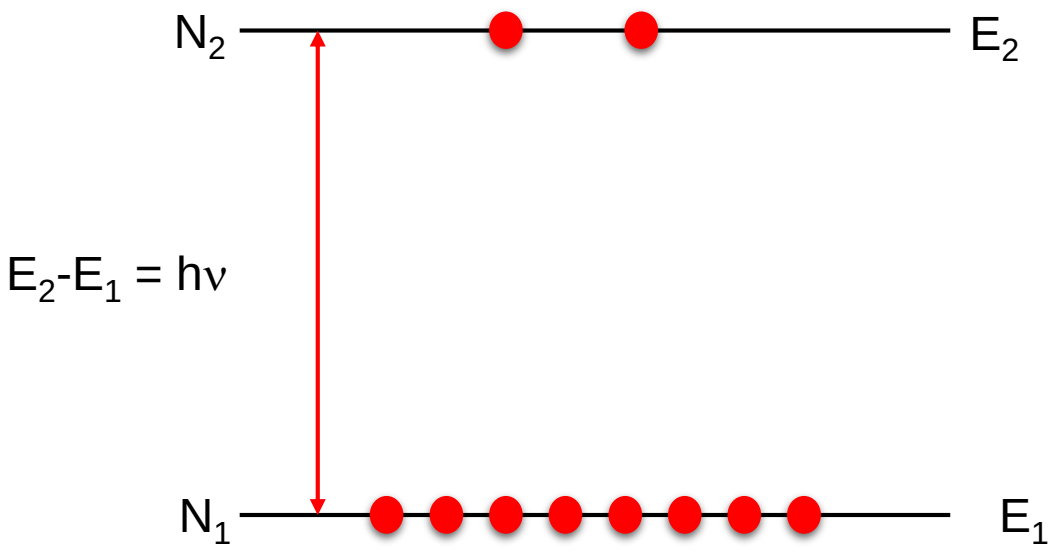

LASER

Previously

- Introduction to LASER.
- Basic concepts of LASER.
- Spontaneous and Stimulated Emission
- Population Inversion.

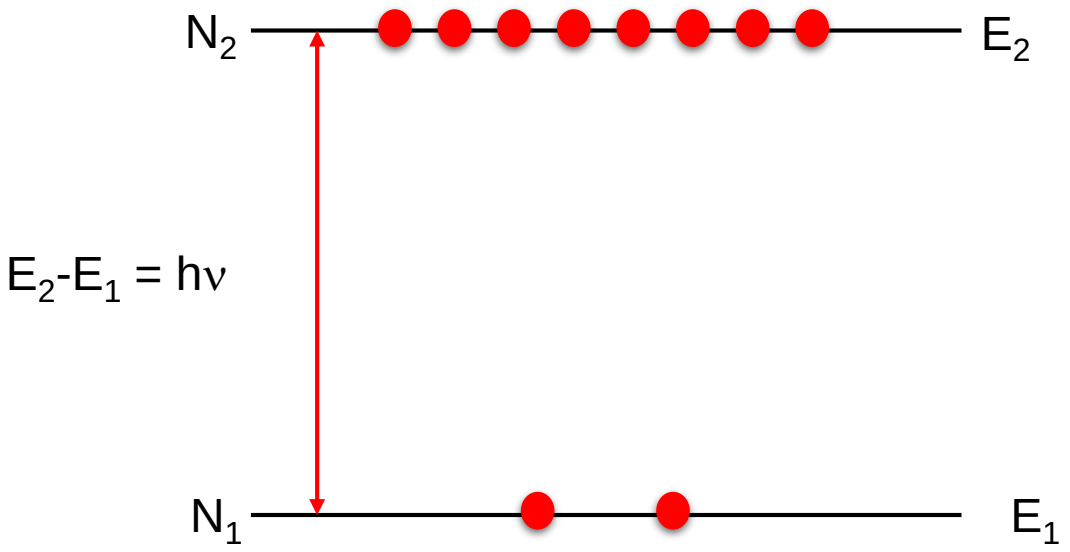
Population Inversion

In thermodynamically equilibrium



$N_1 > N_2$

● -electron



$N_2 > N_1$

Required for LASER Action

Common Components of All Lasers

COMMON COMPONENTS OF ALL LASERS

1. Active Medium / Gain Medium

The active medium may be solid crystals such as ruby, liquid dyes, gases like CO_2 or Helium/Neon, or semiconductors such as GaAs. Active mediums contain atoms whose electrons may be excited to a metastable energy level by an energy source.

2. Pumping (Excitation Mechanism)

Excitation mechanisms pump energy into the active medium by one or more of three basic methods; optical, electrical or chemical.

