4.3 LASER FOR MEASUREMENT OF ACCELERATION

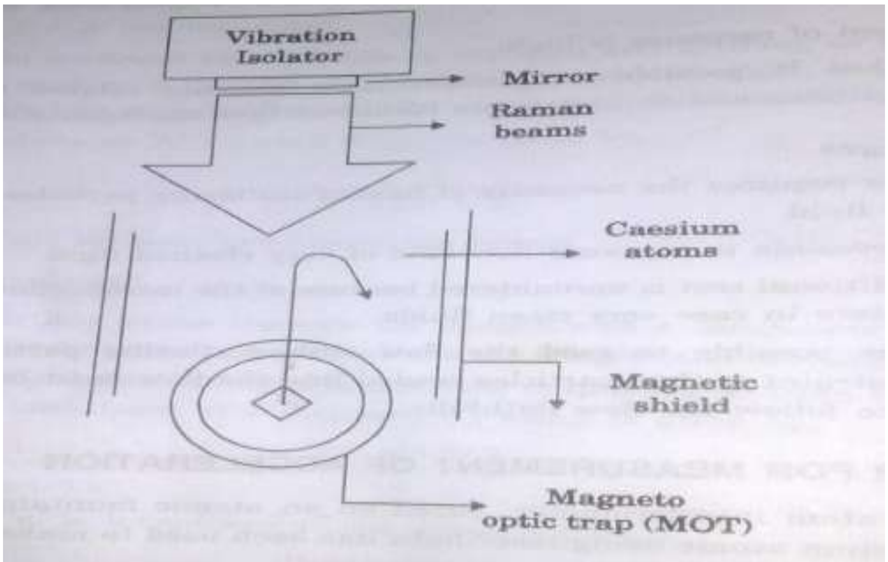

Figure 4.3.1 Laser based Acceleration Measurements

[Source: "Optical Fibre Communications" by J.M.Senior, Page:526]

An atom interferometer based on an atomic fountain of laser cooled caesium atoms using laser light has been used to make a very accurate measurement og 'g'

Principle

In this interferometer, the frequency of the light is changed in a phase continuous way so that it remains resonant with the transitions as the atoms accelerate under the influence of gravity. As a consequences, the phase difference between the two paths in the interferometer is proportional to the gravitational attraction.

Basic atom Interferometer:

Caesium atoms are extracted from a low pressure back ground vapour and loaded into a magneto optical trap during a 600 ms period. The magnetic field is turned off and the captured atoms are launched into the atomic fountain of this sensor using a specialized technique known as moving polarization gradient optical molasses.

During this period, further cooling of the 'launched' atoms occur, using resonant techniques. In the final stage of the launch, the laser intensities are reduced to zero in 400μs so that the atoms are cooled. The launched atoms are subjected to a series of pulses that place the atoms in a specific internal state with an effective internal temperature of 10nK.

This low velocity spreads leads to a high fringe contrast over a period of about 150 ms. The interferometer measurements occur in a magnetically shielded region. This type of device is capable of measuring 'g' better than a part per billion accuracy.

