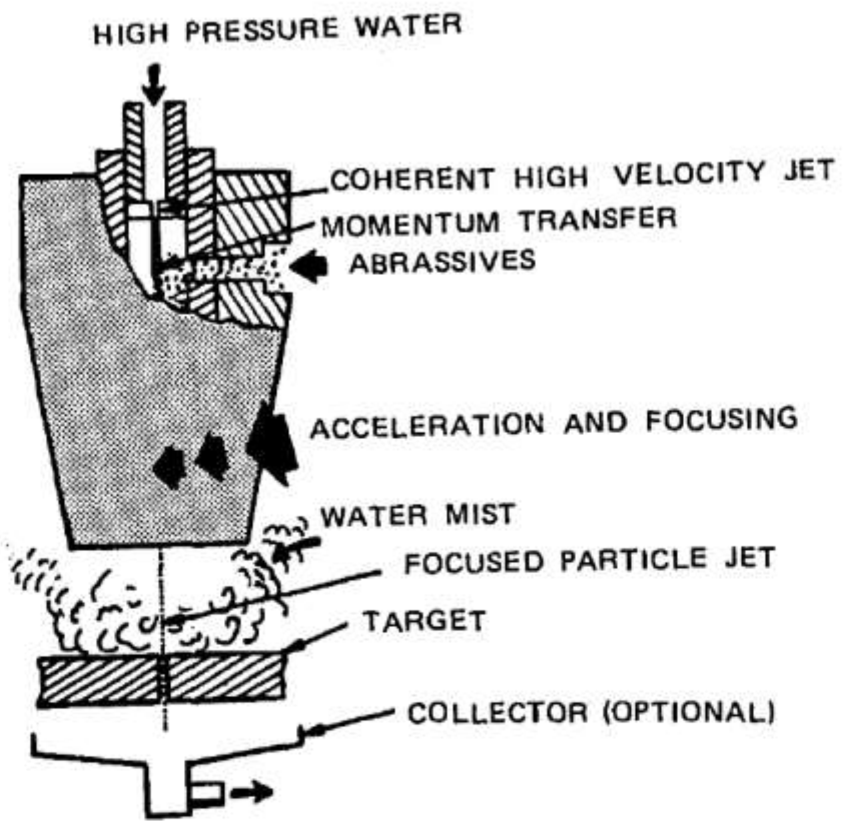
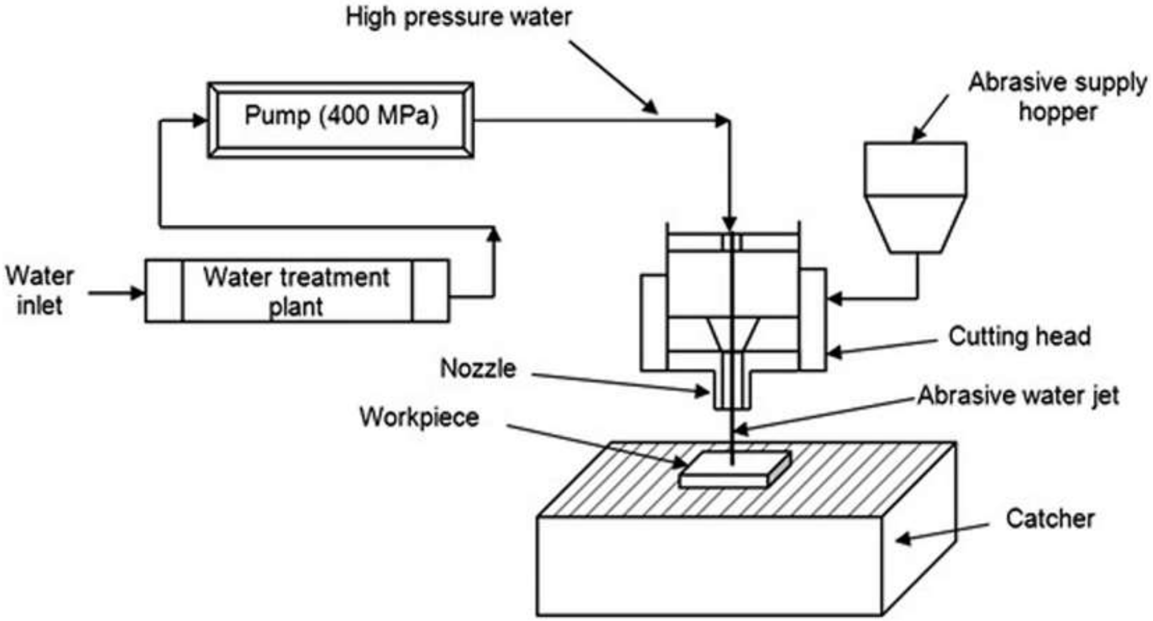
Abrasive Water Jet Machining (AWJM)

