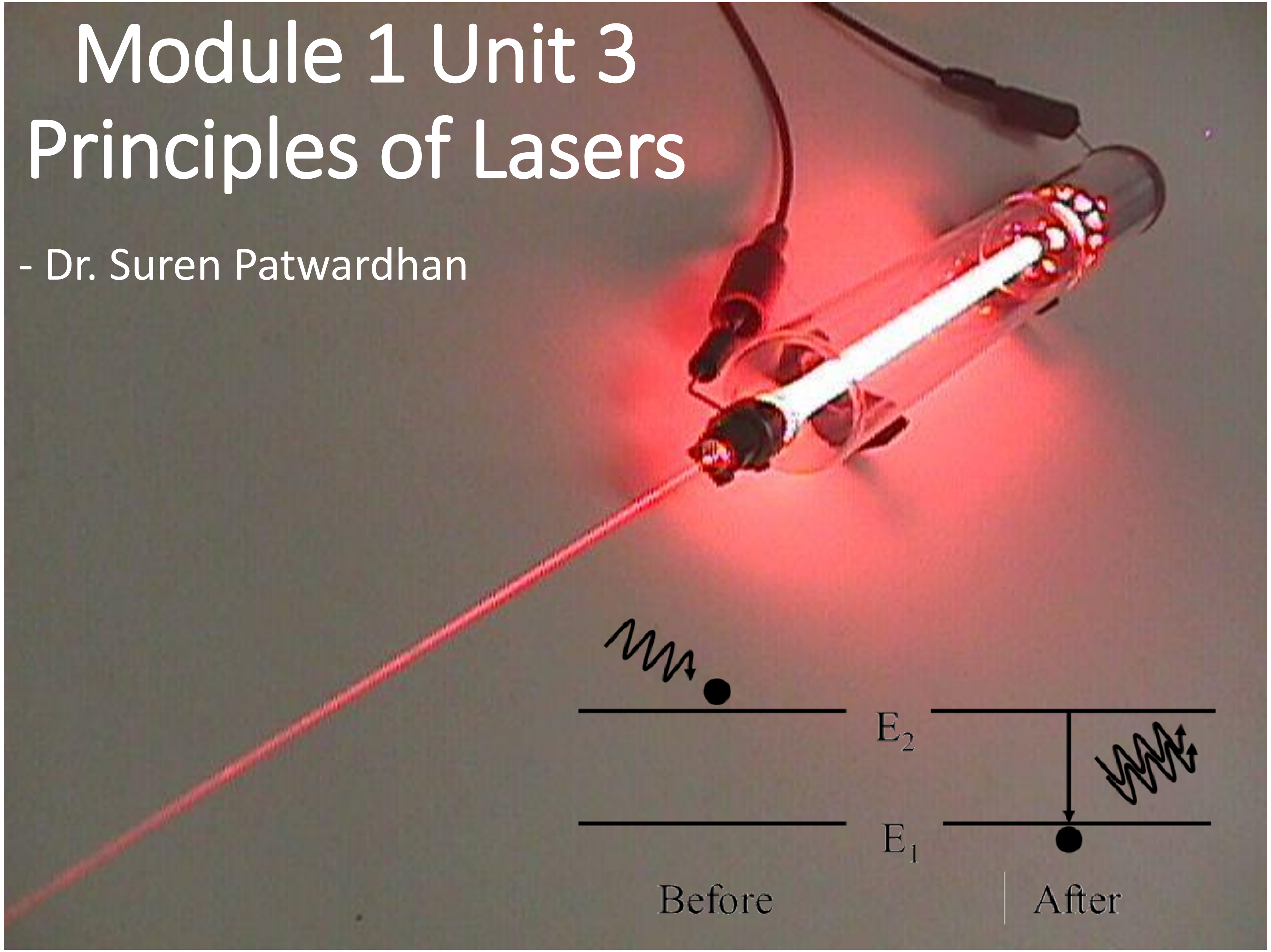
Module 1 Unit 3
Principles of Lasers

- Dr. Suren Patwardhan



SOMAIYA
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LOSER Changed to LASER

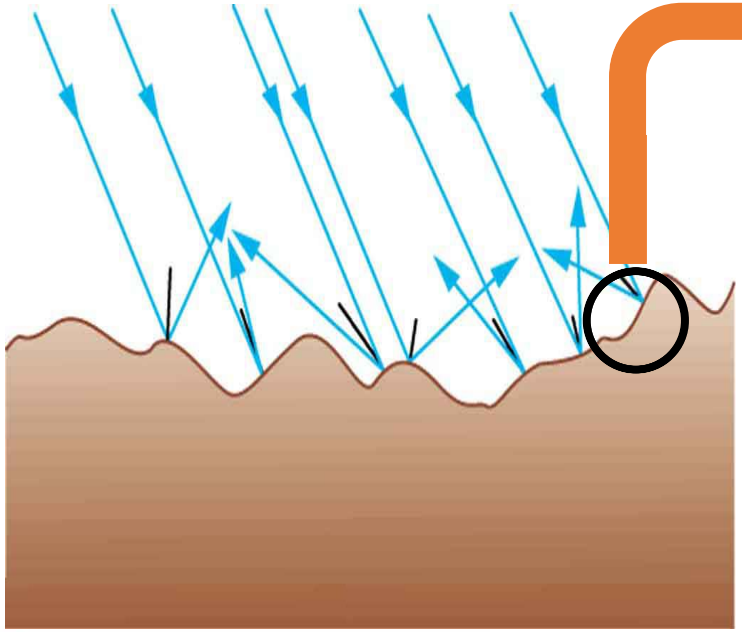
- First discovered by Maiman 1960
- Once teased as discovery in search of applications
- Today, there are hundreds of applications:
    - CO_2 laser used in cosmetics
    - Nd:YAG laser used in machining
    - Ar laser used in surgery
    - Diode laser used in communications
    - Dye lasers used in spectroscopy
    - Nd:Glass laser used in nuclear fusion

