Unit 4 :- Active Microwave Components.

- Limitations of Conventional Tubes.
- O and M type classification of microwave tubes
- Re-entrant Cavity.
- Velocity modulation.
- Construction, operation, performance analysis and applications - Single Cavity and two cavity klystron, Cylindrical wave magnetron and Helix travelling wave.

* Conventional Tubes :-

- Tubes which operates at frequency range of 300 MHz to 3000 MHz .
- In Vaccum tubes, electrons flow from one electrode to another electrode.
- Vaccum Tubes contain one or more grids, cathode and anode.
- These grids are used for controlling action.
- For high frequency applications, conventional tubes cannot be used. Due to following effects :-

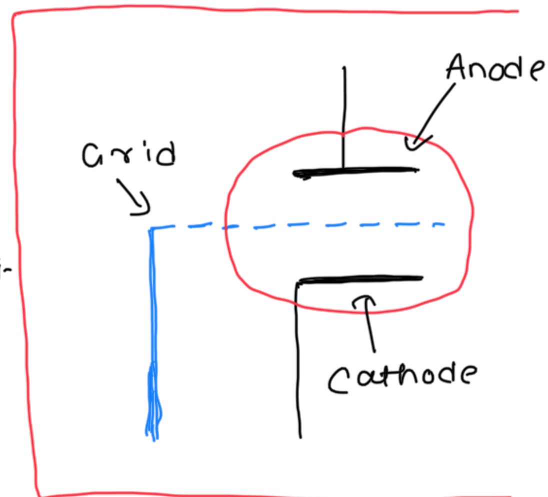


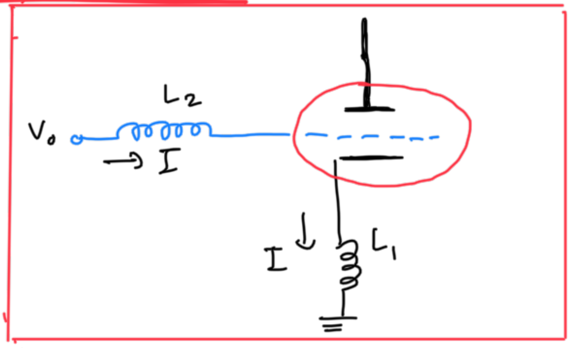
Fig. Vaccum Tube

1. Lead Inductance Effect.
2. Inter electrode capacitance effect.
3. Transit Time effect
4. RF losses.

5. Gain Bandwidth Limitation.

1. Lead Inductance Effect :-

- Lead Inductance is due to active parts of tube structure i.e. between the leads.



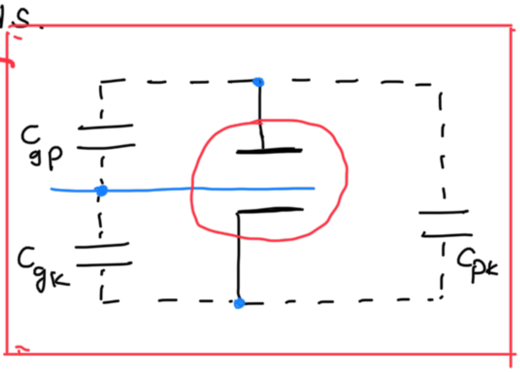
- As frequency increases, reactance X_L increases.

$$\because X_L = 2\pi f_L$$

- L_p, L_g and L_k decreases and begins to short circuit the input and output voltages.

2. Inter-Electrode Capacitance Effect (IEC) :-

- IEC effect is due to the active parts of tube structure i.e. between the leads.



- As frequency increases, reactance X_c decreases.

$$\boxed{X_c = \frac{1}{2\pi f_c}}$$

- C_{gp}, C_{gk}, C_{pk} decreases and begins to short circuit the input and output voltages.

3. Transit Time Effect :-

- Transit time is the time taken for the electron to travel from cathode to anode.

