2.8 CLASSIFICATION OF OPTICAL MODULATORS

According to the properties of the material that are used to modulate the light beam, modulators are divided into two groups: absorptive modulators and refractive modulators. In absorptive modulators absorption coefficient of the material is changed, in refractive modulators refractive index of the material is changed.

The absorption coefficient of the material in the modulator can be manipulated by the Franz- Keldysh effect, the Quantum-confined Stark effect, excitonic absorption, changes of Fermi level, or changes of free carrier concentration. Usually, if several such effects appear together, the modulator is called an electro-absorptive modulator.

Refractive modulators most often make use of an electro-optic effect. Some modulators utilize an acousto-optic effect or magneto-optic effect or take advantage of polarization changes in liquid crystals. The refractive modulators are named by the respective effect: i.e. electrooptic modulators, acousto-optic modulators etc. The effect of a refractive modulator of any of the types mentioned above is to change the phase of a light beam. The phase modulation can be converted into amplitude modulation using an interferometer or directional coupler.

Separate case of modulators are spatial light modulators (SLMs). The role of SLM is modification two dimensional distribution of amplitude and/or phase of an optical wave.

Electro Optic Modulator (EOM)

It is an optical device in which a signal-controlled element exhibiting the electro-optic effect is used to modulate a beam of light. The modulation may be imposed on the phase, frequency, amplitude, or polarization of the beam. Modulation bandwidths extending into the gigahertz range are possible with the use of laser-controlled modulators.

The electro-optic effect is the change in the refractive index of a material resulting from the application of a DC or low-frequency electric field. This is caused by forces that distort the position, orientation, or shape of the molecules constituting the material. Generally, a nonlinear optical material (organic polymers have the fastest response rates, and thus are best for this application) with an incident static or low frequency optical field will see a modulation of its refractive index.

The simplest kind of EOM consists of a crystal, such as lithium niobate, whose refractive index is a function of the strength of the local electric field. That means that if lithium niobate is exposed to an electric field, light will travel more slowly through it.

But the phase of the light leaving the crystal is directly proportional to the length of time it takes that light to pass through it. Therefore, the phase of the laser light exiting an EOM can be controlled by changing the electric field in the crystal.

Note that the electric field can be created by placing a parallel plate capacitor across the crystal. Since the field inside a parallel plate capacitor depends linearly on the potential, the index of refraction depends linearly on the field (for crystals where Pockels effect dominates), and the phase depends linearly on the index of refraction, the phase modulation must depend linearly on the potential applied to the EOM.

The voltage required for inducing a phase change of π is called the half-wave voltage (V_π). For a Pockels cell, it is usually hundreds or even thousands of volts, so that a high-voltage amplifier is required. Suitable electronic circuits can switch such large voltages within a few nanoseconds, allowing the use of EOMs as fast optical switches.

Pockels effect

The Pockels effect electro-optic effect, produces birefringence in an optical medium induced by a constant or varying electric field. It is distinguished from the Kerr effect by the fact that the birefringence is proportional to the electric field, whereas in the Kerr effect it is quadratic to the field. The Pockels effect occurs only in crystals that lack inversion symmetry, such as lithium niobate or gallium arsenide and in other non-Centro symmetric media such as electric-field poled polymers or glasses.

Pockels Cells

Pockels Cells are voltage-controlled wave plates. The Pockels effect is the basis of Pockels Cells operation. Pockels Cells may be used to rotate the polarization of a passing beam. See Applications below for uses.

A transverse Pockels Cell comprises two crystals in opposite orientation, which give a zero order wave plate when voltage is turned off. This is often not perfect and drifts with temperature. But the mechanical alignment of the crystal axis is not so critical and is often done by hand without screws; while misalignment leads to some energy in the wrong ray (for example, horizontal or vertical), in contrast to the longitudinal case, the loss is not amplified through the length of the crystal.

The electric field can be applied to the crystal medium either longitudinally or transversely to the light beam. Longitudinal Pockels Cells need transparent or ring electrodes. Transverse voltage requirements can be reduced by lengthening the crystal. Alignment of the crystal axis with the ray axis is critical. Misalignment leads to birefringence and to a large phase shift across the long crystal. This leads to polarization rotation if the alignment is not exactly parallel or perpendicular to the polarization.

Dynamics within the cell

Because of the high relative dielectric constant of $\varepsilon_r \approx 36$ inside the crystal, changes in the electric field propagate at a speed of only $c/6$. Fast non-fiber optic cells are thus embedded into a matched transmission line. Putting it at the end of a transmission line leads to reflections and doubled switching time. The signal from the driver is split into parallel lines which lead to both ends of the crystal. When they meet in the crystal their voltages add up. Pockels Cells for fibre optics may employ a traveling wave design to reduce current requirements and increase speed.

Usable crystals also exhibit the piezoelectric effect to some degree (RTP has the lowest, BBO and lithium niobate are high). After a voltage change sound waves start propagating from the sides of the crystal to the middle. This is important not for pulse pickers, but for boxcar windows. Guard space between the light and the faces of the crystals needs to be larger for longer holding times. Behind the sound wave the crystal stays deformed in the equilibrium position for the high electric field. This increases the polarization. Due to the growing of the polarized volume the electric field in the crystal in front of the wave increases linearly, or the driver has to provide a constant current leakage.

The driver electronics

The driver must withstand the doubled voltage returned to it. Pockels Cells behave like a capacitor. When switching these to high voltage a high charge is needed; consequently, 3 ns switching requires about 40 A for a 5 mm aperture. Shorter cables reduce the amount of charge wasted in transporting current to the cell.

The driver may employ many transistors connected parallel and serial. The transistors are floating, and need DC isolation for their gates. To do this, the gate signal is connected via optical fiber, or the gates are driven by a large transformer. In this case, careful compensation for feedback is needed to prevent oscillation.

The driver may employ a cascade of transistors and a triode. In a classic, commercial circuit the last transistor is an IRF830 MOSFET and the triode is an Eimac Y690 triode. The setup with a single triode has the lowest capacity; this even justifies turning off the cell by applying the double voltage. A resistor ensures the leakage current needed by the crystal and later to recharge the storage capacitor. The Y690 switches up to 10 kV and the cathode delivers 40 A if the grid is on +400 V. In this case the grid current is 8 A and the input impedance is thus 50 ohms, which matches standard coaxial cables, and the MOSFET can thus be placed remotely. Some of the 50 ohms are spent on an additional resistor which pulls the bias on -100 V. The IRF can switch 500 volts. It can deliver 18 A pulsed. Its leads function as an inductance, a storage capacitor is employed, the 50 ohm coax cable is connected, the MOSFET has an internal resistance, and in the end this is a critically damped RLC circuit, which is fired by a pulse to the gate of the MOSFET.

The gate needs 5 V pulses (range: +-20 V) while provided with 22 nC. Thus the current gain of this transistor is one for 3 ns switching, but it still has voltage gain. Thus it could theoretically also be used in common gate configuration and not in common source configuration. Transistors, which switch 40 V are typically faster, so in the previous stage a current gain is possible.