Resonance cavity

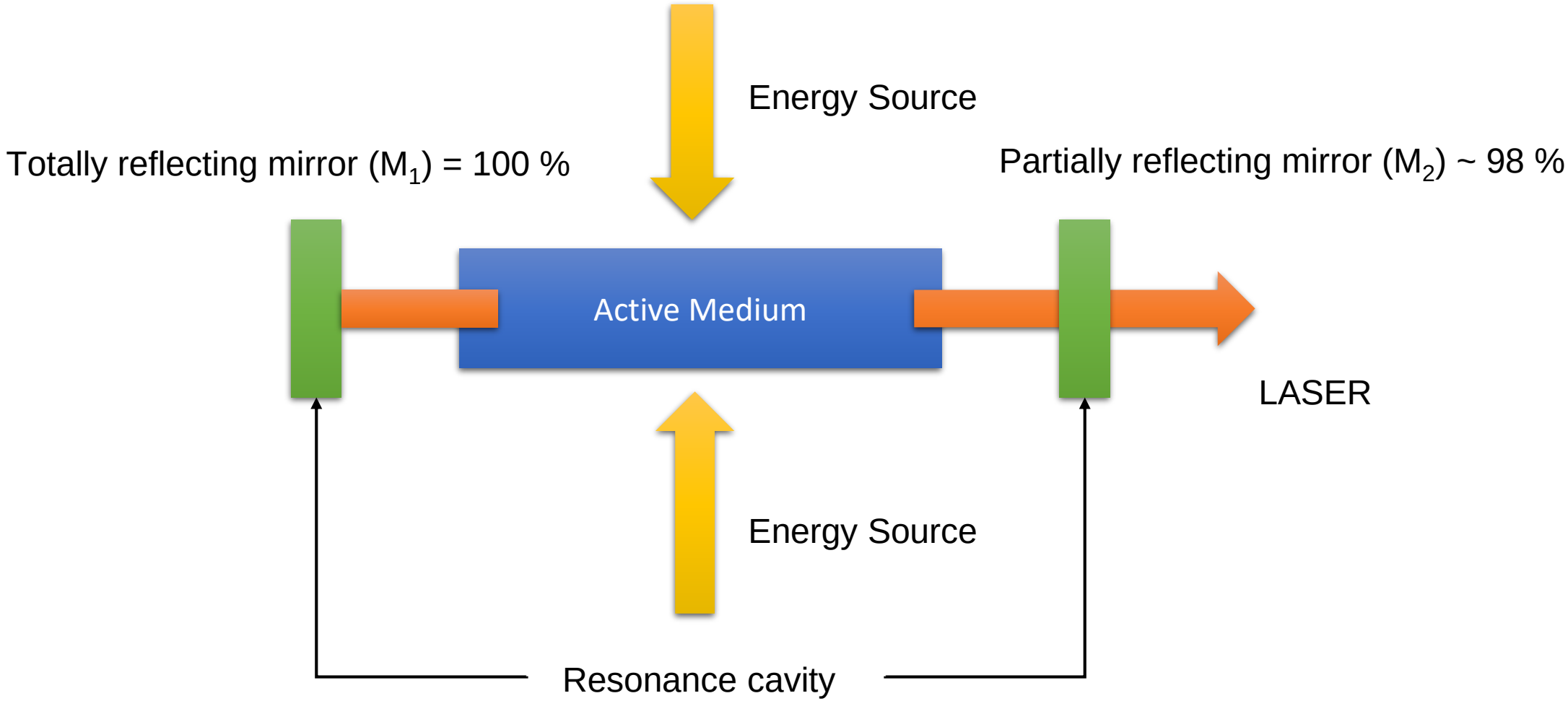
3. High Reflectance Mirror

A mirror which reflects essentially 100% of the laser light.

