# Engineering Optics

## Lecture 25

03/06/2022

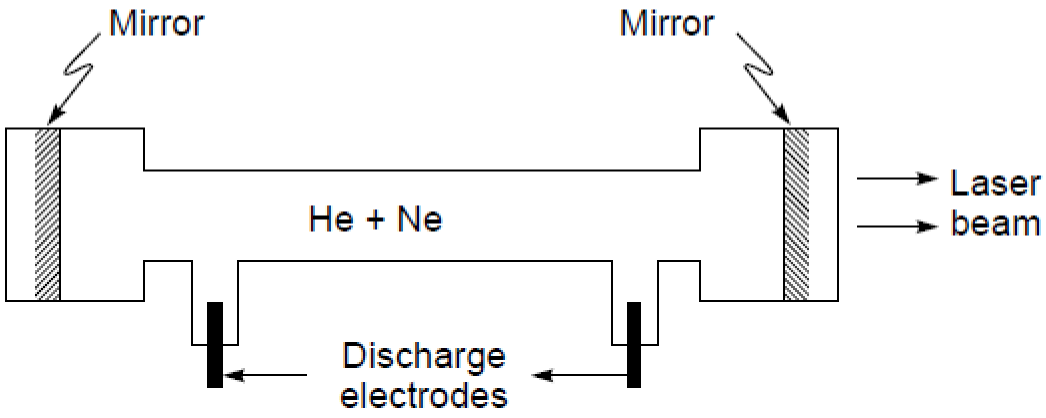
*by*

**Debolina Misra**

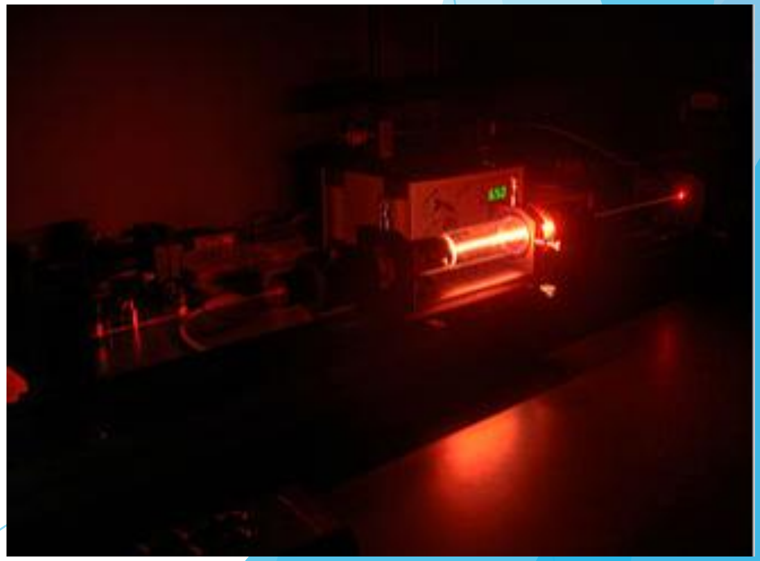
Assistant Professor in Physics
IIITDM Kancheepuram, Chennai, India

# He-Ne LASER

- He-Ne laser which was first fabricated by *Ali Javan* and coworkers at Bell Telephone Laboratories in the United States. → 1$^{st}$ gas laser to be operated successfully.
- The He-Ne laser consists of a mixture of He and Ne (ratio ~10 : 1), placed inside a long, narrow discharge tube
- Fixed pressure inside the rube (1 torr).
- system → enclosed between a pair of plane mirrors → resonator