Applications of Pockels Cells

Pockels Cells are used in a variety of scientific and technical applications:

- A Pockels Cell, combined with a polarizer, can be used for a variety of applications. Switching between no optical rotation and 90° rotation creates a fast shutter capable of "opening" and "closing" in nanoseconds. The same technique can be used to impress information on the beam by modulating the rotation between 0° and 90°; the exiting beam's intensity, when viewed through the polarizer, contains an amplitude- modulated signal.
- Preventing the feedback of a lasercavity by using a polarizing prism. This prevents optical amplification by directing light of a certain polarization out of the cavity. Because of this, the gain medium is pumped to a highly excited state. When the medium has become saturated by energy, the Pockels Cell is switched, and the intracavity light is allowed to exit. This creates a very fast, high intensity pulse. Q-switching, chirped pulse amplification, and cavity dumping use this technique.

Pockels Cells can be used for quantum key distribution by polarizingphotons.

Pockels Cells in conjunction with other EO elements can be combined to form electro-optic probes.

- A Pockels Cell was used by MCA Disco-Vision (DiscoVision) engineers in the optical videodisc mastering system. Light from an argon-ion laser was passed through the Pockels Cell to create pulse modulations corresponding to the original FM video and audio signals to be recorded on the master videodisc. MCA used the Pockels Cell in videodisc mastering until the sale to Pioneer Electronics. To increase the quality of the recordings, MCA patented a Pockels Cell stabilizer that reduced the second harmonic distortion that could be created by the Pockels Cell during mastering. MCA used either a DRAW (Direct Read After Write) mastering system or a photoresist system. The DRAW system was originally preferred, since it didn't require clean room conditions during disc recording, and allowed instant quality checking during mastering. The original single-sided test pressings from 1976/77 were mastered with the DRAW system as were the "educational", non-feature titles at the format's release in December 1978.

Interferometry

- Interferometry is a family of techniques in which waves, usually electromagnetic, are superimposed in order to extract information about the waves.[1] Interferometry is an important investigative technique in the fields of astronomy, fiber optics, engineering metrology, optical metrology, oceanography, seismology, spectroscopy (and its applications to chemistry), quantum mechanics, nuclear and particle physics, plasma physics, remote sensing, biomolecular interactions, surface profiling, microfluidics, mechanical stress/strain measurement, and velocimetry
- Interferometers are widely used in science and industry for the measurement of small displacements, refractive index changes and surface irregularities. In analytical science, interferometers are used in continuous wave Fourier transform spectroscopy to analyze light containing features of absorption or emission associated with a substance or mixture. An astronomical interferometer consists of two or more separate telescopes that combine their signals, offering a resolution equivalent to that of a telescope of diameter equal to the largest separation between its individual elements.

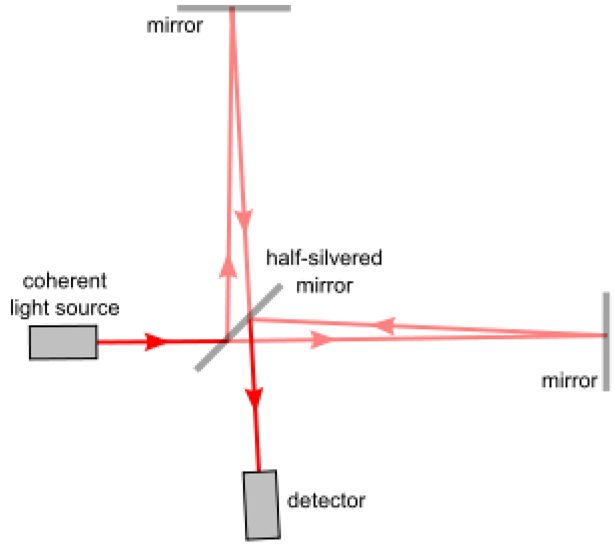

Figure 2.8.1 Interferometry

[Source: "Optical Fibre Communications" by J.M.Senior, Page:251]

- The light path through a Michelson interferometer. The two light rays with a common source combine at the half-silvered mirror to reach the detector. They may either interfere constructively (strengthening in intensity) if their light waves arrive in phase, or interfere destructively (weakening in intensity) if they arrive out of phase, depending on the exact distances between the three mirrors.
- Interferometry makes use of the principle of superposition to combine waves in a way that will cause the result of their combination to have some meaningful property that is diagnostic of the original state of the waves. This works because when two waves with the same frequency combine, the resulting pattern is determined by the phase difference between the two waves—waves that are in phase will undergo constructive interference while waves that are out of phase will undergo destructive interference. Most interferometers use light or some other form of electromagnetic wave.

2.7 END REFLECTION METHOD:

The light from the lambertian source is focused onto the entrance end of the fiber having a length 2 metre. The magnified image of the output end of the fiber is obtained by a lens arrangement and is then passed through chopper. The near field of the output of the chopper is scanned transversly by a p-i-n detector. The detector output is amplified by a preamplifier. The chopper and the preamplifier are linked with the lock in amplifier. So the phase sensitive detected signal is further amplified and plotted directly on a X-Y recorder. For a graded index fiber, the display appears in the form of a Gaussian curve and for a step index fiber it appears in the form of a rectangular shape curve.

Limitation of this method

1. There should not be any contamination on the fiber surface
2. The fiber surface should be optically plane.
3. During scanning proper alignment of the fiber is necessary.

NEAR FIELD SCANNING TECHNIQUES:

When a lambertian source like tungsten filament lamp or LED is used to excite all the guided modes then P® is the near field optical power at a distance'r'from the core axis and p(0) is the optical power at the centre of the core.

Measurement of numerical aperture of the fiber:

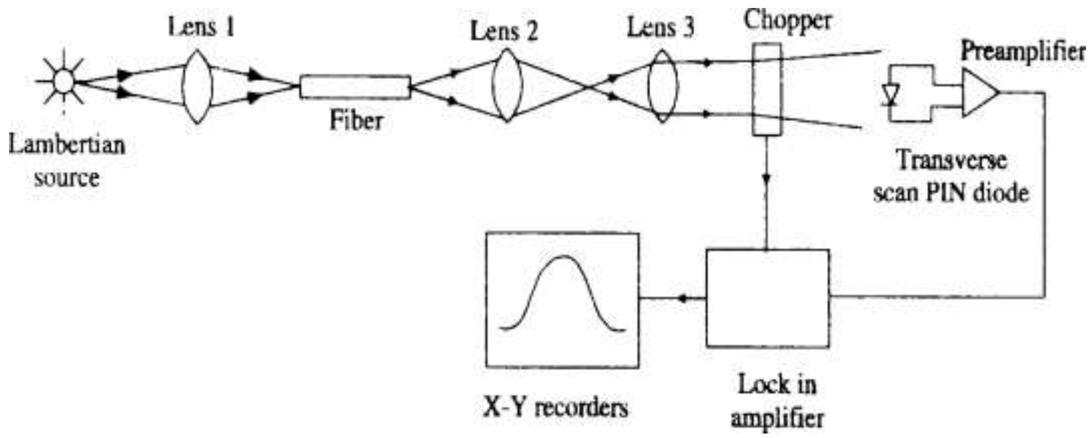

Figure 2.7.1 Numerical Aperture of the Fibre

[Source: "Optical Fibre Communications" by J.M.Senior, Page:251]

The lambertianthe numerical aperture of the fiber from the far end pattern. The lambertian source gives the angled visible light. It is then focused onto the test fiber of length 1m. The far field patteren from the fiber is displaced on the screen which is at a distance ‘D’ from the output end of the fiber. The test fiber is aligned so that there is maximum intensity of light on the screen. The pattern size on the screen is measured as Ametre.