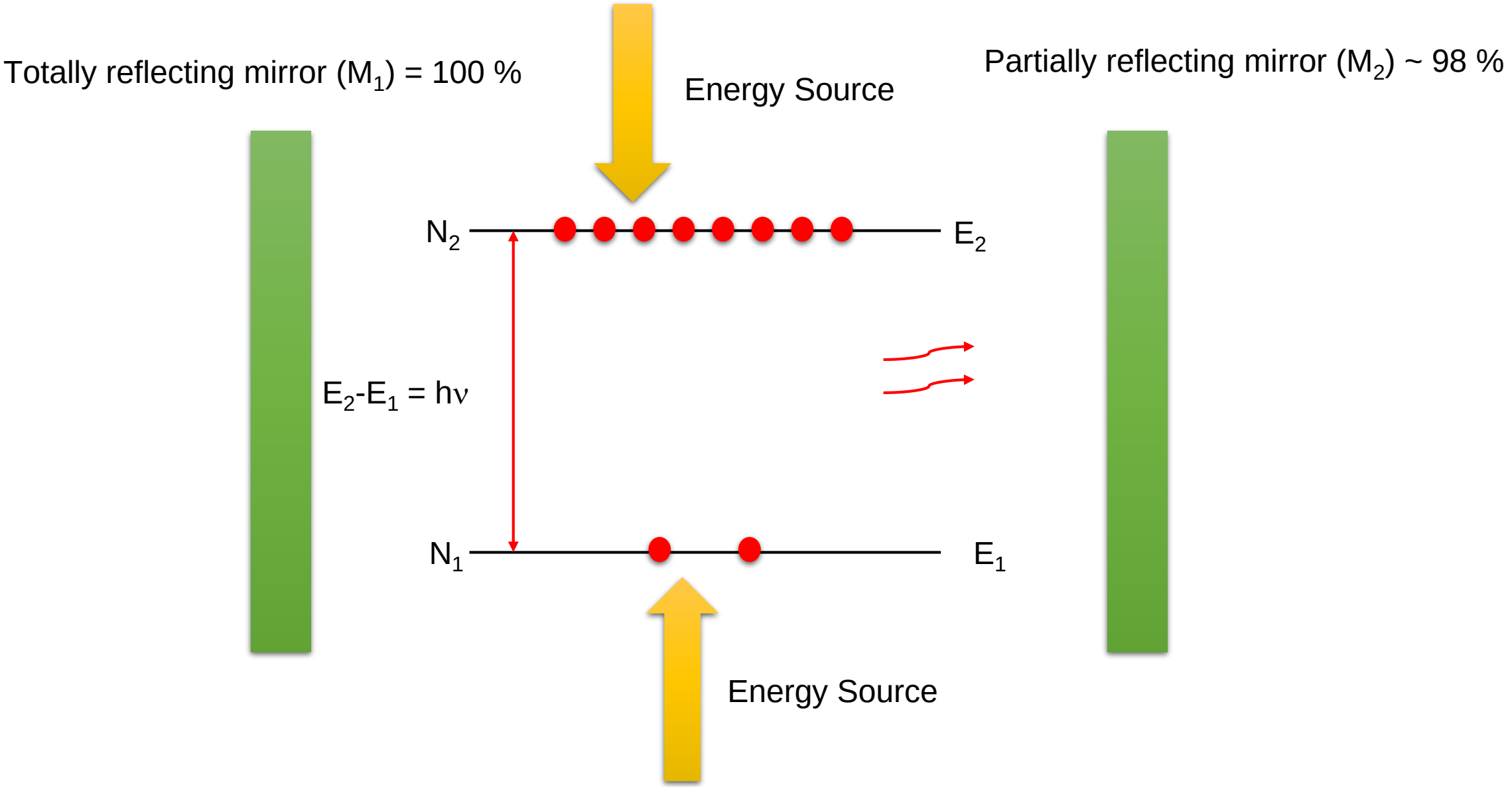
4. Partially Transmissive Mirror

A mirror which reflects less than 100% of the laser light and transmits the remainder.

BLOCK DIAGRAM OF LASER SYSTEM



Optical resonator



Necessary Condition for the laser operation; population inversion

If $N_1 > N_2$
- radiation is mostly absorbed
- spontaneous radiation dominates.

if $N_2 >> N_1$ - *population inversion*
- most atoms occupy level E_2, weak absorption
- stimulated emission prevails
- light is amplified

Population Inversion

This situation in which the number of atoms in the higher state exceed that in the lower state ($N_2 > N_1$) is known as population inversion.

Pumping

- The process of moving the atoms from their ***ground state to an excited state*** is called pumping. The objective is to obtain a non-thermal equilibrium.

  - **Optical Pumping**

- The atoms are excited by bombarding them with photons. Example: Ruby Laser

- Lasers that have a short-lived population inversion produce pulsed output – these are pulsed lasers

  - **Electrical Pumping**

- The atoms are excited by Electron collision in a discharge tube.

Example: He-Ne Laser

- Lasers that maintain a population inversion indefinitely produce continuous output – termed CW (for continuous wave) lasers

TYPES of LASER

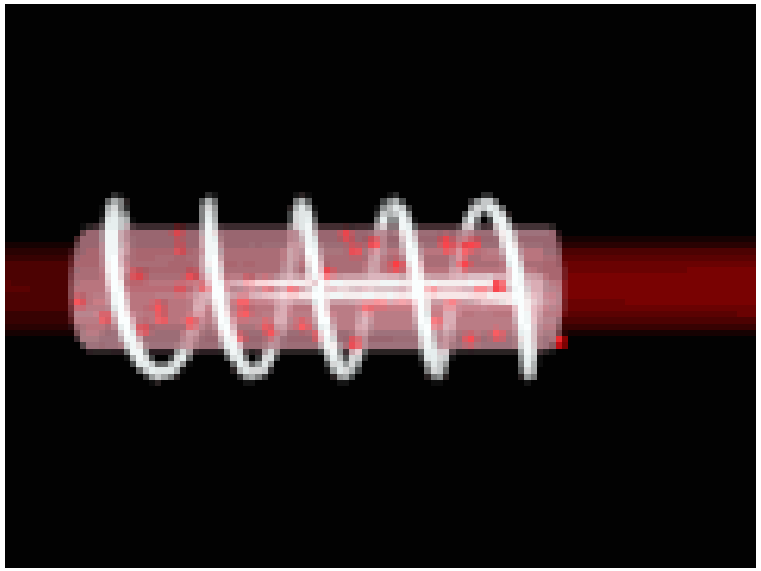
- According to the ***active material***:

  solid-state, liquid, gas, excimer or semiconductor lasers.

- According to the ***wavelength***:

  infra-red, visible, ultra-violet (UV) or x-ray lasers.

Solid-state Laser



- Example: ***Ruby Laser***
- Operation wavelength: ***694.3*** nm (IR)
- 3 level system: absorbs ***green***/***blue***

- ***Active Medium:*** crystal of aluminum oxide (Al_2O_3) with small part of atoms of aluminum is replaced with Cr^{3+} ions.
- ***Pump source:*** flash lamp
- ***Resonance Cavity:*** The ends of ruby rod serve as laser mirrors.

Ruby Laser: Introduction

- A ruby laser is a ***solid-state laser*** that uses a ***synthetic ruby crystal*** as its gain medium.

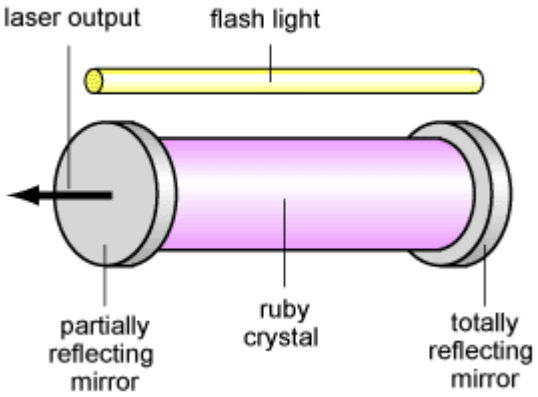
- It was the first type of laser invented, and was first operated by ***Theodore H. "Ted" Maiman*** at Hughes Research Laboratories on ***1960***.