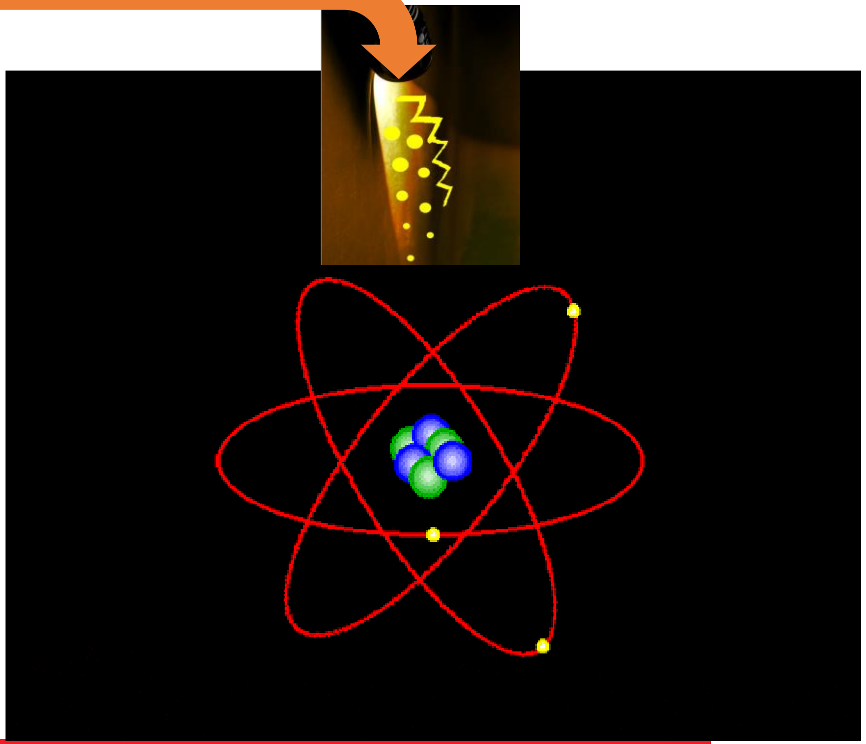
Properties of LASER

➢ Monochromatic	meaning	- Identical wavelength
➢ Coherent		- In phase
➢ Directional		- Same path
➢ Focused		- Low divergence
➢ Bright		- High intensity
➢ Polarized (optional)		- E-M vibrations in same plane

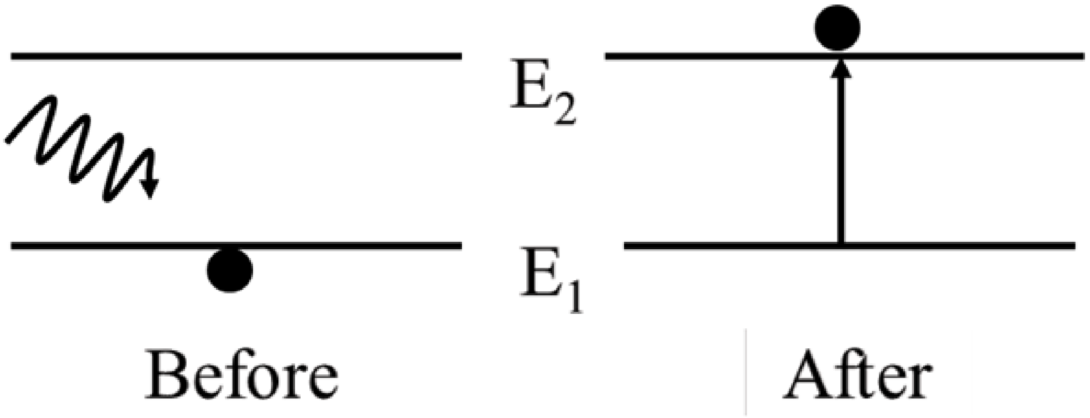
Interaction of Radiation with Matter

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





Absorption i.e. Stimulated Absorption



Rate of transition

$$\left.\frac{dN}{dt}\right|_{ab} = B_{12}N_1Q$$

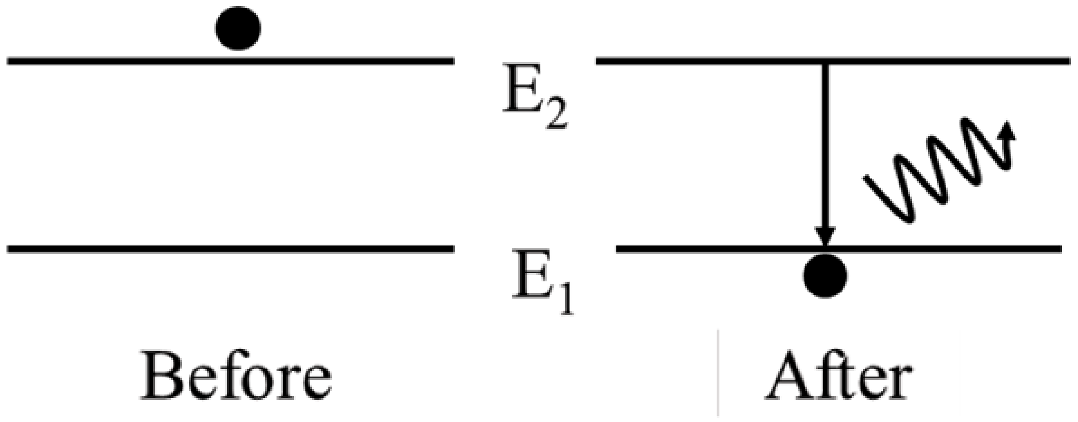
Where,

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

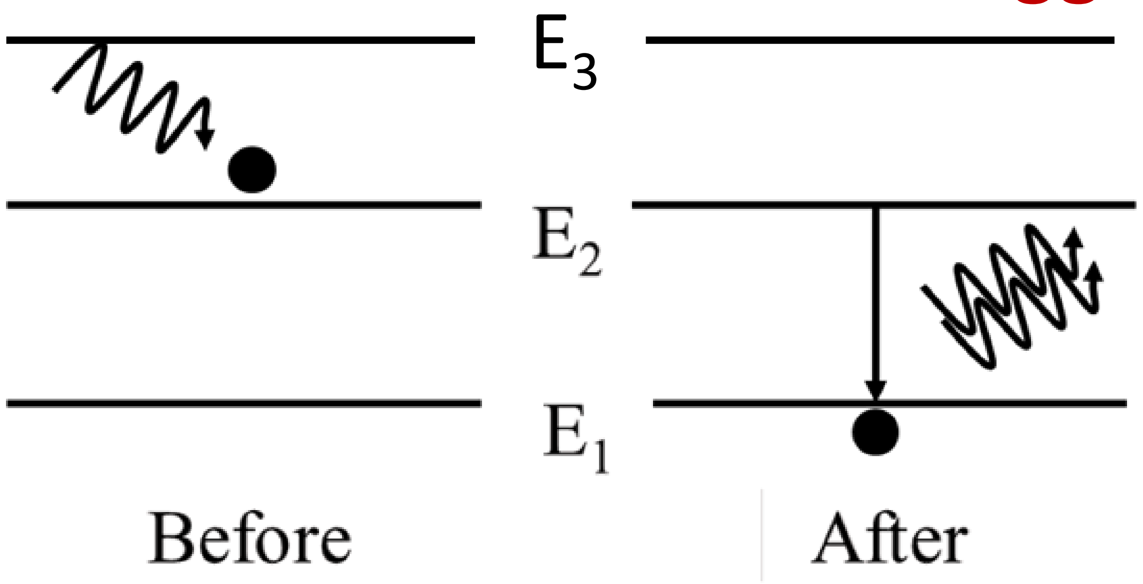
$$\left.\frac{dN}{dt}\right|_{sp} = A_{21}N_2$$