For a graded index fiber

$$N.A(r)=\sin\theta a\ (r) = (n_1^2\ (r)-n_2^2)^{1/2}$$

2.3 EXTRINSIC SENSORS

Extrinsic fiber optic sensors use an optical fiber cable, normally a multimode one, to transmit modulated light from either a non-fiber optical sensor, or an electronic sensor connected to an optical transmitter. A major benefit of extrinsic sensors is their ability to reach places which are otherwise inaccessible. An example is the measurement of temperature inside air craft jet engines by using a fiber to transmit radiation into a radiation pyrometer located outside the engine. Extrinsic sensors can also be used in the same way to measure the internal temperature of electrical transformers, where the extreme electromagnetic fields present make other measurement techniques impossible.

Extrinsic fiber optic sensors provide excellent protection of measurement signals against noise corruption. Unfortunately, many conventional sensors produce electrical output which must be converted into an optical signal for use with fiber. For example, in the case of a platinum resistance thermometer, the temperature changes are translated into resistance changes. The PRT must therefore have an electrical power supply. The modulated voltage level at the output of the PRT can then be injected into the optical fiber via the usual type of transmitter. This complicates the measurement process and means that low-voltage power cables must be routed to the transducer.

Extrinsic sensors are used to measure vibration, rotation, displacement, velocity, acceleration, torque, and twisting.

Phase Modulated Fiber Optic Sensors:

The most sensitive fiber optic sensing method is based on the optical phase modulation. The total phase of the light along an optical fiber depends on the properties like the physical length of the fiber, transverse geometrical dimension of the guide, refractive index and the index profile of the waveguide. If we assume that index profile remains constant with environmental variations, then the depth of phase modulation depends on the other remaining parameters. The total physical length of an optical fiber may be modulated by the perturbations like thermal expansion, application of longitudinal strain and application of a hydrostatic pressure causing expansion via Poisson's ratio. The refractive index varies with temperature, pressure and longitudinal strain via photo elastic effect. Waveguide dimensions vary with radial strain in a pressure field, longitudinal strain in a pressure field and by thermal expansion. The phase change occurring in an optical fiber is detected using optical fiber Inter ferometric techniques that convert phase modulation into intensity modulation's:".

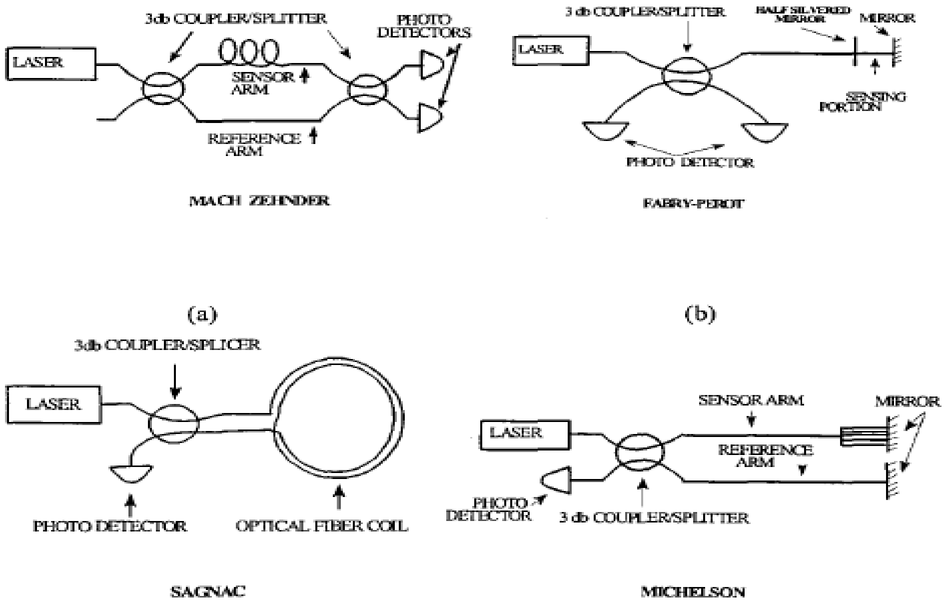

Figure 2.3.1 Phase Modulated Fibre Optic Sensor

[Source: "Optical Fibre Communications" by J.M.Senior, Page:242]

Displacement sensor (Extrinsic Sensor) Principle:

Light is sent through a transmitting fiber and is made to fall on a moving target. The reflected light from the target is sensed by a detector with respect to intensity of light reflected and the displacement of the target is measured.

Description:

- It consists of a bundle of transmitting fibers coupled to the laser source and a bundle of receiving fibers coupled to the detector.
- The axis of the transmitting fiber and the receiving fiber with respect to the moving target can be adjusted to increase the sensitivity of the sensor.

Working:

Light from the source is transmitted through the transmitting fiber and is made to fall on the moving target. The light reflected from the target is made to pass through the receiving fiber and the same is detected by the detector.

Based on the intensity of light received, the displacement of the target can be measured, (i.e.) If the received intensity is more, then we can say that the target is moving towards the sensor and if the intensity is less, we can say that the target is moving away from the sensor.