Cold Atom Gradiometer

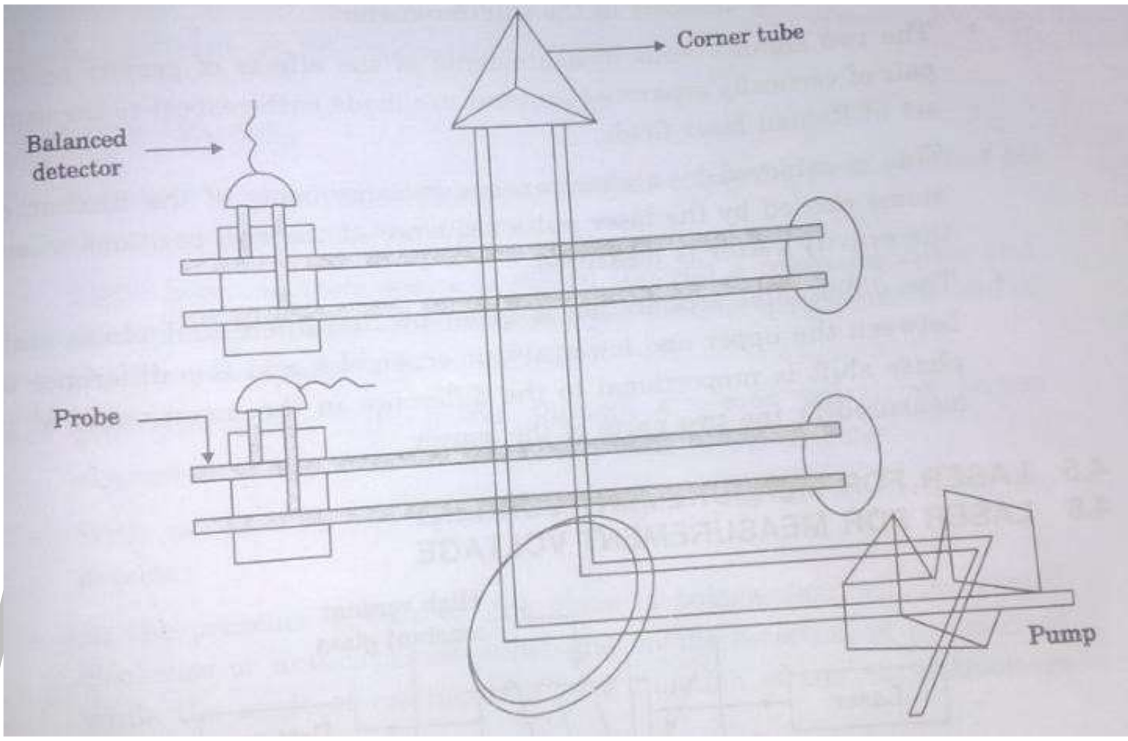

Figure 4.3.2 Cold Atom Gradiometer

[Source: "Optical Fibre Communications" by J.M.Senior, Page:528]

An atom interferometry technique has been used to create a gravity gradiometer using two laser cooled and trapped sources of caesium atoms and a pair of vertically propagating laser beams. The device is arranged so that two independent measurements of acceleration can be made using the two vertically separated ensembles of caesium atoms in free fall under the influence of gravity.

Working:

The caesium atoms are launched into a vertical trajectory form the magneto-optical trap and conditioned to be in a particular internal state using optical and microwave techniques. These atoms are then suitable for interacting with the gravity vector and then changes in the atomic states due to gravitational acceleration which can be detected in the interferometer.

The simultaneous measurements of the effects of gravity on the pair of vertically separated sensors are made with respect to the same set of Raman laser fields. This is achieved by a simultaneous measurements of the fraction of atoms excited by the laser pulse sequence at the two positions where the gravity vector is measured.

The differential acceleration is given by the differential phase shift between the upper and lower atomic ensembles and this difference in phase shift is proportional to the difference in phase shift is proportional to the difference in the mean value of 'g' measured at the two part of the sensor.

LASER FOR MEASUREMENT OF CURRENT AND VOLTAGE

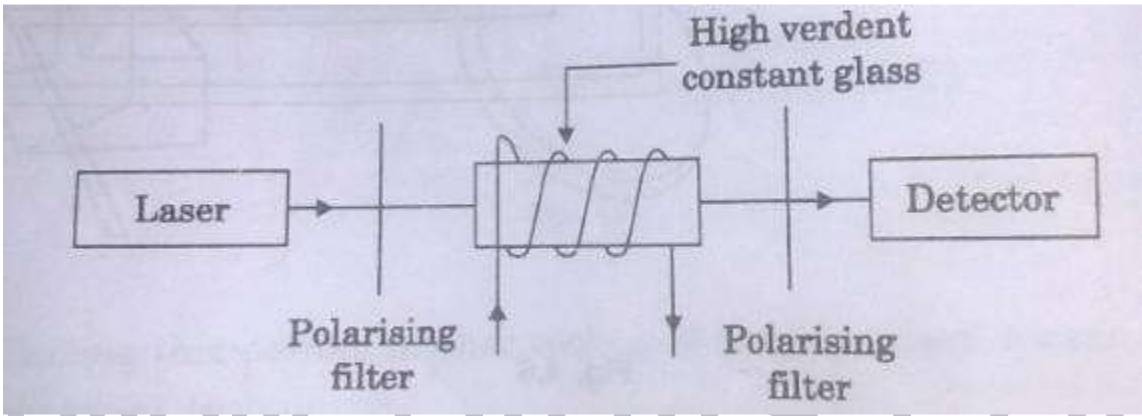

Figure 4.3.3 Laser based measurement of Current and Voltage

[Source: "Optical Fibre Communications" by J.M.Senior, Page:530]

Principle:

If polarized light is passed along a magnetic field of strength H, the plane of polarization is rotated by an amount given by,

$$\Phi = VNI$$

Working:

A system for current/voltage measurement using the faraday effect. Light from the laser source is passed through a polarizing filter and then through a high verdet constant glass rod in the magnetic field of current and voltage to be measured. The transmission to the first screen and then to the detector. With no current flowing, a steady signal will be received at the detector. In the presence of current, the plane of polarization will be rotated clockwise or anticlockwise depending on the direction of the current while the angle of rotation will be a function of the current & voltage magnitude.

