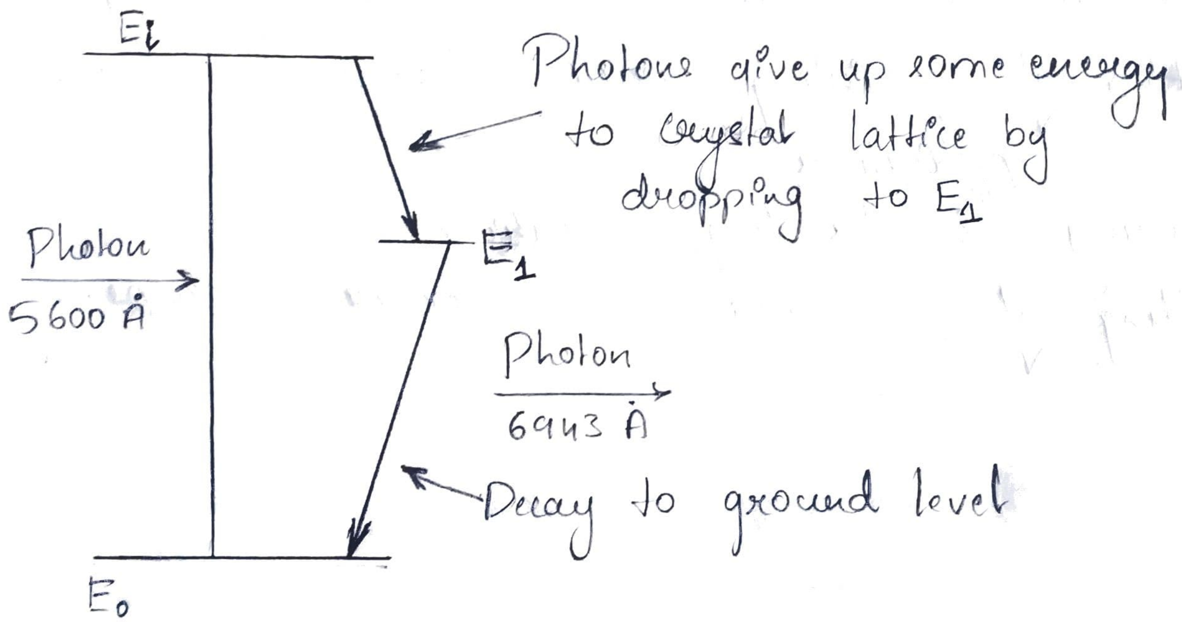
MODULE - 5

LASER BEAM MACHINING (LBM)

Introduction: Laser Beam machining (LBM) is a machining process in which the work material is melted and vaporized by means of an intense, monochromatic beam of light called the laser. The Heat produced in the small area where the laser beam strikes can melt almost any of the known materials.

⟹ GENERATION OF LASER



Energy level diagram for the ruby Laser.

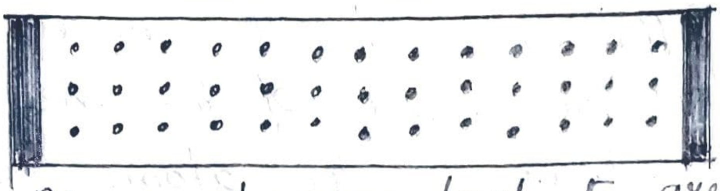
Let us consider that the atoms of a medium (for example, a ruby crystal rod) are at ground state E_0.

when a quantum energy from a source is made to fall on this medium, it causes absorption of radiation by the atoms of the medium. This results in electrons of the atoms of the medium to jump to the upper energy level E_i. The atoms in the upper energy level are then said to be in an excited state. Consider one such atom in an excited state. This atom immediately begins to drop spontaneously to the metastable (intermediate) state E_1. From the metastable state the atom emits one photon at random before it falls to the original level E_0. This radiation of photons is known as spontaneous emission which is extremely rapid (less than a micro-second from the time photon is absorbed).