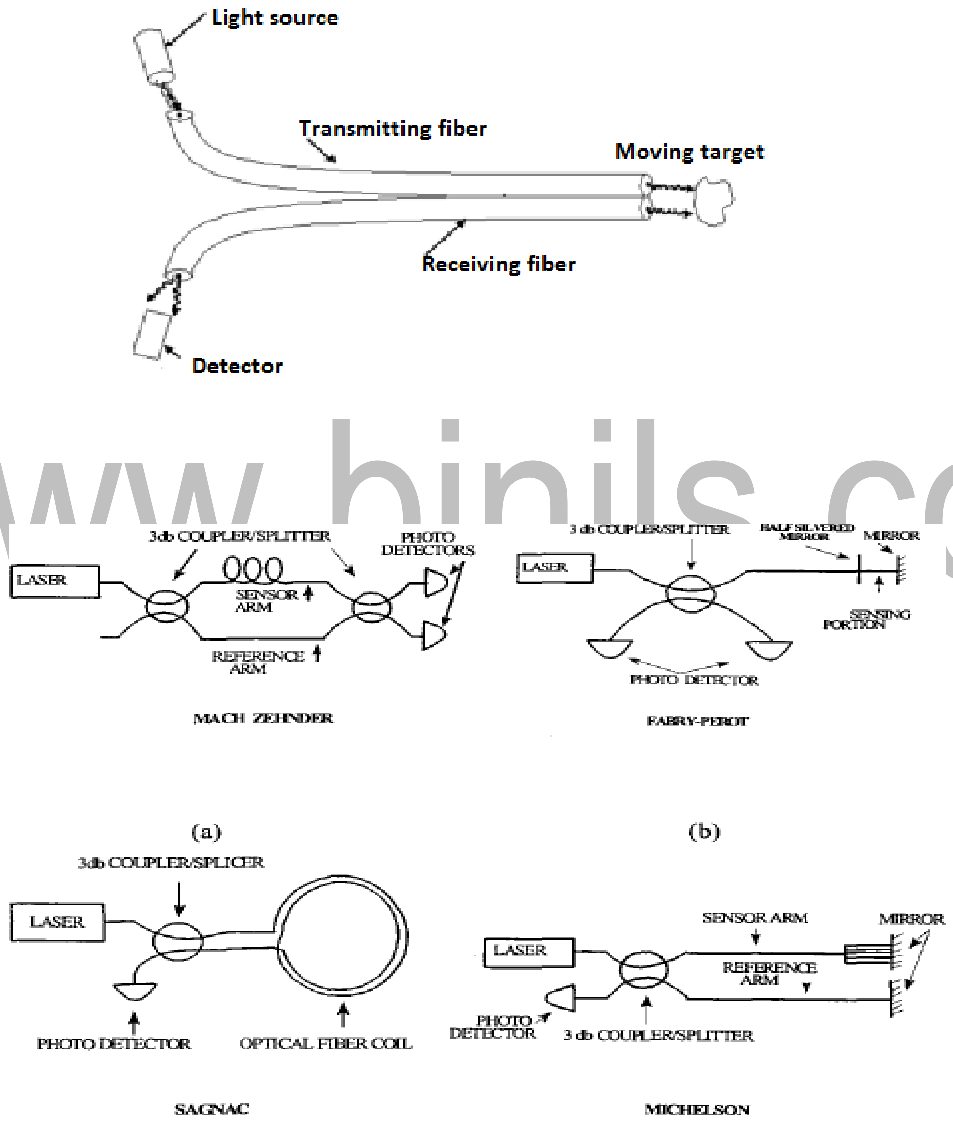

Figure 2.3.2 Displacement Sensor

[Source: "Optical Fibre Communications" by J.M.Senior, Page:242]

2.6 FIBER SCATTERING LOSS MEASUREMENT:

Usually a high power laser source like He-Ne laser or Nd-YAG laser is used to provide sufficient input optical power to the fiber. The focusing lens focuses the light into the input end of the fiber having short length. Before and after the scattering cell or integrating sphere, the cladding mode strippers are used to avoid the light propagating in the cladding so that the scattering measurement is taken only for the light guided by the fiber core. Further the output end of the fiber is in index matched liquid to avoid reflections contributing to the optical signal within the integrating sphere. The light scattered from the fiber core is detected by the series solar cell in the integrating sphere. The integrating sphere also contains the index matching liquid surrounding the fiber. The detected signal by the series of solar cell gives the measurement of the scattered signal. The detected signal is given to lock in amplifier an to then to the recorder or nano voltmeter**.**

FIBER ABSORPTION MEASUREMENT:

Fiber absorption measurement will give the impurity level in the filter.

Fiber absorption loss(bB/km)= Fiber attenuation loss (dB/Km)- Fiber scattering loss(dB/km), Thus the fiber absorption lass istrhe difference between fiber attenuation loss and scattering loss.

Principle: Amount of light energy absorbed by the fiber= Heat energy developed in the calorimeter.

Construction:

Here there are two fibers one is the fiber under measurement and other is the dummy fiber. The dummy fiber is meant for compensation of any radiation loss of heat energy developed. These two fibers are mounted separately in silica capillary tubes surrounded by the low refractive index liquid like methanol in the calorimeter for good electrical contact. The light from the laser source is well focused on the fiber under measurement.

The dummy fiber is not connected with light input. Then the fiber guided light is inserted into the cladding mode stripper which removes the light propagated in the cladding of the fiber. After passing through the capillary tube, the fiber with light is immersed in the index matching liquid to avoid reflections contributing to the optical signal within the capillary tube.

Procedure;

When the light enters the fiber under measurement there is a temperature rise in the capillary tube containing the fiber with light. The temperature rise due to absorption tube containing the fiber with light. The temperature rise due to absorption of energy by the fiber is measured for every 10 seconds by a thermocouple which is spirally around the silics tubes. The hot junction of the thermocouple and the cold junction of the thermocouple are connected with a nano voltmeter. Electrical calibration is done by placing a thin wire instead of fiber such that and passing known amount of current such that

$$mST=I^2RT=VIt$$

Fiber dispersion measurements:

Dispersion is measured in terms of pulse broadening. There are two types of fiber dispersions. One is intermodal dispersion and the other is intra nodal (or) chromatic dispersion. Both dispersion measurements can be performed using the same except the light source. Internodal dispersion measurement is made by the monochromatic laser with narrow spectral width.

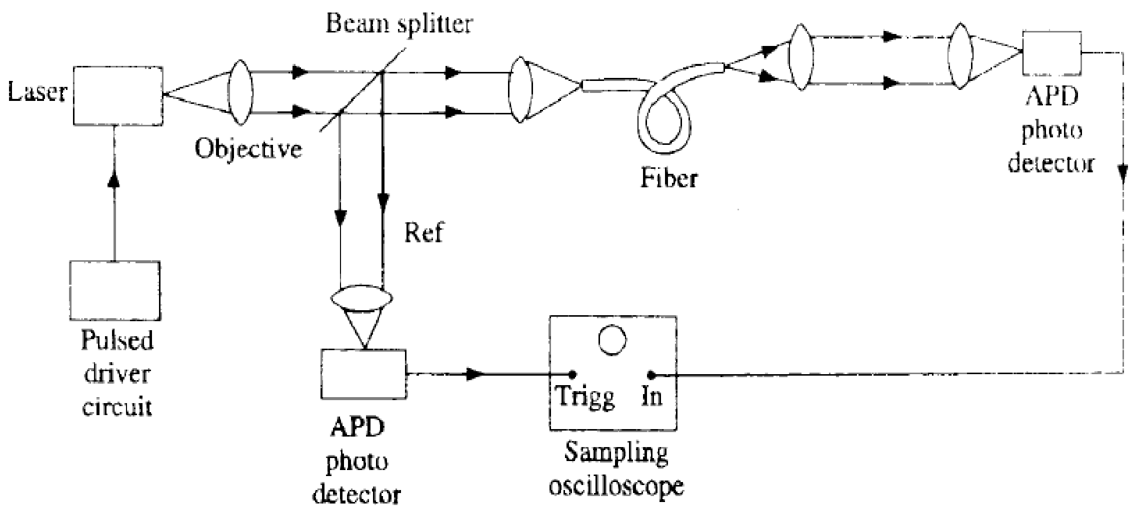

Figure 2.6.1 Fibre Dispersion Measurement

[Source: "Optical Fibre Communications" by J.M.Senior, Page:249]

This intermodal dispersion is dominant in the multimode fibers. The intra nodal dispersion measurement is made by the injection laser whose frequency or line width increases with respect to time.