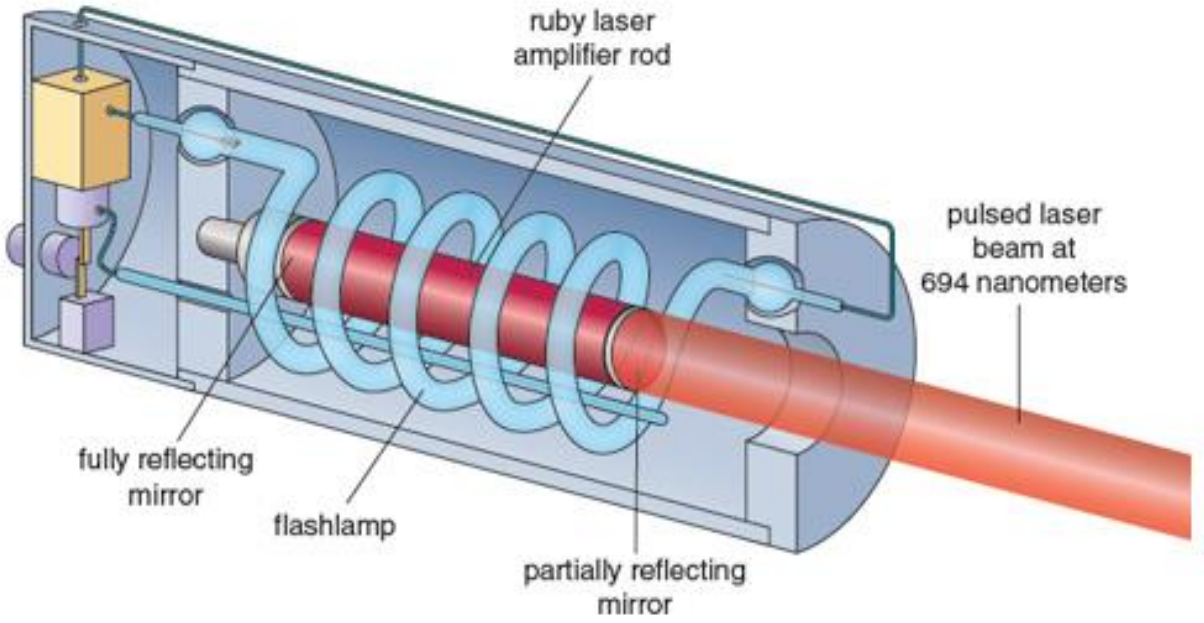
- The ruby mineral (corundum) is aluminum oxide with a small amount (about 0.05%) of chromium which gives it its characteristic pink or red color by absorbing green and blue light.

- The ruby laser is The ruby laser is used as a pulsed laser, producing red light at ***694.3 nm***. After receiving a pumping flash from the flash tube, the laser light emerges for as long as the excited atoms persist in the ruby rod, which is typically about a millisecond.

Construction of Ruby laser

A RUBY LASER is a three level solid state laser that uses a ruby crystal as its Active medium.





Construction of Ruby Laser

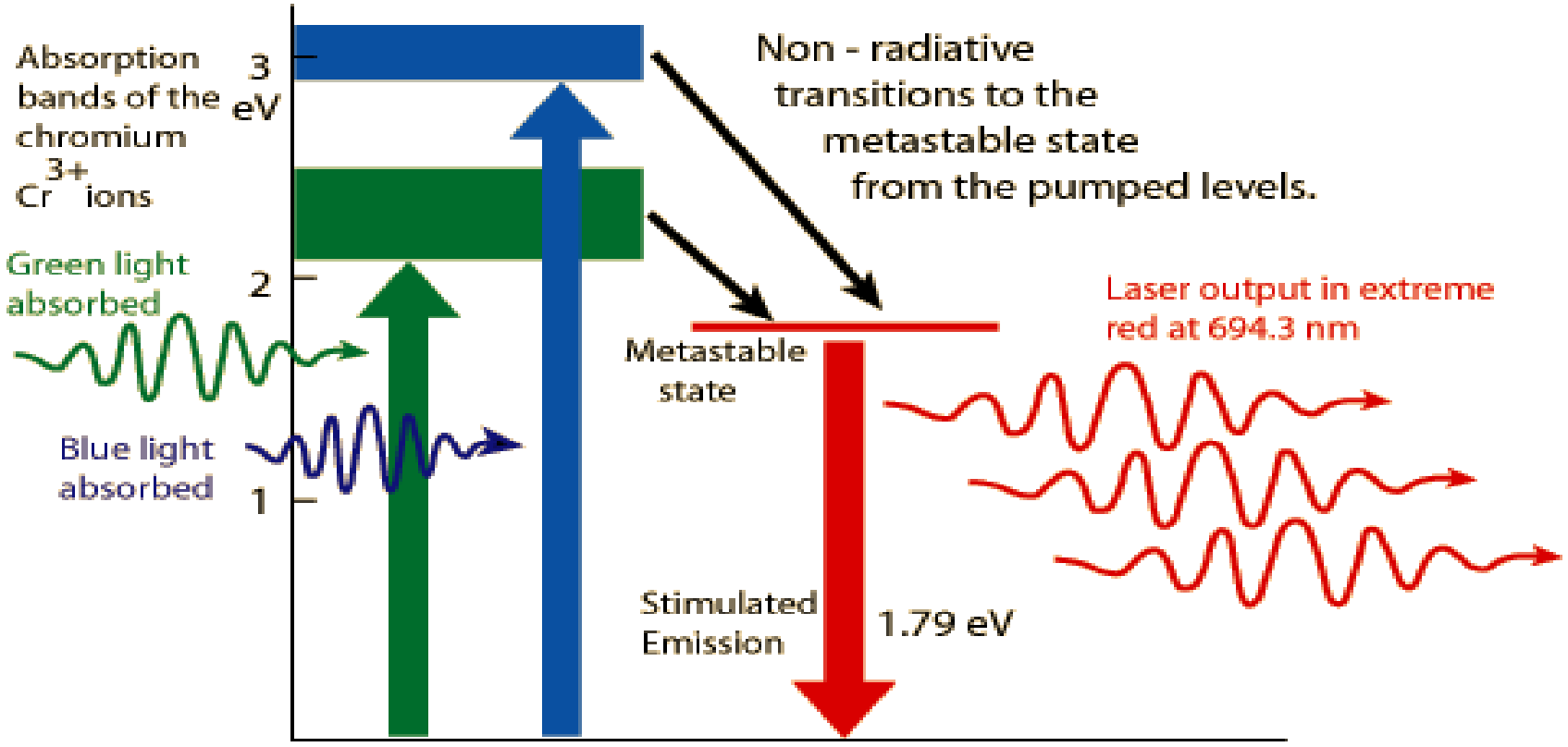
- Ruby is a crystal of aluminum oxide (Al_2O_3) in which some of the aluminum ions are replaced by chromium ions. These chromium ions give the crystal a pink or red color.