- At low frequencies, transit time is negligible, but at higher frequencies, the transit time 'T' is appreciable which reduces the output.

4. Gain Bandwidth Limitation:-

- Gain Bandwidth product is given by:- $A_{max} \times B.W$

- At higher freq. for a particular circuit or tube, higher gain can be achieved by decreasing the bandwidth.

- It can be overcome by use of Re-entrant Cavities.

* Microwave Tubes:-

Microwave Tubes
- O-type
- M-type

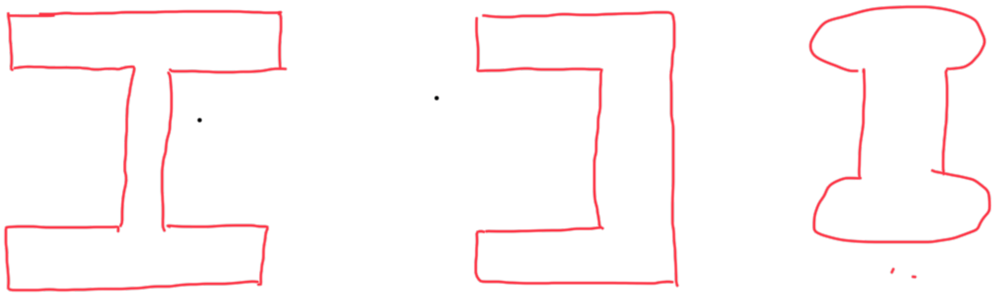
'O' type	'M'-type
- 'O'-type tubes are also called linear beam tube.	- 'M'-type of tubes are called cross field devices.
- Electric field is in direction as the static magnetic field.	- Static Magnetic field is perpendicular to electric field.
- Example: Klystron Tube, Travelling Wave Tube	- Example: Magnetron.

* Re-entrant Cavity :-

- The heart of any vaccum tube is its resonating circuit. At low frequencies they are designed using Resonant Circuit.

- But at microwave frequencies, the resonant circuit is replaced with re-entrant cavities.

- A re-entrant cavity is a metallic tube of any shape which is shorted on both ends. Structure is shorted at its both ends, it can be termed as cavity.
- Various shapes of re-entrant cavities :-



- The cavity dimensions are feq. dependent.

- It supports infinite number of frequencies.

* Velocity Modulation :-

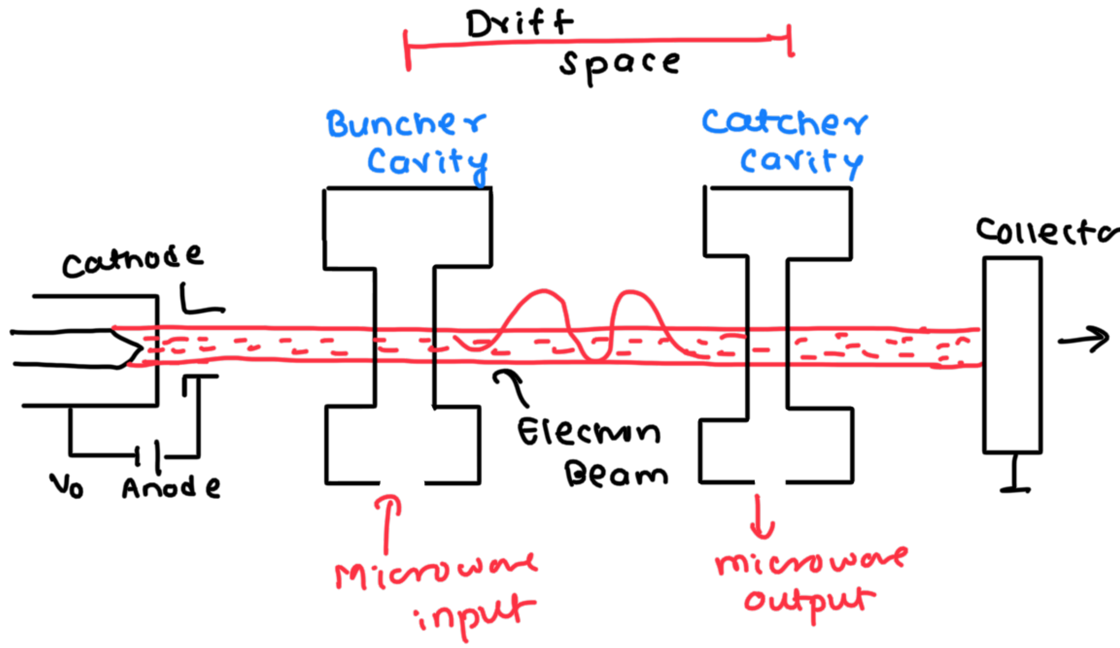
- When electron move inside the microwave tube, their velocity varies.
- The process of the variation in the velocity of electrons is known as velocity modulation