Abrasive Water Jet Machining (AWJM)

- This process combines the principles of *WJM and AJM* to create a unique process that relies on the *erosive action* of an ***abrasive-laden water jet*** for application to cutting and drilling hard materials and for general cleaning.
- 1960 : abrasive mud jets for oil well drilling.
- Then wet abrasion blasting-cleaning and descaling.
- 1980: steel-cutting applications.



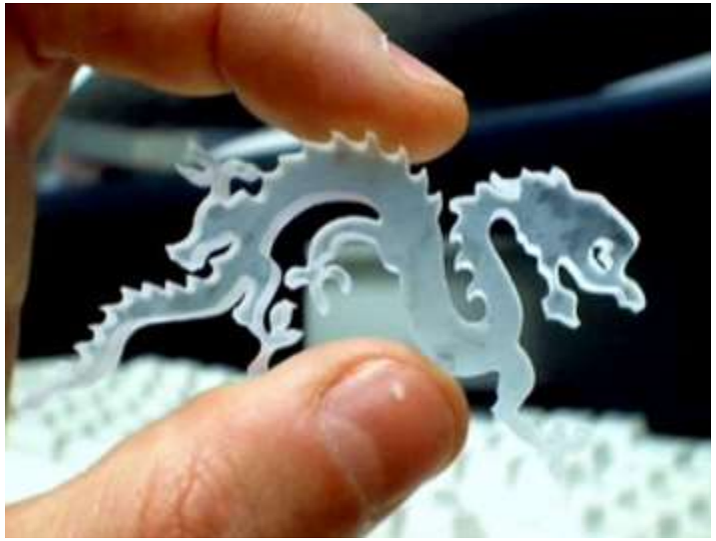
Schematic of AWJM



Products

Steel rack (75 mm thick)

Ceramic Part



Bullet Proof Glass Part

Introduction

- However in all variants of the processes, the basic methodology remains the same.
- Water is pumped at a sufficiently high pressure, *200-400 MPa* (2000- 4000 bar) using intensifier technology.
- An intensifier works on the simple principle of *pressure amplification* using hydraulic cylinders of different cross sections.
- When water at such pressure is issued through a suitable orifice (generally of *0.2 - 0.4 mm* diameter), the potential energy of water is converted into kinetic energy, yielding a high velocity jet (*1000 m/s*).
- Such high velocity water jet can machine thin sheets/foils of *aluminium, leather, textile, frozen food etc.*

