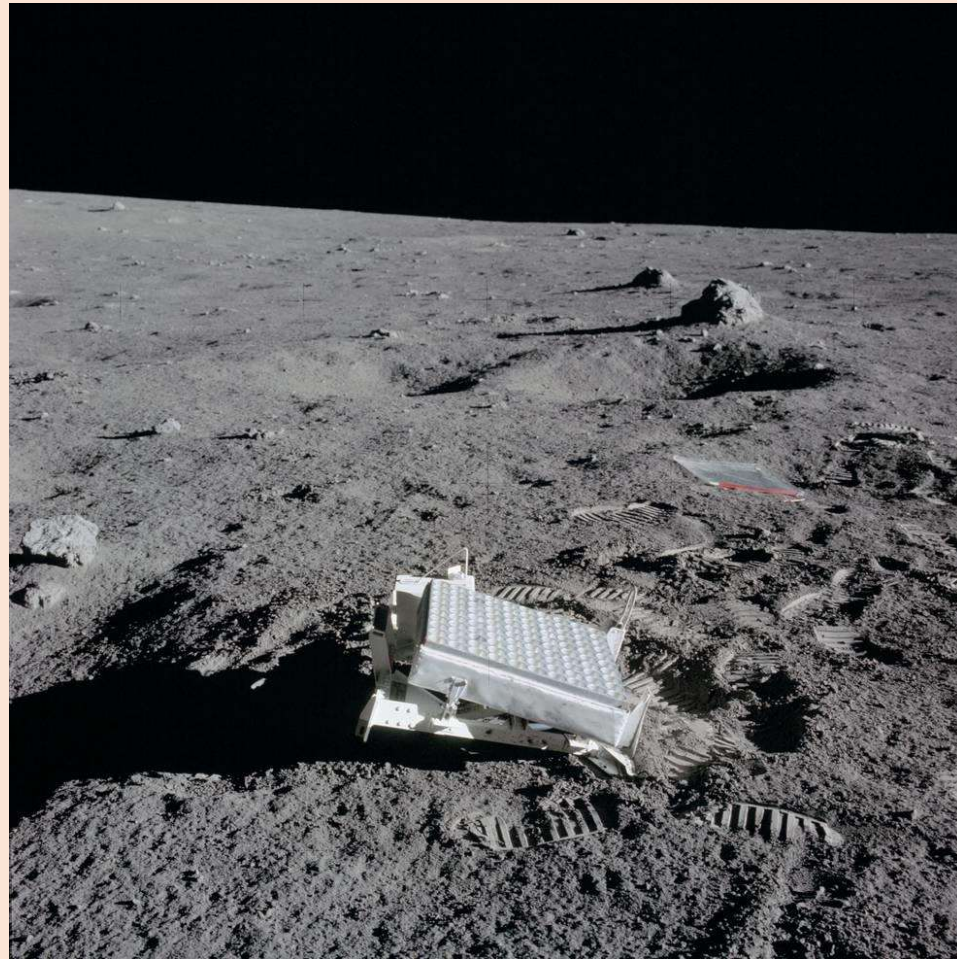


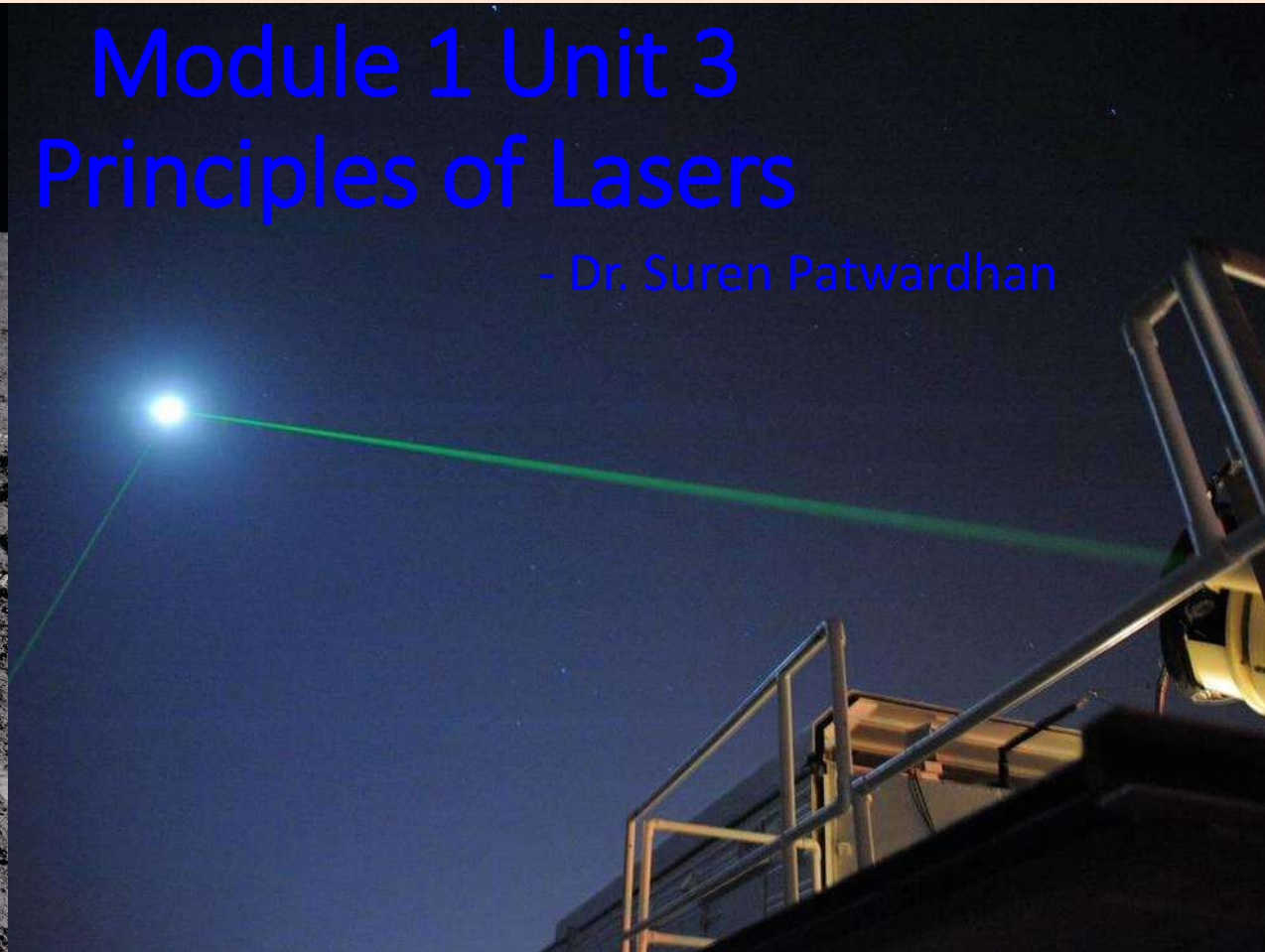
Module 1 Unit 3

Principles of Lasers

- Dr. Suren Patwardhan



The Moon



Geophysical and Astronomical Observatory at NASA's Goddard Space Flight Center in Greenbelt, Md., USA

Image Courtesy: <https://www.nasa.gov/multimedia/imagegallery>

Dr. Suren Patwardhan

Properties of LASER

Light Amplification by Stimulated Emission of Radiation

- Monochromatic
 - Unique wavelength
 - Coherent
 - All waves are In phase
 - Directional
 - Light emitted along same path
 - Focused
 - Low divergence/ Low spreading
 - Bright
 - High intensity/ High power
 - Polarized (optional)
 - E-M vibrations in same plane
- Most of the lasers are in the IR to Green range
 - Difficult to get Violet-Ultraviolet lasers
(Nitride-based semiconductors have made it possible)
 - May not be possible to get X-ray lasers (at least on Earth)

Some Popular Laser Sources

| Name of laser source | Emission wavelength | Applications |
|----------------------|---------------------|----------------------------|
| He-Ne laser | Red, green | Mainly laboratory purpose |
| Ar laser | Blue-green | Eye surgery |
| Nd:YAG laser | Invisible (IR) | Machining |
| Ruby laser | Extreme Red | High speed photography |
| GaAs/GaN lasers | Red to Blue | Fibre optic communications |
| CO2 laser | Invisible (IR) | Dermatology |

