Laser beam versus water jet machining

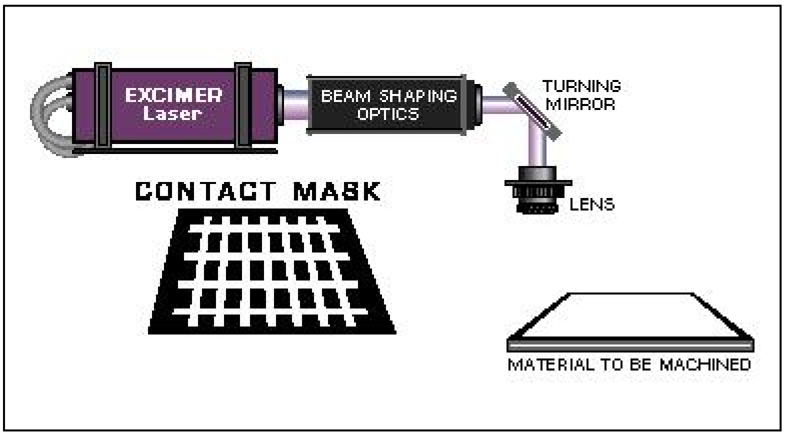
INTRODUCTION

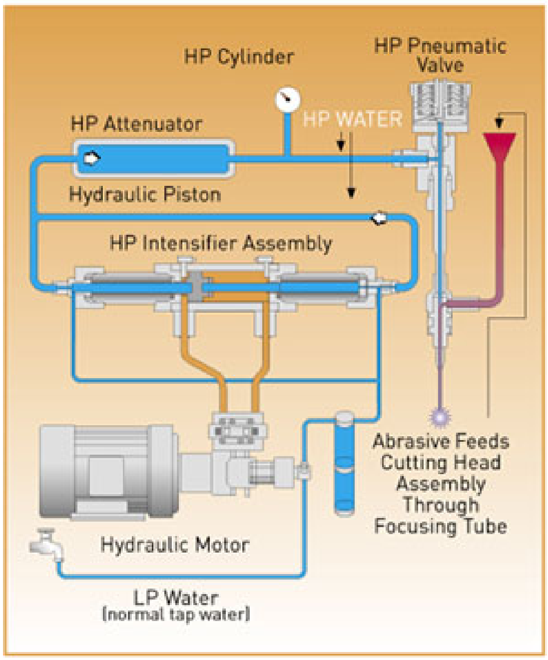
Laser beams and water jets when used for cutting can be broadly suitable for similar tasks.The two technologies can be considered for use in fabrication and sheet metal working departments to work alongside, and as a supplement to, existing press equipment.

Press tools (working on the shearing principle) are a very quick and efficient way to produce components from sheet or strip stock in large quantities, they are however time consuming to set up and expensive to tool.By adding a laser beam/water jet machine to a company's plant list they will be in a much better position to be able to quote competitive prices and lead times for one-off and small production runs.

Laser machines have a significant advantage over water jet machines (in a fabrication department) because as well as being able to cut intricate shapes they are also able to weld with great precision.

Both laser and water jet machines have a good life expectancy due to the absence of dynamic machining forces and metal to metal contact during the cutting process. The machine construction may be substantially lighter because of this, reducing the static loading and also the dynamic loading during positioning.