4.1 LASER FOR MEASUREMENT OF DISTANCE

There are literally thousands of references on the theory and practical uses of lasers. They are used in everything from portable CD players to sophisticated weapons systems. The term LASER is an acronym for "Light Amplification by Stimulated Emission of Radiation," and is defined as "any of several devices that emit highly amplified and coherent radiation of one or more discrete frequencies." At Northeast Laser & Electropolish, we utilize pulsed Nd:Yag (Neodymium-Doped Yttrium-Aluminum- Garnet) type lasers for welding. The Nd:Yag rod, when stimulated by a flash lamp, emits light in the ultraviolet range with a wavelength of 1.06 microns. This light is then focused and delivered to the work piece, where the high energy density beam is used to weld.

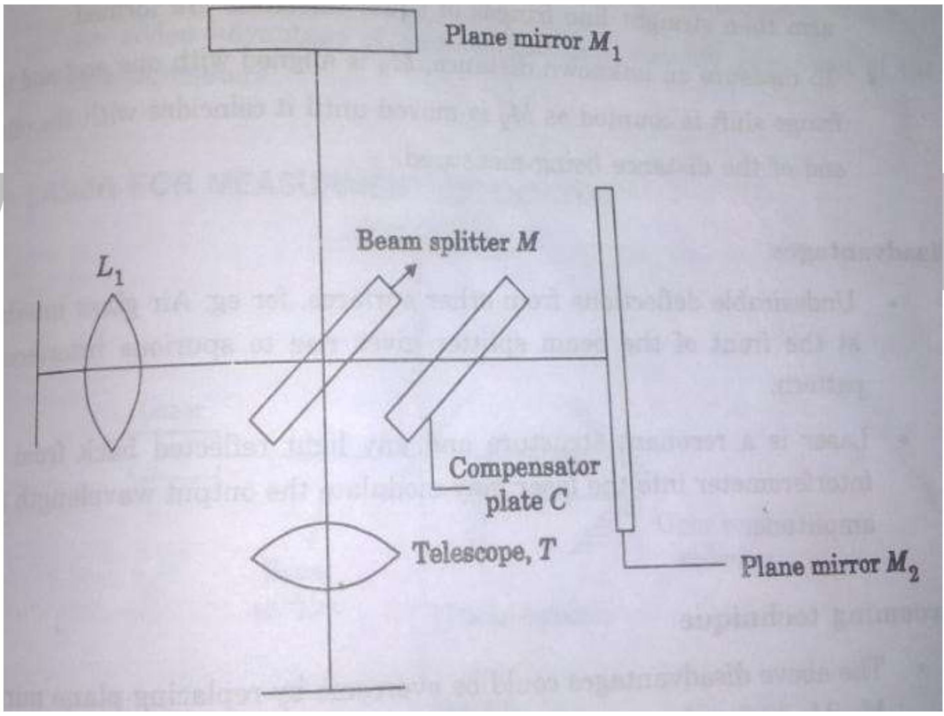

Figure 4.1.1 Laser-based Distance Measurements

[Source: "Optical Fibre Communications" by J.M.Senior, Page:517]

Laser-based distance measurements can be done using interferometric principles. Measurements of length using optical interferometry have been performed since the 19th century. But the limited intensity and coherence of conventional light sources restricted the measurements, which were difficult and suitable for used only over distances of a few centimeters. The development of lasers removed these restrictions. Lasers have allowed interferometer to develop into a fast, highly accurate and versatile technique for measuring longer distance.

Interferometric measurement of distance can be highly accurate. It offers a higher degree of precision than the pulsed time-of-flight or beam-modulation telemetry methods. However, it is best suited to measurements made in a controlled atmosphere (for example, indoors) over distances no greater than a few tens of meters.

Most laser-based interferometric systems for measurement of distance use a frequency stabilized helium-neon laser. An unstabilized laser, operating in a number of longitudinal modes, will have a total line width around 109 Hz. This spread in the frequency (or wavelength) will cause the interference fringes to become blurred and to lose visibility as the distance increases. An unstabilized laser is suitable for measurement only over distances of a few centimeters. Stabilized lasers, usually in a temperature-controlled environment and operating in a single longitudinal mode, are used for longer distances.