LOSER Changed to LASER

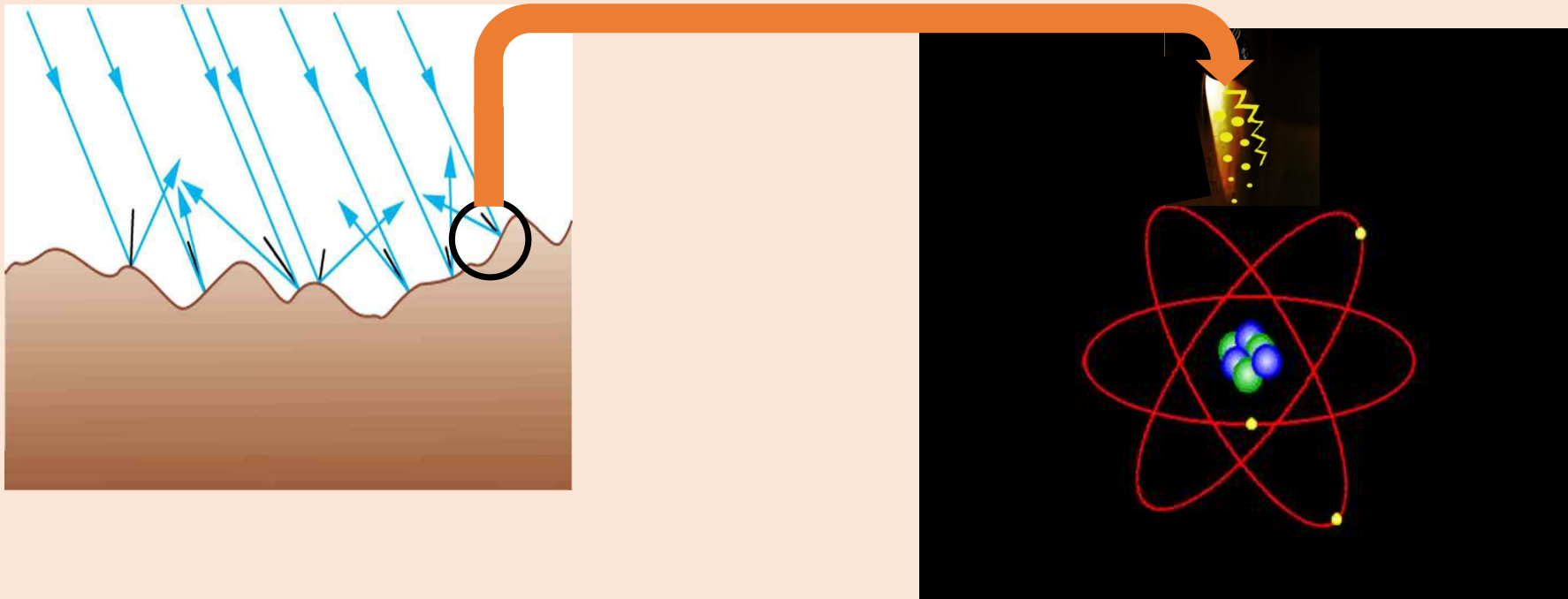
~~Oscillations~~

Amplification

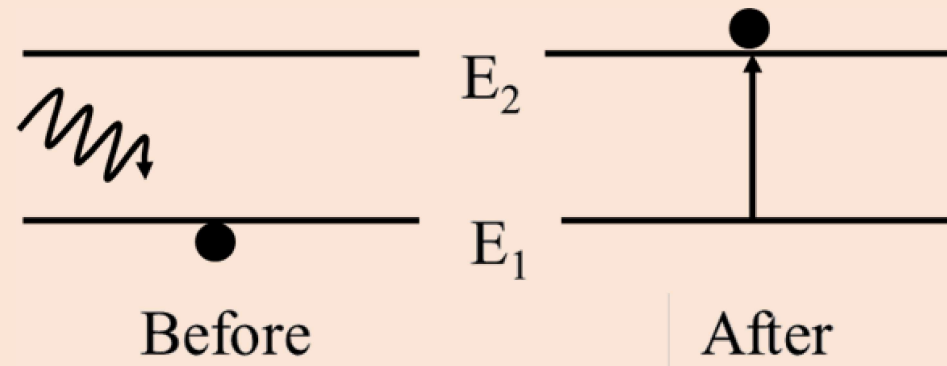
- First discovered by Maiman 1960 (kind of MASER – M for Microwaves)
- Once teased as discovery in search of applications, today has hundreds of applications
 - CO₂ laser used in cosmetics
 - Nd:YAG laser used in machining and surgery
 - Ar laser used in surgery
 - Diode laser used in communications
 - Dye lasers used in spectroscopy
 - Nd:Glass laser used in nuclear fusion
 - He-Ne laser used laboratory experimentation

Interaction of Radiation with Matter

1. Absorption - Energy supplied
2. Spontaneous emission - Energy emitted
3. Stimulated emission - Energy emitted



Absorption i.e. Stimulated Absorption



Rate of transition

$$\left. \frac{dN}{dt} \right|_{ab} = B_{12} N_1 Q$$

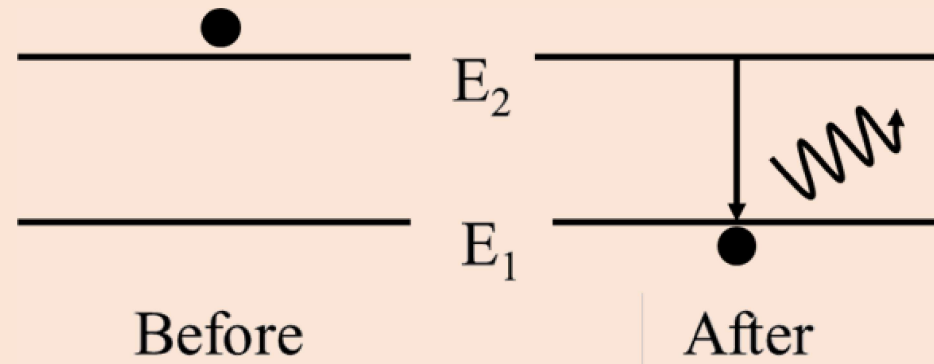
Where,

B_{12} : probability of absorption process

N_1 : number of atoms in lower energy level E_1

Q : energy density of incident radiation per unit frequency (J-s/m^3)

Spontaneous i.e. Natural Emission



Rate of transition

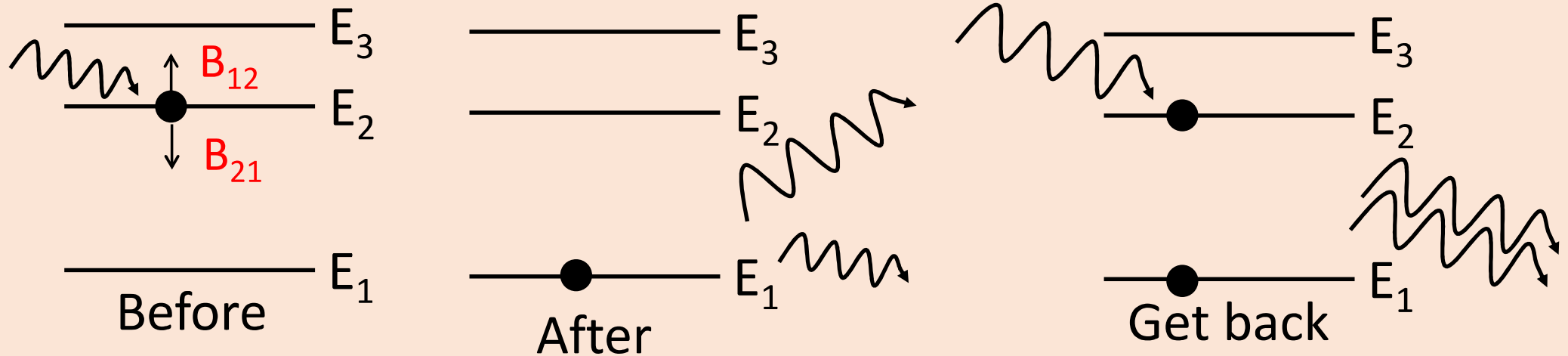
$$\left. \frac{dN}{dt} \right|_{sp} = A_{21} N_2$$