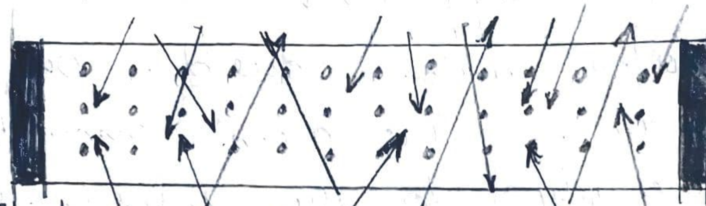
There is another way for the excited atoms to return to ground level energy state E_0. If, while the atom is in an excited state, a photon of the proper frequency strikes the atom, it results in the release of a second photon. The second photon is exactly in phase with the first photon, and it travels in the same direction. This is known as <u>Stimulated radiation</u>

To achieve stimulated radiation, a flash lamp is kept firing continuously, feeding the atoms into the upper energy level. At a particular instance, the population of excited atoms is more at level E_i than at E_0. At this point, the photons begin to interact with atoms at E_i to a significant extent. This results in a stimulated emission of other identical photons and a cascade begins.

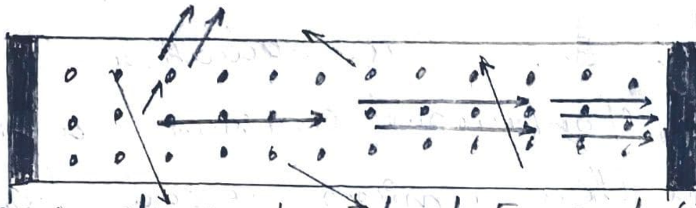
LASER ACTION IN A RUBY ROD



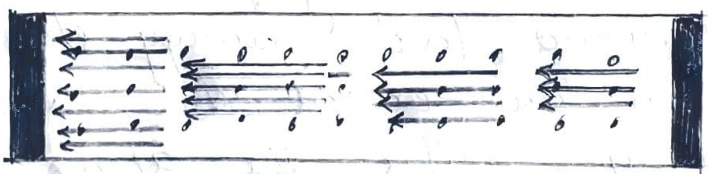
Atoms of energy level E_0 are shown as black dots



Flash lamp begins pumping raising atoms to excited levels, light dots

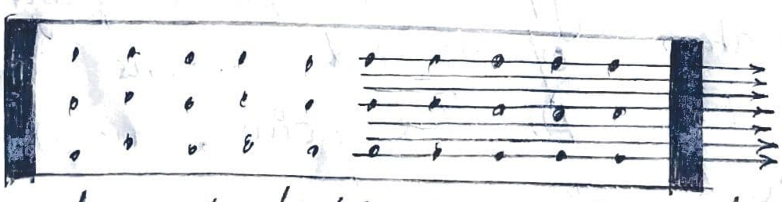


Excited atoms drop to level E_1 and begin emitting photons. Those travelling parallel to long axis of rod, strike other atoms in excited states, and also emit photon



Process continues, as intensity within ruby rod grows (All photons are emitting in step)

Reflection from mirrored face turns wave in other directions as intensity continues to grow.

