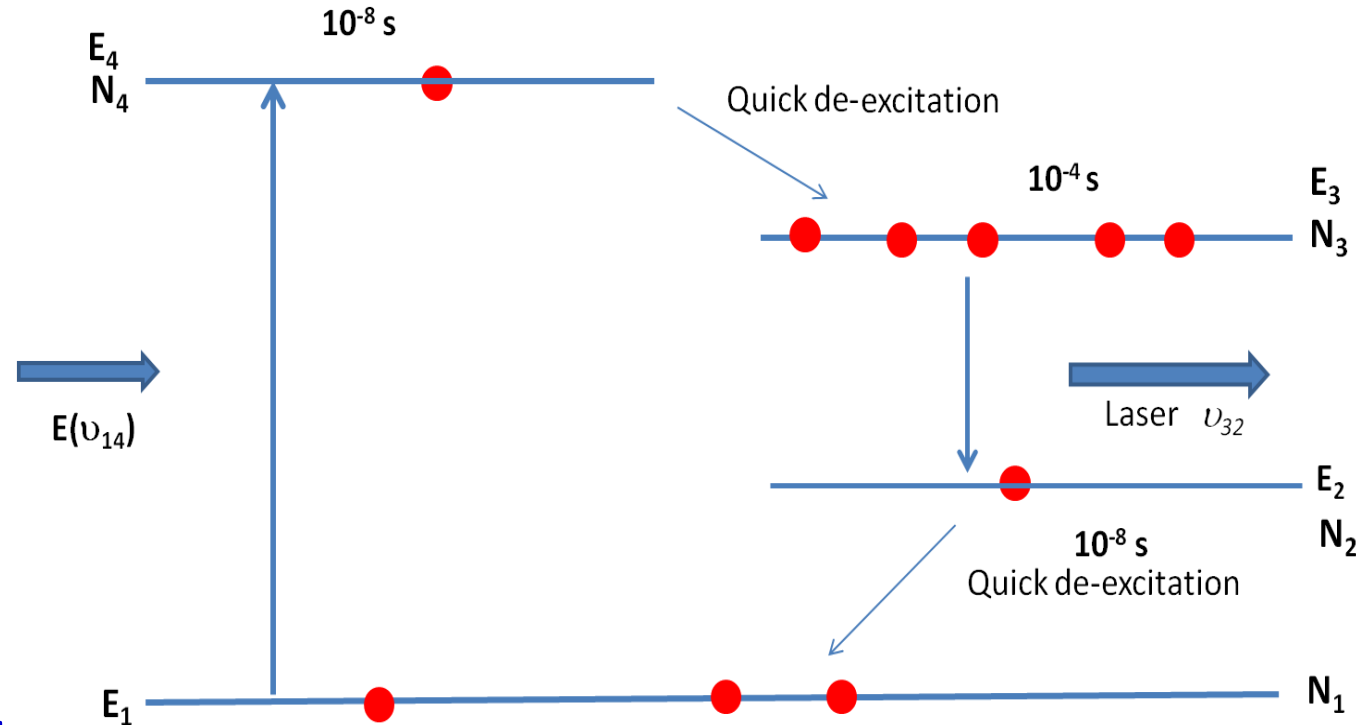


*Population Inversion is energy  
demanding as we work  
against the heavily  
populated ground state*

*Pulsed laser*



- Frequency Decoupled Pump  $E(\nu_{14})$  and Laser  $E(\nu_{32})$
- 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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