Where,

A_{21} : probability of spontaneous emission process

N_2 : number of atoms in higher energy level

Stimulated i.e. triggered emission



Einstein showed $B_{12} = B_{21}$

$$\text{Rate of transition } \left. \frac{dN}{dt} \right|_{st} = B_{21} N_2 Q$$

Where,

B_{21} : probability of stimulated emission process

N_2 : number of atoms in higher energy level E_2

Q : energy density of incident radiation per unit frequency

Advantages

Emitted radiation has same
Wavelength

Direction of propagation

Phase

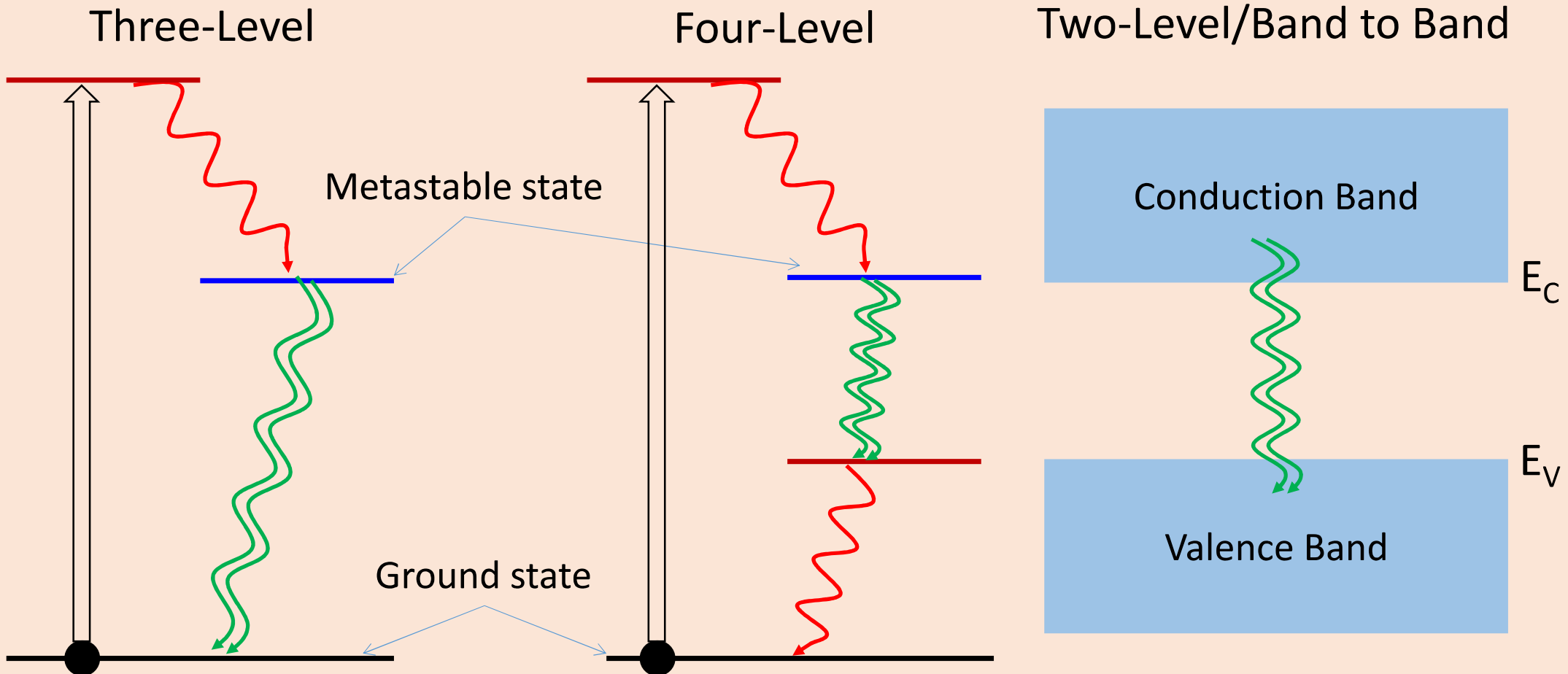
Lasing Condition

- At equilibrium, $N_1 \gg N_2$
- Lower states E_1 are far more “populated” than upper states E_2
- For laser emission we need everything उल्टा
 1. $N_2 > N_1$ i.e. “population inversion”
 2. Non-equilibrium, against natural distribution of atoms
 3. More gain than losses

This is achieved by two important concepts:

1. Metastable states – ensures stimulated emission
2. Optical Resonator – ensures light amplification

Pumping Schemes and Metastable States



Pumping and its Types

Pumping: *Process of supplying trigger/input energy to achieve population inversion*