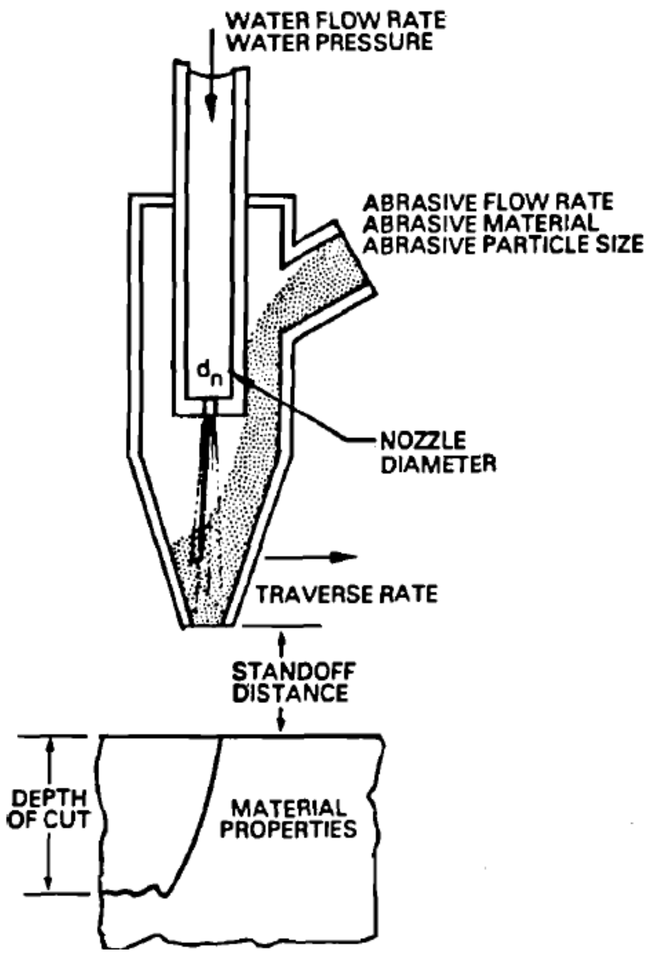
Introduction

- In AWJM, abrasive particles like *sand (SiO_2), glass beads* are added to the water jet to enhance its cutting ability.
- In entrained type AWJM, the abrasive particles are allowed to entrain in water jet to form abrasive water jet with significant velocity of *800 m/s.* Such high velocity abrasive jet can machine almost any material.
- The *cutting ability* of water jet machining can be improved drastically by *adding hard and sharp abrasive* particles into the water jet.
- **WJM** : "softer" and "easy-to-machine" (thin sheets and foils, non-ferrous metallic alloys, wood, textiles, honeycomb, polymers, frozen meat, leather etc)
- **AWJM**: "harder" and "difficult-to- machine" (thick plates of steels, aluminium and other commercial materials, metal matrix and ceramic matrix composites, reinforced plastics, layered composites etc)

Commercial CNC water jet machining system and cutting heads

Process variables governing the AWJM process

- The water jet pressure affects - abrasive particle velocity.
- The relationship between *pressure and depth* of cut is *approximately linear*.
- *Depth of cut* is affected by varying the water flow rate (*increasing the nozzle diameter*) while maintaining constant pressure.
- As the *nozzle diameter increases* and the *water flow rate increases*, the rate of increase in the particle velocity is reduced, thus reducing the depth of cut.
- *Abrasive flow rate* versus depth of cut is a *linear relationship.*



AWJM

Applications

The applications and materials, which are generally machined using WJ and AWJ, are given below:

- Paint removal
- Cleaning
- Cutting soft materials
- Cutting frozen meat
- Textile, Leather industry
- Surgery
- Cutting
- Drilling
- Turning

Advantages

WJM and AWJM have certain advantageous characteristics, which helped to achieve significant penetration into manufacturing industries.