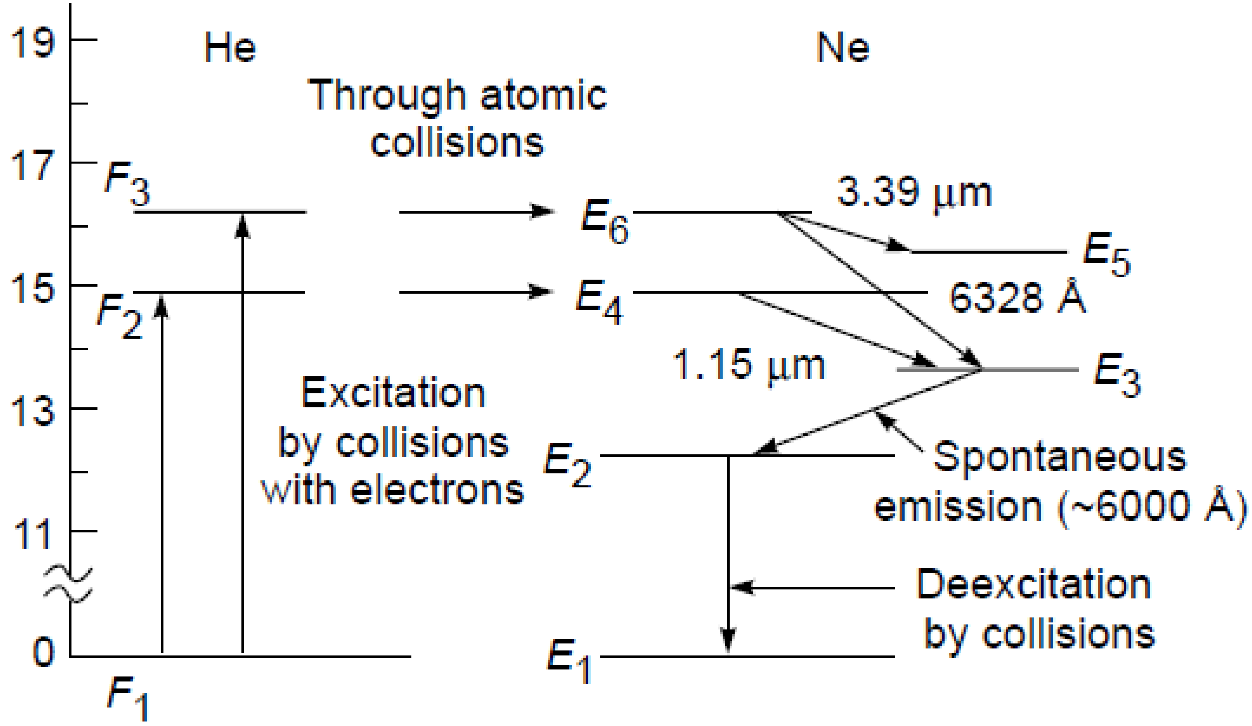

The helium-neon laser.