* Two Cavity Klystron :

- The two cavity klystron is used as microwave amplifier.

- It's operation is based on the following two principles:
  1. Velocity modulation of electron beam.
  2. Current modulation of velocity modulated electron beam.

• Operation:



- The electron beam is emitted from cathode. High electron beam produced by accelerating anode.

- This focused beam now enters into buncher cavity.

- The process of velocity modulation took place inside the buncher cavity.

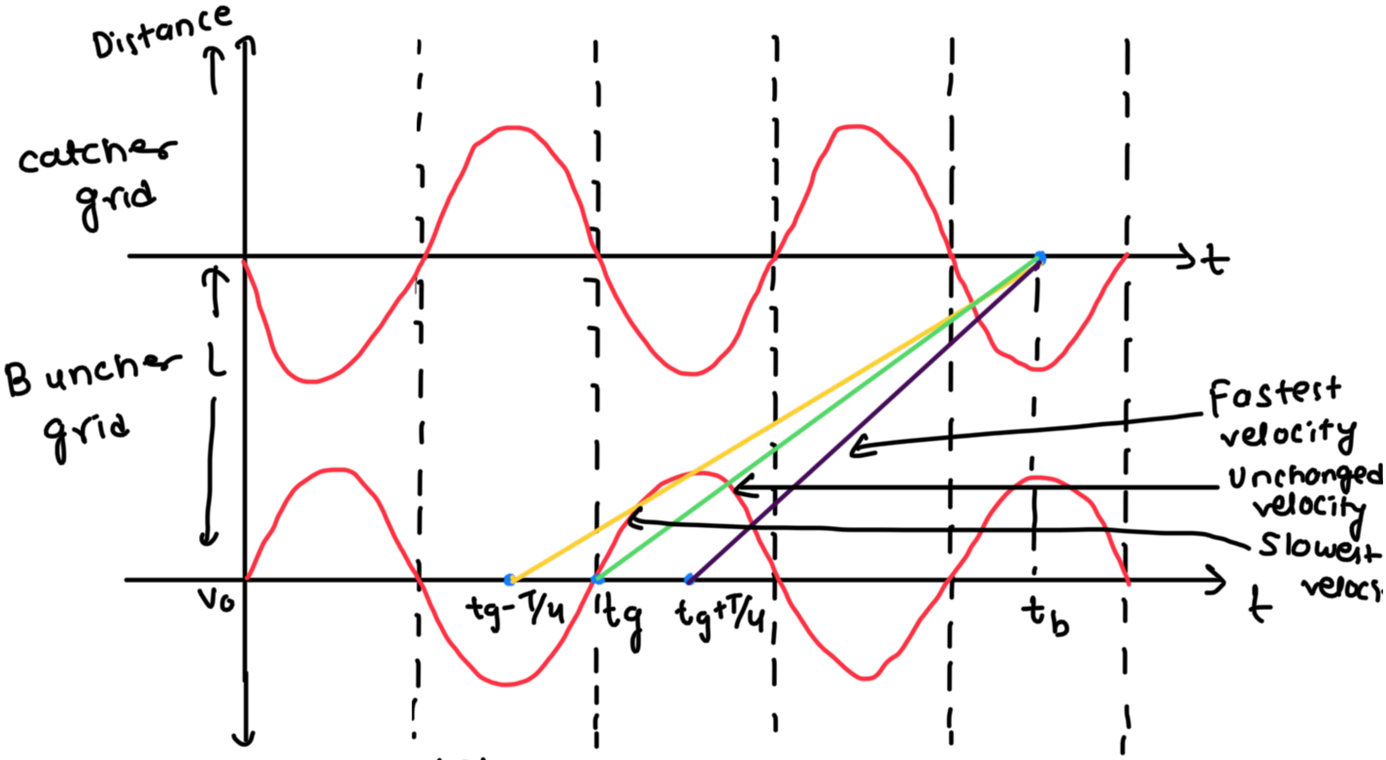
Buncher cavity — Two Electric field
- RF input
  - Positive cycle
  - Negative cycle
- Electron beam

