SUBJECT : M.R.E (Notes by Krishna ma'am)

Microwave Tubes

- Basic Principle
- Klystron → Linear beam tube.
  - 2 cavity Klystron - Amplifier
  - Multi cavity " - Amplifier
  - Reflex Klystron - Oscillator
- BWO - Oscillator } Linear Beam tubes.
- TWT - Amplifier }
- Magnetron } cross field device → oscillator.
- Cyclotron } (means $\vec{E} \perp^{ar} \vec{H}$)

→ **Basic principle of microwave Tube** : The basic principle of operation of microwave tube involve transfer of power from a (DC) source DC voltage to source AC voltage by means of current density modulat electron beam.

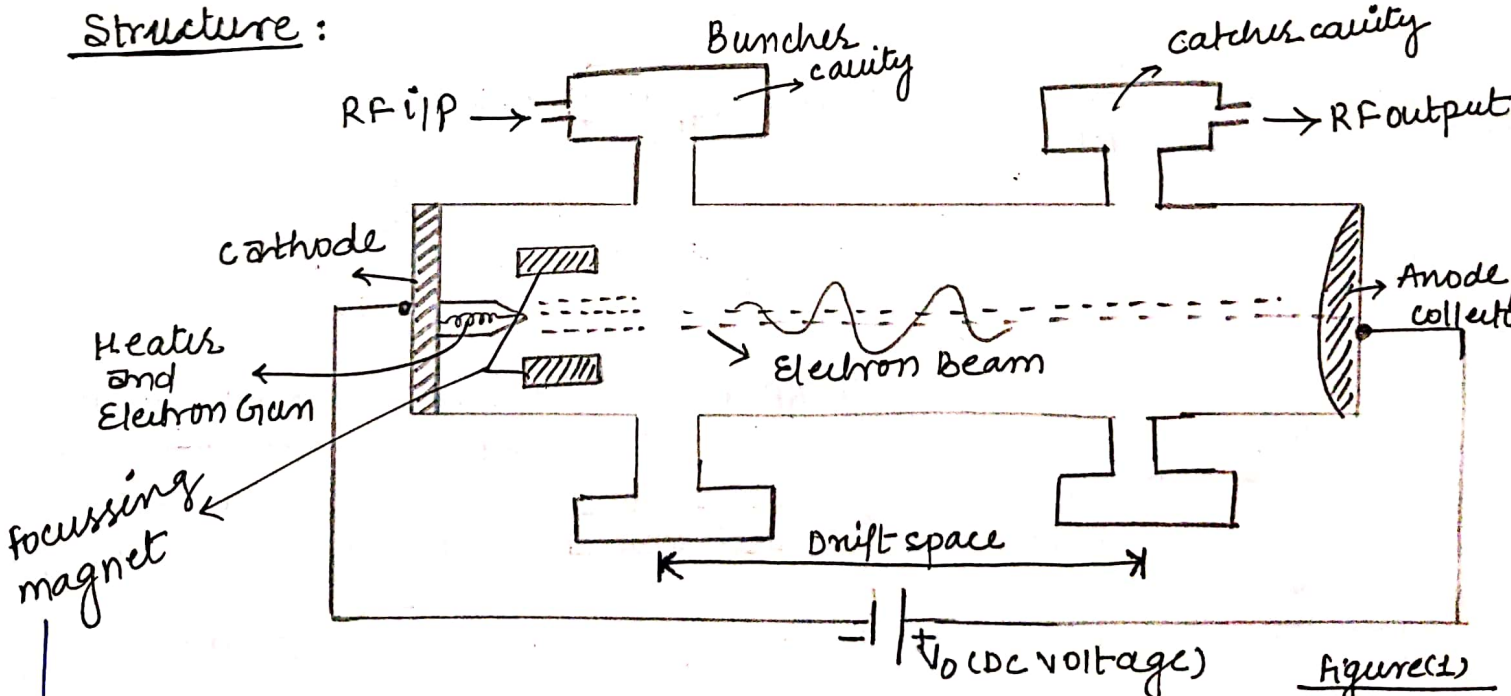
Source DC $\xrightarrow{\text{energy}}$ Electron $\xrightarrow{\text{energy}}$ RF signal.

we knows, $\frac{1}{2} m u_0^2 = qV_0$

$$u_0 = \sqrt{\frac{2q}{m} \times V_0} \text{ m/sec.}$$

Here, u_0 → Velocity of Electron
V_0 → Applied DC voltage

Structure :



figure(1)

Velocity modulation occure at Buncher cavity.
Current density modulation occure at Catcher cavity.

Electron Gun will generate linear beam of electrons. So any two electron beam may face Repulsive force. That's why we use focussing magnet to stop scattering of Electrons.