The laser with driver circuit gives short narrow pulses of light. The laser light is focused onto the beam splitter. The beam splitter is used for triggering the oscilloscope and for input pulse with measurement. One of the beams passing through the beam splitter is again focused into the fiber under measurement. Normally its length is 1 km. The focused output laser beam is incident on the avalanche photodiode and it gives the output pulses. The input pulse and output pulse are displayed separately on the screen of sampling oscilloscope and they are in Gaussian shape.

2.4 FIBER OPTIC INSTRUMENTATION SYSTEM

Introduction

The communication engineers need the fiber characteristics to design the optical fiber link with an efficient waveguide without any loss or dispersion. Similarly, the fiber manufactures need the fiber characteristics for further development. Generally, the fiber attenuation measurement are used to determine repeaters spacing and light source power dispersion measurements are used to determine the maximum bit rate. Refractive index profile measurement are to know the number of modes propagating the fiber and to determine its numerical aperture.

Measurement of Attenuation (by cut back method)

Light from a halogen lamp or white light source is couple into the experimental fiber having length about 1 km. The lens placed in front of the source focuses the light on to the interference filter or monochromatic prism or grating. The light with a given wavelength is incident on the chopper which is used to convert d.c light into square pulses of light (a.c). It also sends the reference signal to the lock in amplifier. Monitor is used to view the intensity of the optical beams. The cladding mode strippers are connected at the input end and output end of fiber.

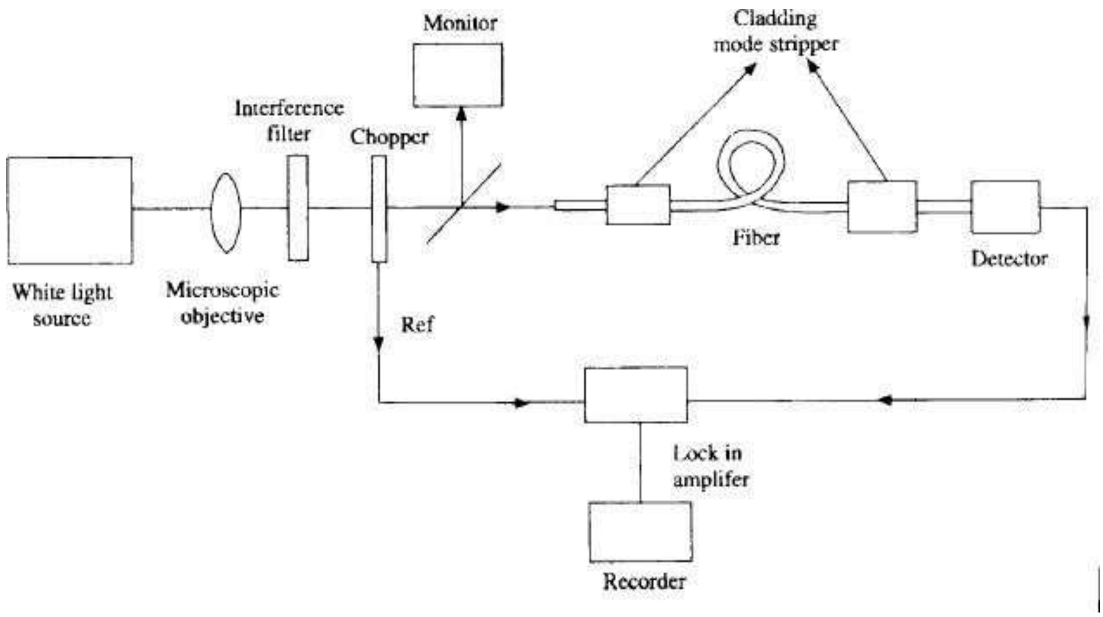

Figure 2.4.1 Measurement of Attenuation

[Source: "Optical Fibre Communications" by J.M.Senior, Page:246]

The cladding mode stripper is used to remove the cladding light or cladding modes. Then the jacket fiber is placed in an index matching liquid whose refractive index is slightly higher than that of cladding.

This arrangement is called cladding mode stripper which will attenuate the light propagating through the cladding. After travelling through the fiber of 1Km length, the given height reaches the index matched photodetector whose output is given to the lock amplifier. The lock amplifier delivers a output to the recorder or nanovoltmeter. Then the fiber is cut back, leaving typically 2m of the fiber and the experiment is repeated. In this case the output power is noted $P_r(\lambda)$ is noted. This procedure is repeated for other wavelength also. Thus the fiber attenuation at a given wavelength 'λ' is given by,

Where L is the length of the fiber cut back in Km. In the case of multimode fibers, there are mode scrambler used to get the uniform intensity distribution among all the modes and order sorting filter acting as a mode selector to determine the fiber loss for each mode.

Advantage:

This method is very accurate and simple.

Drawback

i) This method cannot be utilized to find the fiber attenuation in a working fiber optic link.

ii) It is a destructive testing method.

2.1 FIBER OPTIC SENSOR

Fiber optics for the commercial and industrial industries provide communication, data links, imaging, data collection, and application specific connectivity solutions in a wide range of capacities. The large majority of commercial & industrial applications in which fiber optic technology is used require each product to have specific construction and/or performance attributes to ensure adequate functionality.

While industry standard fiber optic products can be successfully implemented in some commercial & industrial applications, most standard products do not have the necessary durability and adverse condition performance capabilities necessary to support these applications.

Timber con fiber optic products for the commercial and industrial industries are designed and manufactured to provide the necessary performance, ruggedization, and durability to support even the most demanding applications. From precision tuned ruggedized polarization maintaining cable assemblies for sensors, to direct burial multi-fiber cables for oil field communications, we have a product solution to fit your requirements.

A fiber optic sensor is a sensor that uses optical fiber either as the sensing element or as a means of relaying signals from a remote sensor to the electronics that process the signals. Fibers have many uses in remote sensing. Depending on the application, fiber may be used because of its small size, or because no electrical power is needed at the remote location, or because many sensors can be multiplexed along the length of a fiber by using light wavelength shift for each sensor, or by sensing the time delay as light passes along the fiber through each sensor. Time delay can be determined using a device such as an optical time- domain reflectometer and wavelength shift can be calculated using an instrument implementing optical frequency domain reflectometry.