- Extremely fast set-up and programming
- Very little fixturing for most parts
- Machine virtually any 2D shape on any material
- Very low side forces during the machining
- Almost no heat generated on the part
- Machine thick plates
- Material of any hardness can be cut

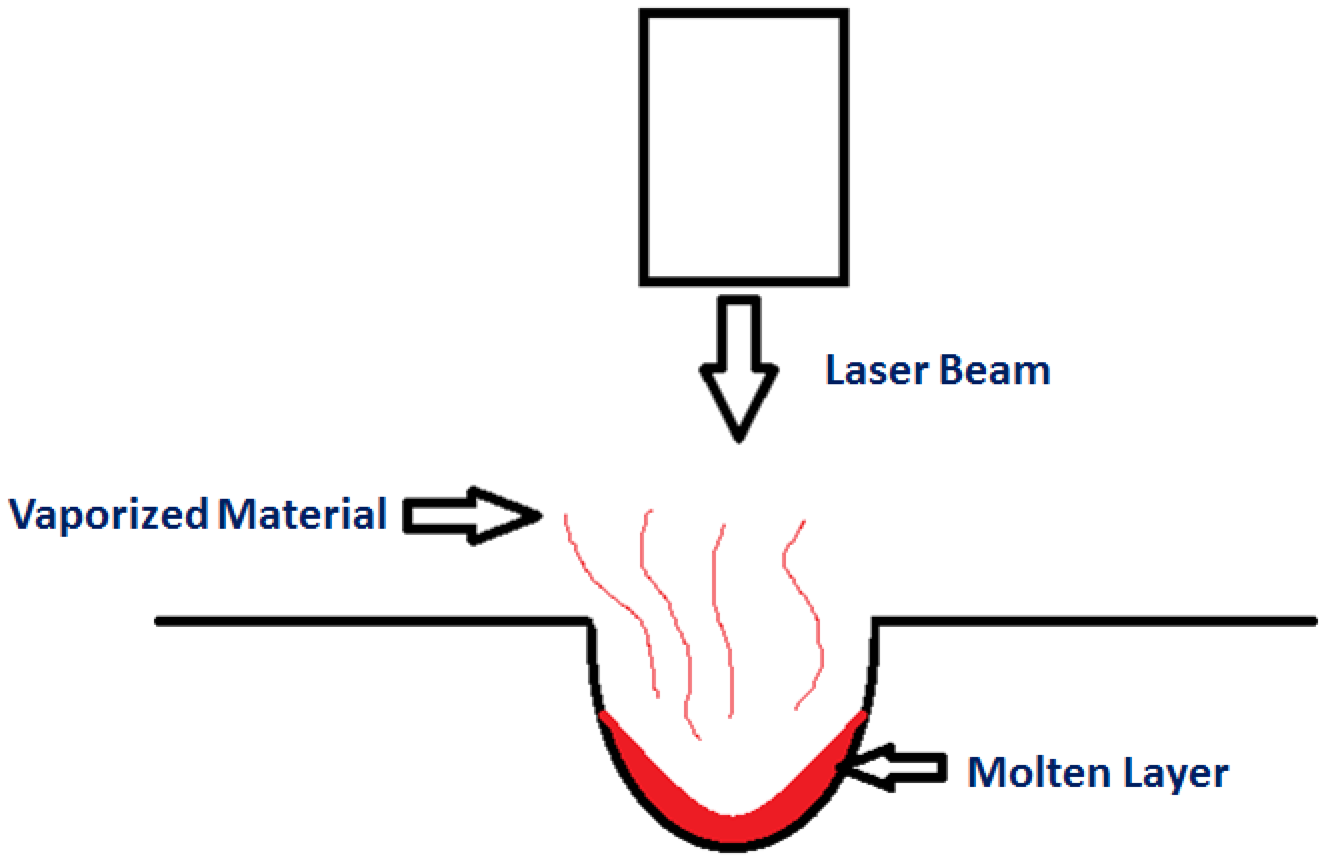
Numerical problems

1. Assuming no losses, determine water jet velocity, when the water pressure is 4000 bar, being issued from an orifice of diameter 0.3 mm