- Force of attraction and repulsion betw two field changes velocity of electron beam. Termed as 'velocity Modulation'.

- Modulated velocity beam passes through drift space.
- The drift space has no external potential. Therefore, velocity modulated electron beam starts giving up its energy.

- Energy gets collect at catcher cavity. The kinetic energy of velocity modulated electron beam is converted to its equivalent electrical energy across load. This load is connected across catcher cavity. Known as Current Modulation.

- Process of velocity and current modulation is explained in Applegate diagram.



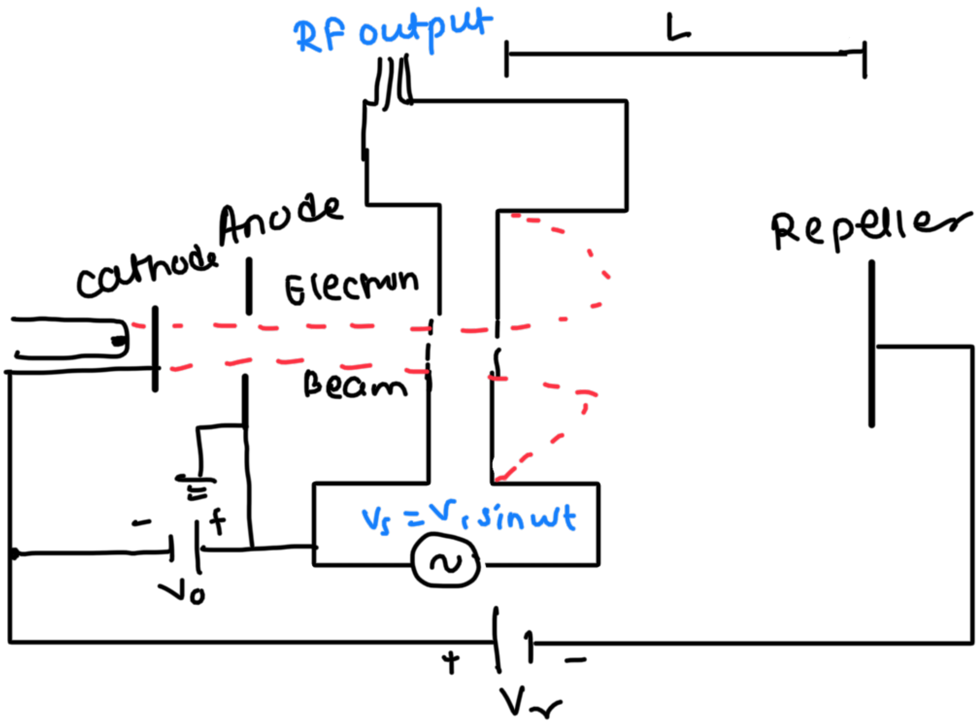
* Applications: used as Amplifier:
  1. UHF TV transmitter
  2. satellite commn ground station.
  3. Radar transmitters.