Where,

A_{21}: probability of spontaneous emission process

N_2: number of atoms in higher energy level

Stimulated i.e. triggered emission



Emitted radiation has same

i. Wavelength
ii. Direction
iii. Phase

Rate of transition

$$\left.\frac{dN}{dt}\right|_{st} = B_{21}N_2Q$$

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

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

- Active medium

  Region of the laser source where population inversion is achieved

Lasing Condition

- At equilibrium, $N_1 = \frac{g_1}{g_2} N_2 e^{(E_2 - E_1)/kT}$
- Since $E_2 > E_1$, at equilibrium, $N_1 >> N_2$
- Lower states E_1 are usually more *populated* than upper states E_2
- For laser emission, we need $N_2 > N_1$
- This is a non-equilibrium state
- Achieved by using pumping and metastable state/s

Types of Pumping

- 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

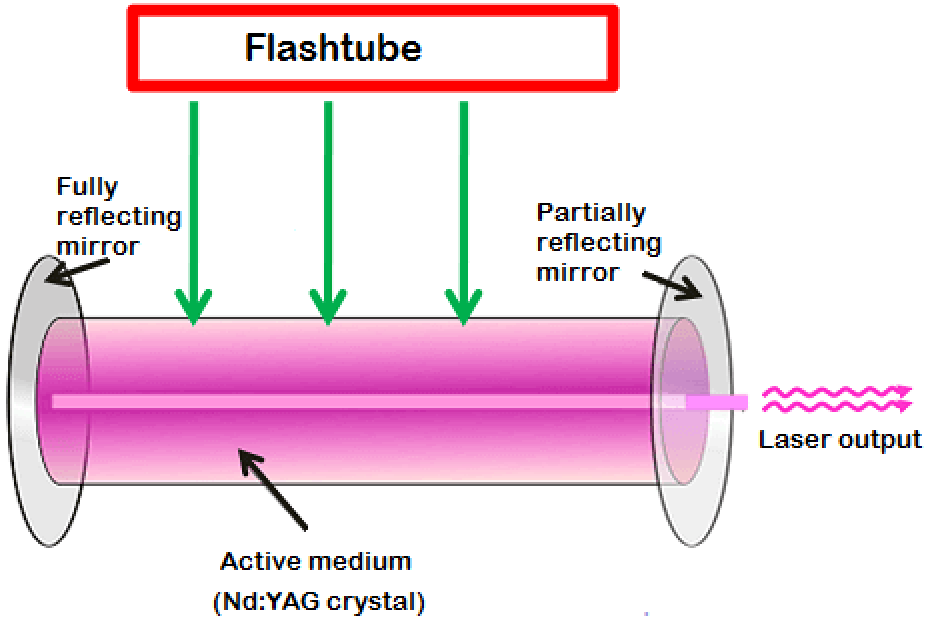
  Example: He-Ne laser, CO_2 laser, Ar laser

