Radiation sensors

⇒ Radiation sensor is a device which convert incident radiation sig's into electrical output signals

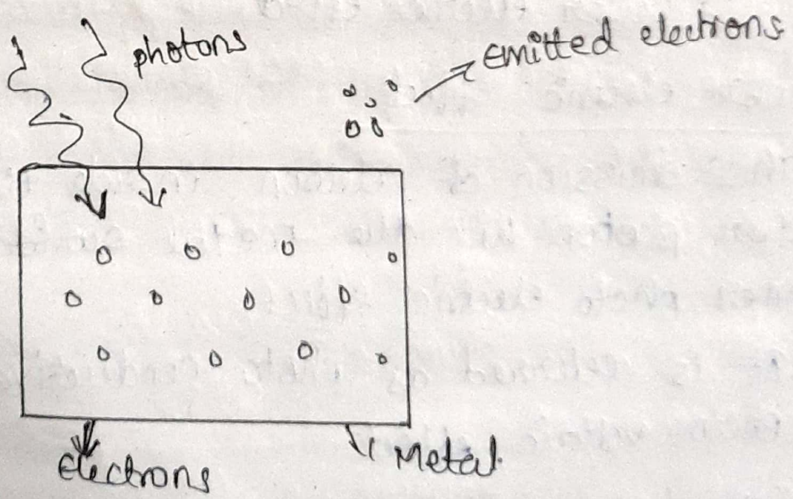
⇒ Ex:- Electromagnetic, neutrons, fast neutrons, electrons, & Heavy charged particles

Radiation sensor classification

⇒ There are mainly classified into three types

1. photo conductive cells
   Ex:- light
2. photo emf cells.
   Ex:- photovoltaic, barrier cells
3. photo electric cell.
   Ex:- photo emissive.

photoelectric effect Imp



⇒ when a light is incident on the matter or metal, the electrons gets excited.

⇒ they come back to ground state emitted electrons on the surface. The phenomenon is known as photo electric effect. Electrons that are emitted in this process is called photo electrons

⇒ Using plancks equation the energy of a photon can be expressed as

$$\boxed{E = h\nu}$$

let h = plancks constant $= 6.626 \times 10^{-34}$ J-sec

ν = frequency of radiation (Hz).

⇒ The photon energy is must be equal to the energy of the electron emitted from the atom & the energy required & release the electron from the metal.

$$E = KE$$

$$E = \frac{1}{2}mv^2$$

$$\Rightarrow h\nu = \frac{1}{2}mv^2$$

Types of photo electric effect

There are two types of PEE namely

1. Inner electric effect
2. outer electric effect

Inner electric effect

⇒ The emission of electron inside the material when photon hit the metal surface is Called Inner photo electric effect

⇒ It is referred as photo conductive effect (or) photo voltaic effect

outer photo electric effect

⇒ The emission of electron outside ~~from~~ the ~~metal surface~~ material when photon hit the metal surface is called outer photo electric effect.

⇒ It is referred as light sensitive resistors

Basic characteristics of Radiation Sensors (or) photo detectors

1. Working function
2. spectral sensitivity (or) spectral Threshold.
3. static & dynamic response.
4. Quantum yield & Quantum voltage.
5. static fatigue & dynamic fatigue.
6. Drift.
7. Time lag

1. Working function

⇒ It is define as minimum amount of energy required to emit an electron from a surface.

⇒ Mathematically it is expressed as

$$\boxed{\phi = \frac{E}{e}}$$

let E = photon energy
e = charge of electron

⇒ It is totally depends on the nature of the metal

⇒ Metallic elements with High atomic number has small working function. Hence they are used in fabrication

2. spectral sensitivity & spectral Threshold

⇒ spectral sensitivity is the relative efficiency of detection of light & wave length.

⇒ spectral sensitivity is expressed in microampere.

⇒ The condition for the electron to escape from the metal surface is given as $h\nu > \phi e$.

⇒ The above equation arise the velocity of the electron in photon energy is zero.

⇒ Threshold (or) critical frequency is the minimum frequency of the incident radiation to start the photo electric effect is expressed as.

$$\boxed{\nu_0 \geq \frac{\phi_e}{h}}$$

⇒ And threshold wavelength is expressed as.

$$\boxed{\lambda_0 \leq \frac{hc}{\phi_e}}$$

3. Static & dynamic response.

⇒ The ratio of the output to the input for Static illumination is called static response.

⇒ Mathematically it is expressed as.

$$\boxed{S_{st} = \frac{i_a}{\phi_l}}$$

let i_a = anode current
ϕ_l = light flux incident

⇒ The ratio of the ~~out~~ change in the output to the corresponding change in the input for dynamic illumination is called dynamic response

⇒ Mathematically it is expressed as.

$$S_{dynamic} = \frac{\partial i_a}{\partial \phi_l}.$$

$$\boxed{S_{dynamic} = \frac{\partial i_a}{\partial t} \Big/ \frac{\partial \phi_l}{\partial t}}$$

4. Time lag

⇒ It is defined as the time interval between the incidence of light on metals & emission of electrons

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S.NO	Photo sensitors	Time delay
1.	photo emissive cells	10^{-8} sec.
2.	Light sensitive resistors	5×10^{-2} sec.
3.	Gas filled photo cells	10^{-5} sec.

⇒ The time response characteristics of the photo sensitor can be obtained from the below relation

$$\boxed{y = y_0 (1 - e^{-at})}$$

let y_0 = constant.

5. Quantum yield of Quantum voltage

⇒ It is defined as the ratio of number of electrons emitted to the number of electrons (or) photons received.

$$Q_f \Rightarrow \frac{\text{no. of electrons emitted}}{\text{no. of electrons (or) photons received}}$$

⇒ Energy required to free an electron. is given as

$$\boxed{E_\lambda = \frac{1.2395}{\phi} \text{ (eV)}}$$

⇒ when the light strikes the metal surface with some energy. such it emits electrons photo electric effect, that time process is called obtain some voltage. is called as Quantum voltage

⇒ The maximum kinetic energy that an electron contain after emitting from the metal surface. is expressed as.

$$E_m = E_\lambda - \phi$$

$$\boxed{E_m = E_\lambda - \frac{hv}{e}}$$

⇒ Maximum kinetic energy, E_m provides the electron velocity for which the photo electron travels in the perpendicular direction. Therefore $E_m = 0$.

$$\boxed{E_\lambda = \frac{hv}{e}}$$

6. Static fatigue & dynamic fatigue (damage to the materials)

⇒ when a light strikes the metal surface with high energy, the detector response will not be correspondent with that of the input

⇒ It appears mostly photovoltaic cells.

⇒ when the light strikes the metal surface fluctuates over 100 Hz frequency, the detector response in many cases will be something than it supposed to be ~~LED~~

⇒ It is mostly appears in the LED

7. Drift

⇒ It is defined as the suddenly change in the response over a span period of time after that the cell exposed to radiation.

photo Resistors / photo detectors

There are of three types. They are.