wikipedia

Optics, Ghatak

# He-Ne LASER

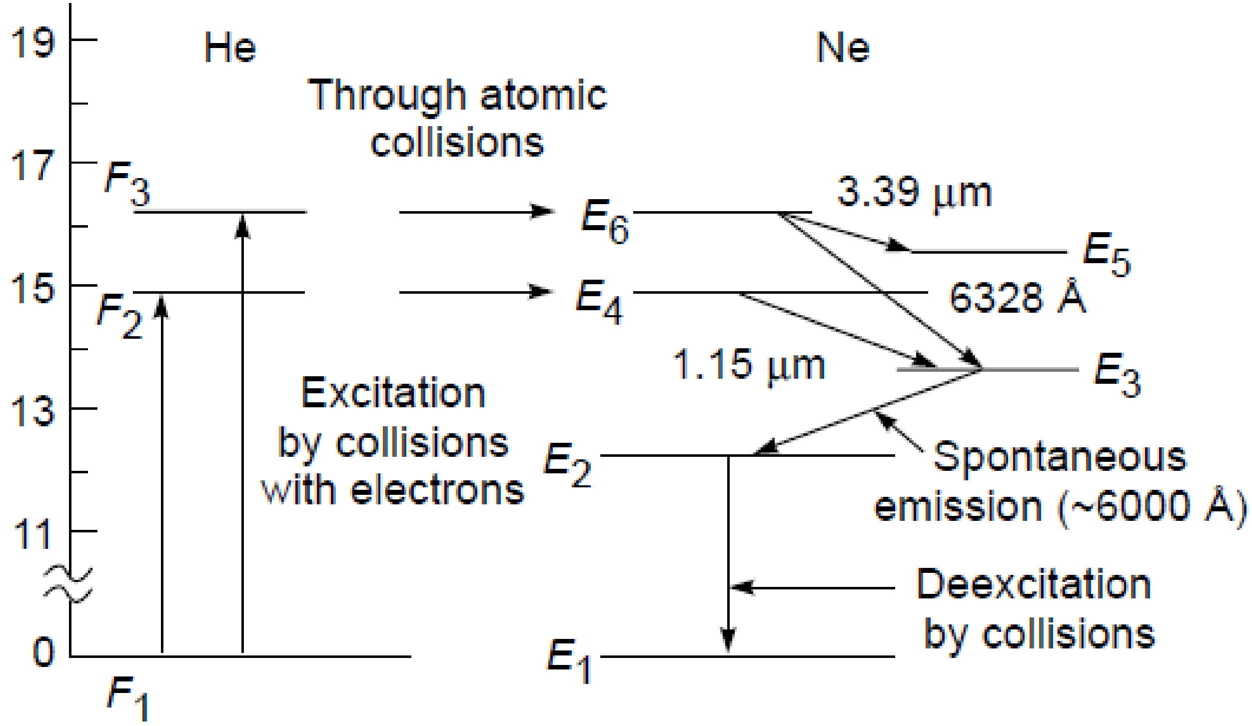



Relevant energy levels of helium and neon.

- When an electric discharge is passed through the gas, the electrons → collide with the ***He atoms***
- ***He atoms excited*** *from the ground state $F_1$ to $F_2$ and $F_3$.*
- He atoms excited to these states stay in these levels before losing energy through collisions.
- Collisions with whom?? → Ne atoms present in the same tube
- Due to collision → these collisions, the Ne atoms are excited to $E_4$ and $E_6$
- Thus when the atoms in levels $F_2$ and $F_3$ collide with unexcited Ne atoms, they raise them to the levels $E_4$ and $E_6$, respectively.

Optics, Ghatak

# He-Ne LASER

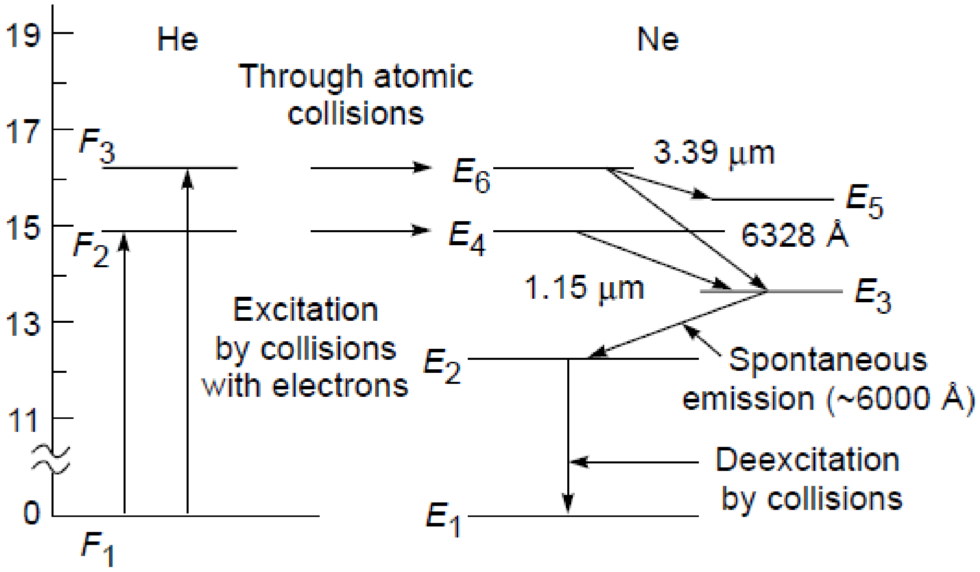



Relevant energy levels of helium and neon.