- **Optical pumping**

A broad and bright source of light (photons) is used to supply energy

Example: Xenon flash lamp in Ruby laser, Nd:YAG laser, Dye lasers

- **Electrical Pumping**

High electric field is set up by a pair of electrodes

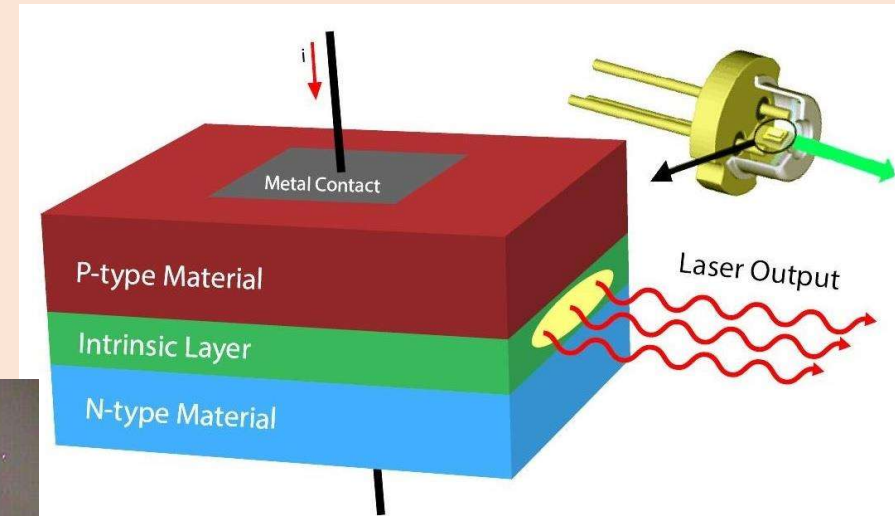
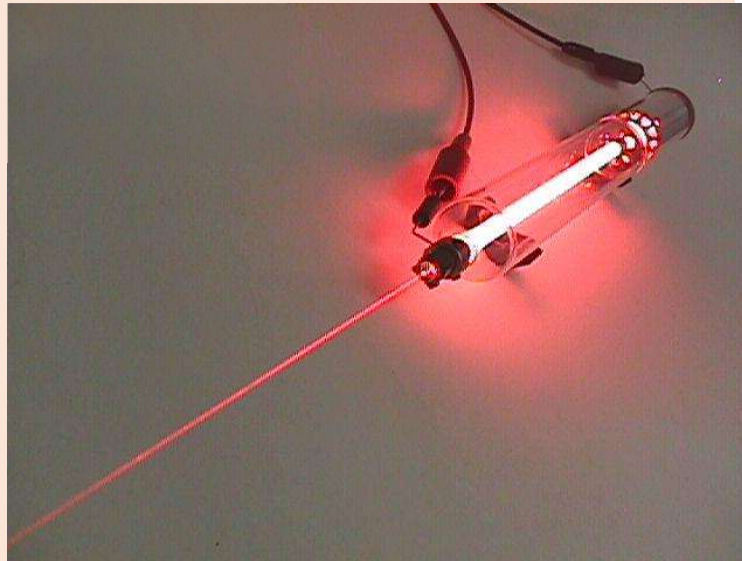
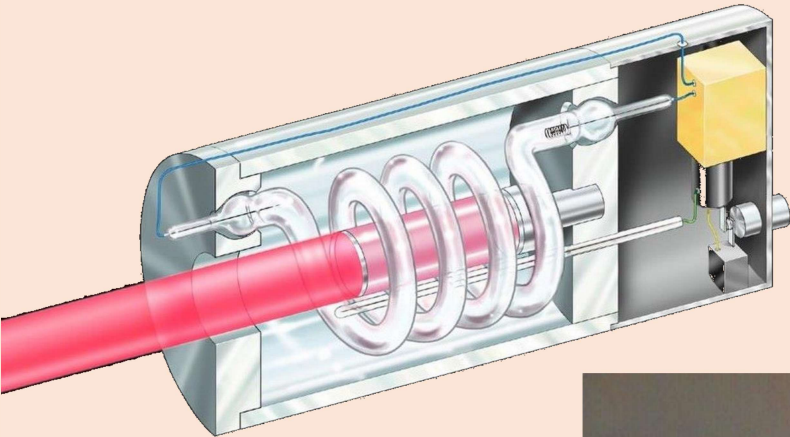
Example: He-Ne laser, CO₂ laser, Ar laser