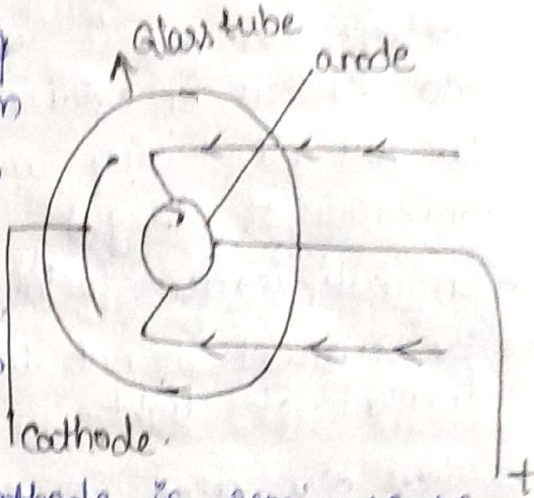
1. photo emissive cells
   - ⇒ Vaccum type photo emissive cells
   - ⇒ Gas filled photo emissive cells

2. photo multiplier

3. photo conductive cells

1. photo emissive cell.

→ photo emissive cells consisting glass tube filled with vaccum and a pair of electrodes such as cathode, Anode.



→ photo emissive cell is a device which converts light energy into electrical energy

→ According to the figure cathode is semi cylindrical & coated with light sensitive metal & anode is round circle.

→ These two electrodes are placed inside a glass tube

→ when the light strikes the coated surface of the cathode photo electrons are emitted & are attracted by anode. As a result thus generates a small photo electric current in the circuit

→ The flow of photo electric current in the circuit can be determined by connecting a resistors & battery source.

→ The photo electric current depends on the incident of radiation & anode to cathode voltage.

Types of photo emissive cells

i) vaccum type photo emissive cells

→ In this cell having glass tube

→ when the. is incident on the coated surface of the cathode the electrons are emitted & attracted by anode producing photo electric current flowing in the circuit.

→ The current is directly proportional to the incident of light & incident of radiation

→ These types of cells used in Television & photometry

ii) Gas filled photo emissive cells

→ In this cell consisting glass tube filled with the gas at low pressure.

⇒ When the voltage is applied b/w cathode & anode exceed the critical value, and it accelerate photo electrons, the gas is ~~inozi~~ ionized by the photo electron into electron & cataion.

⇒ In this cell having more output current due to ionization of the gas

⇒ In multiplication factor called gas factor is > 10

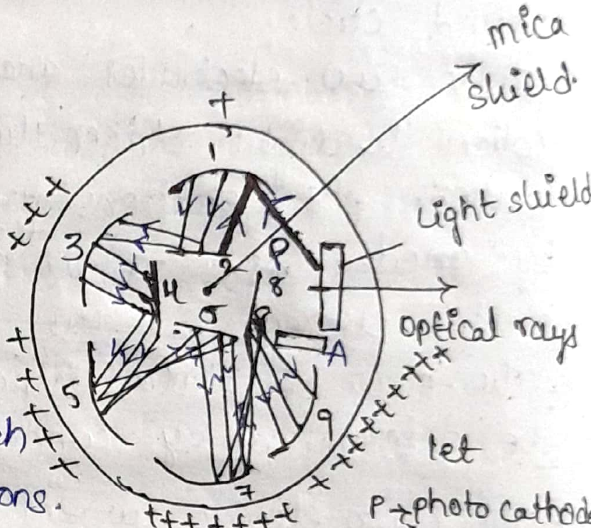
⇒ The current is not directly proportional to the incident of light.

⇒ These are used in cinematography like recording.

2. photo multiplier: Imp

⇒ According to the figure, photo multiplier consisting

* Mica shield
* Light shield
* Anode
* Cathode
* Dynodes.



⇒ A Multiplier is a device which is converts electrons into photons.

let
P → photo cathode
A → Anode
1-9 → dynodes

⇒ Light shield : It is used to allow the optical rays to fall on the photo cathode.

⇒ Mica shield :- It is placed b/w photo cathode & dynodes to provide better isolation & block the emission of electrons.

⇒ photo cathode : It is an electrode used to generate photo electrons when a light fall on it

⇒ Anode : It is a electrode which attrack the emitted (or) generated electrons from the dynode & generate all currents.

⇒ Dynodes : ⇒ It is a electrode placed at higher potential serially inside the glass tube. They are attracted photo electrons from the photo cathode.

Working

⇒ when light is strikes the surface are photo cathode it emits electrons called primary electron.

⇒ this electron will move towards dynodes 1 generates secondary electrons then the electron generated at dynode - 1 are moving towards dynode 2.

⇒ In this manner the electrons are moved towards all the dynodes generates a large steam of electrons at the anodes. similarly the electron at the anode generates the large output current is expressed as.

$$\boxed{I = I_p K^n}$$

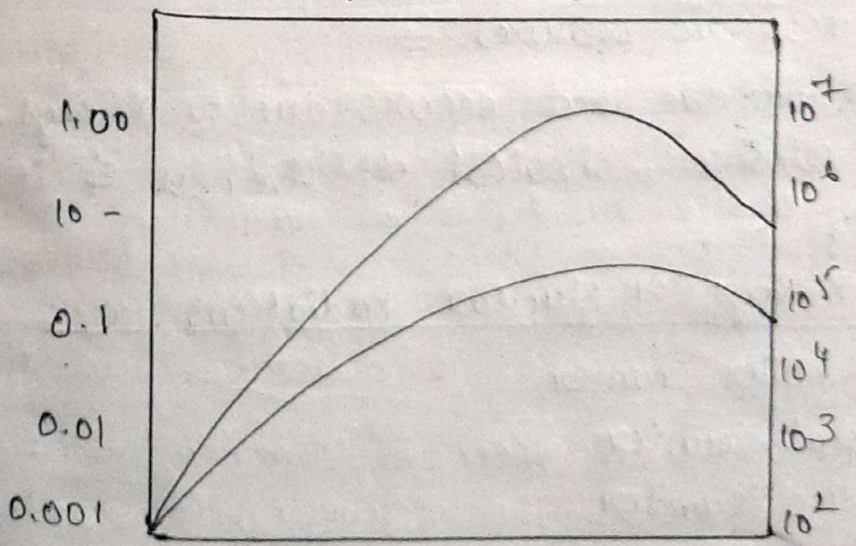
let I_p = Initial primary current
K = Dynode emission co efficient
n = number of dynode stage.

⇒ sensitivity of the photomultiplier is expressed as

$$\boxed{S = K_s V^{n/2}}$$

let K_s = constant
V = voltage for dynode pair.
n = No. of dynode stages.