Fiber optic sensors are also immune to electromagnetic interference, and do not conduct electricity so they can be used in places where there is high voltage electricity or flammable material such as jet fuel. Fiber optic sensors can be designed to withstand high temperatures as well Fiber optic sensors are excellent candidates for monitoring environmental changes and they offer many advantages over conventional electronic sensors as listed below:

- Easy integration into a wide variety of structures, including composite materials, with little interference due to their small size and cylindrical geometry.
- Inability to conduct electric current.
- Immune to electromagnetic interference and radio frequency interference.
- Lightweight and Robust, more resistant to harsh environments.
- High sensitivity and Multiplexing capability to form sensing networks.
- Remote sensing capability.
- Multifunctional sensing capabilities such as strain, pressure, corrosion, temperature and acoustic signals.

Fiber Optic Sensor principles

The general structure of an optical fiber sensor system. It consists of an optical source (Laser,LED, Laser diode etc), optical fiber, sensing or modulator element (which transduces the measurand to an optical signal), an optical detector and processing electronics (oscilloscope, optical spectrum analyzer etc).

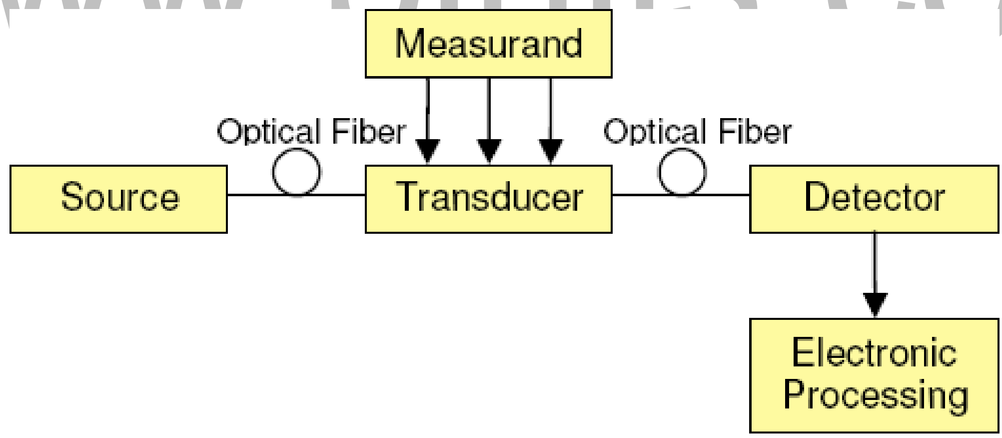

Figure 2.1.1 Fibre Optics Sensor

[Source: "Optical Fibre Communications" by J.M.Senior, Page:214]

Fiber optic sensors can be classified under three categories: The sensing location, the operating principle, and the application. Based on the sensing location, a fiber optic sensor can be classified as extrinsic or intrinsic. In an extrinsic fiber optic sensor the fiber is simply used to carry light to and from an external optical device where the sensing takes place. In this cases, the fiber just acts as a means of getting the light to the sensing location.

2.9 MEASUREMENT USING FIBER OPTICS SENSOR:

Measurement of Pressure:

All the displacement sensors can be used to measure pressure. Here the pressure is first converted in to displacement and the change in intensity is reflected or transmitted light is measured in terms of displacement. The pressure sensor based on reflective concept. Depending upon the value of pressure, the radius of curvature of the diaphragm is changed. Hence, the intensity of the reflected light is changed. The response curve shows that as the pressure increases, output voltage decreases. With increase of pressure, the intensity of reflected light is decreased and hence the output voltage decreases.

Measurement of Temperature:

The bimetallic strip acts as a sensing element. It consist of steel and brass which are welded together to form a strip. The brass has higher linear expansively compared to steel. The strip is attached to a bifurcated reflective fiber optic probe. The strip is designed to move continuously and its movement is directionally proportional to temperature. The amount of reflected light is converted in to voltage by a photodiode. The amount of light reflected decreases with increase of temperature. So that output of photodiode decreases with increase of temperature.

Phase modulated Temperature Sensor:

Here, the phase shift produced in the sensing relative to reference fiber is a function of temperature. This is given by the equation,

L fiber length

n refractive index

The arrangement is called mach-zender.

The Semiconductor laser acts as a light source.

A 3 db splitter acts as the beam splitter which sense the light through the sensing and reference fiber.

Another 3 dB coupler acts as a combiner of these two beams.

A series of light and dark fringes are formed when light form two fiber interface on the display screen.

A phase changes of 2φ radians causes a displacement of 1 fringe.

By counting the fringe displacement, The magnitude of temperature is determined.

- This is called Quadrature condition and sensitivity is zero when the phase shifts are π,2π,3π,4π etc.
- By taking the difference between the two output signals from the sensing fiber and reference fiber, Sensitivity of the sensor is doubled.

Measurement of Current:

The linearly polarized laser light from the negative laser is launched in to fiber. Cladding mode stripper removes cladding modes. The direction of polarization of the light in the fiber rotated by the longitudinal magnetic field around the current carrying conductor.

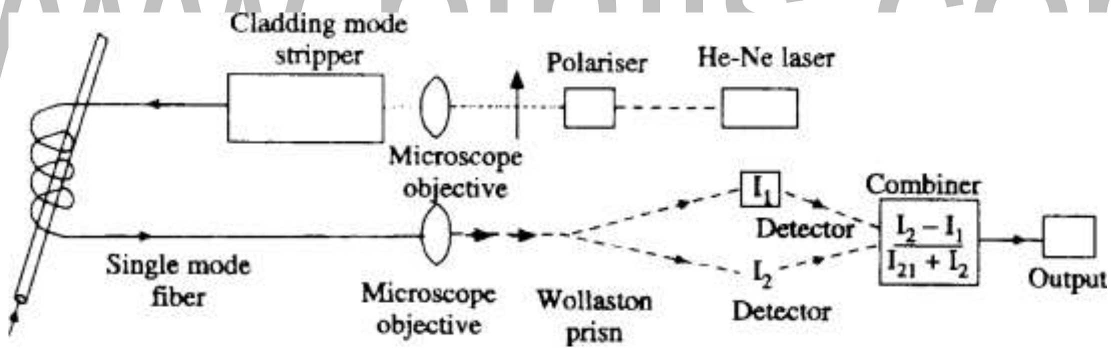

Figure 2.9.1 Measurement of Current

[Source: "Optical Fibre Communications" by J.M.Senior, Page:261]

- The returning light from the fiber loop is passed through the Wallaston prism which is used to sense the resulting rotation and it resolves the emerging light in to two orthogonal components I_1 and I_2. These components are separately detected by photodiode detectors and the difference and sum of these signals are found out.

Measurement of Voltage

The variation of refractive index with respect to electric field E is written as

$$n_o = + rE + RE^2$$

Where

n_o-refractiveindex before the application of electric field. r – Linear electro optic coefficient

R – Quadratic electrooptic coefficient

In this crystal, when we apply electric field/ voltage along Z axis, the light which is linearly polarized at an angle 45° with respect to X axis under goes a phase shift or phase retardation.