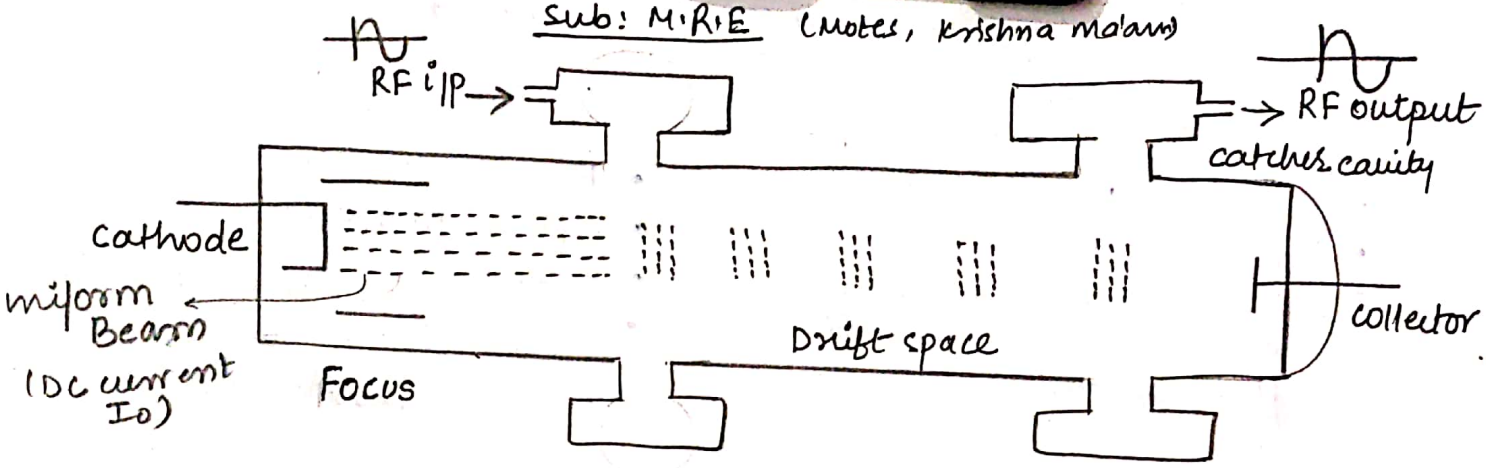


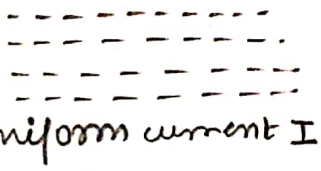
figure-(2)

- RF signal need a resonant structure to exist.
- Bunches and catcher cavity are — Re-entrant cavity
- Re-entrant cavity are specially designed structure for HIGH FREQUENCY.

(∵ Inductance and capacitance (equivalant) is very low, so, we can get HIGH frequency (in GHz.))

∵ $f_0 = \frac{1}{2\pi\sqrt{LC}}$, $L \downarrow C \downarrow \rightarrow f_0$ very high.

WORKING: Let's consider we have uniform electron beam, interact it with RF signal.



uniform current I_0

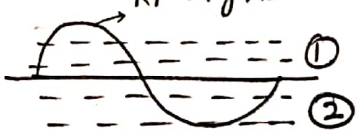
↓

so, there net transfer of energy will be ZERO

↓

[So, uniform beam NOT USEFUL.]

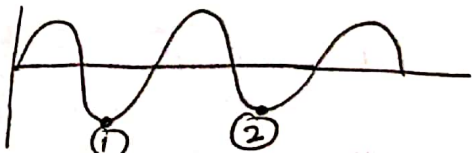
RF signal = $v_s = v_m \sin\omega t$



① RF signal will loose energy to electrons.
so, $v_0 \uparrow$, $v_0 = \sqrt{\frac{2q}{m}(v_s + V_0)}$

② Electrons will loose energy to RF signal.
so, $v_0 \downarrow$, $v_0 = \sqrt{\frac{2q}{m}(V_0 - v_s)}$

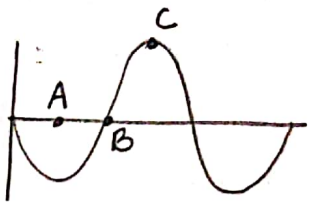
Note: As we use 2 cavity klystron as amplifier, so, all electron Beam should interact with maximum Retarding point of RF signal.

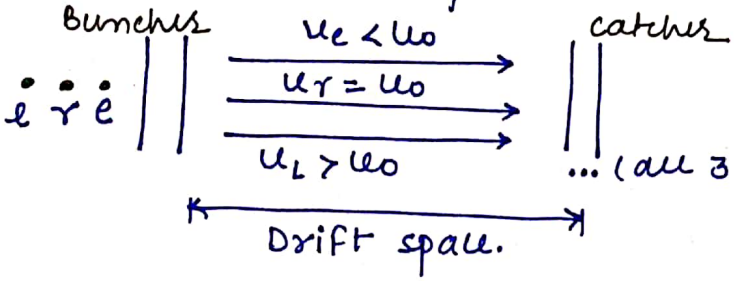


①, ② → Maximum Retarding Point.