⇒ The current sensitivity / amplification characteristics of photo multiplier for various dynodes voltage is shown in below figure.



3. photo conductive cells

⇒ When an intrinsic semiconductor is exposed to externa light source, the electrons present in it gets excited & Jump from the conduction band.

⇒ The electrons generates holes in the valency band, leading to the formation of (E+HP) Electron Hole pair in the semiconductor.

⇒ As a result, the concentration of recharge carriers increase there by conductivity, the phenomena is called as photo conductivity. The device exist this phenomena is known as photo conductive cell.

Note:

The change in conductivity of electrons, when the semiconductor metal is subjected to incident of light or radiation is known as photo conductive effect.

X-Rays & Nuclear Radiation Sensors

⇒ There are having high energy Radiations compared to optical range of radiation & have different units of measurement for their energy content at different parameters

⇒ For ex. ROENTGEN is a measure intensity of radiation & it is define the charge for pressure (0 to 1 atmospheric pressure)

⇒ Radiation damage that occurs due to X-Rays, γ-Rays is called relative bilogical effectiveness & it is denoted by "R".

Types of X-Rays & Nuclear Radiations are:

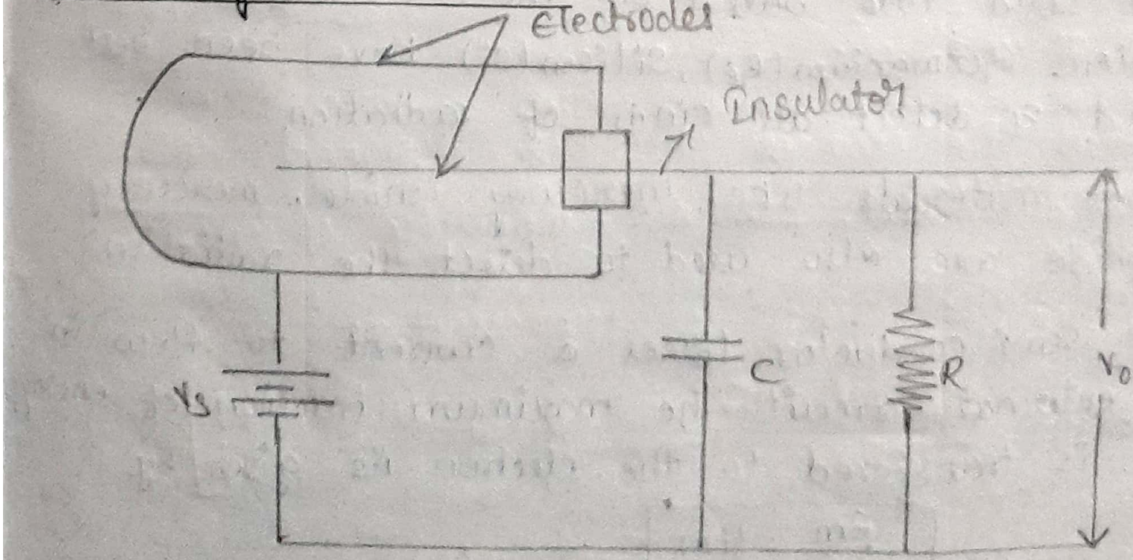
1. Geiger-muller Counter
2. proportional Counter
3. Skindillation Counter
4. Ionisation chamber.
5. Electron multiplier tube
6. Non-dispersive detectors.

⇒ The nuclear radiations from radioisotopes are.
1. alpha particles
2. Beta particles
3. γ - Rays.

⇒ These are ionisation radiations ~~are~~ neutrons & x-Rays are
1. ultra violation radiation optical types
2. Extremely low frequency, radio frequency, microwaves.

S.No	Ionising radiation	characterisation.	Detectors.
1.	α - particle	positively charge, highly ionising, low penetration descrete energy levels	Ionising chamber, proportional counter, skindillation counter
2.	β - particle	More penetration than α-particle & continuous energy	Geiger muller counter, proportional counter & skindillation counter.
3.	γ-Rays, X- Rays.	penetrating electro magnetic types.	Geiger muller counter, proportional counter.
4.	Neutrons	Indirect ionising	semiconductor diode.

1. Ionising chamber



⇒ According to the figure the ionisation chamber is also called gas filled chamber is designed by central electrode is kept separated from the chamber which is also an electrode by an insulator.

⇒ A supply voltage or no load voltage impressed between the resistance "R" inparallel with capacitor

$$\boxed{V_0 = \frac{Q}{C}}$$

⇒ The charge "c" resulting the emission of three types of ions in the chamber there are electrons, positive ions, negative ions.

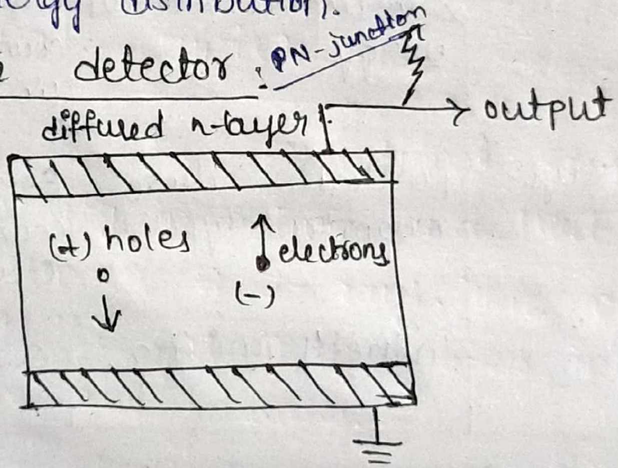
⇒ For large specific ionisation, pulse type measurement is made with an information

(i) Number of ionising particles

(ii) Time interval between incidence

(iii) Energy distribution.

Solid state detector :



⇒ The solid state based on the semi-conductor based detection. Germanium (Ge), Silicon (Si) have been best suited & detect all kinds of radiation.

⇒ other materials like mercury ionide, mercury sulphide are also used to detect the radiation.

⇒ The semi conductor forces a current to flow in the external circuit. The maximum fraction of energy that is transfered to the electron is given by.