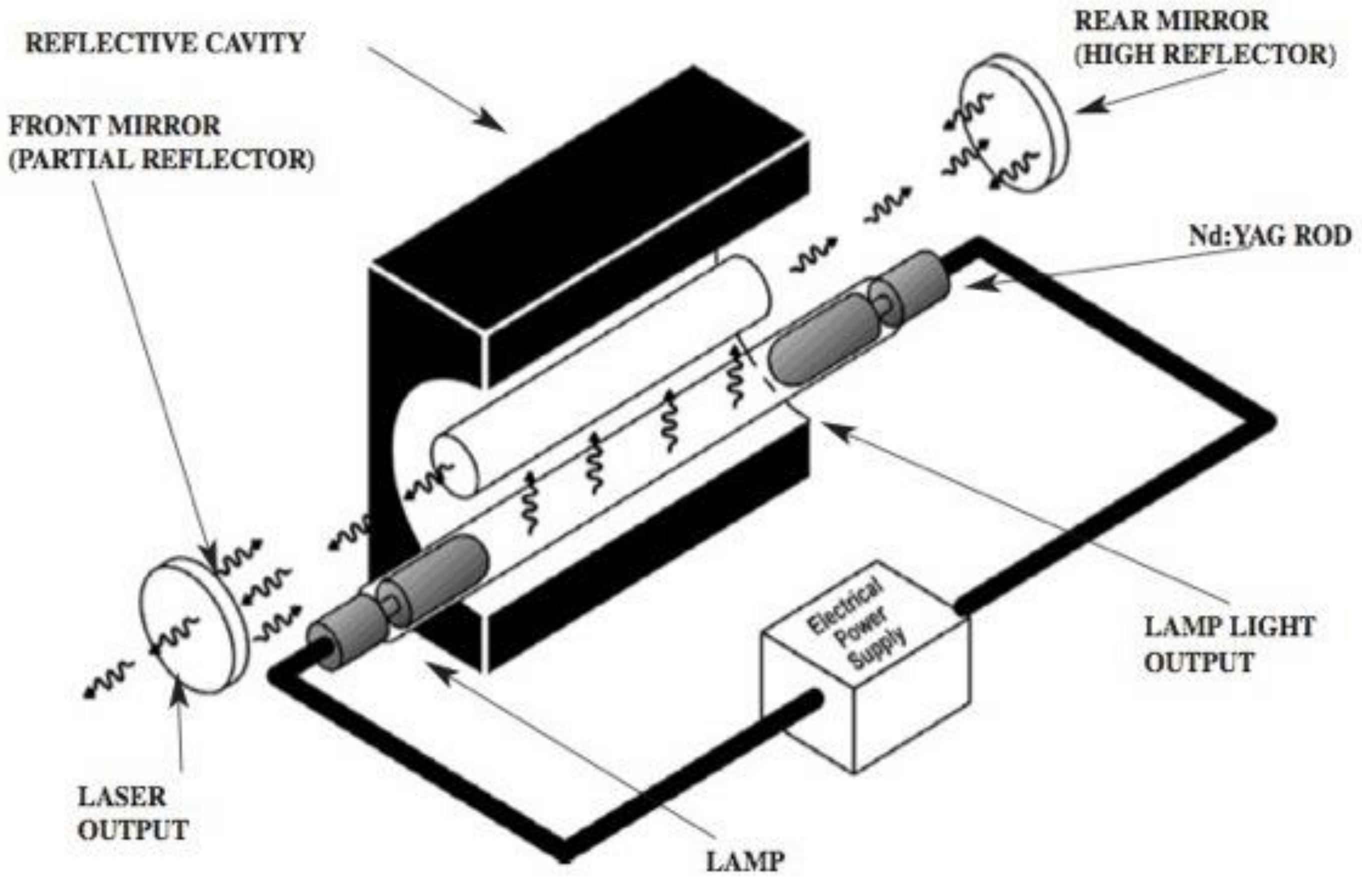
- Direct conversion

  By passing an electric current

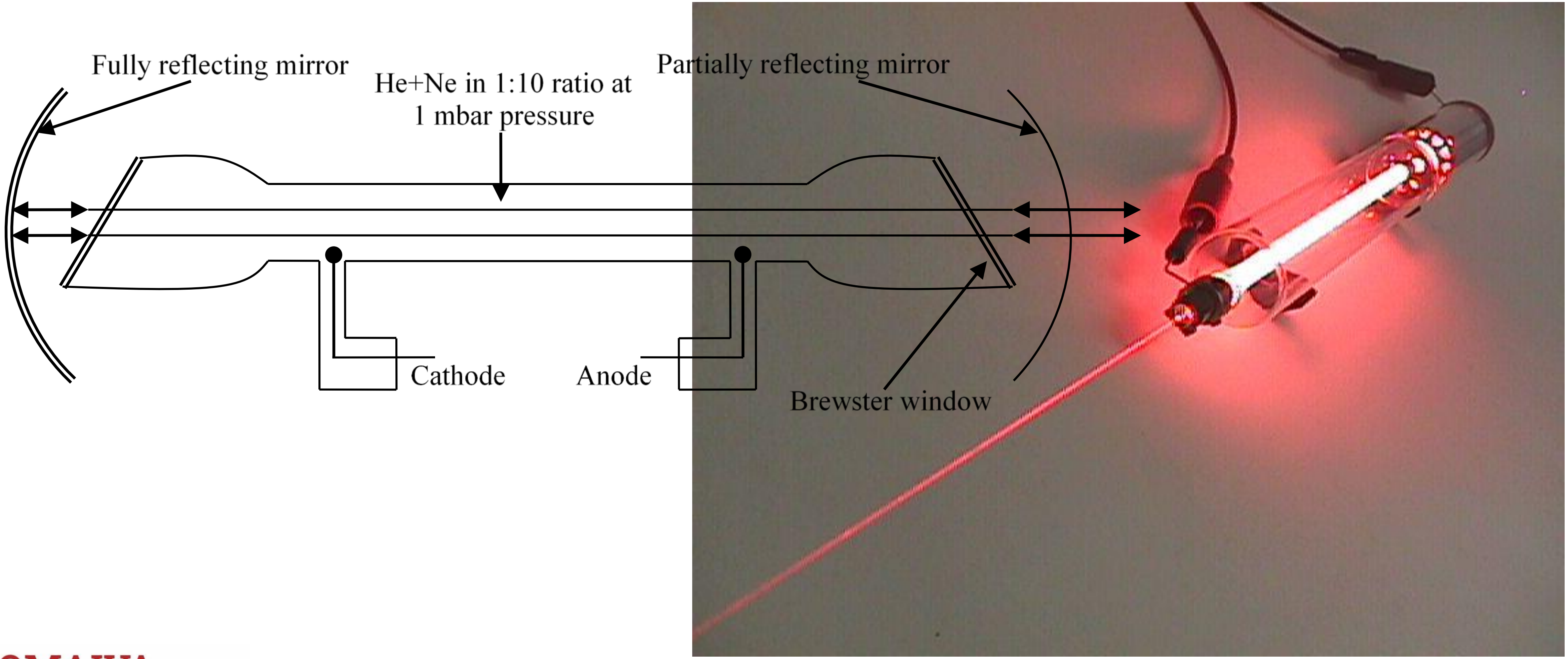
  Example: Semiconductor diode lasers