2. Determine the mass flow rate of water for the given problem assuming all related coefficients to be 1.

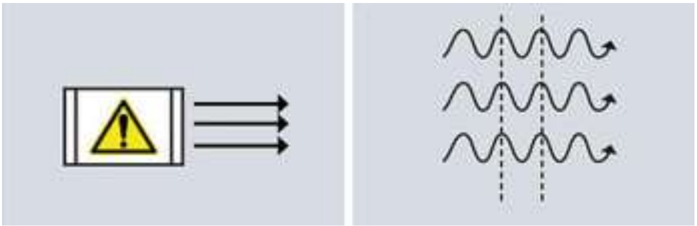
3. If the mass flow rate of abrasive is 1 kg/min, determine the abrasive water jet velocity assuming no loss during mixing process using the above data (data of Question. 1, 2 and 3)

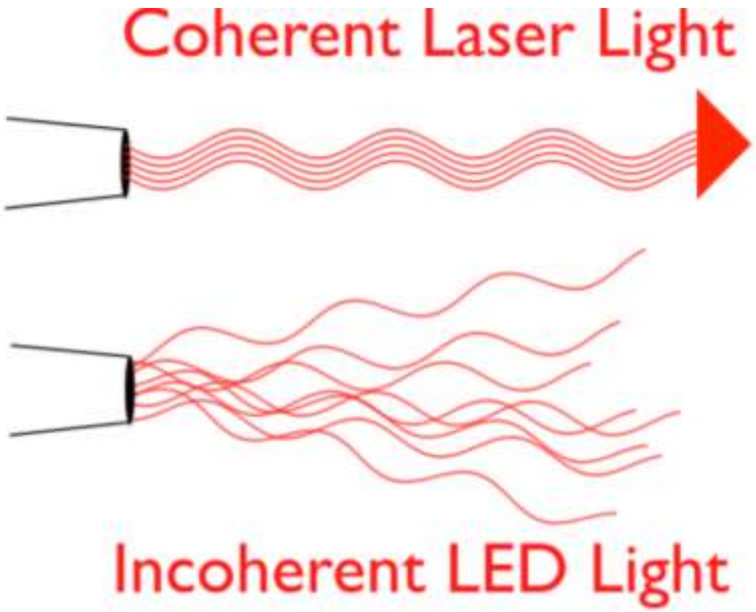
Laser Beam Machining



Laser beam machining

- Laser capable of producing very power density beam.
- laser is a highly coherent beam of electromagnetic radiation and the wavelength (0.1 to 70 microns).
- However, the power requirement for a machining operation restricts the effectively usable wavelength range (0.4-0.6 microns)
- Rays of laser beam are perfectly parallel and monochromatic , it can be focused to a very small diameter and can produce a power density as high as 10^7 W/ mm^2.
- For developing a high power normally a pulsed ruby laser is used.
- The continuous CO_2-N_2 laser has also been successfully used in machining operations.