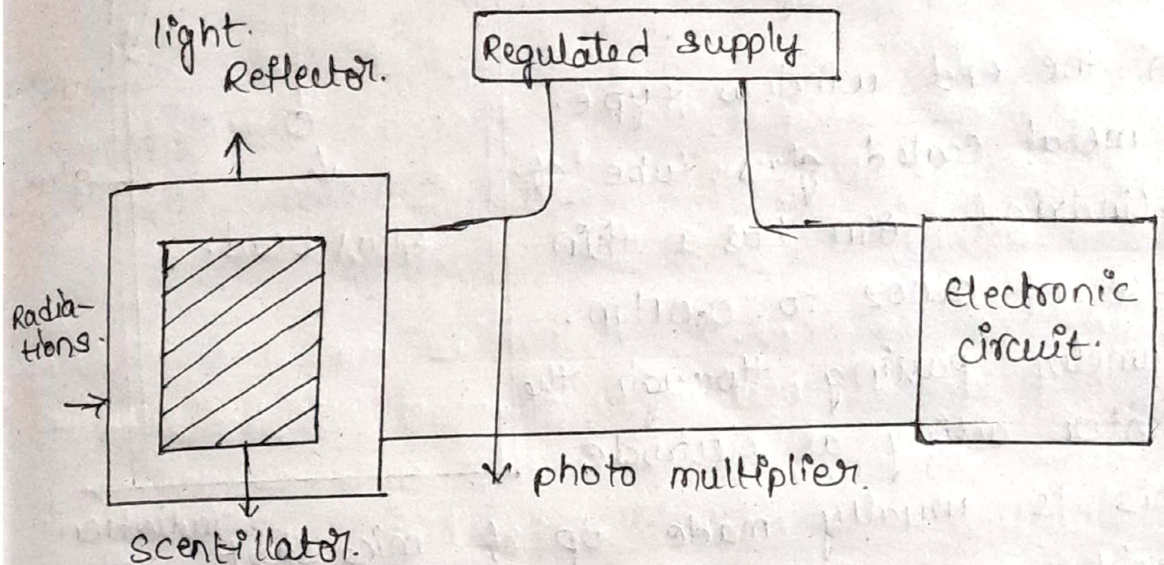
$$\boxed{\frac{E_m}{E} = 4m}$$

let E_m = maximum energy transferred

E = energy of ionising particles

m = electron to particles mass ratio.

Scentillation detector:



⇒ Scentillation of the flash are very short duration light pulses produce when a single crystal of organic material, once activate electronic circuit when they receive higher energy radiation & this materials of scentillators"

⇒ This detectors basically consists of a scentillator, a photo multiplier that converts light pulses into electrical pulses.

⇒ If the radiation energy received by the crystal is 'ϵ', The no. of photo electrons produce is 'n' & is given by.

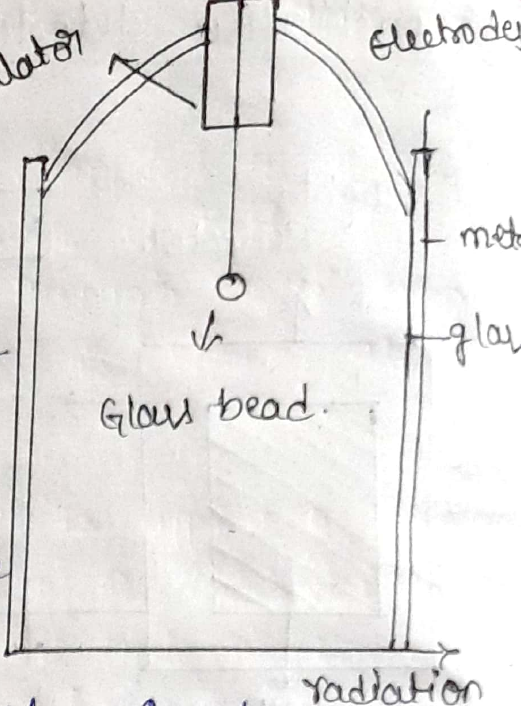
$$\boxed{n = K_1 K_2 \epsilon}$$

$$\boxed{K_2 = f_1 f_a f_e f_c}$$

Geiger muller counter.

⇒ It is the most commonly used gas filled counter named as geiger muller counter (or) GM counter. it can measure all types of radiations with high sensitivity & high output. there are widely three types of Geiger muller (GM) counter.

1. The end-window type
2. The cylindrical type
3. The needle type.



⇒ In the end window type. a metal coated glass tube of cylindrical form has a thin wire of 0.002 to 0.011m. diameter passing through the center acting as electrode.

⇒ This is usually made up of mica sheet. To avoid spark over the central electrode it terminates into a glass bead & radiation received by the end window.

<u>proportional counter</u>

⇒ According to the proportional counter this are more sensitivity in nature and used for. α, β particles sources & x-rays. This are also gas filled chamber & the gas multiplication increases the pulse size also increases.

⇒ The gas multiplication changes between 10^3 & 10^4 to around 10^5.

⇒ From the counter chamber designed data, applied field, pressure, mobility of ions.

⇒ The pulse size is expressed as.

$$V_p(t) = \frac{-n_0 e}{c}\left[-\frac{\ln(d_0/d_n)}{(d_0/d_c)} + \frac{\ln(d_0/d_p)}{(d_0/d_c)}\right]$$

$$V_p(t) = -\frac{n_0 e}{c}\left[\frac{\ln(d_0/d_c)}{(d_0/d_c)}\right]$$

let,

d_o - dia of outer electrode.

d_c - dia of collecting electrode.

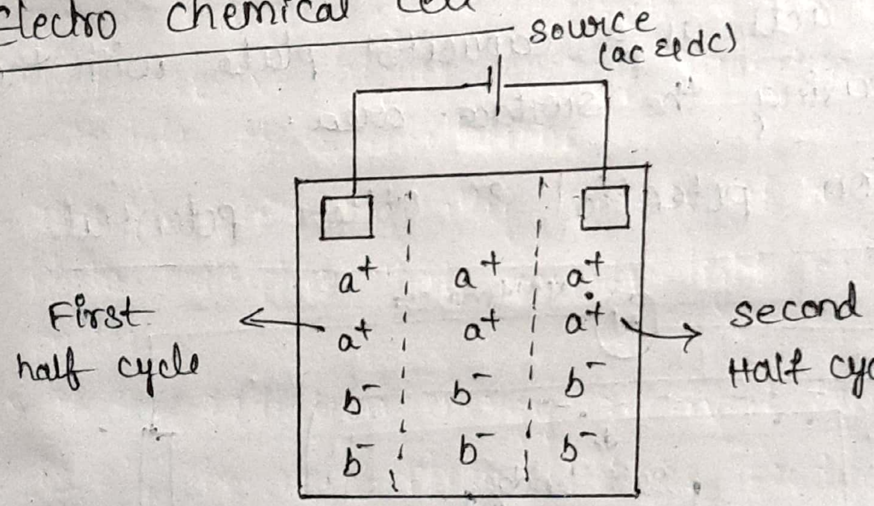
d_p - distance of positive ion from central axis

d_n - distance of negative ion from central axis

C - chamber of capacitance.

m - no. of ions pairs produced.

Electro chemical cell



=> The electro chemical cell is mainly made up of two electrodes (cathode & anode) and an electrolyte. The two electrodes are dipped in the electrolyte connected to metal conductors

=> An electro chemical cell is a combination of two equivalent half cycles. It has same electrodes but may have different electrolyte

=> According to the figure

* The anode & its electrolyte concentration are shown on the left side

* The cathode & its electrolyte concentration are shown on the right side.