Optical Pumping - Schematic

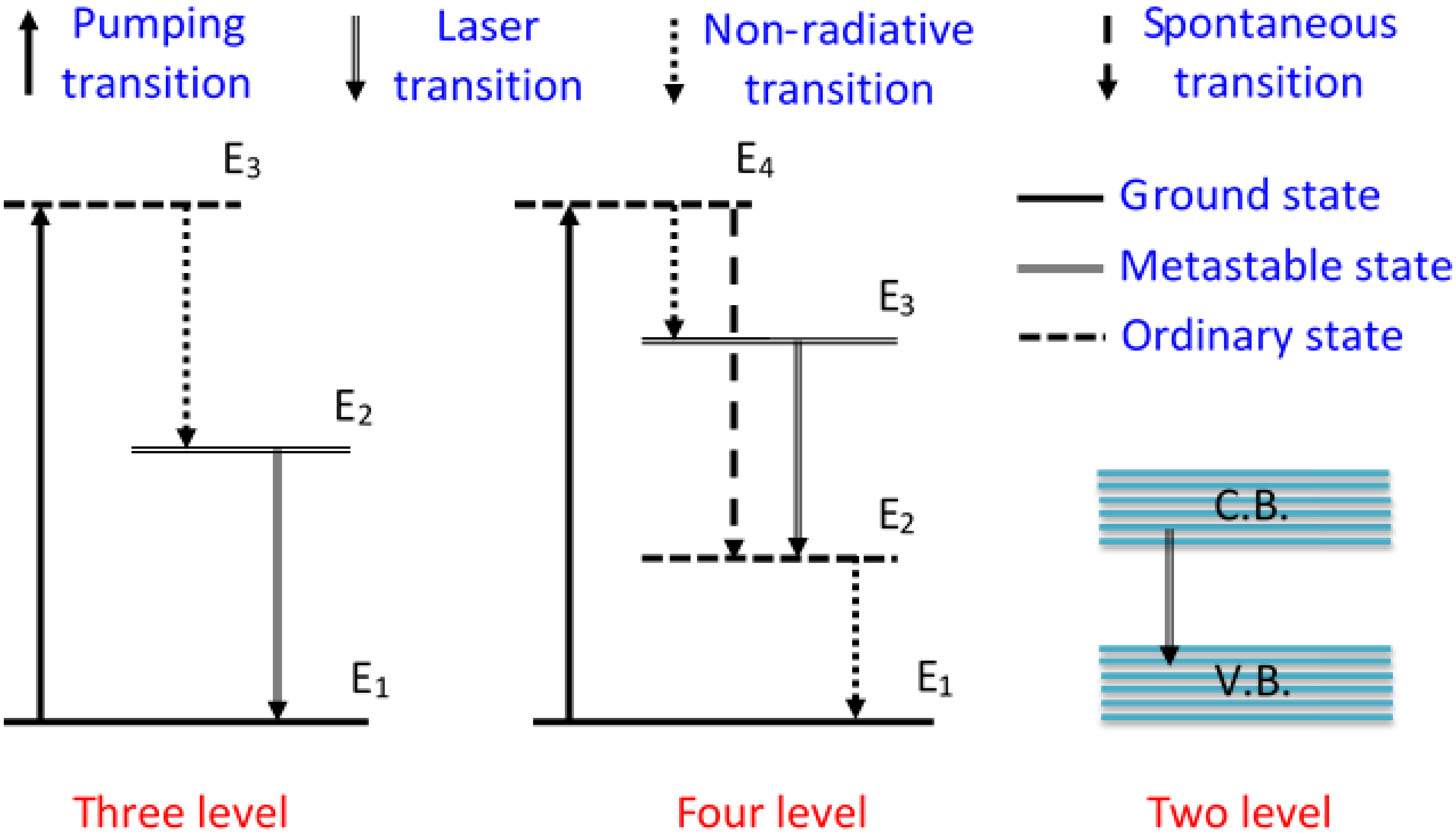




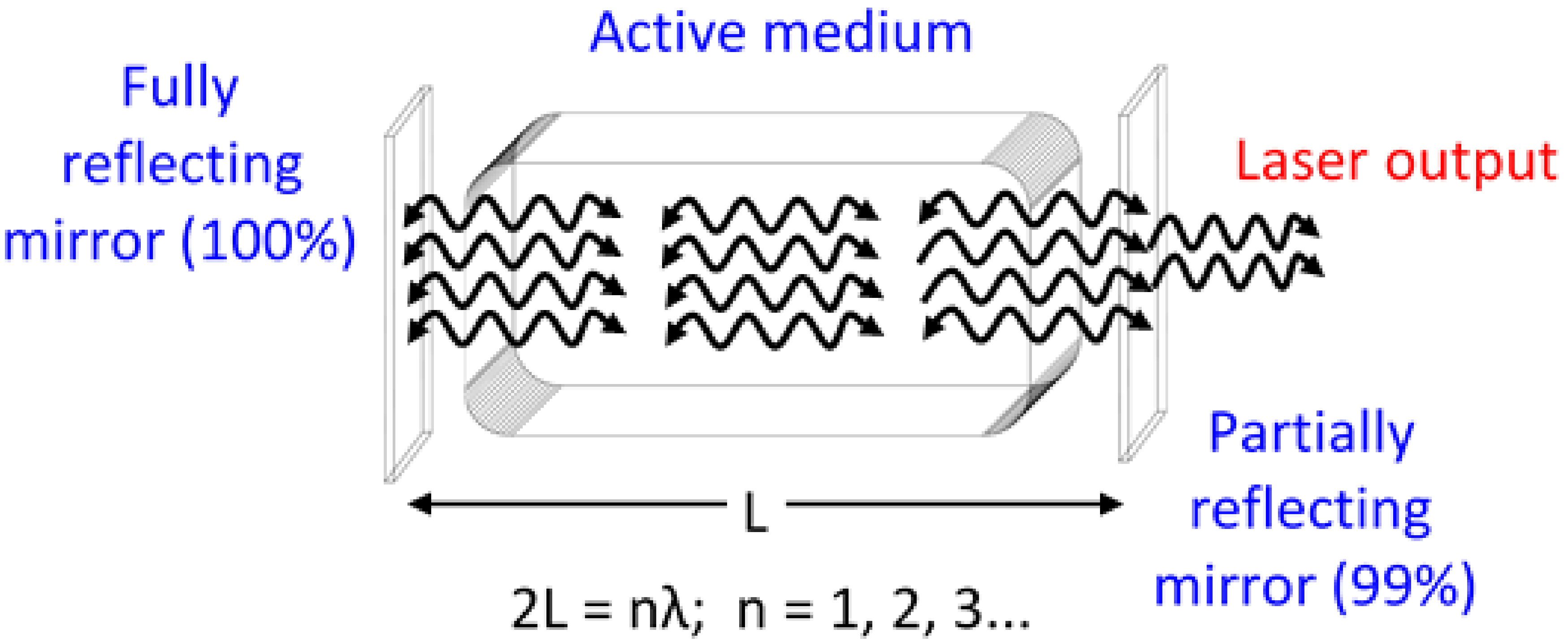
Electrical Pumping - Schematic



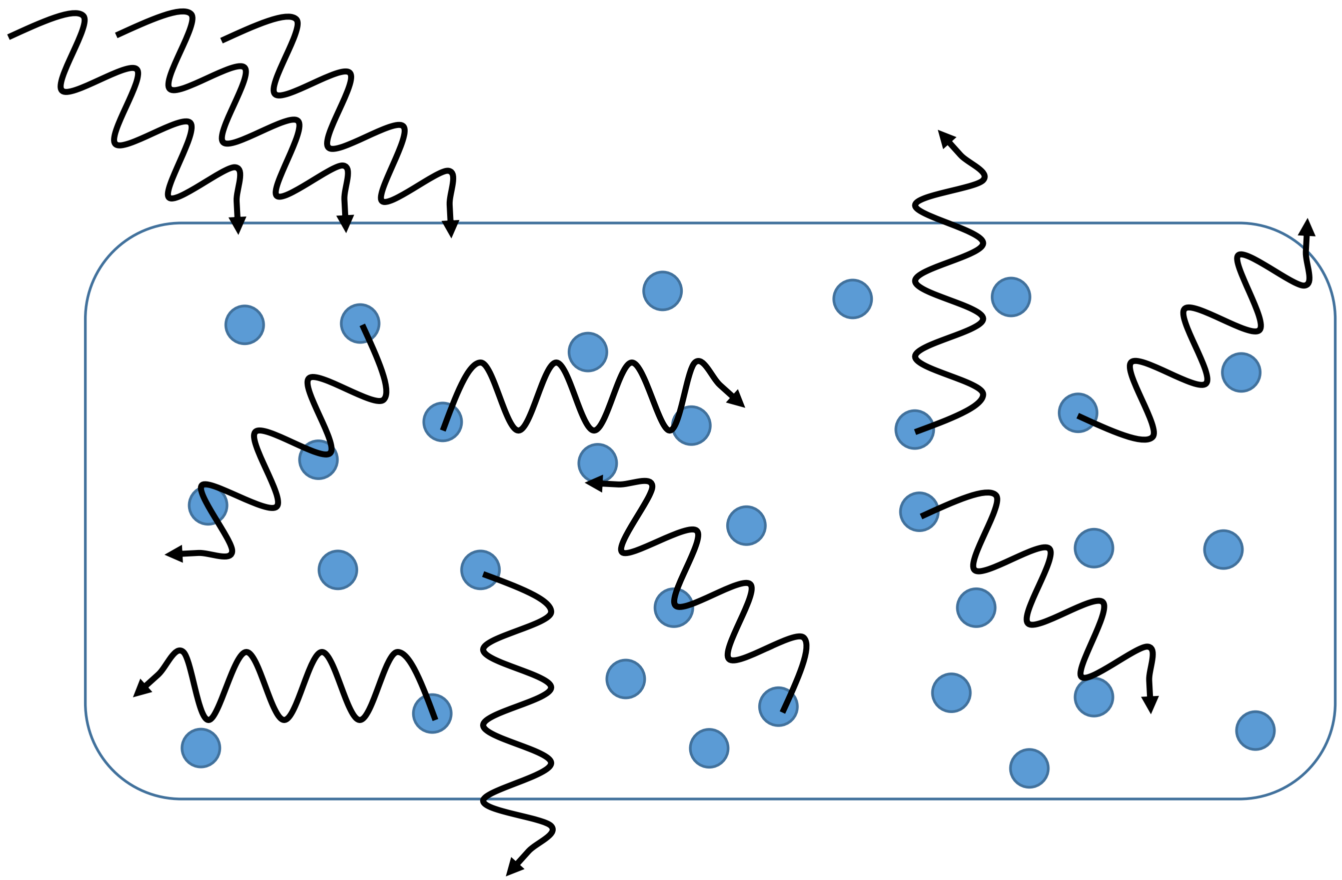