- **Direct conversion**

By passing an electric current

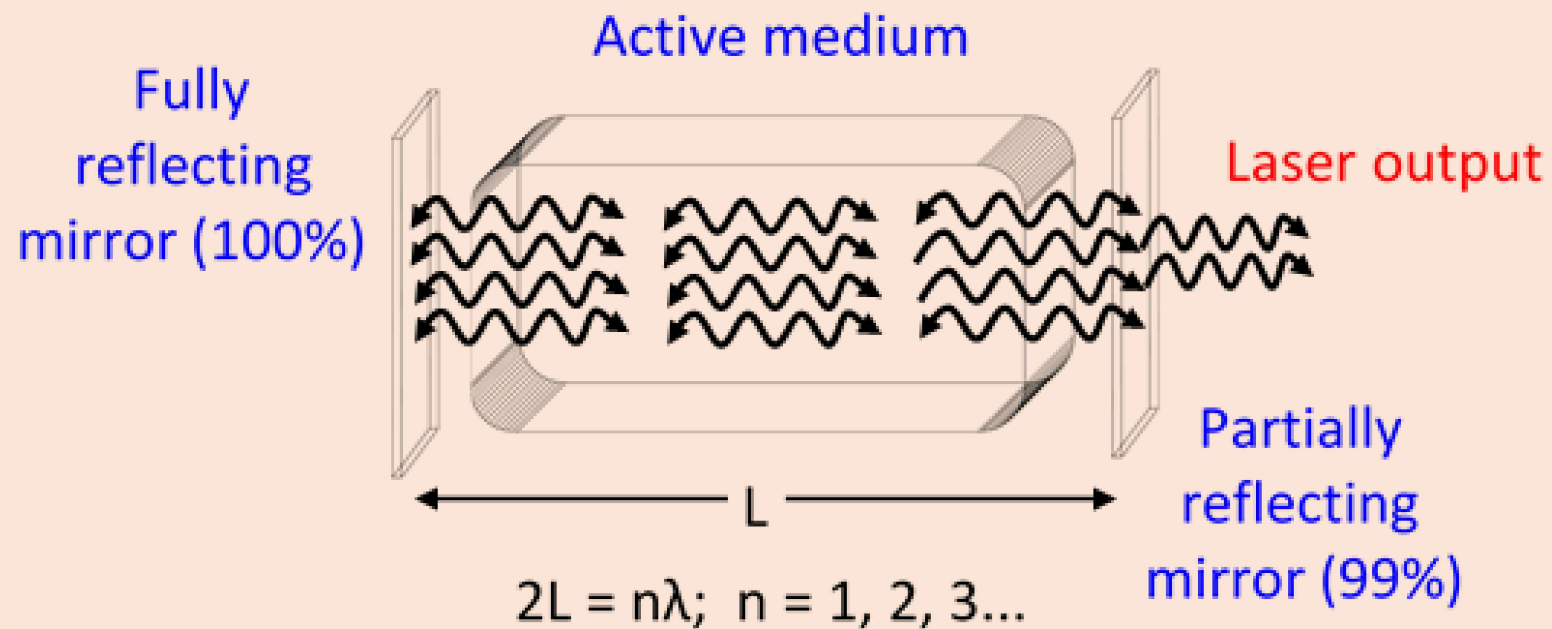
Example: Semiconductor diode lasers

Types of Pumping - Schematics