* Reflex klystron:

→ oscillator.

- The disadvantage of multi-cavity klystron is overcome by single cavity klystron known as Reflex klystron.

* How reflex klystron generates oscillations?



- Electron beam is generated from cathode surface and is accelerated by accelerating grids
- This beam passes through the re-entrant cavity. Thus cavity has two I/P, one is electron beam and other is RF signal.
- There are two electric fields present within cavity which interact with each other. During positive half cycle of RF signal, force of attraction increases beam velocity. During negative half cycle, force of repulsion decreases beam velocity. Thus velocity modulation occurs.

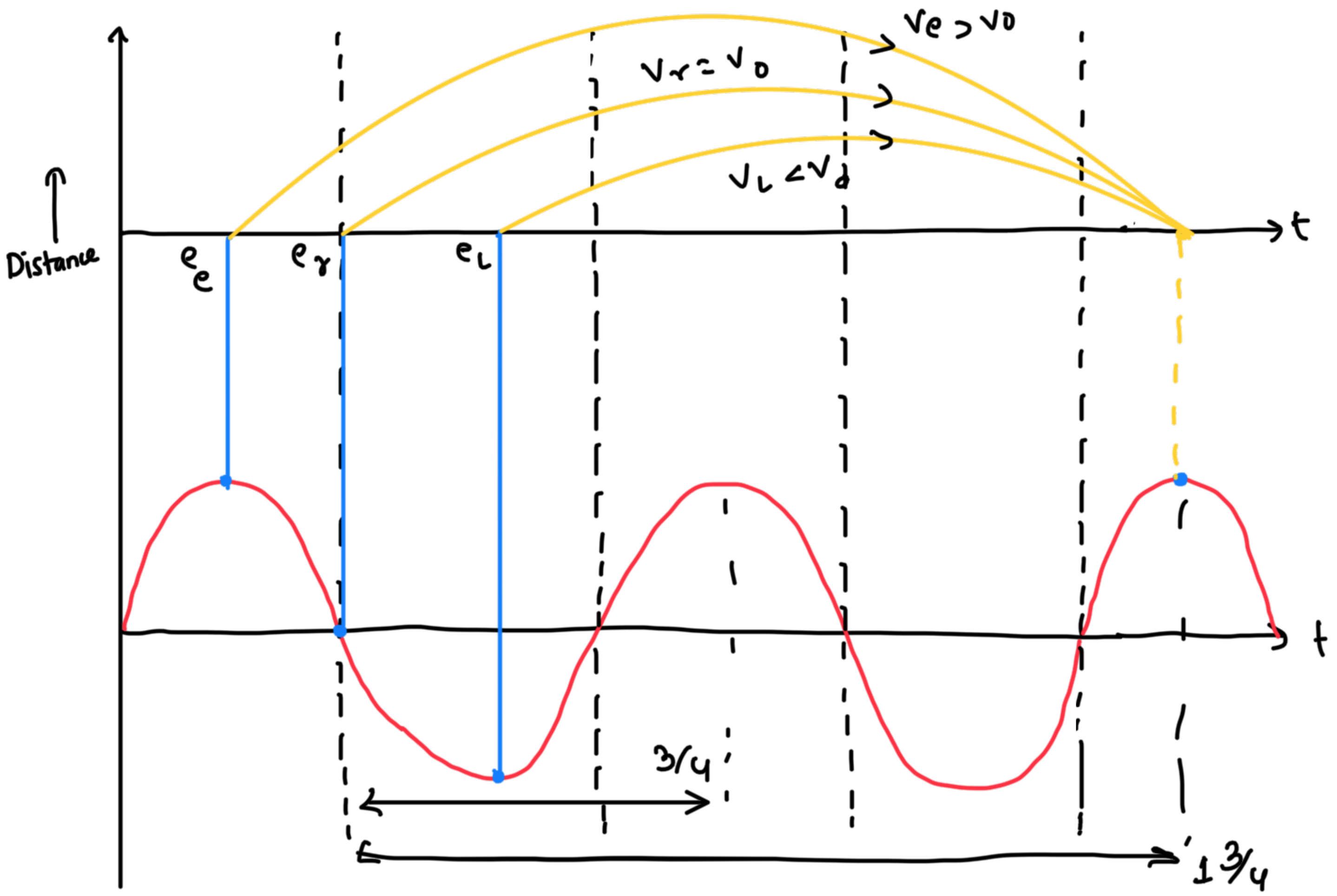
- when this velocity modulating beam enters drift space, it experiences force of repulsion from repeller. The repeller is always at negative potential.