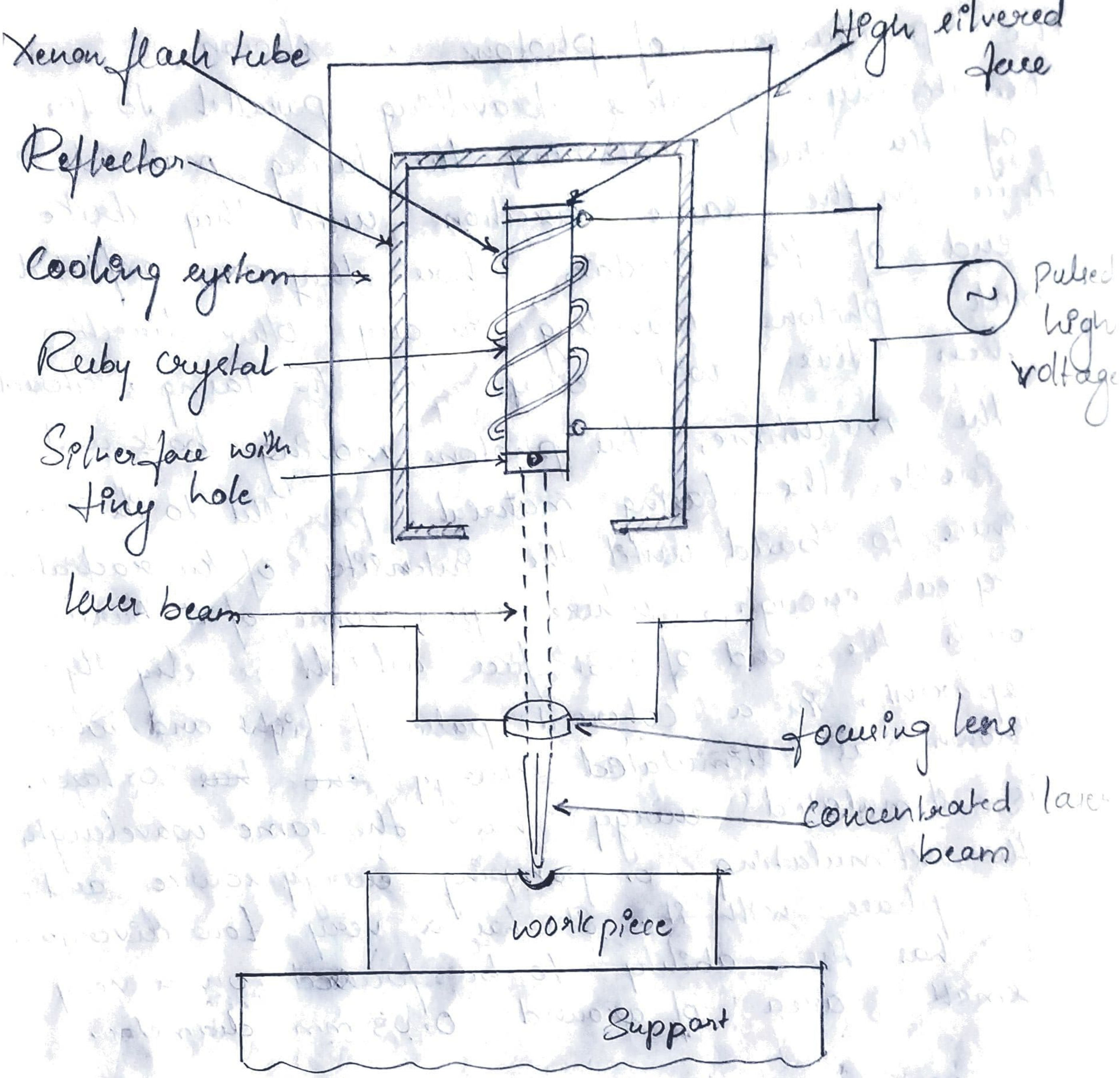


A burst of coherent light is emitted from slightly transparent face.

The production of photons is shown schematically. photons travelling parallel to the axis of the tube containing the lasing materials continue in the same direction until they strike the end of the crystal, where they are reflected back. photons travelling in any other direction other than this will escape from the lasing material. In the meantime, the photons moving back and forth inside the lasing material, parallel to its axis, continue to build until the intensity of the radiation is great enough, where upon some of it bursts through the end of that face which is slightly transparent, in a coherent pulse of light and which is known as stimulated energy ~~or~~ ~~has~~ or laser. This stimulated energy has the same wavelength as the stimulating or pumping energy source and is in phase with it. It has a very low divergence and has the ability to be focussed on a very small area of around 0.05 mm diameter.

EQUIPMENT AND MACHINING PROCEDURE OF LBM.

The figure shows a schematic setup of the laser machining operation. The laser beam produced in the optical cavity is permitted to escape through a partially coated reflecting ~~m~~ mirror. The emitted light radiation is almost completely a parallel beam having a maximum divergence angle θ of 10^{-2} and 10^{-4} radians.