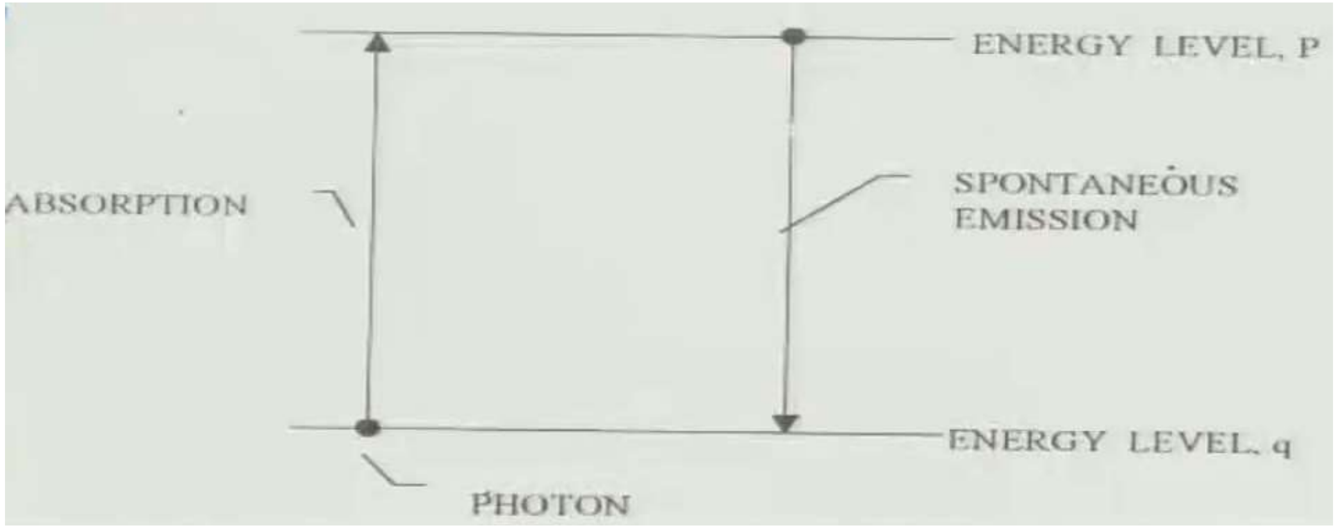




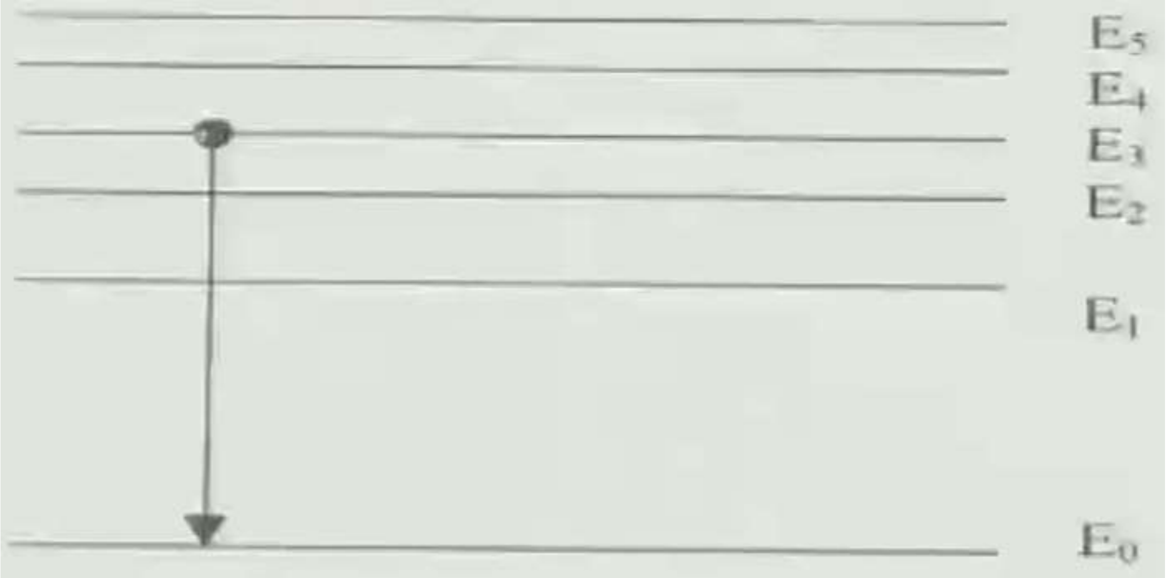
Principles of Laser

- LASER- Light amplification of Stimulated Emission of Radiation
- Under conditions appropriative conditions light energy of a particular frequency would be used to stimulate the electron in an atom to *emit the additional light* with the exactly *same characteristics* of the original stimulating light source.
- An atom initially in any excited state does not remain forever in that state.
- When an atom at ’q’ energy level has the light of right frequency acting on it, it absorbs the photon of that energy and the transition takes place from lower energy level ‘q’ to higher level ‘p’.