- Since repeller is at negative potential, it exerts force of repulsion on velocity modulated electron beam. Thus electrons pushes back to cavity. This acts as feedback.

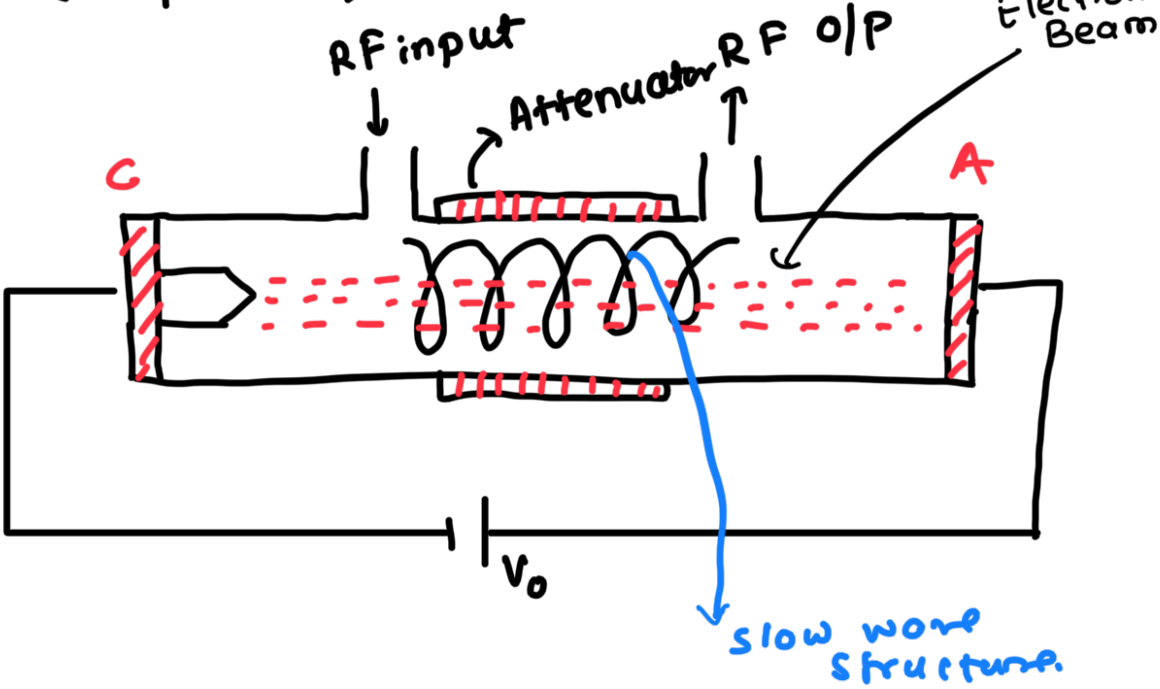
- Process of velocity modulation results in amplification and repulsion of electron beam from repeller results in positive feedback. Thus amplifier along with positive feedback results in oscillations at microwave freq. Thus reflex klystron generates in oscillation.