* the vertical imaginary line boundary.

Working

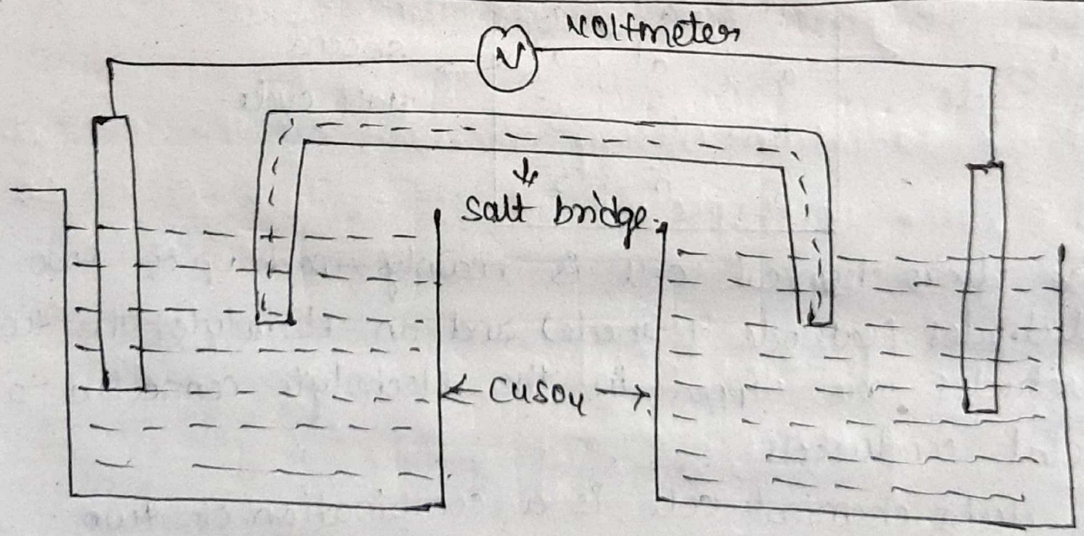
⇒ when external DC voltage is applied to the electrolyte the electronic conductivity of the electrodes drives the ions. electrolyte causing through oscillation reduction reaction. This process is known as. faradiac. process.

⇒ when the external. ac voltage is applied a layer of one half cycle is oscillation & losses electrodes to its electrolyte solution. , one more half cycle is undergoes. to reduction. Therefore the electrical energy is then converted into heat due to mobility of ions.

Note:

⇒ Each electrode acts as a capacitor plate with the current decreasing the surface area.

Liquid junction potential & other potential.



⇒ Liquid junction potential. arises when two electrolyte solution of different chemical composition coming contact because of unequal distribution of positive ion (cathoion) & negative ion (Anion) across the junction

⇒. The speeds are governed by the concentration difference b/w the electrolyte since migration occurs from higher to lower concentration of solution

Besides mobility ... speed of the ion.

⇒ The function potential may be quiet large in value.

⇒ salt bridge is actually a concentrated electrolyte solution that joins the two half cell electrolyte, saturated KCl is used as salt bridge because of high concentration level w.r.to the half cell electrolyte concentration

⇒ with a current flowing in the cell there occurs a drop. ohm's law (V=IR) Therefore, the relation expressing the mechanism

$$E_{thermodynamic} = E_{cathode} - E_{anode}.$$

$$E_{cell} = E_{thermodynamic} - IR$$

$$\boxed{E_{cell} = E_{thermodynamic} - E_{cathode} - E_{anode}}$$

(or)

$$\boxed{E_{cell} = E_{cathode} - E_{anode} - IR.}$$

The cell potential.- Standard hydrogen electrode.

⇒ The potential an electrochemical cell depends on the electrode potentials which are the characteristics of the half cell with the concerned electrodes & the effect of concentration & their product in the solution

⇒ From thermodynamic consideration the maximum work obtain from the cell having constant temperature and pressure depends on Gibb's law (or) Free energy: a reaction is given by.

$$\boxed{\Delta G = RT \ln B - RT \ln A}$$

let R = Gas constant

T = temperature

A = Equilibrium constant for the reaction given by

$$A = \frac{[a^+][b^-]}{[ab]}$$

where A stands for acid, b stands for base & ab for activity.

→ The term B expressed as.

$$B = \frac{[a^+]_x [b^-]_x}{[ab]_x}$$

where x denotes instantaneous constant.

→ ∴ The amount of free energy is depends on the cell potential E_c. is related to the free energy

$$\boxed{E_c = F}$$

Gibbs free energy

$$\boxed{\Delta G = -n E_c F}$$

where n = no. of equivalent of electricity, the electron associated with the oxidation & reduction process. Therefore the

∴ The cell ~~potential~~ cellp. is expressed as.

$$\boxed{E = E_c^\circ - \left[\frac{RT}{nF}\right] \ln \frac{[a^+][b^-]}{[ab]}}$$

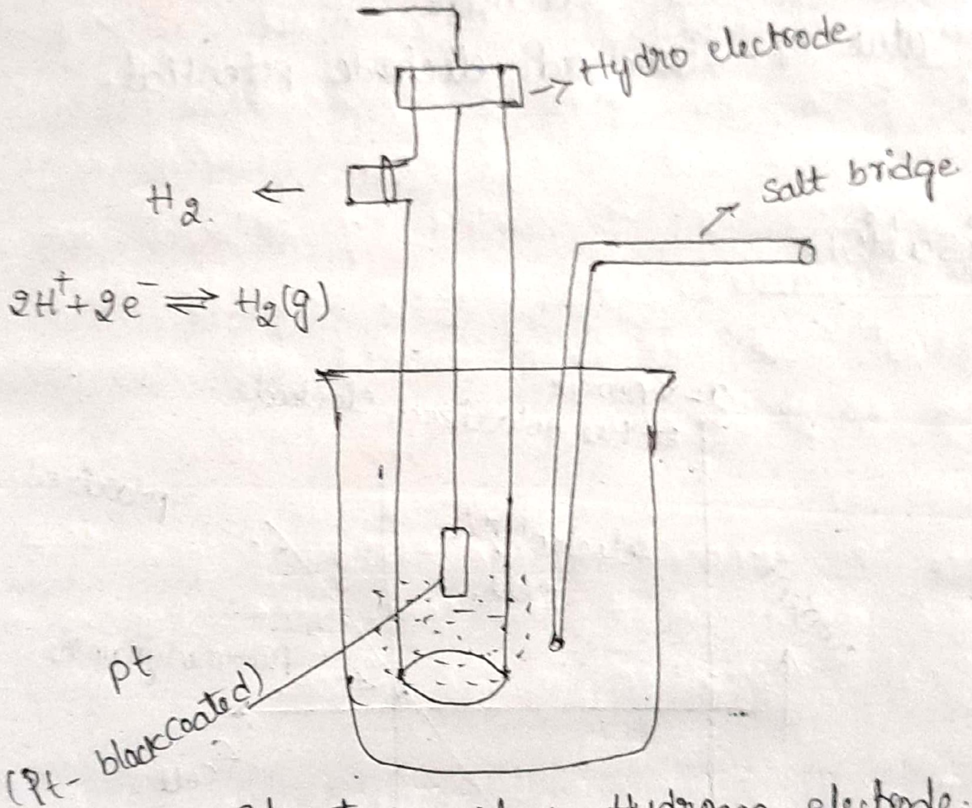
where $E_c^\circ = \left[\frac{RT}{nF}\right] \ln \frac{[a^+][b^-]}{[ab]}$