- ***Pumping source:*** A helical flash lamp filled with xenon is used as a pumping source. The ruby crystal is placed inside a xenon flash lamp.

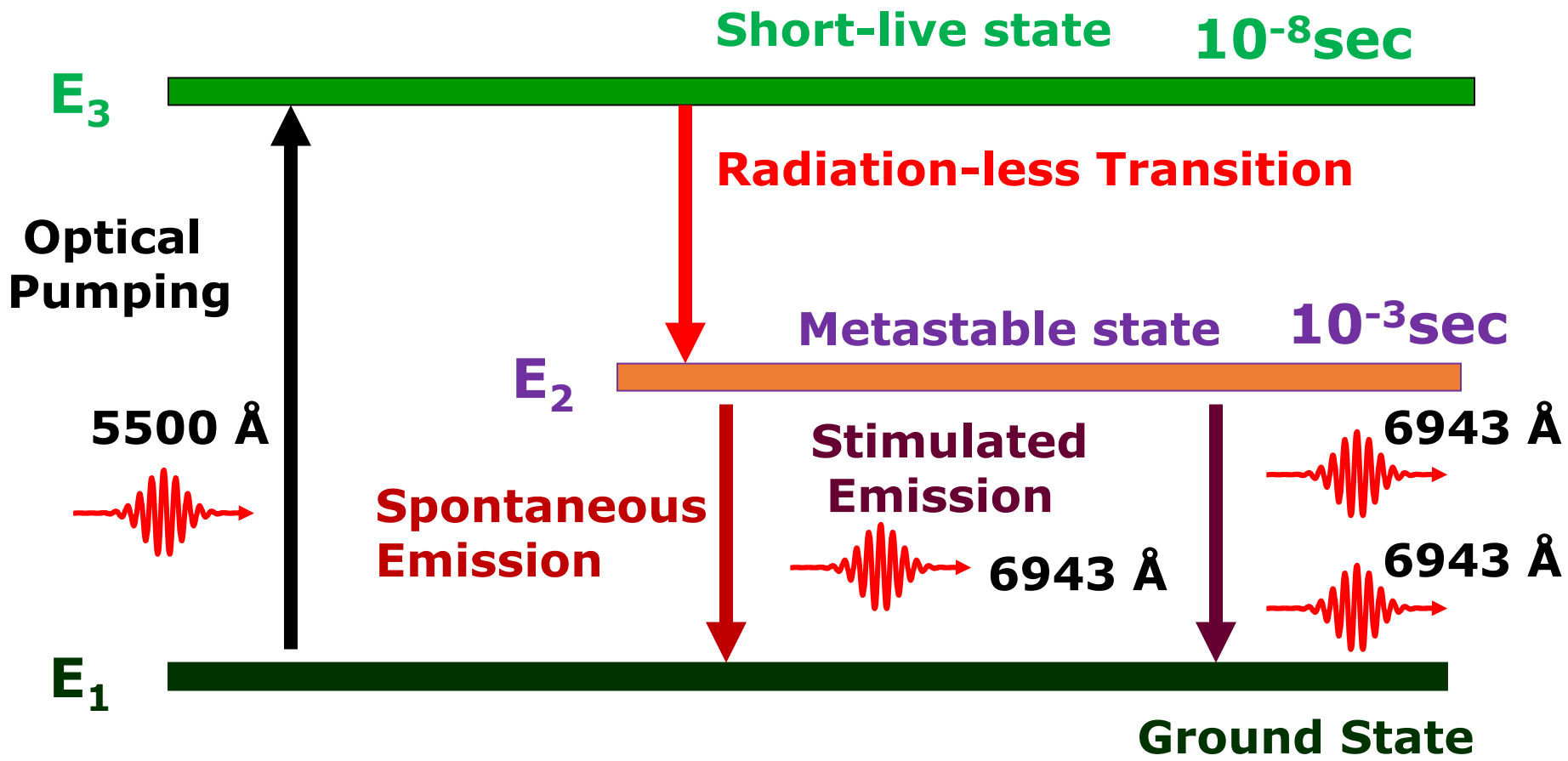
- ***Optical resonator system:*** One of the ends is completely silvered while the other one is partially silvered. Thus the two polished ends act as optical resonator system.

Working of Ruby laser

Ruby laser is based on ***three energy levels***. The upper energy level E_3 short-lived, E_1 is ground state, E_2 is metastable state with lifetime of 0.003 sec.