- The phenomenon of movement of an atom to a higher energy level is called absorption.
- On the other hand the transition from ‘p’ to ‘q’ is called emission.



Principles of Laser



- Emission can be of two kinds :
    1. spontaneous emission (independent of the intensity)
    2. stimulated emission (dependent on light intensity)
- Horizontal line indicates the allowed value of the energy level.
- Let the atom of the molecule be brought to a higher energy level E3 by an external energy source from ground state E0.

- When it is decay back to E0, photon is released.
- If this photon comes in contact with another molecule or atom at higher energy level 'E3' then this atom will also decay back to the ground state *releasing another photon*.
- The *chain of events* would produce photons having *same characteristics* (wavelength, phase, direction and energy)
- This sequence of triggering clone photons from stimulated atoms is known as **stimulated emissions**.
- *Population Inversion:* to produce a working laser the energy source should be so powerful that most of the atoms or molecules of the laser medium area higher states.

Feedback mechanism for laser

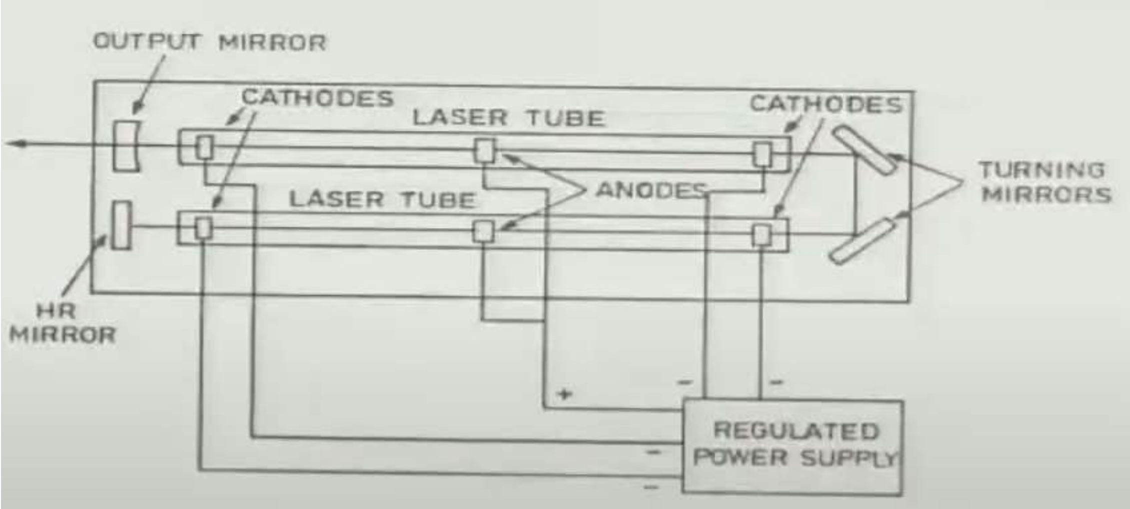
- Feedback mechanism is an essential element of the laser producing system.
- It captures and redirects a part of the coherent photons back into the active medium.
- These photons further stimulate the emission of some more photons to exit the system in the form of laser light.
- Rest of the photons remain in the system and are used to maintain the amplification process through stimulated emission.

Types of lasers

- Two types – Solid state laser and gas lasers
- **Solid state lasers:** Because of poor thermal properties of the solid state laser, they cannot be used for the heavy duty work (1-2Hz)
- They are used for low pulse application like drilling, spot welding etc
- However, the Nd-YAG lasers, most powerful in solid state lasers is also used in cutting operations.

Types of lasers

- **Gas lasers:**
- In this type of laser , CO_2, He, Nitrogen act as the lasing medium. These gases are recirculated and replenished to reduce the operating cost.
- Direct electrical energy is used to provide the energy for stimulating lasing medium.
- Its power delivering capacity is usually 100 W each meter length of the tube.
- Some details of gas laser systems:
  - Large amount of gas volume is used.
  - The resonant mirrors are positioned to reflect the beams several times before it escapes through the output mirrors.