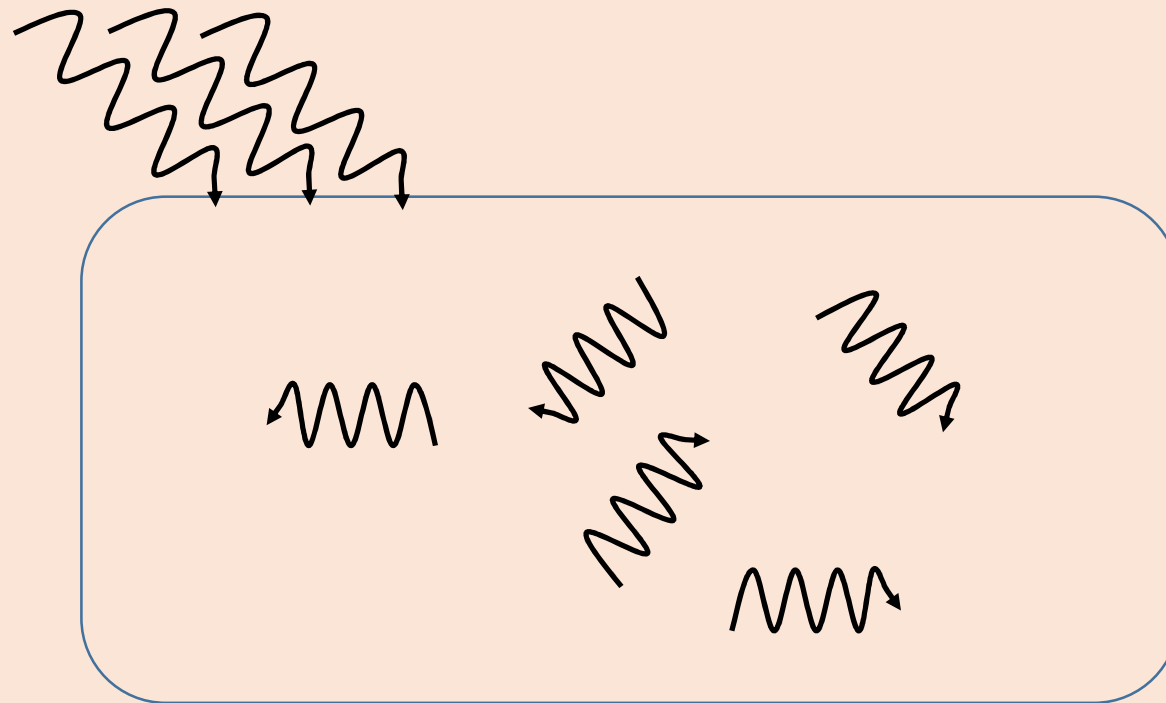


Optical Resonator/Active Medium

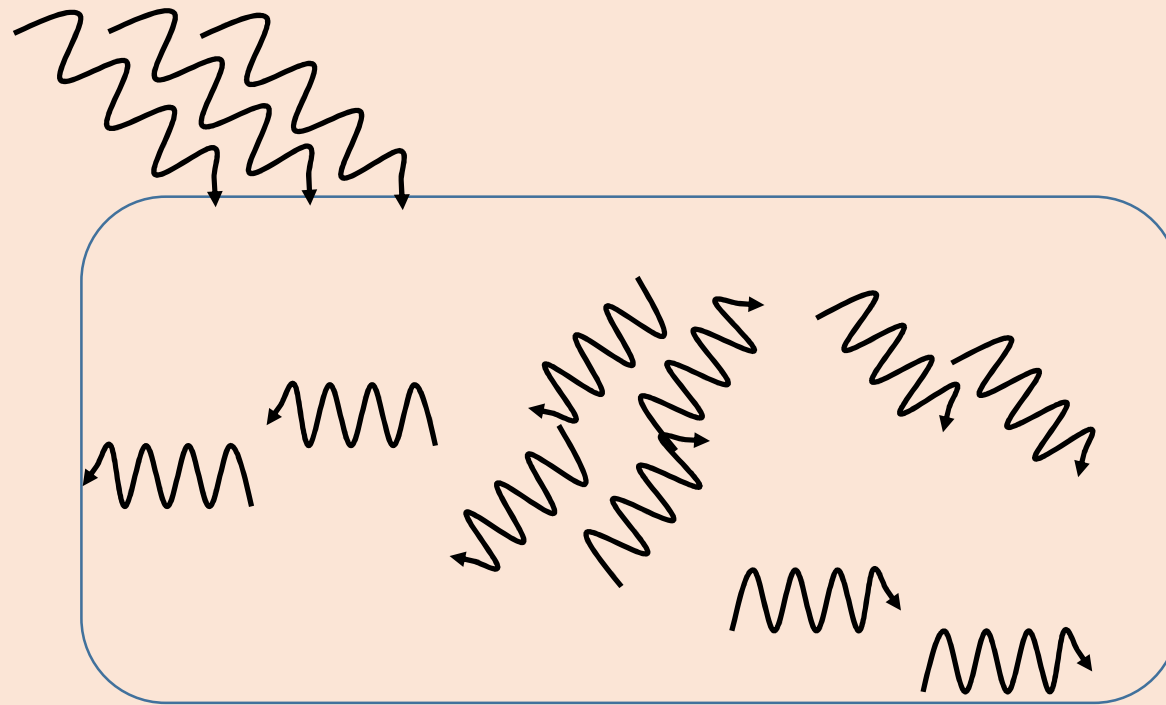
Active medium: *Region of the laser source where population inversion is achieved*