Ruby Laser (Three Level Laser)



Application of Ruby laser

1. Drilling holes through diamond because of its high power beam.

2. Ruby laser were extensively used in tattoo and hair removal.

3. Used in to produce holographic portraits.

Advantages of Ruby Lasers

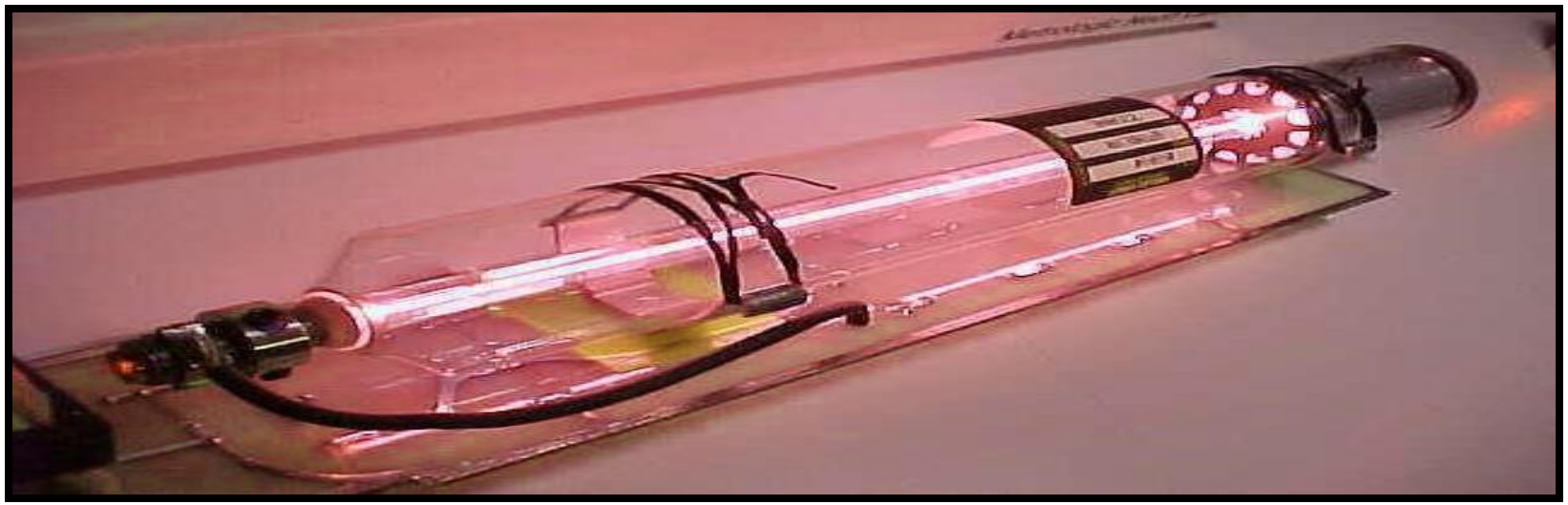
1. Ruby lasers are economical.
2. Output power is not as less as in He-Ne gas lasers.
3. Construction and function of ruby laser is self explanatory.

Disadvantages of Ruby Lasers

1. Ruby laser is pulsed laser.
2. Optical cavity of ruby laser is short as compared to other lasers.
3. High power is required to achieve the population inversion.
4. Efficiency of ruby laser is comparatively low.

Gas Laser

- Example: ***Helium-neon laser (He-Ne laser)***
- Operation wavelength: ***632.8 nm***
- Pump source: ***electrical discharge***
- Active medium : ratio 10:1 mixture of helium and neon gases



He-Ne Laser (Four Level Laser)

- Ruby laser ***does not*** generate a ***continuous*** laser beam.

- To over come this difficulty***, Ali Javan in 1961***, developed a gas laser which emits a continuous laser beam. It is a mixture of He-Ne gases.

- The excitation of He & Ne atoms to higher energy states is performed by means of radio (high) frequency electromagnetic field.

- He-Ne laser is a four-level laser.

- Its usual operation wavelength is 632.8 nm, in the red portion of the visible spectrum.