Pumping Schemes and Metastable States



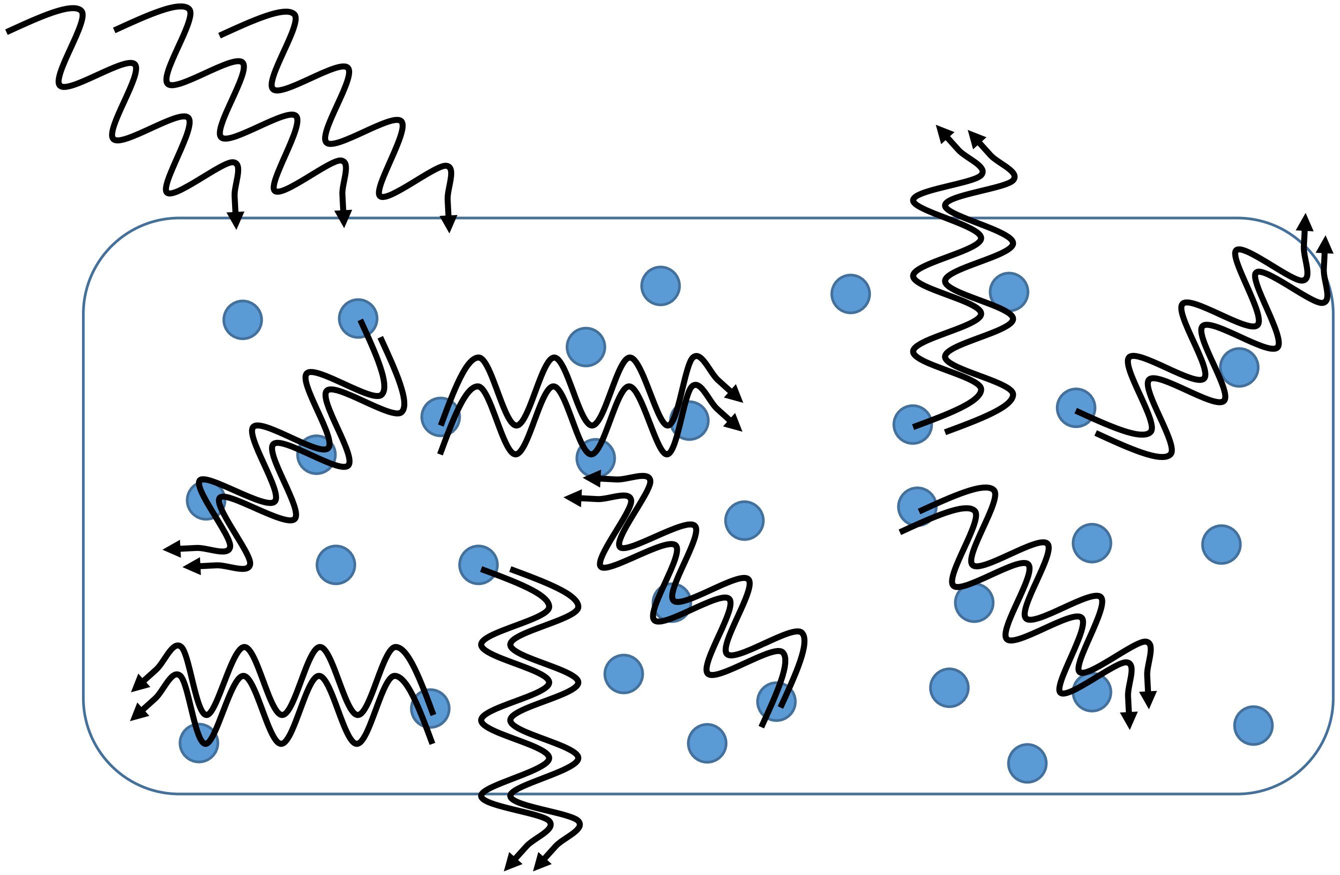
Optical Resonator



Action of Optical Resonator



Action of Optical Resonator