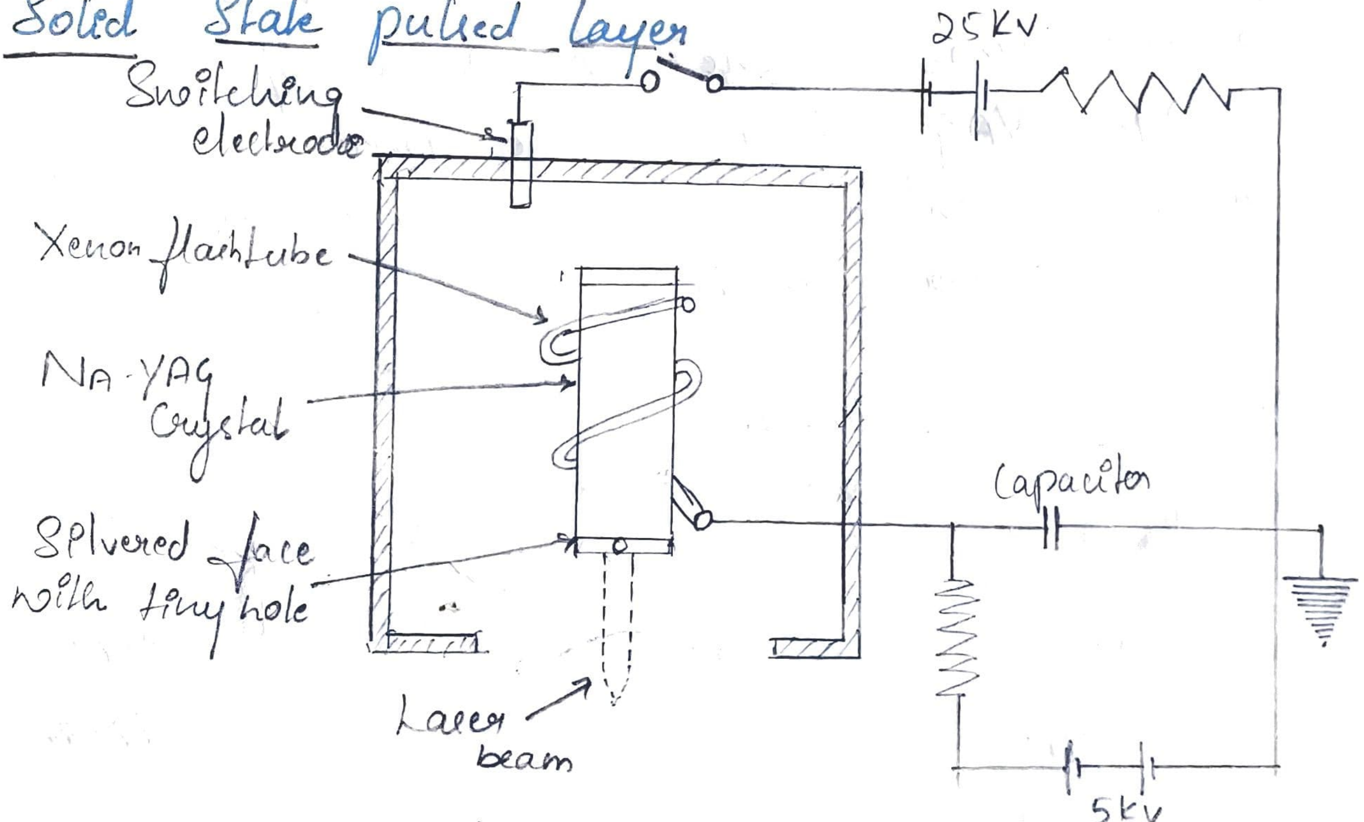
Because of its low divergence and monochromatic nature, the can be focused ~~on~~ with a simple, less to obtain high power density in small areas.

Additional Equipment required for laser Beam machining include a microscope for focusing the beam & a work table to position or move the workpiece in three directions in relation to the laser Beam.