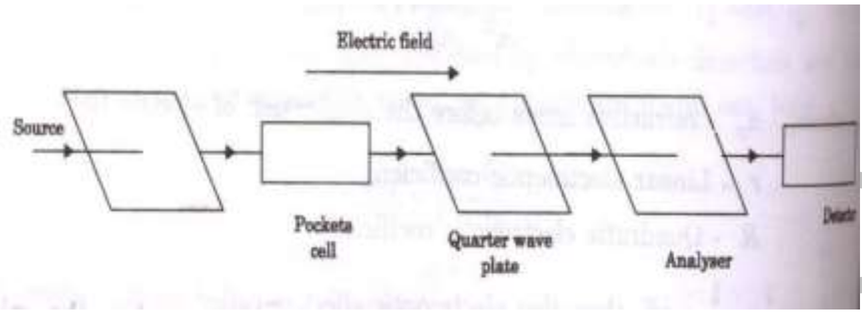

Figure 2.9.2 Interferometry

[Source: "Optical Fibre Communications" by J.M.Senior, Page:262]

If I_0 be the incident light intensity, then the intensity of the transmitted light through crystal is $I = I_0 \sin 2$. Thus, phase produced in the linearly polarized wave is directly proportional to applied electric field/ voltage. The polarizer converts the incident ordinary light in to a linearly polarized light. When there is applied voltage across the pocket cell, phase shift is produced for the transmitted polarized beam. Quarter wave plate produces a phase shift of θ/2. The transmitted light is then analysed through a analyzers.

Measurement of Strain:

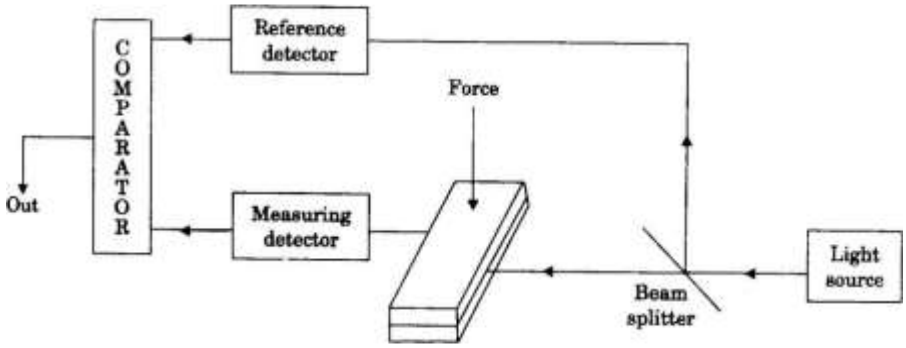

Figure 2.9.3 Measurement of Strain

[Source: "Optical Fibre Communications" by J.M.Senior, Page:263]

Micro bending losses are produced in the fiber when the top block presses the fiber by the applied external force. The micro bend losses are found to increase in force applied to the top block. The intensity changes produced by the applied force are measured with reference to a direct unmodulated signal from the light source. The comparator compares these two values and gives the value of strain produced.

Measurement of liquid level

Liquid level sensor consists of two fibers which are connected at the base of a glass micro prism. When the tip of the prism is immersed in the liquid, there is no output at the detector. When the tip of the prism is just above the liquid level, due to contact with air, there is total internal reflection and output is got in the detector.

Disadvantage:

Not useful for sensing multi liquid level since it operates in digital mode.

2.5 OPTICAL DOMAIN REFLECTOMETERS

The OTDR is the instrument which is used both in laboratory and field measurements for determining fiber attenuation, joint losses and detecting fault losses. When the fiber attenuation varies with distance, then the OTDR is the only instrument which can measure the fiber attenuation along the fiber optics link. The OTDR measurement is a non- destructive measurement.

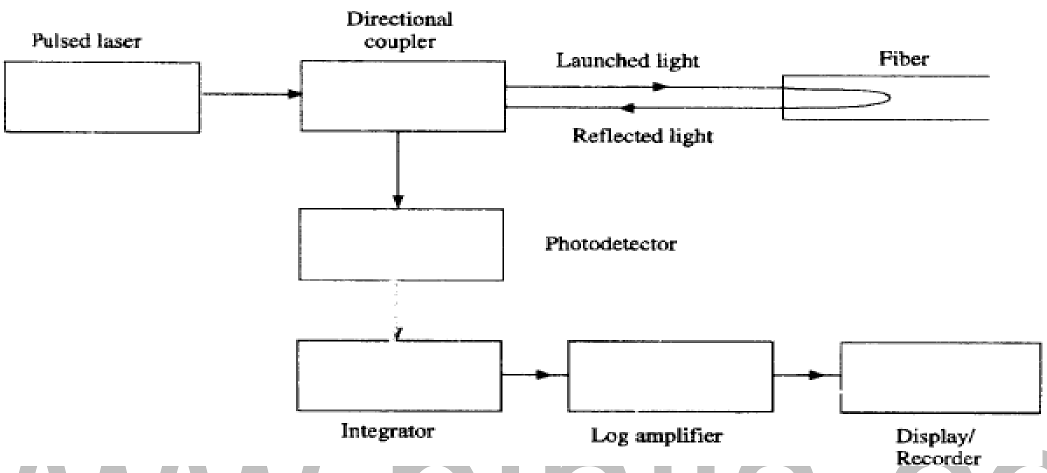

Figure 2.5.1 Block Diagram of Optical Domain Reflectometer

[Source: "Optical Fibre Communications" by J.M.Senior, Page:246]

Principle:

This method is often called the both scatter method. It is based on the measurement and analysis of the fraction of light which is reflected back within the numerical aperture of the fiber due to Rayleigh scattering.

Construction and working:

A light pulse from a pulsed laser is launched into the fiber through a directional coupler. The back scattered light from the fiber is received by a photo detector like APD, through the directional coupler. A box car integrator is mainly used to improve S/N ratio by taking arithmetic average over a number of measurements taken at one point within the fiber. The signal from the integrator is fed to the logarithmic amplifier and its output is given to the recorder in DB.