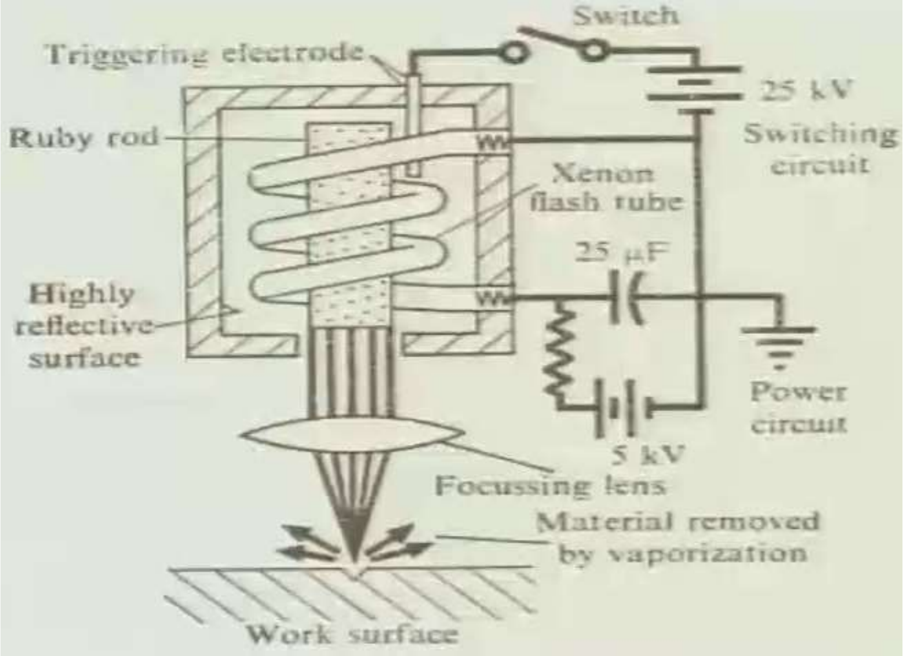


Some facts of laser machining process

- The efficiency of LBM is very low (0.3-0.5%)
- The typical output energy of the laser is 20J with a pulse duration of 1 millisecond.
- The peak power reaches a value of 20 kW.
- The divergence of the beam around 0.002 radians and using a lens with 25 mm focal length, the spot diameter becomes 50 microns.
- LBM is used to drill micro holes and cutting very narrow slots.
- Holes 250 microns diameter can be easily drilled by laser.
- The dimensional accuracy is around ± 0.025 mm.
- When the work piece thickness is more than 0.25 mm, the taper of 0.05 mm per mm thickness is noticed.

Mechanics of Material removal

- Typical pulsed ruby laser
- A coiled Xenon flash tube is placed around the lasing material and the internal surface of the container walls containing the lasing system is well polished and is made highly reflecting so that maximum light falls on the ruby rod for pumping operation.
- The capacitor is charged and very high voltage is applied to the triggering electrode for the initiation of the flash.
- The emitted laser beam is focused by a lens system and the focused beam meets the work surface, removing a small portion of the material by vaporization and high speed ablation.
- A very small fraction of molten metal is vaporized so quickly that a substantial mechanical impulse is generated, throwing out a large portion of liquid material.
- Since, the energy released by the flash tube is much more than the energy generated at the lasing head therefore the system needs to be continuously cooled.



Advantages

- In laser machining there is no physical tool.
- Thus no machining force or wear of the tool takes place.
- Large aspect ratio in laser drilling can be achieved along with acceptable accuracy or dimension, form or location.
- Micro-holes can be drilled in difficult – to – machine materials.
- Though laser processing is a thermal processing but heat affected zone specially in pulse laser processing is not very significant due to shorter pulse duration.