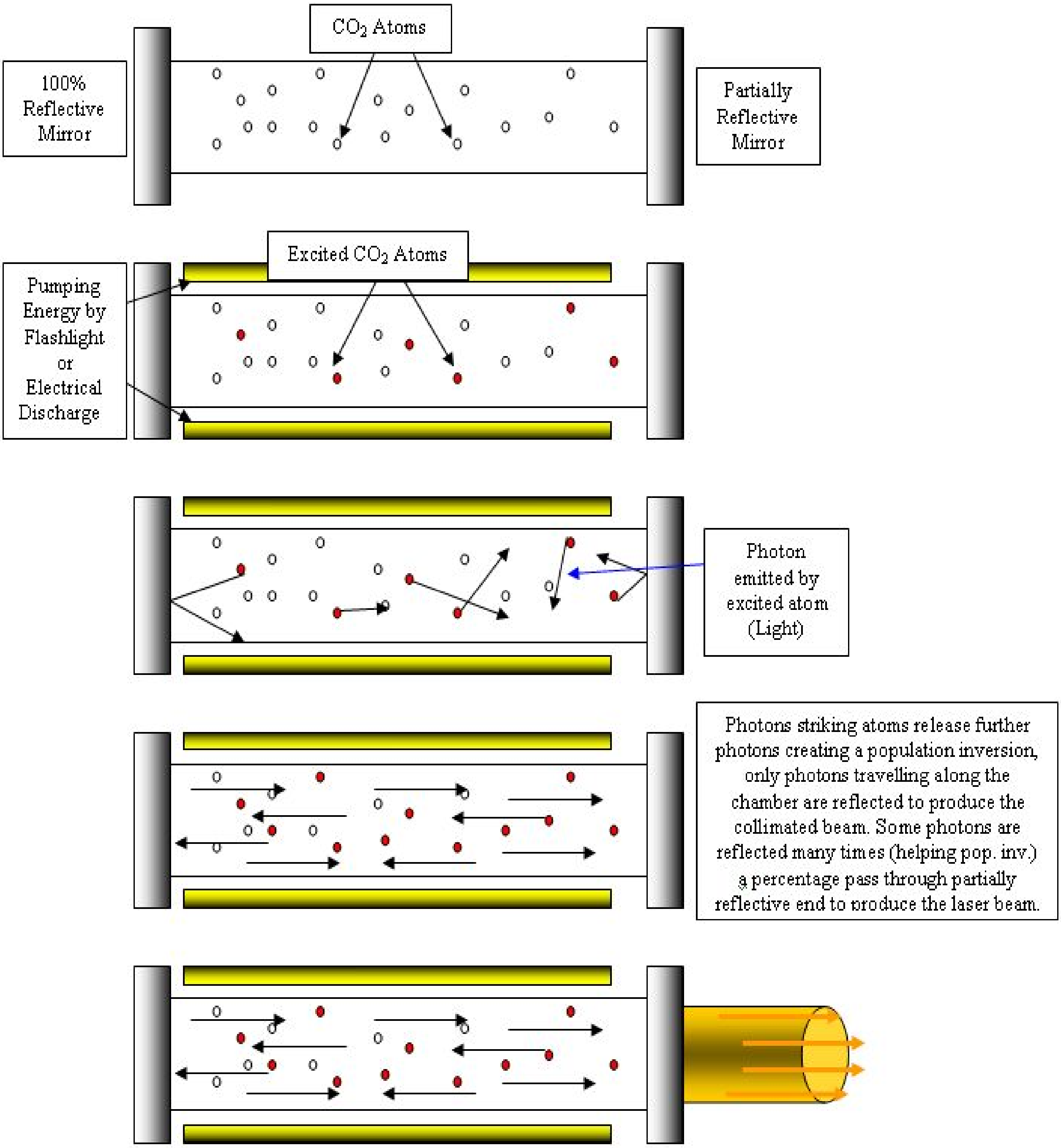




LASER BEAMS

The word *laser* is an acronym for Light Amplification by the Stimulated Emission of Radiation.

Below is a simple representation of how a CO_2 laser beam is generated.



The three most important attributes of laser light are:

1- It is coherent i.e. all photons that make up the beam are in phase with each other.

2- It is collimated, because photons that diverge from the parallel are lost through the chamber walls a very parallel beam is issued.

3- It is monochromatic, literally one colour, that is of one wavelength. Different media used to stimulate the photons generate different wavelengths, but each type of laser has a specific wavelength (e.g. CO2 is 10.6 mM). The purity of the medium used is of paramount importance.

TYPES OF LASER

There are two types of laser commonly in use in manufacturing today, the CO_2 and Neodymium-doped, Yttrium Aluminium Garnet (Nd:YAG).

The CO_2 laser is the more powerful of the two (typically 400W to 1500W) and is used primarily for cutting and profiling. They are capable of cutting up to 25mm thick carbon steel, however laser beams in general tend to create a tapered cut due in part to the spread of the beam past the focal point.

Note: although lasers produce a collimated beam from the chamber, this is generally of the order of 20–30mm in diameter; this beam is then focused down to a point typically microns in diameter. This concentration of energy is how what might at first appear to be the low power rating of a laser can generate enough heat to quickly cut metal.