We describe first the operation of a system based on the Michelson interferometer, because it is easy to understand the basic principles of interferometer distance measurement with reference to the Michelson interferometer. Later we will describe variations that provide better stability under conditions of atmospheric turbulence.

The beam from the laser falls on a beam splitter that reflects half the beam in one direction (the reference arm) and transmits the other half (the measurement arm). The two beams are each reflected by mirrors, a stationary mirror in the reference arm and a movable mirror in the measurement arm. In practice the mirrors are often cube corner reflectors (retroreflectors) which offer better stability against vibrations than conventional flat mirrors.

Schematic diagram of the application of a Michelson interferometer to measurement of distance The two reflected beams are recombined at the beam splitter to form an interference pattern that is viewed by an observer or measured by a recorder such as a photo detector. The character of the fringes is related to the different optical path lengths traveled by the two beams before they are recombined.

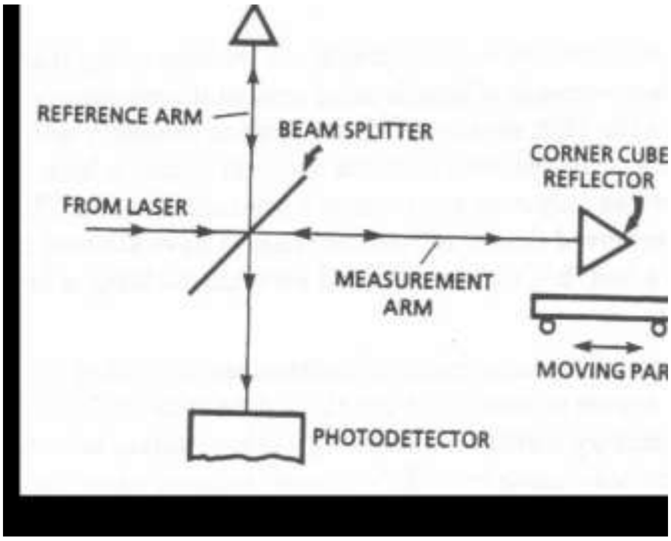

Figure 4.1.2 Schematic diagram of a Michelson interferometer

[Source: "Optical Fibre Communications" by J.M.Senior, Page:518]

Suppose, for example, that the detector is viewing a bright fringe in the interference pattern when the movable mirror is at a certain position. If the movable mirror moves a distance equal to 1/4 of the wavelength of light, the round-trip distance traversed by the light in the measurement arm will change by 1/2 wavelength, and the fringe pattern will change so that the detector now views a dark fringe. The distance mesurement thus consists of counting the number of fringe variations as the mirror moves. Each complete fringe corresponds to a phase variation equal to 2p . The variation in phase d is determined by using the equation

$$d = 4p\ D\ x/l$$

where l is the wavelength of the light,

D x is the distance that the movable mirror has moved.

It is apparent that this method offers high precision, allowing measurements of D x to be made with an accuracy of the order of a fraction of the wavelength of light.

(55)The maximum distance D x that can be measured in this way is given by: D x *max*

$$= c/\mathrm{D}v$$

Where, c = velocity of light.

D v = linewidth (i.e., spread in frequency) of the laser.