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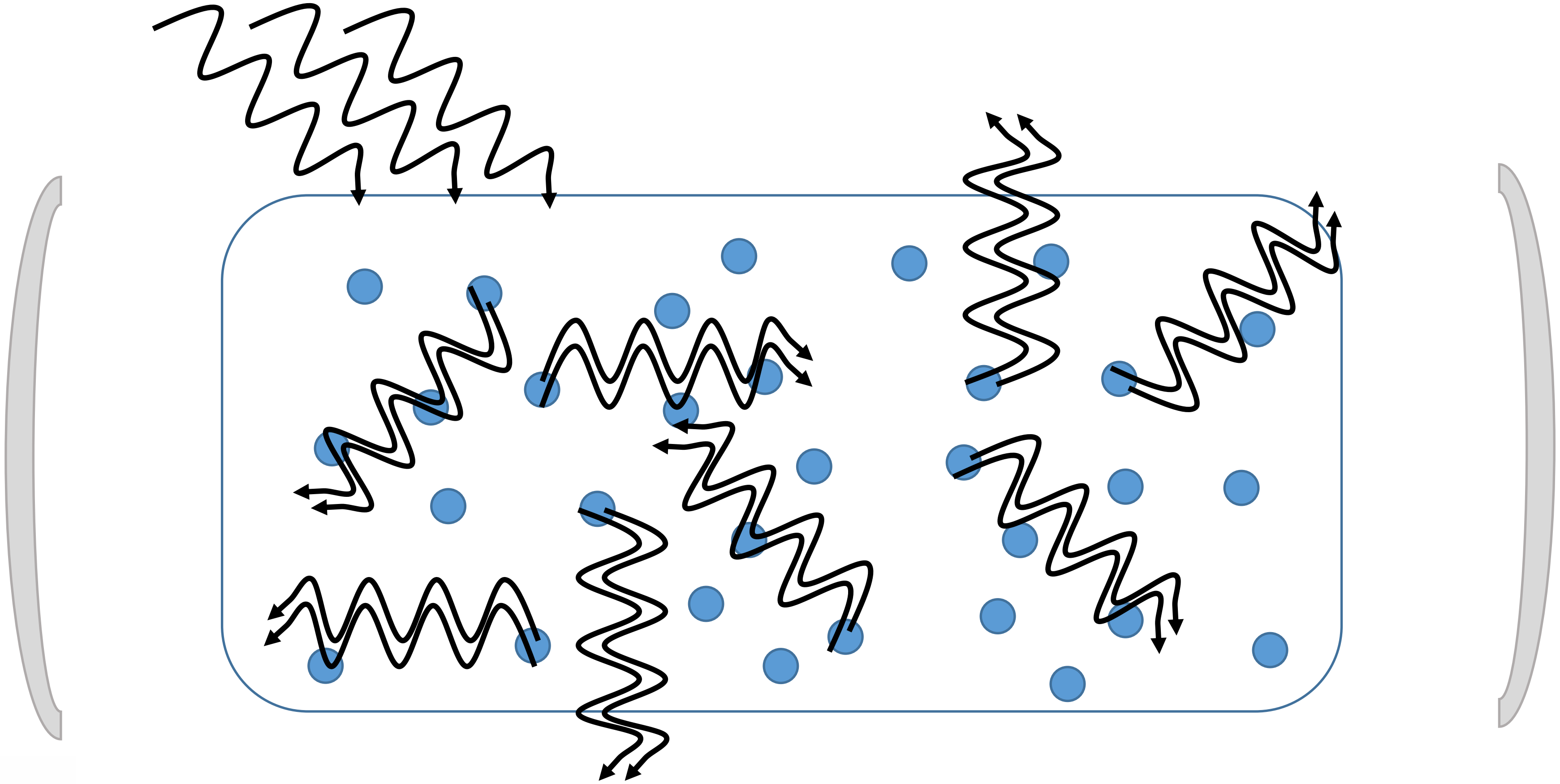

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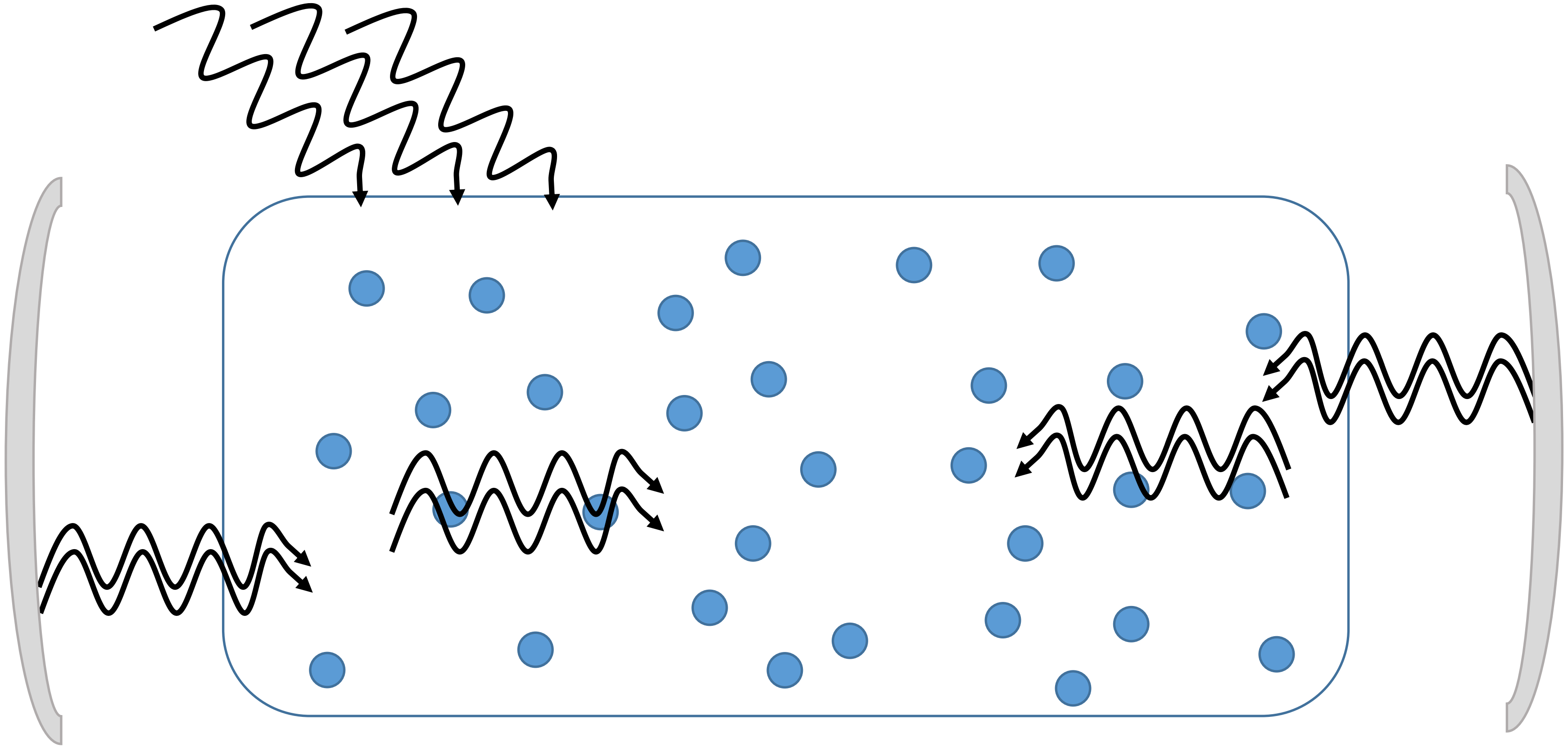