The Nd:YAG laser while lacking the 'brute force' of the CO_2 has many uses. It is particularly suitable for drilling small holes (2-3mM) to a depth approximately six times diameter. They are also used for engraving and etching (e.g. Part and issue numbers for traceability in aerospace components etc.).

A significant advantage of the YAG laser is that the beam may be transmitted through fibre-optic cable. This is particularly useful when welding because it means that the focus head may be fitted to a robot arm or similar multi-axis manipulator to weld complex intersections. The CO_2 laser beam cannot be transmitted through fibre-optic cable and must be re-directed by means of mirrors. This generally means that the focus head on a CO_2 machine moves only in one (Z) axis to provide height and focus adjustment, the X and Y axes being controlled by movement of the table, thus increasing the effective footprint of the machine.

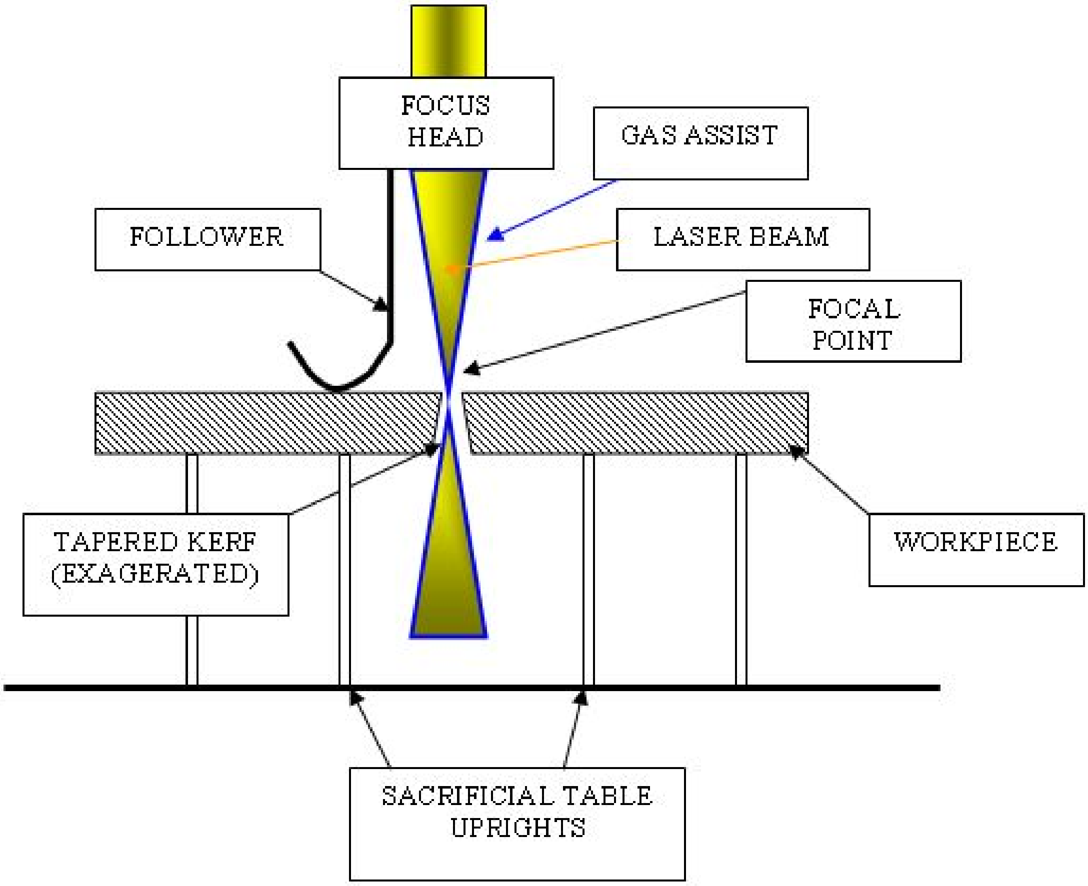
MATERIALS THAT MAY BE CUT:

A wide range of materials may be cut using a laser beam, however care must be taken in choosing the correct type of laser. Below is a table outlining the suitability of both CO_2 and Nd:YAG lasers for materials likely to be encountered in the course of an average manufacturing business.