4.2 LASER FOR MEASUREMENT OF LENGTH

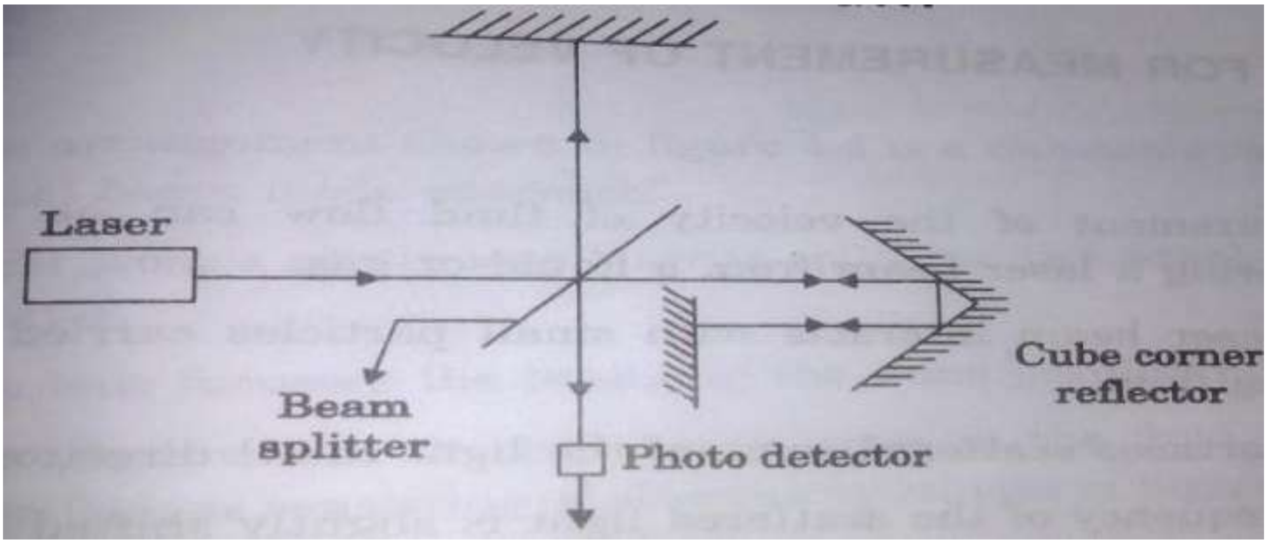

Figure 4.2.1 Laser-based Length Measurements

[Source: "Optical Fibre Communications" by J.M.Senior, Page:522]

The large coherence length and high output intensity coupled with a low divergence enables the laser t find applications in precision length measurements, using interfermetric techniques. Here the laser beam is split into two parts, and they are made to interfere after traversing two different paths. One of the beam emerging from the beam splitter is reflected by a fixed reflector and the other by a cube corner reflector. The two reflected beam interfere to produce either constructive or destructive interference**.**

As the reflecting surface is moved one would get alternatively constructive and destructive interference which can be detected with the help of a photo detector. Since the change from a constructive to a constructive and destructive interference corresponds to a change of a distance of half a wave length. One can measure the distance transverse by the surface on which the reflector is mounted by counting the number of fringes which have crossed the photo detector.

Accuracies upto 0.1μm can be obtained by using such a technique. This technique is used can be obtained by using such a technique. This technique is used for accurate positioning of aircraft components

On a machine tool, for calibration and testing of testing of machine tools, for comparision with standards.

LASER FOR MEASUREMENT OF VELOCITY

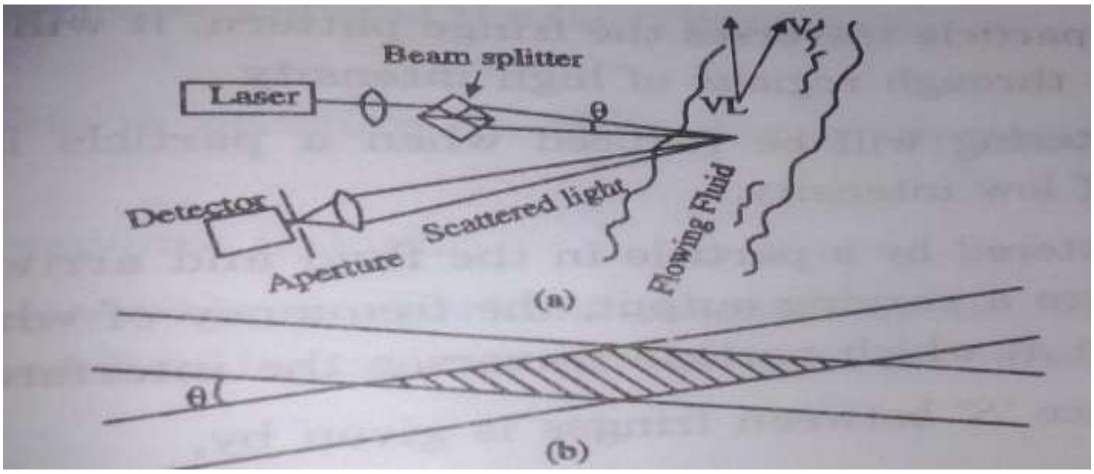

Figure 4.2.2 Laser-based Velocity Measurements

[Source: "Optical Fibre Communications" by J.M.Senior, Page:524]

Principle

Measurement of the velocity of fluid flow can be performed by scattering a laser beam from a liquid or gas. The laser beam interacts with small particles carried along by the flowing fluid. The particles scattered light is slightly shifted by the Doppler Effect. The magnitude of the frequency shift is proportional to the velocity of the fluid. Measurement of the frequency shift directly gives the flow velocity.

Construction:

The measurement techniques basically consist of a focusing laser light at a point within the flowing fluid. Light scattered from the fluid or from particles entrained within the fluid flow is collected and focused on an optical detector. Signal processing of the detector output yields the magnitude of the Doppler frequency shift and hence the velocity of flow.