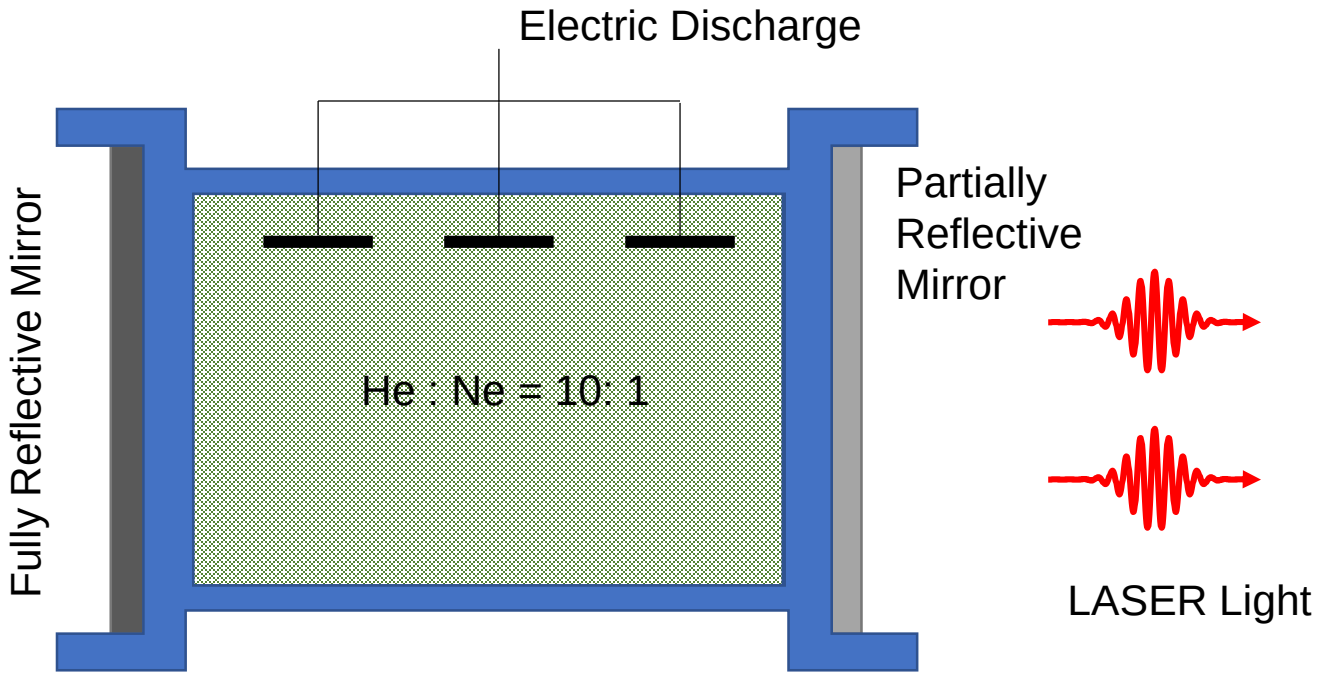
Construction of He-Ne laser

- ***Active medium:*** The active medium of the laser, as suggested by its name, is a mixture of helium and neon gases, in a ***5:1 to 20:1 ratio***, contained at low pressure (an average 50 Pa per cm of cavity length) in a glass envelope.

- ***Pumping:*** The energy or pump source of the laser is provided by an electrical discharge of around 1000 volts through an anode and cathode at each end of the glass tube. A current of 5 to 100 mA is typical for CW operation.

- ***Resonant Cavity:*** The resonant cavity consists of a discharge tube of length approximate 50 cm and bore diameter of approximate 1 cm. The optical cavity of the laser typically consists of a plane, high-reflecting mirror at one end of the laser tube, and a concave output coupler mirror of approximately 1% transmission at the other end.

He-Ne Laser (Four Level Laser)



Working of He-Ne laser

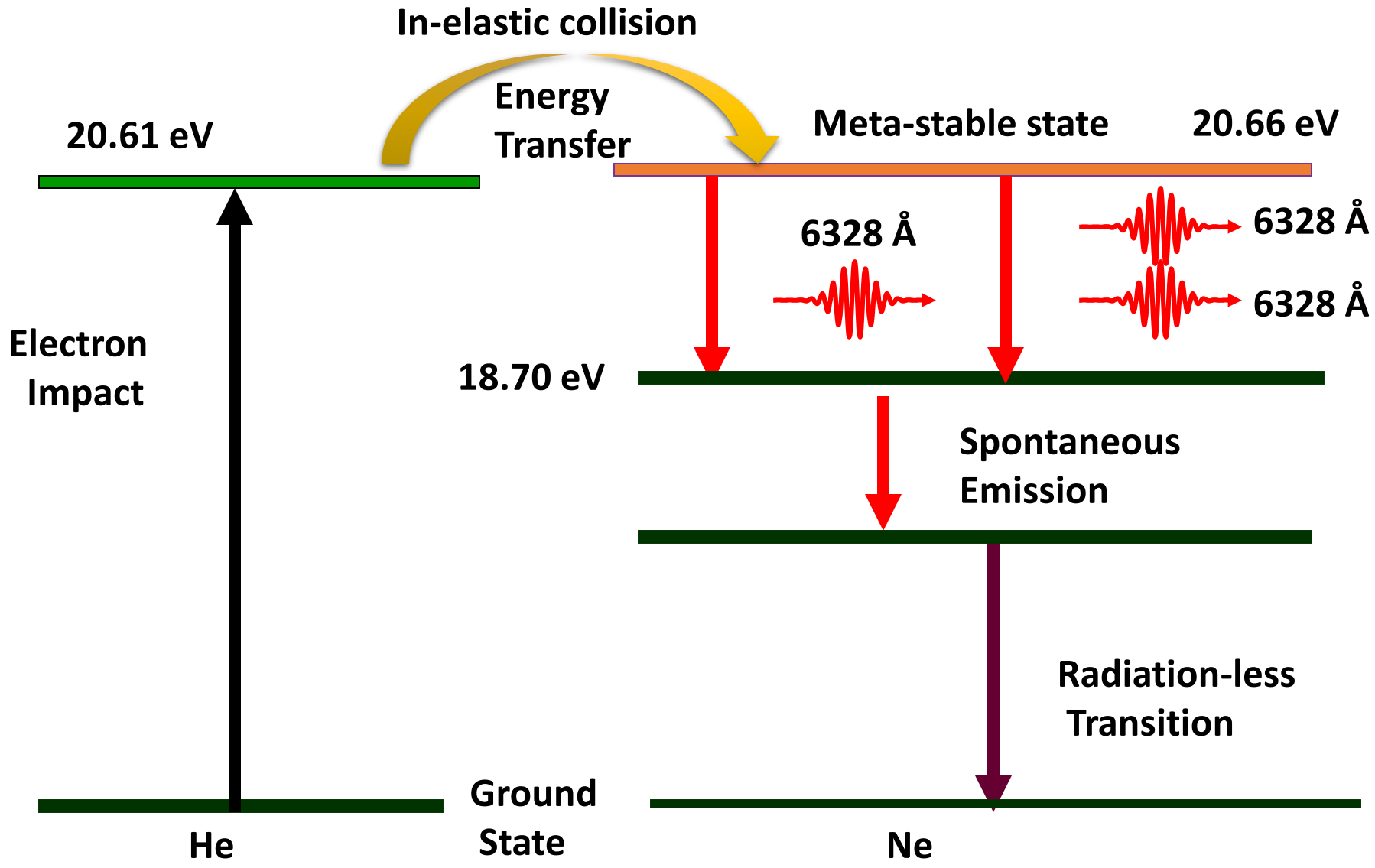
- The working of He-Ne laser is based on the fact that the Ne has energy levels very close to meta-stable energy levels of He.

- When the power is switched on, the electrons from the discharge tube excite the gaseous atoms, thereby pumping takes place and He & Ne atoms excited and reaches to excited energy levels at meta stable state of 20.61 eV.