The table can also be supplied with numerical control to enable continuous path cutting or drilling a number of holes in a plate by means of pre-programming the details on a punched tape. The laser equipment need cooling of the optical cavity because of their low conversion efficiency. A refrigerated water cooling system is generally used for this purpose.

TYPES OF LASER :-

1) Solid State pulsed layer



ND-YAG LASER

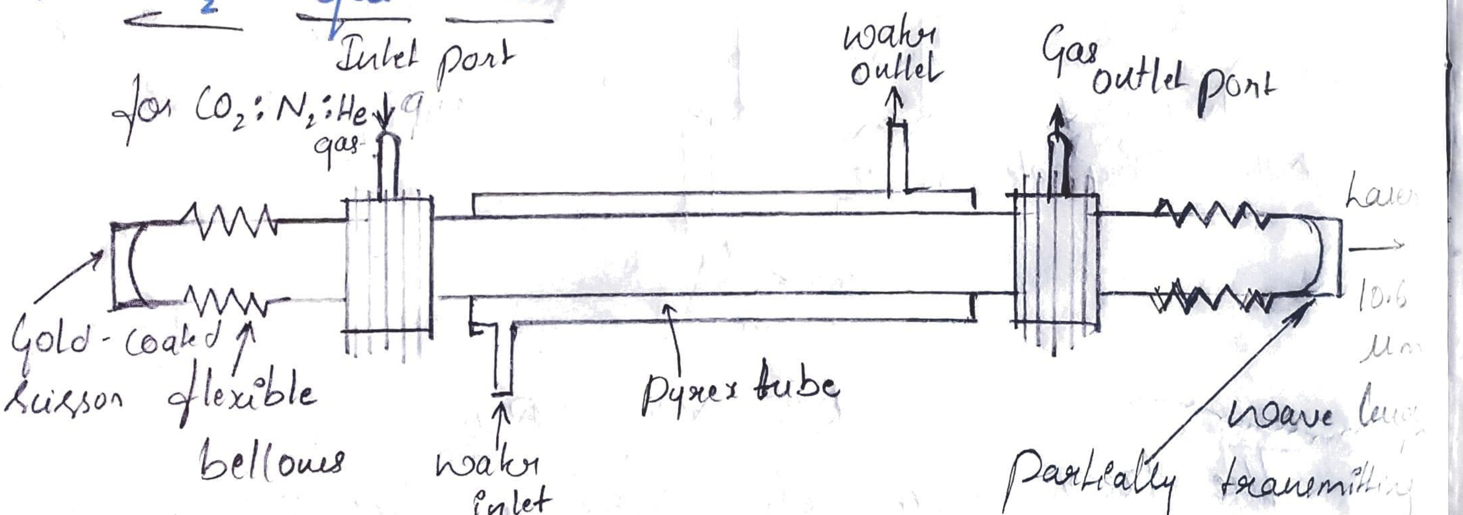
The laser materials used in this process are ruby, neodymium glass, neodynamic-yittrium aluminium garnet [Nd-YAG] are widely used in machining applications. These laser material are fabricated into rods & their ~~rods~~ ends finished to high optical tolerances.

The method used to inject energy into the material is by generating a very intense light flux which can be absorbed by their laser materials and then converted into a collimated laser beam.

The light flux of high intensity is provided by Xenon filled flash temperature. The life of this temp. lamp is around 10,000 - 1,00,000 pulses. Neodymium glass generates only in a pulsed mode with a pulse duration of a few billionths of a second to maximum of one millionth of second.

Nd - YAG laser can be operated either pulsed or in a continuous wave to produce continuous power output.

2) CO_2 Gas laser.



CO_2 laser

The CO_2 laser system uses three gases, i.e. nitrogen, Carbon - di - oxide & helium through a glass discharge tube. Nitrogen functions as an intermediate b/w

Electrical energy & vibrational energy of CO_2 molecules. Helium cools the gas mixture so that it may be re-excited again. When an electrical discharge energy is generated through these gases, photons are generated when some of energy absorbed by CO_2 molecule is released.