Working:

The approach towards measurement is called Dual beam approach. Light from a continuous laser is split into two equal parts by a beam splitter. Light from a continuous laser is split into two equal parts by a beam splitter. The lens focuses the beam to the same position in the fluid. The place where the two beams crosses in the fluid, they interfere to form fringes consisting of alternating regions of high and low intensity.

when the particle transverse the fringe pattern, it will scatter light when it passes through regions of high intensity.

The scattering will be reduced when a particle is passing through regions of low intensity. Light scattered by a particles in the fluid and arriving at the detector will produce a varying output, the frequency of which is proportional to the rate at which particle transverses the interferences fringes. The distance S between fringes is given by

θ – Angle between two converging beams λ- wavelength

If a particle passes through the fringes with a component of velocity V_T in the direction perpendicular to the fringes the output signal from the detector will be modulated at a frequency 'f' which is given by

A factor 'n' is introduced in the above equation,

This factor is introduced because the wavelength λ is the wavelength in the fluid which differs from the vacuum wavelength λ0, by a factor equal to 'n'.

Advantages

- No critical contacts with a fluid. Flow is not disturbed.
- Hot or corrosive fluids can be measured without problems.
- The nano spectral width of the laser light makes accurate measurement possible.

It is possible to measure the flow velocity ranging from cm/s to 100s of m/s.

- Speed of response is high.
- Makes it possible to perform measurements related to transient conditions and to investigate turbulent flow characteristics

Disadvantages

These require the necessity of having scattering entrained in the fluid. Impossible to measure flow rate of very cleaned fluid.

Additional cost is encountered because of the introduction of scattering centers in case very clean fluids.

It is possible to seed the flow with scattering particles. But the constraint is that particles seeded into the flow must be very small so as to follow the flow faithfully.

4.6 LASER MELTING

Due to rise in temperature, there is local melting. In case of surface mobification, the surface is locally melted and cooled with or without additions of alloying/ hardening materials. For welding, the surfaces to be welded are locally melted and bonded together. In case of cutting and drilling, there is vapourisation after local melting and a hole is formed.

The two methods of melting are:

i. Conduction limited melting/ Melting by low power laser.

ii. Deep penetration melting or key hole melting.

CONDUCTION LIMITED MELTING:

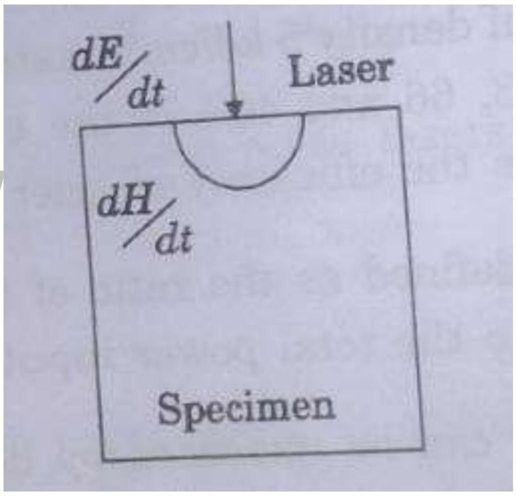

Figure 4.6.1 Conduction Limited Melting

[Source: "Optical Fibre Communications" by J.M.Senior, Page:541]

Here the metal absorbs the incident beam on the surface and heat is conducted through the metal to the sub-surface region. In this melting, the shape of the melted region in the form of hemispherical.

Low power lasers are used in this method. So depth of penetration is limited. The main application for this type of melting is for surface treatments and welding and cutting of thin specimens. The weld shape is hemispherical due to uniform thermal conduction in all direction.

KEY HOLE MELTING

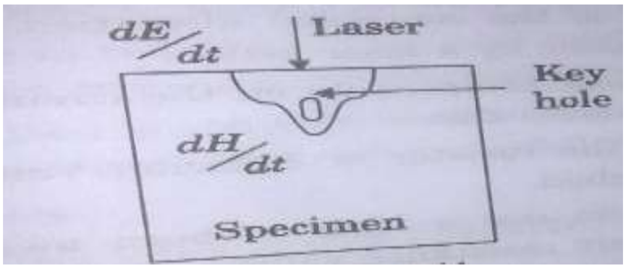

Figure 4.6.2 Key Hole Melting

[Source: "Optical Fibre Communications" by J.M.Senior, Page:542]

In this mode of melting high power lasers are used. The incident laser beam melts the small cylindrical volume of metal through the thickness of material. A column of vapour is trapped inside this volume surrounded by molten metal. As the beam is moved, the vapour column moves along with that, melting the metal in front of the column through the depth. The molten metal flows along the base of the column and solidifies on the trailing end. The molten metal present in the walls of the cylindrical column of vapour is held firmly by the equilibrium between high vapour pressure of vapour and the surface tension of the molten metal.