→ Electrode potential basically form the electrical cell ~~pothe~~ potential. Therefore it is expressed as.

$$\boxed{E_c = E_{cathode} - E_{anode}.}$$

→. where Ecathode & Eanode are electrode potential for the corresponding half cell reaction therefore the liquid equation is expressed as.

$$\boxed{E = E_c - \frac{0.0159}{n} \ln \frac{[a_1^+][a_2^+]}{[b_1^-][b_2^-]} \cdots}$$



Structure of a Hydrogen electrode.

⇒ The standard Hydrogen electrode, since the absolute potential of a Half cell. is not measurable. and it is the potential difference i.e measured, a second half cell has to be formed. if this second half cell can be made. as a common reference electrode this measured value would be avaiable as a relative one but w.r.to standard reference.

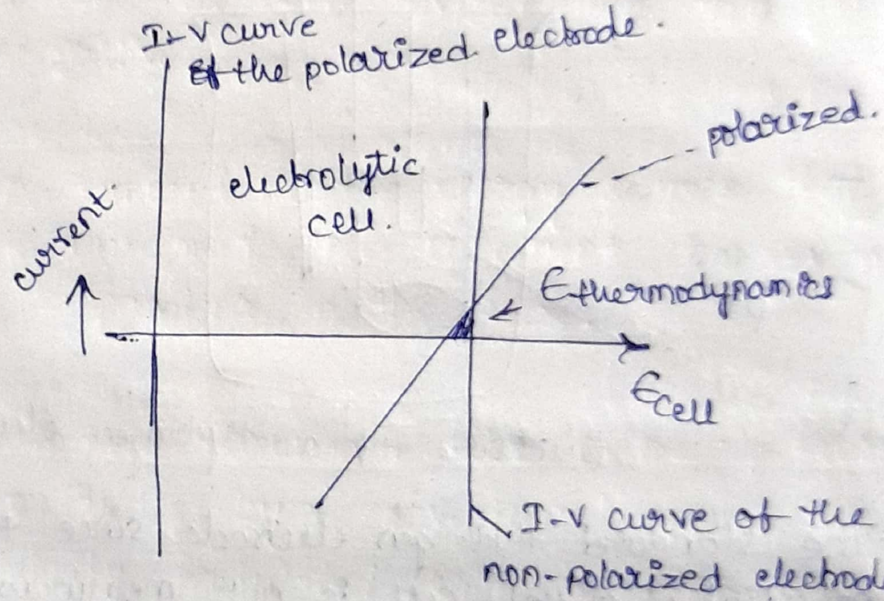
⇒. Standard Hydrogen electrode is not easily reproducable and instant conviently. produce secondary standard. electrode are used to measure potentials.

$$2H^+ + 2e^- \longrightarrow H_2(g).$$

⇒ In above equation the platinum electrode was a platinum coated with platinum block to provide a large surface area & reversable reaction with the Hydrogen solution near the electrode kept saturated w.r.to the gas.

⇒ For measurement of potential using standard Hydrogen electrode two things are important
* polarities of the electrode.
* the value of standard electrode potential.

Polarisation



⇒ The polarisation the electrode potential being constant, in this case, the cell potential should be linearly related to the cell current.

⇒ But sometime this is not the situation the non-linearity that aries is due to mainly to polarisation which is manifested as reduction of current

⇒ There are four types of polarisation.
(i) Concentration polarization
(ii) Reduction polarization.

(iii) Absorption polarisation
(iv) charge transfer polarisation

(i) concentration polarisation

oxidation - Reductions at the electrode surface can occur normally when the moment of electrons across the bulk of the electrolyte by mass transfer is normal. If non reaction rate decrease and also decrease the current. This is due to what is known as concentration polarisation.

(ii) Reaction polarisation

If there is intermediate chemical reaction in any half cell producing oxidation or reduction that travels to electrode and which participate in electron transfer.

(iii) Absorption polarisation

Some times the current is limited by process is such as absorption of the reactance & hence this is called absorption polarisation.

(iv) charge transfer polarisation.

charge transfer takes places from the electrode to oxidation from reduction to the electrode. The rate of charge transfer is reduced because of the cell. of the existance of a charge surface around the electrode.

Fibre optic sensor

→ Fibre optic sensor could be classified as a separate group of sensors, there are consider for sensing different types of variables.

1. Temperature
2. Liquid levels.
3. Fluid levels.
4. Magnetic field (or) Micro Bend Sensing

⇒ optical fibre are basically considered as communication channels, but it has been noticed that the optical transmission is effected by external parameters such as vibrations, Temperature, magnetic field.

⇒ the optical fibre has been divided into two groups. Active & passive.

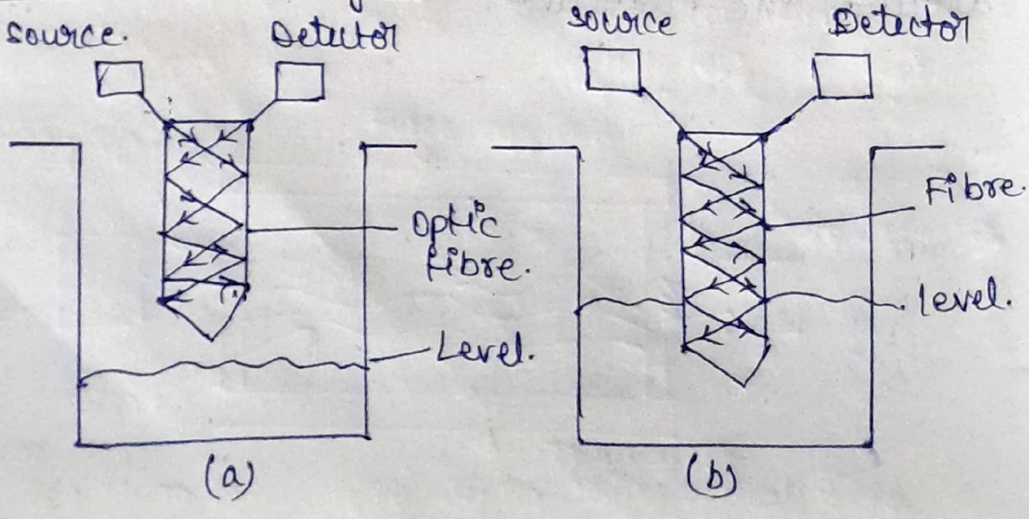
Active:

⇒ The fibre is exposed to the energy source that effect the measurement and consequent changes in the optical propagation in the fibre.