0 = IMPOSSIBLE / DANGEROUS, 5 = EXCELLENT

MATERIAL	CO_2	Nd:YAG	BOTH
MILD AND CARBON STEEL			5
STAINLESS STEEL			4 / 5
ALLOY STEEL			4 / 5
TOOL STEEL			5
ALUMINIUM ALLOYS	2 / 3	4 / 5	
COPPER ALLOYS	1	3	
TITANIUM			4
PLASTICS	5	0 / 1	
RUBBER	4	1	
PAPER (GASKETS ETC)	5	3 / 4	
CERAMICS			3 / 4

THE MECHANICS OF LASER CUTTING/WELDING



- **The workpiece rests on a sacrificial table (minimal point contact, when heavily pitted by laser overshoot is simply thrown away, hence the name). Workholding is minimal due to absence of cutting forces and when used is mainly for location.**
- **The focal point of the laser is focused onto the surface of the workpiece. The follower takes into account any variation in height of the workpiece.**
- **The material vapourises instantly, producing a kerf in the material.**
- **The machine axes move to generate the correct profile. The speed of cutting is such that the Heat Affected Zone (HAZ) is minimal - compared to flame cutting.**
- **A gas assist jet clears the molten metal that has not vapourised (as in oxy-fuel cutting). Note: the gas assist gas may be one of two types, inert and exothermic. Inert gasses commonly used are Nitrogen and Argon. Exothermic gasses, Air or pure Oxygen. Inert gasses help keep oxidisation to a minimum, cool the cutting zone and prevent flammable materials burning. Exothermic gasses cause a reaction that improves cutting performance.**

- **Welding is broadly similar except for the omission of the gas assist jet. In this case the column of molten metal needs to remain in place until after the beam has passed, to allow solidification.**
- **A significant advantage of laser welding is that filler rods need not be used and two dissimilar metals can be welded. The two pieces to be welded are butted together (to a close tolerance) the laser beam passes along the intersection, melting both sides and 'stirring' the metals together. Very accurate welds with good structural integrity (due in part to the small HAZ) can be made with a laser beam.**

CONSUMABLES AND OPERATING COSTS

The primary consumables to consider when using a laser machine are:

- **Electricity**
- **High purity gas (for the laser generating chamber)**
- **Assist gas**
- **Optical equipment**

A typical 1500-watt CO_2 laser will have a running cost in the region of £10 - £20 per hour.

Considering the nature of the work that these machines can be used for; intricate and complex; development and prototype etc, the return on investment can be quite high. For the purposes of quotation £50 - £150 per hour charge is the norm for this type of work.

WATER JET MACHINING

Water Jet Machining (WJM), otherwise known as Hydrodynamic Machining may be used for tasks similar to those for a laser. Excepting welding for obvious reasons.

Water jet machining is used extensively for cutting plastics, fabric, rubber, paper and leather due in part to the absence of heat. It produces a very narrow kerf, and if set correctly produces a very smooth edge with no rag or burrs. Water jet machining is a very clean operation with no dust or odours and very little noise, in fact the health and safety and environmental implications are almost negligible.

The nozzle can be mounted on a multi axis robot arm to cut complex three-dimensional shapes; in fact this setup has been successfully employed cutting vehicle dashboards out of laminated foam.

To cut harder and more resistant materials such as metal, abrasive particles such as Garnet or Alumina are added to the water prior to entering the cutting zone. This is known as Abrasive Water Jet Machining (AWJ).

The pressures involved can be as high as 1400 MPa although 400 MPa is more usual for efficient operation. The abrasive slurry is forced through an orifice in the nozzle between 0.05mm and 1mm in diameter at a rate of 0.5 litres to 25 litres per minute. This results in a jet velocity in region 520 – 914 metres per sec. This acts like a saw blade, rapidly eroding many materials. In fact due to the continually changing abrasive particles fresh cutting edges are always being presented to the workpiece, therefore they will not become dull or blunt however resilient the material being cut.

The nozzle orifices are generally made of very hard materials, man-made ruby and sapphire as well as carbide based composites are currently in use.

Similarly to lasers the maximum thickness of cut, for most practical purposes is in the region of 25 mm.