The appearance of hole is in the form of key hole surrounded by molten metal then solidified metal. This provides greater path penetration due to high absorption of vapour column. Here the shape of the melted region is in the form of key hole.

4.7 TRIMMING OF MATERIAL

It is a term used for describing the manufacturing process of using a laser to adjust the operating parameters of an electronic circuit

Process of Laser Trimming

Laser trimming is the controlled alteration of the attributes of a capacitor or a resistor by a laser action. Selecting one or more components on the circuit and adjusting them with the laser .The trim changes the resistor or capacitor value until the nominal value has been reached. Usually laser is used to burn away small [portions of resistor, raising the resistance value. The burning operation can be conducted while the circuit is being tested by automatic test equipment, leading to extremely accurate final values for trimming of resistors. The resistance value of a film resistor is defined by its geometric dimensions as well as the resistor material. A lateral cut in the resistor material by the laser narrows the current flow path and increases the resistance value. The same effect is obtained whether the laser changes a thick film or a thin film resistor on a ceramic substrate.

Types of Trim:

Passive Trim:

It is the adjustment of a resistor to a given value

Active Trim

If the trimming adjusts the whole circuit output is called active trim. During the trim process, the corresponding parameter is measured continuously and compared to the programmed nominal value. The laser stops automatically when the value reaches the nominal value.

Construction and Working:

The resistor to be trimmed is kept inside a [pressurized chamber below the surface of the tempered pressure glass. The laser beam is made to fall on the resistor arrangement and the change of value continuously monitored. After perfect arrival of nominal value, the next resistor arrangement is put into the experimental set up.

Advantages:

- Better cleanliness when compared to conventional method of abrasive trimming. Better control of final resistance. Result in a higher yield the larger fraction of the resistor are obtained within the prescribed tolerance

4.5 MATERIAL PROCESSING

LASER INSTRUMENTATION FOR MATERIAL PROCESSING

The output from the laser beam is incident on the plane mirror. After refelection, it passes through a shutter to control its intensity. A focusing lens assembly is used to get affine beam.

Shielding gas jet:

To remove the molten material and to favour vaporization and also to provide cooling effect. It also protect the focusing optical arrangement against smoke and fumes and to increase the absorption of energy by the sample. During cutting of readily inflammable glass material like ceramics, wood and paper, nitrogen gas is used. This will increase the cutting rate by blowing the molten material out of the hole produced by laser energy further it reduces firing and fire accident. Oxygen gas is mainly used for brittle materials and metals.

Powder Feeder:

Used to spray metal powder on the substrate for alloying or cladding.

Laser Heating:

When the laser beam is incident on the surface of the specimen, there is simultaneous absorption and reflection. Particularly, metals are good reflectors of light. Thus most of the incident energy is wasted in the form of reflected energy. To reduce reflection, antireflection coating are made on the surface so as to increase the absorption energy. Absorptivity increases with increase of laser beam densities and the temperature. Absorptivity is directly proportional to the square root of resistivity of the specimen and it decreases with increase in wave length. Rate of absorption is more in vapour phase than in liquid and solid phase. The absorbed energy creates lattice vibration and heating of materials.

LASER WELDING

Types of welding

i. continuous/seam welding- done by continuous wave beams or overlapping pulses
ii. Pulse/spot welding- done by Micro-welding.

WORKING:

- High power laser radiation incident on metal gives rise to the following process Electron and ion emission due to heating effects.
- Melting , vaporization and ejection of droplets of melt from the interative region. Thermal radiation and X-radiation upto 2 KeV. Ultrasonic vibrations in metal due to the periodicity of heating and thermal expansion in the interaction of pulses whose substructure consists of spikes. Part of the energy of incident radiation is reflected from the target surface itself without contributing to the work process.

ADVANTAGES

- High input to the welding spot by the focused beam of high power density. Low heat release in welding elements.
- High weld rates.
- Possibility of welding dissimilar metals difficult to weld by other techniques.

STEPS TO BE FOLLOWED

- Select the proper type of laser.
- Design the weld joint of adequate configuration.
- Estimate the optimal pattern of the beam and the beam parameters depending on the materials of joint elements, their thickness and limitations and heating temperature Design the experiment so as to make the most of laser welding practice.

- The choice of the type of the laser depend on the total laser power required, power loss due to reflection from the surface of pieces to be welded, weld efficiency and other factors.