Passive:

⇒ Light transmitted through a fibre called i/p fibre is first modulated by a conventional optical sensor & this intensity modulated light is propagated through a second fibre called o/p fibre.

Liquid level sensing



=> According to liquid level sensing the light propagates through a fibre by total internal reflection with appropriate (or) the light fade incidence angle is properly selected.

=> This is because the refractive index of air w.r.t the fibre that know to no refractive index takes place.

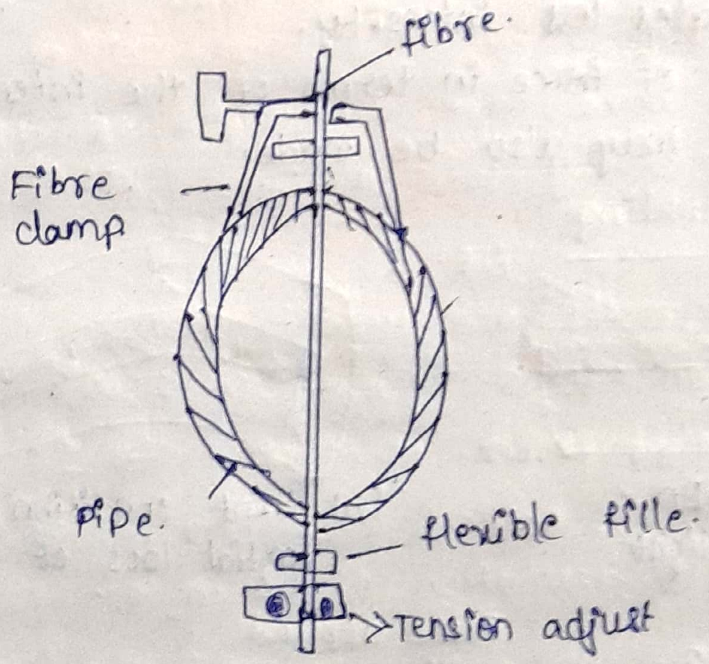
=> The bottom end of the fibre is like prism so that with large difference in refractive index of the fibre

=> According to fig (a) when liquid level rises to cover the bottom of the fibre, the light refract into the liquid & the detector fails to show any output.

=> According to fig(b) The single position level detected for discrete multi step detection. converting the entire height of the tank.

=> In this a step index multimode fibre is used & the fibre goes down carrying the light.

Fluid flow Sensing



=> According to fluid flow sensing has been sensed by optical fibre mounted surroundingly in a pipe line through which is flows. because of the fibre mounted across the flow which is turn causes diameter of the pipe & speed of the fluid range and also affected by the vibration, the vibration frequency is proportional to fluorine & also diameter is 0.2 - 0.3 m/s & ab dete special detecting technique flow rate over a range - 0.2 - 3 m/s.

⇒ The fibre is kept under tension by a tension adjusting system and a fibre clamp.

Microbend sensors

⇒ Acoustic pressure sensing can be done by the microbending of a multimode fibre. figure (a) & figure (b) show how light loss occurs in microbends of a fibre

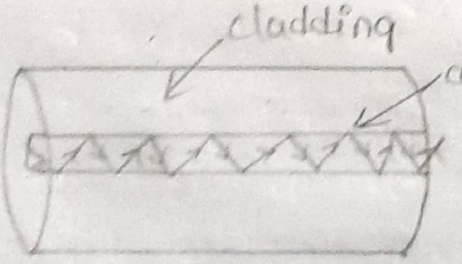
⇒ the technique is ~~used~~ utilized as shown in figure (c).

⇒ optical fibre is placed in two corrugated plates to form a transducer as shown. as shown

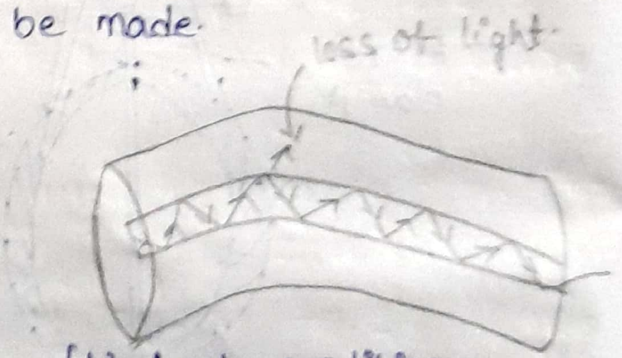
⇒ Applied force causes micro bending in the fibre.

⇒ Consequently, more light is lost and the receiver detector indicates less intensity.

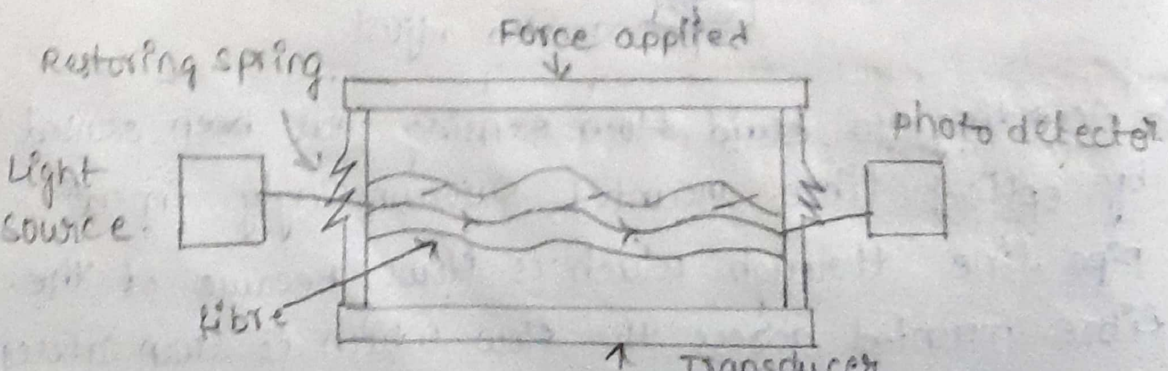
⇒ A calibration of force in terms of the intensity of detected light may also be made.



(a) Normal condition ; no loss of light



(b) bent condition ; partial loss of light



(c) Micro bend force sensor using optical fibre

Temperature Sensors

⇒ when two identical ~~se~~ optical fibres are used to propagate radiation from a source, say a laser source, and if one of these fibres is in a medium with temperature different than that of the other, the optical outputs from the two fibres would have a phase difference which is a function of the difference of temperature as mentioned.