- Some of the excited He atoms transfer their energy to Ne atoms by ***inelastic atom-atom collision*** with an amount of 0.05 eV. Thus, the purpose of He atoms is to help in achieving the ***population inversion*** in Ne-atoms.

- When an excited Ne-atom passes through the excited state of 20.66 eV to the lower state of 18.70 eV, it emits a photon of wavelength ***6328 Å (or 632.8 nm).***

WORKING of He-Ne Laser



WORKING of He-Ne Laser

- This photon travel through the gas mixture, and if it is moving parallel to the axis of the tube, it reflect back and forth by the mirror ends until it stimulates an excited Ne-atom and causes it to emits a fresh photon of 6328 Å in exact phase with the stimulating photon.

- This stimulated transition from 20.66 eV to the lower state of 18.70 eV level is the laser transition. This process is continue for all the excited Ne-atoms and when a beam of coherent radiation becomes sufficiently intense, a portion (and all) of it escapes through the partially silvered end.

- The Ne atoms passes from the 18.70 eV level, spontaneously to the lower meta-stable state emitting incoherent radiation and finally the Ne atoms come down to the ground state through collision with the tube walls. The radiation from lower meta-stable state to the ground state is radiation less transition.

Application of He-Ne Laser

- A He-Ne laser operates in ***continuous wave mode***. The narrow red beam of this laser is used in super markets to read the bar codes. The optical output powers is ranging from 1 mW to 100 mW.

- The He- Ne Laser is used in ***Holography in producing the 3D images*** of objects.

- He-Ne lasers have many industrial and scientific uses, and are often used in ***laboratory demonstrations*** of optics.

Applications of A LASER

APPLICATIONS OF LASER

- Lasers are profitably used in every field of science including fundamental research. The common applications of laser are;
- Laser beams are very intense so are used for welding, cutting of materials.
- Laser beam is used to vaporize unwanted materials during the manufacture of electronic circuits on semiconductors chips.
- CO_2 gas laser of about 100 w output are helpful in surgery as they seal small blood vessels. Lasers are used for eye surgery, treatment of dental decay and skin diseases.
- Lasers are used to detect and destroy missiles during war.

APPLICATIONS OF LASER

- Low power semiconductors laser are used in compact disc players, laser printers and laser copiers etc.
- High power semiconductors laser are used to bring about thermo-nuclear reactions which would become the ultimate power source for human civilization.
- Lasers are being employed for separating the various isotopes of an element.
- The narrow red beam of He-Ne laser is used in super markets and library to read the bar codes.
- The He- Ne Laser is used in Holography in producing the 3D images of objects.

INDUSTRY AND COMMERCIAL

-Cutting, welding, marking

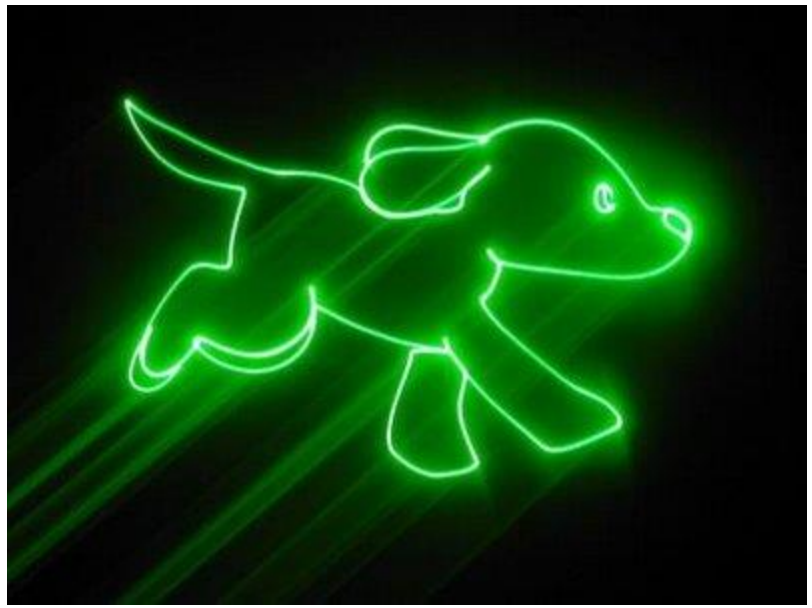
-CD player, DVD player

-Laser printers, laser pointers

-Photolithography

-Laser light display

Laser shows are quite popular and the special effects are amazing. These use lasers that are in the visible spectrum along with vibrating mirrors to paint images in the air.



- Another example of laser entertainment is the use of laser signs at trade shows

LASER SAFETY MEASURES

Types of Laser Hazards

1. ***Eye*** : Acute exposure of the eye to lasers of certain wavelengths and power can cause corneal or retinal burns (or both). Chronic exposure to excessive levels may cause corneal or lenticular opacities (cataracts) or retinal injury.

2. ***Skin :*** Acute exposure to high levels of optical radiation may cause skin burns; while carcinogenesis may occur for ultraviolet wavelengths (290-320 nm).

3. ***Chemical :*** Some lasers require hazardous or toxic substances to operate (i.e., chemical dye, Excimer lasers).

4. ***Electrical :*** Most lasers utilize high voltages that can be lethal.

5. ***Fire :*** The solvents used in dye lasers are flammable. High voltage pulse or flash lamps may cause ignition. Flammable materials may be ignited by direct beams or specular reflections from high power continuous wave (CW) infrared lasers.

Liquid Laser

- ***Example:* DYE LASER**
- ***Gain medium:*** complex organic dyes, such as rhodamine 6G, in liquid solution or suspension.
- ***Pump source:*** other lasers or flashlamp.
- Can be used for a wide range of wavelengths as the tuning range of the laser depends on the exact dye used.
- Suitable for tunable lasers.