4.8 MATERIAL REMOVAL AND VAPORIZATION:

Material processing refers to a variety of industrial operation in which the laser operation in which the laser operates on a work piece to modify it. Some of the possible applications include welding, hole drilling, cutting, trimming of electronic components, heating and alloying. Properties of laser light that enables material processing applications are its collimation, radiance and focus ability. Because of these properties, laser light can be concentrated by a lens to achieve extremely high irradiance at the surface of a work space.

PROCESS OF MATERIAL REMOVAL:

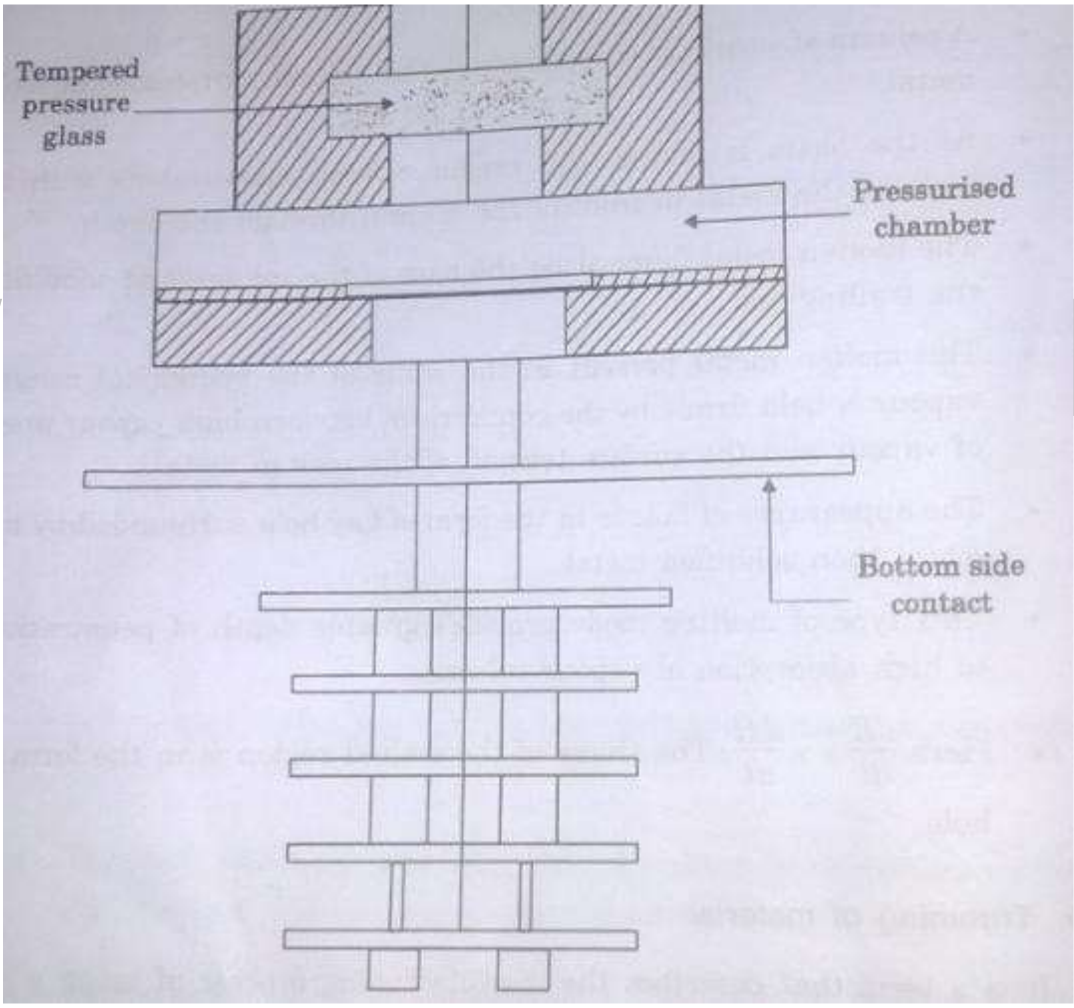

Figure 4.8.1 Material Removal Process

[Source: "Optical Fibre Communications" by J.M.Senior, Page:552]

When laser radiation strikes a target surface, part of it is absorbed and part is reflected. The energy that is absorbed begins to heat the surface then penetrates into the target by thermal conduction. When the surface reaches the melting temperature, a liquid interface propagates into the material. With continued irradiation, the material begins to vaporize. If the irradiance is high enough, absorption in the blow off material leads to a hot opaque plasma. The plasma can grow back towards the laser as an LSA (Laser supported Absorption) wave.