The CO_2 laser has several advantages over solid state laser, such as, relatively high & continuous power output & high conversion efficiency (20%) of power. As compared to this ruby is 1-3% efficient & the Nd-YAG can reach 10%. In addition, the CO_2 laser system fewer maintainance problems, unlike solid state laser systems which require ~~syst~~ regular replacement of flash lamps.

PROCESS PARAMETERS OF LBM

[Process characteristics]

A typical laser system, having an output energy of 20 joules with a pulse duration of 10^{-3} sec can produce a peak power of 20,000 W. With a beam divergence of 0.002 radian, a spot diameter of 0.05 mm exposed to the focussed laser beam can result in a power density of 1.2×10^{9} W/cm².

* A power density of this magnitude is sufficient to melt & vapourize almost any material including diamond. The power density can be calculated by the formula

$$D = \frac{4P}{\pi f^2 \theta^2 T}$$

where,
- D = power density w/cm²
- P = laser energy output w.
- T = laser pulse duration, sec
- θ = beam divergence, radian
- f = focal length of lens.

The product fθ gives the diameter d of the spot produced by the laser.

To permit laser beam machining the following requirements are to be fulfilled.

→ The ~~radiation~~ Power supplied must be greater that which is conduct away by convection, thermal, conduction & radiation.

→ The radiation must generate & be absorbed into the material.

All metallic materials reflect some radiation energy at their surface. The few micrometre. The absorption of laser wavelength of laser, composition of the material, surface quantity of the workpiece & the transition from solid to liquid star or gaseous state. metallic material absorbs 5-15% of the incident radiation.

while non-metallic materials absorbs b/w 50-96% of the incident radiation.

Machining rate :-

Laser can be used for cutting as well as drilling. The material removal rate in LBM is comparitively low & is of the order of $400 mm^3/hr$. The obs cutting rate for both metals & non-metals is given by

$$C = \frac{KP}{EAT}$$

where,

C = cutting rate
A - Area of laser beam at local point
E - vaporization energy
P - laser power incident on surface, w
t - thickness of material, mm

The laser cutting or drilling process can be accelerated if a gas jet is directed co-axially with the laser beam.

Accuracy :-

The hole drilled by laser are not round. In order to overcome this difficulty the workpiece is rotated as the whole in laser - drilled. Other problems associated with laser drilling are taper and recast structure in the heat affected zone. In order to achieve the best possible results in drilling, material must be located within tolerance of ±0.8mm of focal point. ∴ while drilling thicker materials it is required that the focal point is moved down the hole as it is drilled.

Accuracy in profile cutting with numerical control or photo electric trace unit is about ±0.1mm.

ADVANTAGES OF LBM

- There is direct contact b/w laser & w/p
- machining of any material including non-metals is possible, irrespective of their hardness & brittleness
- Heat affected zone is small
- Extremely small holes can be machined.
- There is no tool wear problem.
- Soft materials like rubber & plastics can be machined.
- The process can be easily automated.

LIMITATIONS OF LBM

- The overall efficiency is extremely low (10-15%).
- The process is limited to thin sheet plates.
- low material rate.
- The machined holes are not round & straight.
- cost is high.
- life of flash lamp is short
- Effective safety procedures are refined.
- low metal removal rate.
- low thermal efficiency.

APPLICATIONS OF LBM.

- LBM is suitable for machining very small holes and cutting complex profiles in thin, materials like Ceramics.
- It is also used in partial cutting and engraving
- Though LBM process is not a mass material removal process, because of its rapid repetitive machining characteristics

& ease of control. It is possible to use this process for mass micro-machining production.

→ Other applications include sheet metal trimming, blanking and resistor trimming

→ Almost all materials can be cut/drilled with laser. Metallic materials that can be machined by laser are steel & steel alloys.

→ Among non-metals, laser can be used to cut polyethylene, polycarbonate, pvc, leather, ~~wood~~, rubber, reinforced plastic, wood & cotton.