Velocity Modulation ⇒ Amplification
Repulsion from Repeller ⇒ Positive feedback
⇒ Oscillations.

* Applegate :



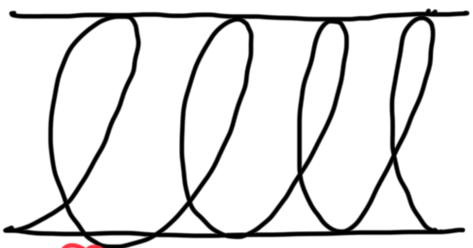
* TWT: (Amplifier)



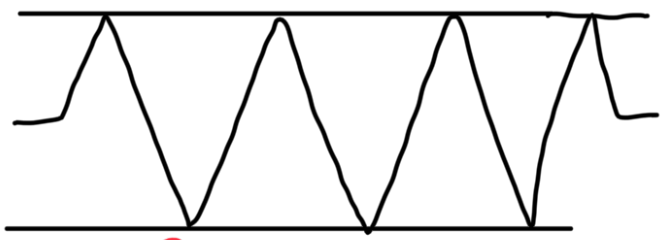
- **Slow wave structure:**
  - TWT uses slow wave structure.
  - Slow wave structure is non-resonating circuit which are purposely designed to obtain high power microwave freq. range.

Imp - Gain bandwidth is limited for resonant circuit, the LC resonator cannot generate large output. To overcome this problem, slow wave structure are used.

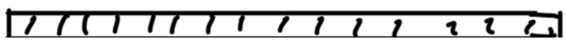
- These are available in various forms such as helical line, zigzag line or corrugate waveguide.

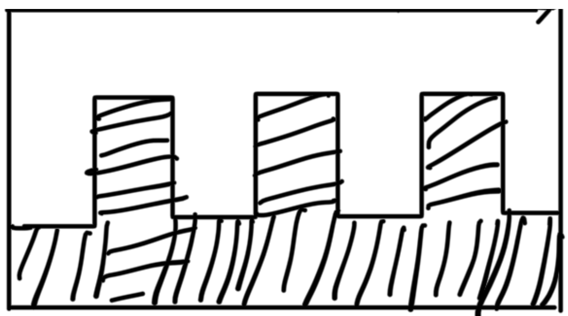


ⓐ Helical line



ⓑ Zigzag line





ⓒ Corrugated wave guide

- For proper interaction of electron beam with RF I/P, slow wave structures are designed. These structures elongates path of propagation which results in delay i.e. reduction in effective velocity.

Working of TWT:

- The electron gun is at one end of tube and slow wave helical structure is placed betw cathode and anode.
- Electron gun produces narrow beam of electron which passes through the axis of helical slow wave structure.
- The signal to be amplified is applied at I/P terminal of slow wave structure.
- At first winding of helical structure, the interaction changes beam velocity. This process is known as 'velocity modulation'.
- This velocity modulated beam again undergoes the process of velocity modulation when it enters in second winding of helical structure.

- Electron beam moves along the axis of slow wave, RF field is conducting through slow wave structure. Velocity of RF signal is greater than of beam velocity. This helps in transfer energy. Large amplification of signal voltage occurs at end of slow wave structure.

- Total helical structure are amplifier connected in cascade.

- Thus interaction results in high gain.

- Why attenuator:
  1. Control amplifier gain so that it won't go saturation.
  2. Prevents reflections from load side to cathode. If there reflections get added with the amplified signal it may acts as positive feedback. May results in unwanted oscillations.

* Advantage:

1. Helix is non-resonance structure, very large bandwidth can be obtained by TWT.
2. Suitable for high power and high freq.
3. Low noise amplifier.