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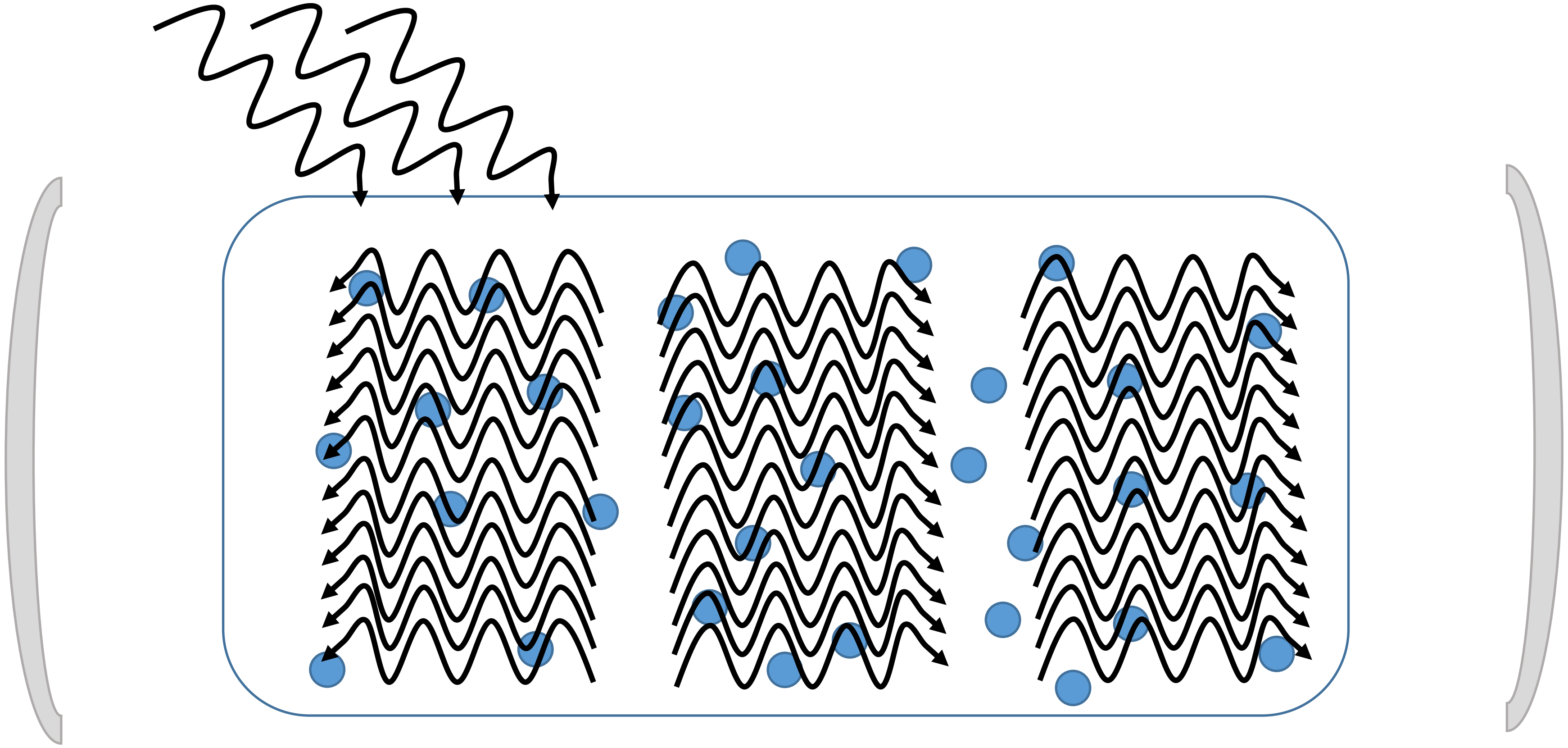

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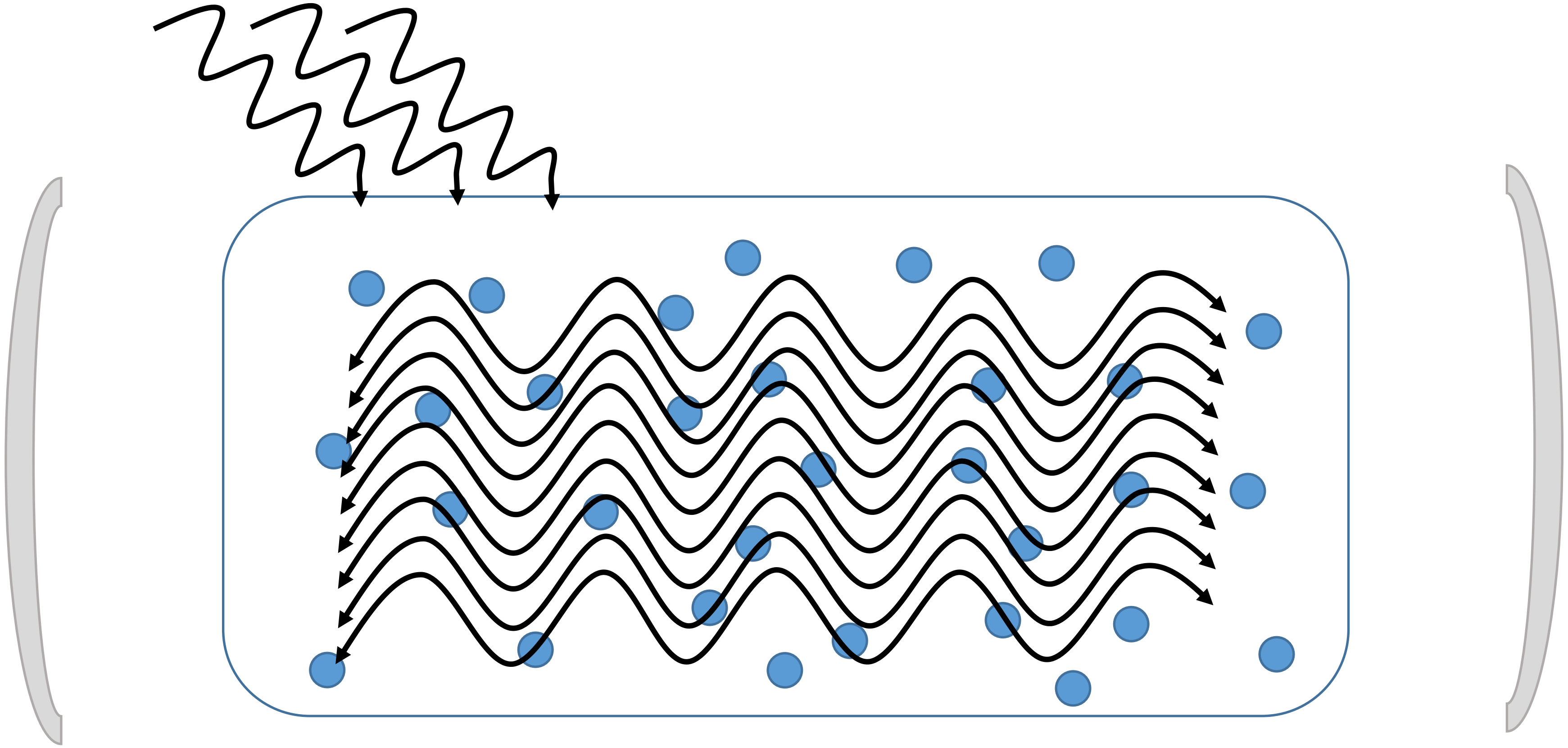

Thanks!

Blackbody Radiation at Different Temperatures