⇒ This phase difference is due to optical path length variations in the two paths occurring due to temperature difference and is so small that it can only be measured by producing interference patterns.

⇒ Two schemes are given in figure ⓐ & ⓑ that use He-Ne laser as a source & the first one uses Mach-zender interferometer as the detector while the second one uses a michelson interferometer

⇒ The beam-splitter (BS) and mirrors (M_0) in the first case have been dispensed with using fibre couplers in the second.

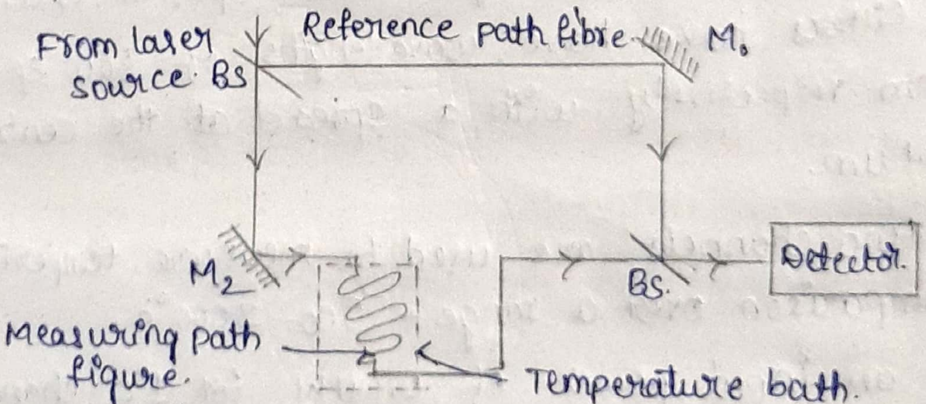
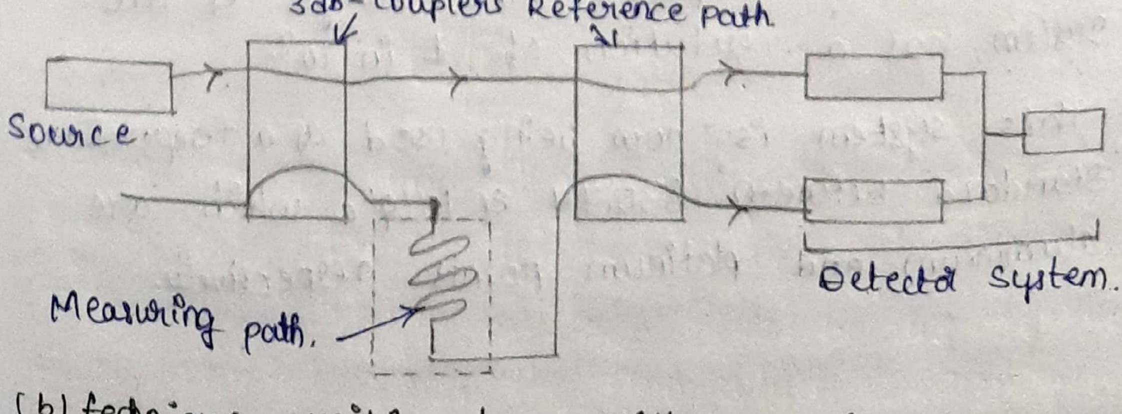


figure.
(a) phase difference method.



(b) technique avoiding beam splitter & mirror.

⇒ Another optical fibre temperature sensor is used on the principle that a black body cavity changes radiance with varying temperature.

⇒ Thus, at the end of a ~~bi~~ fibre black body cavity is formed.

⇒ The fibre is a high temperature fibre, usually a Sapphire fibre, of diameter 0.25 - 1.25 mm.

⇒ A thin film of iridium is sputtered onto the end surface and a protective cover of Aluminium oxide (Al_2O_3) is then provided. This measuring fibre has a length usually within 0.3m & not less than 5cm.

⇒ This propagates the radiation from the formed cavity which is being heated by the heat of the process.

⇒ At the propagation end, another fibre, a low temperature fibre made of glass about 0.6mm diameter is coupled that has a length usually within 10m.

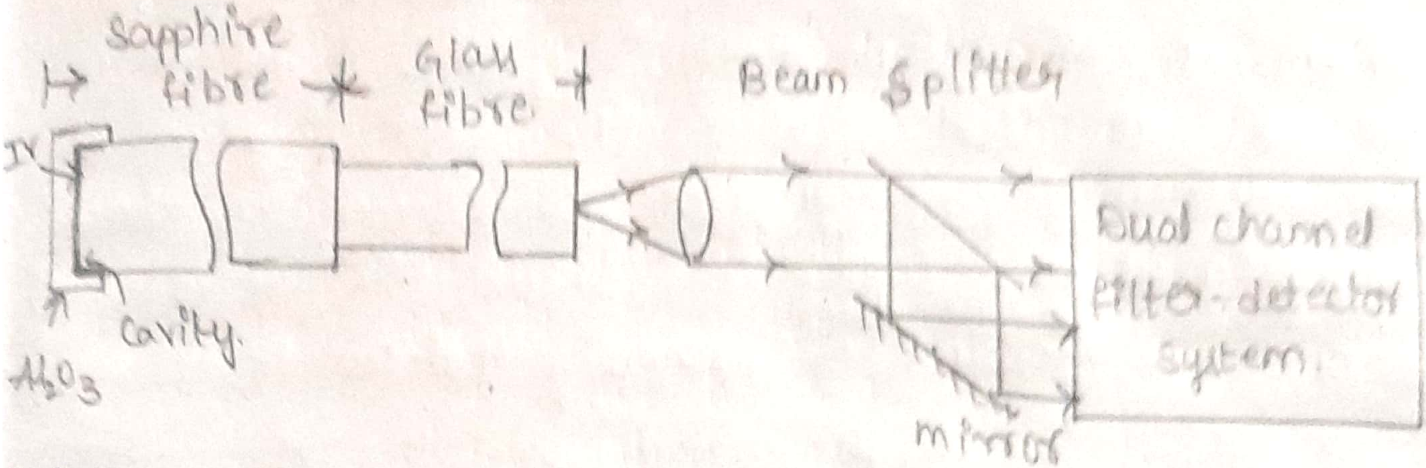
⇒ The detector system consists of one lens & two narrow band filters of close range middle wavelengths, two photomultiplier tubes in two measuring channels fed by a beam - splitter & a mirror.

⇒ The filters have have wavelengths of 600 & 700nm respectively with a spread at the centre of 0.1um.

⇒ The two channels are used to measure temperature by comparison over a range 500 - 2000°c.

⇒ With an input power of 0.1uW for 1°c change there occurs 2% optical flux change & the system has a resolution of 1 in 10^8.

⇒ This system is now being used as a temperature standard between 630.74 & 1769°c which are aluminium and platinum points respectively.



(a) Temperature sensor fibre black body cavity.