- To amplify the RF signal first form non-uniform electron beam.

Velocity modulation → let's take 3 electrons, as early, reference and late electron, at buncher cavity. We want all 3 $\bar{e}$'s to reach catcher cavity at same time.



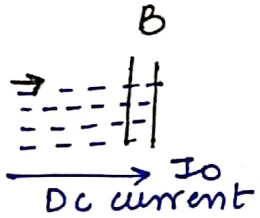


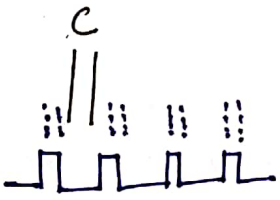
$u_L > u_r > u_e$

... (all 3 electron reach catcher cavity at same time)

→ Velocity modulation start at buncher cavity.

→ Process of velocity modulation occuse in drift space. So, drift space is compulsory for velocity modulation, so as Transit time. (Transit time is time taken by $\bar{e}$ to reach catcher cavity from buncher cavity).

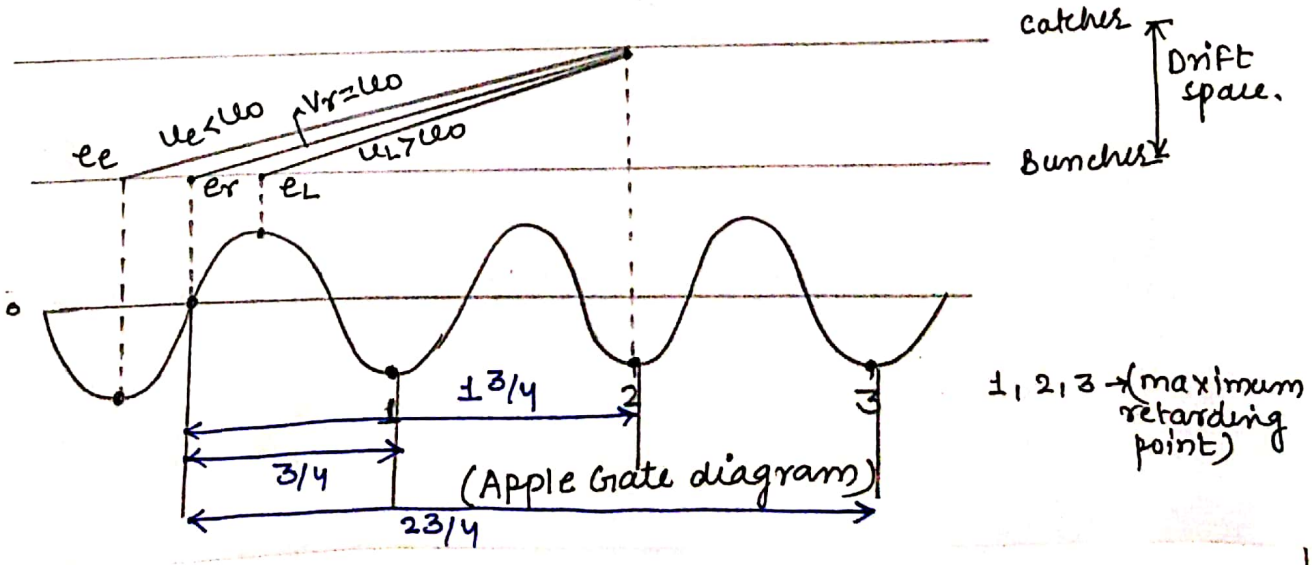




pulsating stream of electron

So, DC current converted to pulsating current (AC signal) so, it's called current modulation.

- We want the Electron beam to interact maximum Retarding point of RF signal. (1/2/3).



mode of operation : it depend on the point (maximum retarding point) you choose.

for point ① → 3/4 mode of operation

for point ② → 1 3/4 mode of operation --- etc.

$N = 3/4, 1\,3/4, 2\,3/4$ --- (mode of operations)

$\boxed{N = (n - 1/4)}$, $n = 1, 2, 3, 4$ ---

transit cycle : No. of cycle completed by RF signal during transit time.

$\boxed{N = (n - 1/4)}$, N : No. of transit cycle.

transit angle : change in phase of RF signal during transit time.

$$\theta = 2\pi N = 2\pi (n - 1/4)$$

$$\boxed{\theta = (2\pi n - \pi/2)}$$

* 2 cavity Klystron amplifier used as amplifier and frequency multiplier.

→ ① efficiency (η) ≃ 40% practically
[theoritically maximum efficiency = 58%]

② Power Gain ≃ 30dB.

③ Output power ≃ 500KW (continuous wave power)
30MW (pulse power)