- ***What happens next?***
- He atom in excited state $F_3$ + Ne atom in ground state → He atom in ground state + Ne atom in excited state E6
- Similarly, He atom in excited state $F_2$ + Ne atom in ground state → He atom in ground state + Ne atom in excited state $E_4$
- **Consequence?** population of $E_4$ and $E_6$ >> $E_3$ and E5. → population inversion is achieved
- Light amplification can be achieved

Optics, Ghatak

# He-Ne LASER




Relevant energy levels of helium and neon.

Wikipedia/ Optics, Ghatak

- **Possible transitions:**
- The transitions from $\mathbf{E_6}$ to $E_5$, $\mathbf{E_4}$ to $E_3$, and $E_6$ to $E_3$ result in the emission of radiation having wavelengths of 3.39 μm, 1.15 μm, and 6328 Å, respectively.
- Note that the laser transitions corresponding to 3.39 and 1.15 mm are not in the visible region→ infrared
- The 6328 Å transition corresponds to the well-known red light of the He-Ne laser.

A laser cavity tends to select specific wavelengths (Fig. 5) within the normal gain bandwidth of the laser gain medium that have an exact integral number of waves that fit between the mirrors (modes). These modes, which (if there are more than one) are equally spaced in frequency or wavelength and tend to be amplified at the expense of other wavelengths that suffer losses by not exactly “fitting” between the mirrors.

https://www.sciencedirect.com/topics/physics-and-astronomy/laser-cavities

# Few points to note

- Ne and not He is related to the lasing action. He → buffer
- Not optical but electrical pumping method is used
- The tube containing the gaseous mixture is made ***narrow*** so that Ne atoms in level $E_2$ can get de-excited by collision with the walls of the tube.
- There are a large number of levels grouped around $E_2$, $E_3$, $E_4$, $E_5$, and $E_6$. Only those levels are shown in the figure which correspond to the important laser transitions.
- Advantages: more directional and more monochromatic. ***Why?*** This is so because of the absence of such effects as crystalline imperfection, thermal distortion, and scattering, which are present in solid-state lasers.
- Gas lasers are capable of operating continuously ***without need for cooling***.

- A large group of gas lasers operate across the spectrum from the far IR to the UV (1 mm to 150 nm).
- Primary among these are helium-neon, argon, and krypton, as well as several ***molecular gas systems***, such as carbon dioxide, hydrogen fluoride, and molecular nitrogen ($N_2$).

Optics, Ghatak

# Other Lasers

- The semiconductor laser—alternatively known as the junction or diode laser—was invented in 1962, soon after the development of the light-emitting diode (LED).
- Today it serves a central role in electro-optics, primarily because of its spectral purity, high efficiency (100%), ruggedness, ability to be modulated at extremely rapid rates, long lifetimes, and moderate power (as much as 200 mW) despite its pinhead size.
- Now RT diode lasers → available
- Transitions occur between the conduction and valence bands, and stimulated emission results in the immediate vicinity of the p-n junction
- Excimer laser: UV/Noble gas+F/Cl → eye/photolithography
- Dye Laser: organic dye/liquid → blood vessel/kidney stone/ stain removal

Semiconductor Lasers

| Type | Wavelengths (nm) |
|---|---|
| AlGaAs | 630–900 |
| AlGaInP | 630–900 |
| GaAlAs/GaAS | 720–900 |
| GaAs/GaAS | 904 |
| GaInPAs/GaAS | 670–680 |
| GaN/SiC | 423, 405–425 |
| InGaAsP/InP | 1000–1700 |
| PbSnSe | 8000–30 000 |

Optics, Hecht

# Thank You