The recorder will display the averaged measurements for successive points

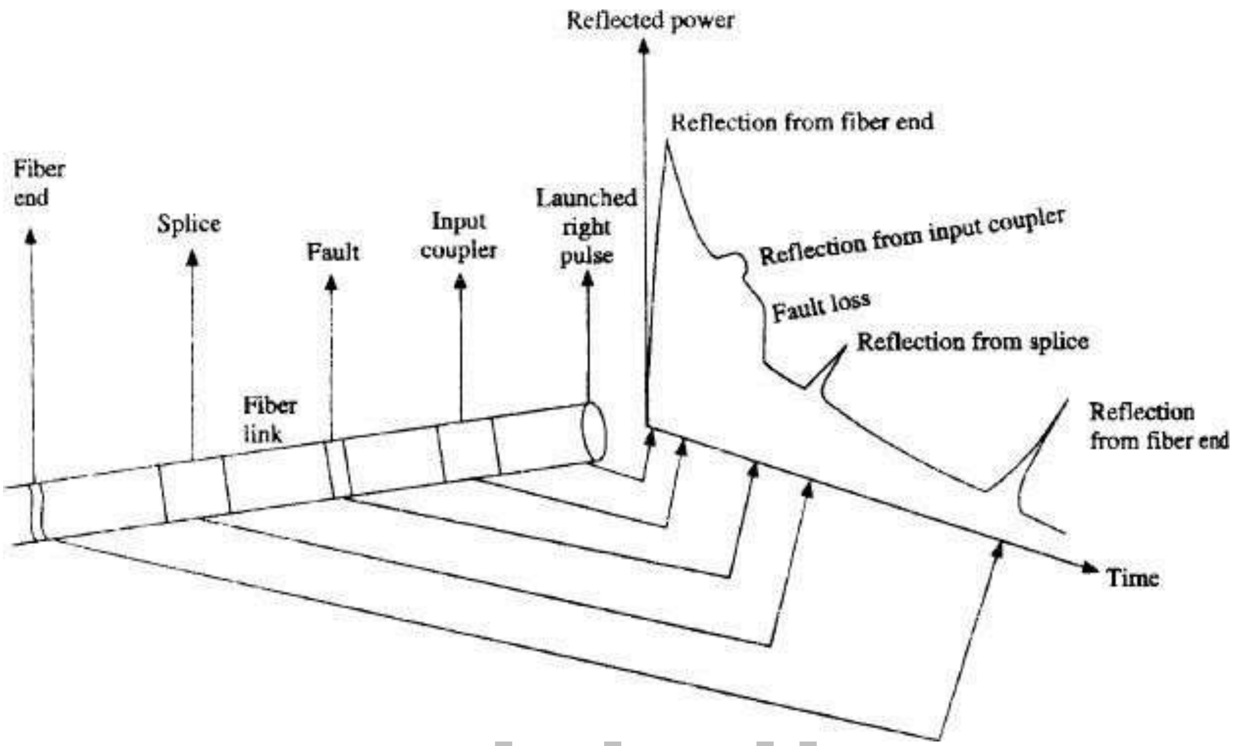

Figure 2.5.2 Optical Domain Reflectometer

[Source: "Optical Fibre Communications" by J.M.Senior, Page:246]

within the fiber. The initial peak is caused by the reflection at the fiber end. The reflection from the input coupler is as small increase in the reflected power. There is a long tail caused by Rayleigh scattering of the input pulse as it travels through the fiber link in the forward direction. Due to presence of a fault in the fiber link. There is a sudden decrease of reflected power. Next peak is caused by splice or joint. Finally there is a peak due to Fresnel reflection of the fiber end where the reflected power is more than that of splice.

2.2 TYPES OF FIBER OPTICS SENSOR

- Intrinsic sensor
- Extrinsic sensor

Optical fibers can be used as sensors to measure

- Strain,
- Temperature
- Pressure

Intrinsic sensor -Temperature/Pressure sensor Principle:

It is based on the principle of Interference between the beams emerging out from the reference fiber and the fiber kept in the measuring environment.

Working:

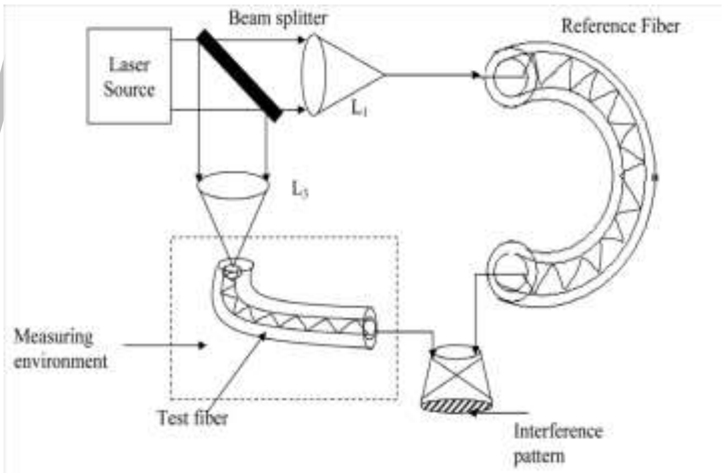

Figure 2.2.1 Fibre Optics Sensor

[Source: "Optical Fibre Communications" by J.M.Senior, Page:231]

- A monochromatic source of light is emitted from the laser source.
- It consists of a Laser source to emit light. A beam splitter, made of glass plate is inclined at an angle of 45° used to split the single beam into two beams.
- The main beam passes through the lens L1 and is focused onto the reference fiber which is isolated from the environment to be sensed.
- The beam after passing through the reference fiber then falls on the lens L2.

- The spitted beam passes through the lens L3 and is focused onto the test fiber kept inthe environment to be sensed.
- The splitted beam after passing through the test fiber is made to fall on the lens L2.
- The two beams after passing through the fibers, produces a path difference due to thechange in parameters such as pressure, temperature etc., in the environment.
- Therefore a path difference is produced between the two beams, causing the interference pattern.
- Thus the change in pressure (or) temperature can be accurately measured with the help of the interference pattern obtained.

And other quantities by modifying a fiber so that the quantity to be measured modulates the intensity, phase, polarization, wavelength or transit time of light in the fiber. Sensors that vary the intensity of light are the simplest, since only a simple source and detector are required. A particularly useful feature of intrinsic fiber optic sensors is that they can, if required, provide distributed sensing over very large distances.

Temperature can be measured by using a fiber that has evanescent loss that varies with temperature, or by analyzing the Raman scattering of the optical fiber. Electrical voltage can be sensed by nonlinear optical effects in specially-doped fiber, which alter the polarization of light as a function of voltage or electric field. Angle measurement sensors can be based on the Sagnac effect.

Special fibers like long-period fiber grating (LPG) optical fibers can be used for direction recognition. Photonics Research Group of Aston University in UK has some publications on vectorial bend sensor applications.

Optical fibers are used as hydrophones for seismic and sonar applications. Hydrophone systems with more than one hundred sensors per fiber cable have been developed. Hydrophone sensor systems are used by the oil industry as well as a few countries' navies.

Both bottom-mounted hydrophone arrays and towed streamer systems are in use. The German company Sennheiser developed a laser microphone for use with optical fibers.

A fiber optic microphone and fiber-optic based headphone are useful in areas with strong electrical or magnetic fields, such as communication amongst the team of people working ona patient inside a magnetic resonance imaging (MRI) machine during MRI-guided surgery.

Optical fiber sensors for temperature and pressure have been developed for down hole measurement in oil wells. The fiber optic sensor is well suited for this environment as it functions at temperatures too high for semiconductor sensors (distributed temperature sensing).

Optical fibers can be made into Interferometric sensors such as fiber optic gyroscopes, which are used in the Boeing 767 and in some car models (for navigation purposes). Theyare also used to make hydrogen sensors.

Fiber-optic sensors have been developed to measure co-located temperature and strain simultaneously with very high accuracy using fiber Bragg gratings. This is particularly useful when acquiring information from small complex structures. Brillouin scattering effects can be used to detect strain and temperature over larger distances (20–30 kilometers).