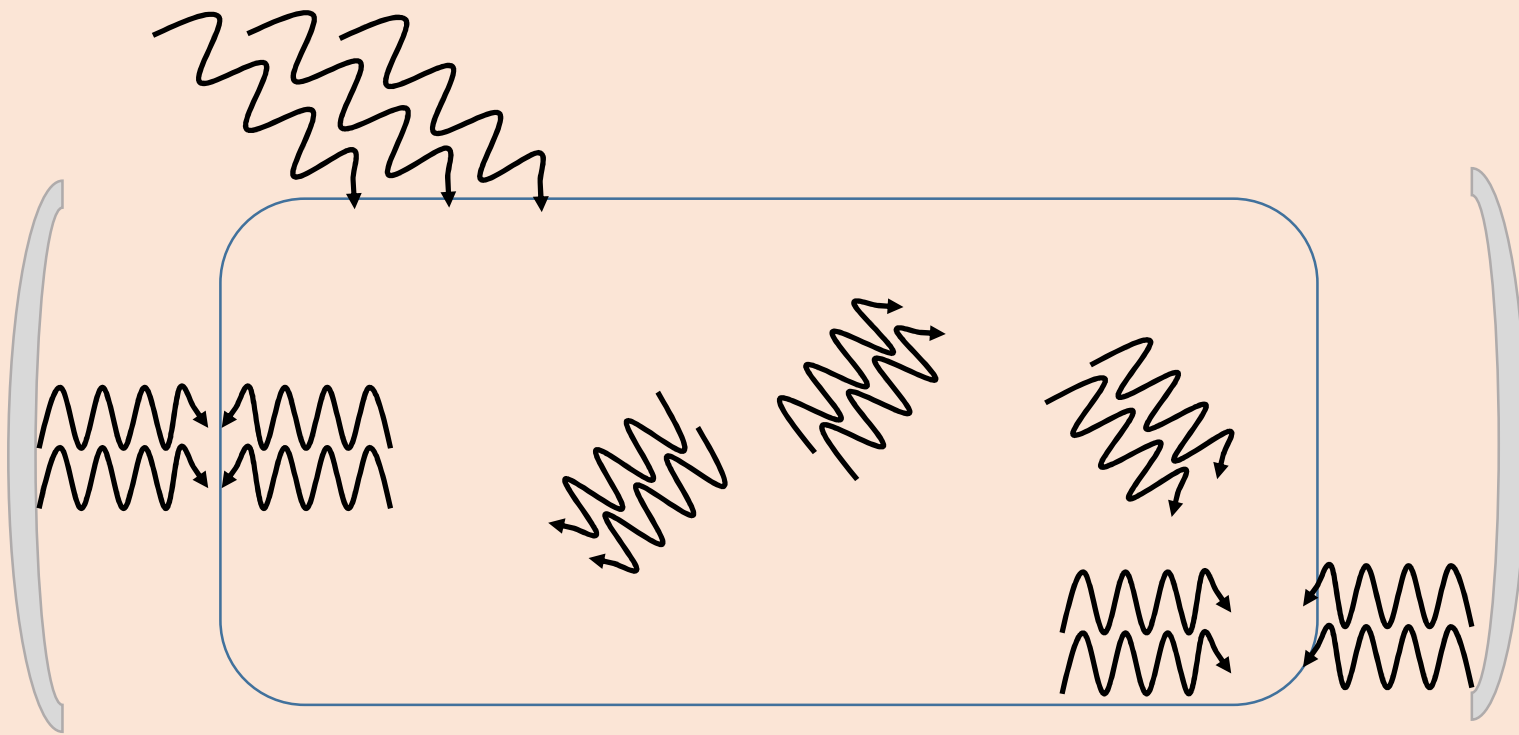
Action of Optical Resonator



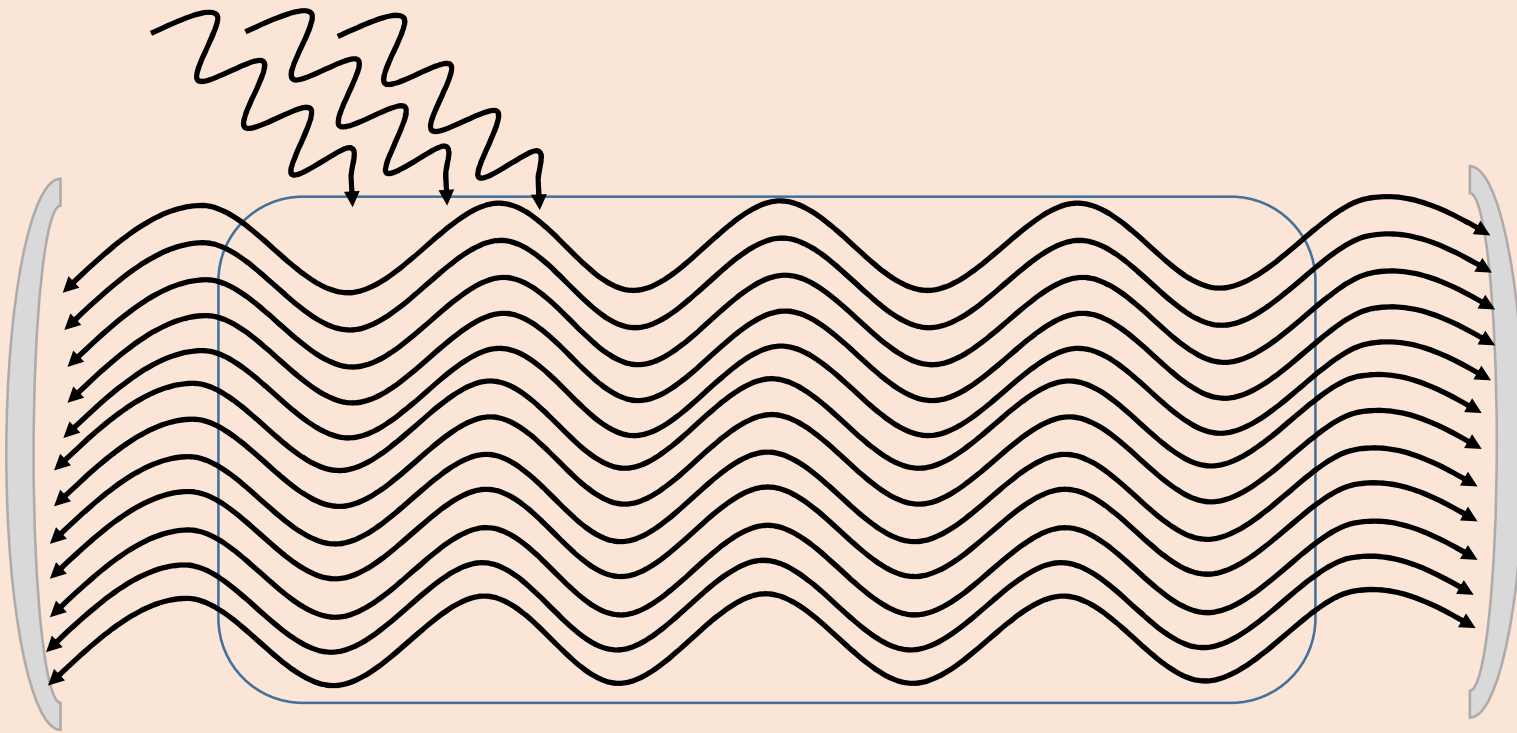
Action of Optical Resonator



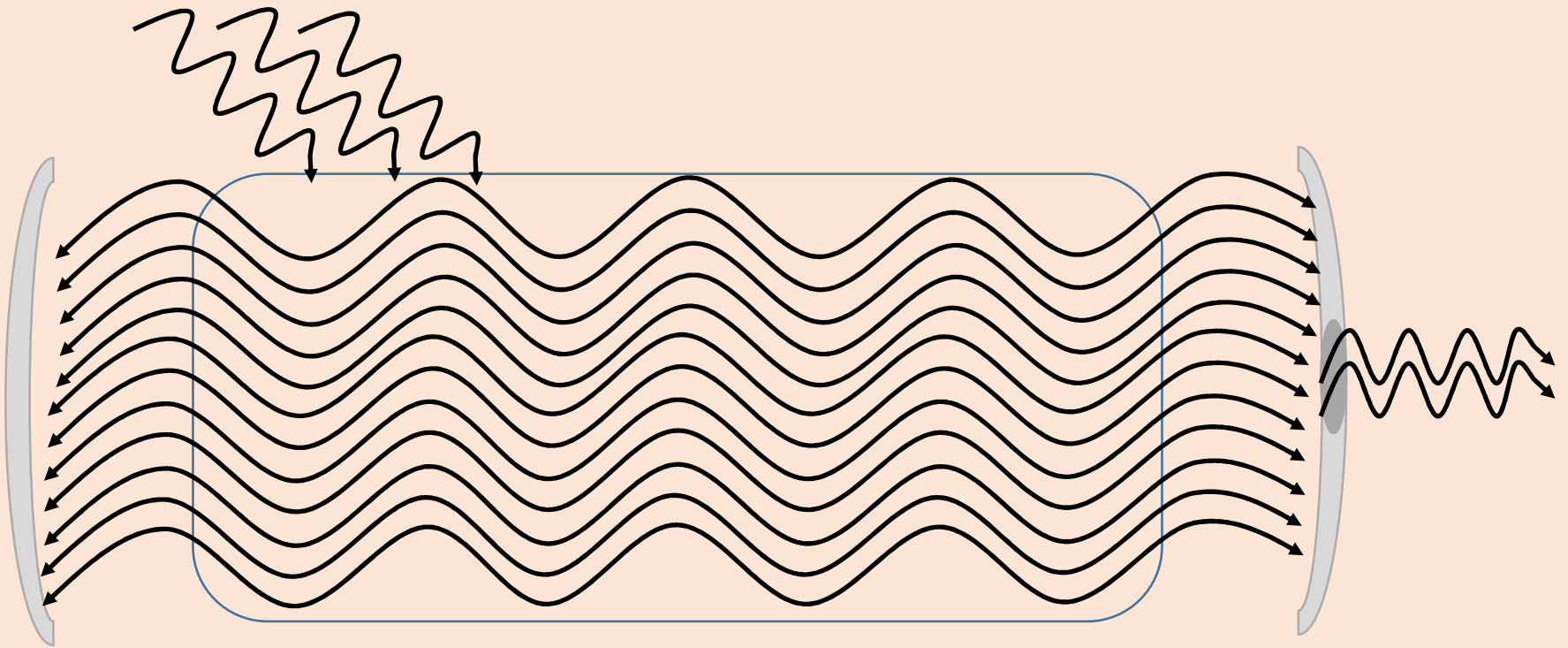
Action of Optical Resonator



Action of Optical Resonator



Action of Optical Resonator



Important Laser Physics Terms

- Population

The number of active atoms occupying a particular energy state

- Population Inversion

Creating a non-equilibrium state with more atoms in excited states

- Pumping

Process of supplying trigger/input energy to achieve population inversion

- Metastable State

Special energy levels having unusually high lifetime than normal excited states

- Active medium

Region of the laser source where population inversion is achieved

Thanks!

Blackbody Radiation at Different Temperatures