* Disadvantage:

1. Close proximity of helix may generates unwanted feedback.
2. Attenuator is req.

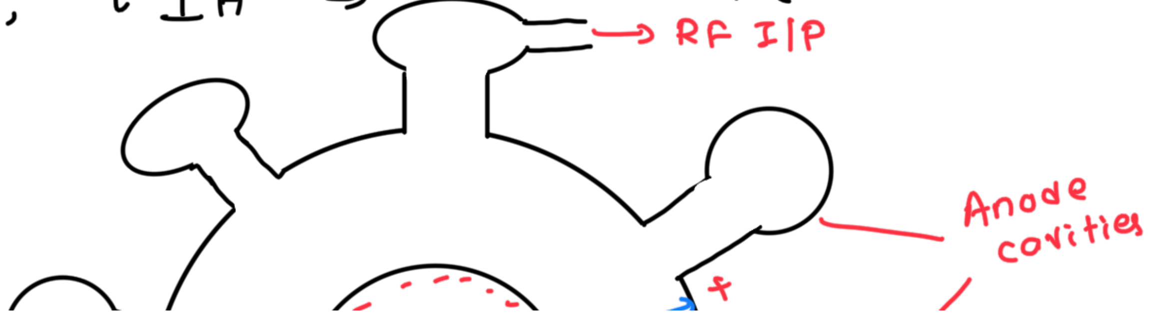
* Applications:

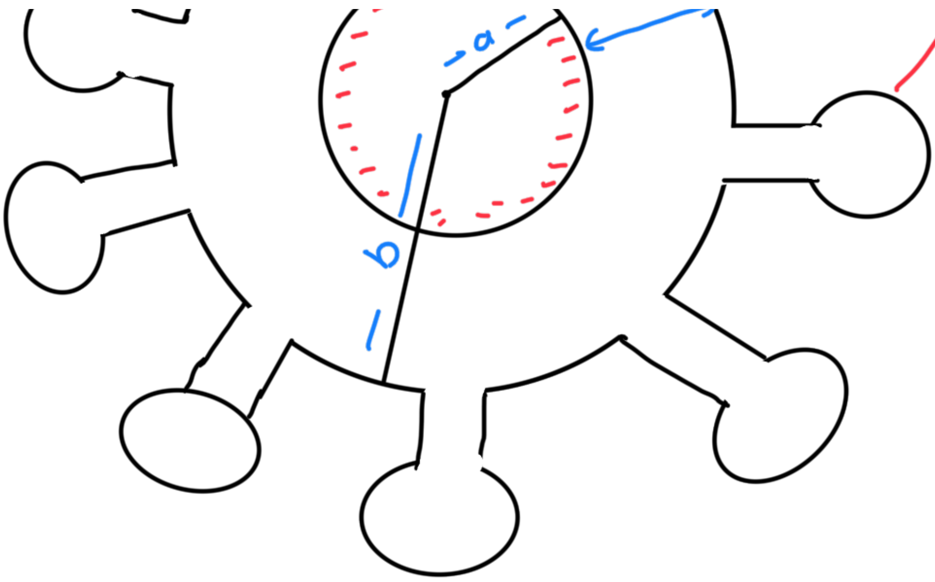
1. Medium and high power satellite operation
2. Air borne and ship borne radar.

* Cylindrical Magnetron: (Oscillator)

- A magnetron oscillator is used to generate high microwave power.
- Uses both electric and magnetic field for its operation.

As, $E \perp H \Rightarrow$ Cross field device





- Consists of cylindrical cathode of radius 'a' and cylindrical anode of radius 'b'.

- Here, cylindrical anode is a slow wave structure consists of re-entrant cavities around circumference of cylindrical cathode.

- DC voltage applied betw cathode and anode, This generates radial electric field.

- Magnet is placed along z-direction which generates magnetic field.

- Due to applied DC voltage, electron is emitted from cathode surface. Electron experiences two forces perpendicular to each other.

- Due to RF Noise present in cavity, the velocity modulation occurs.

- The accelerated electron when retarded by RF field, transfer of energy from electron to RF cavities, RF Oscillations grows.