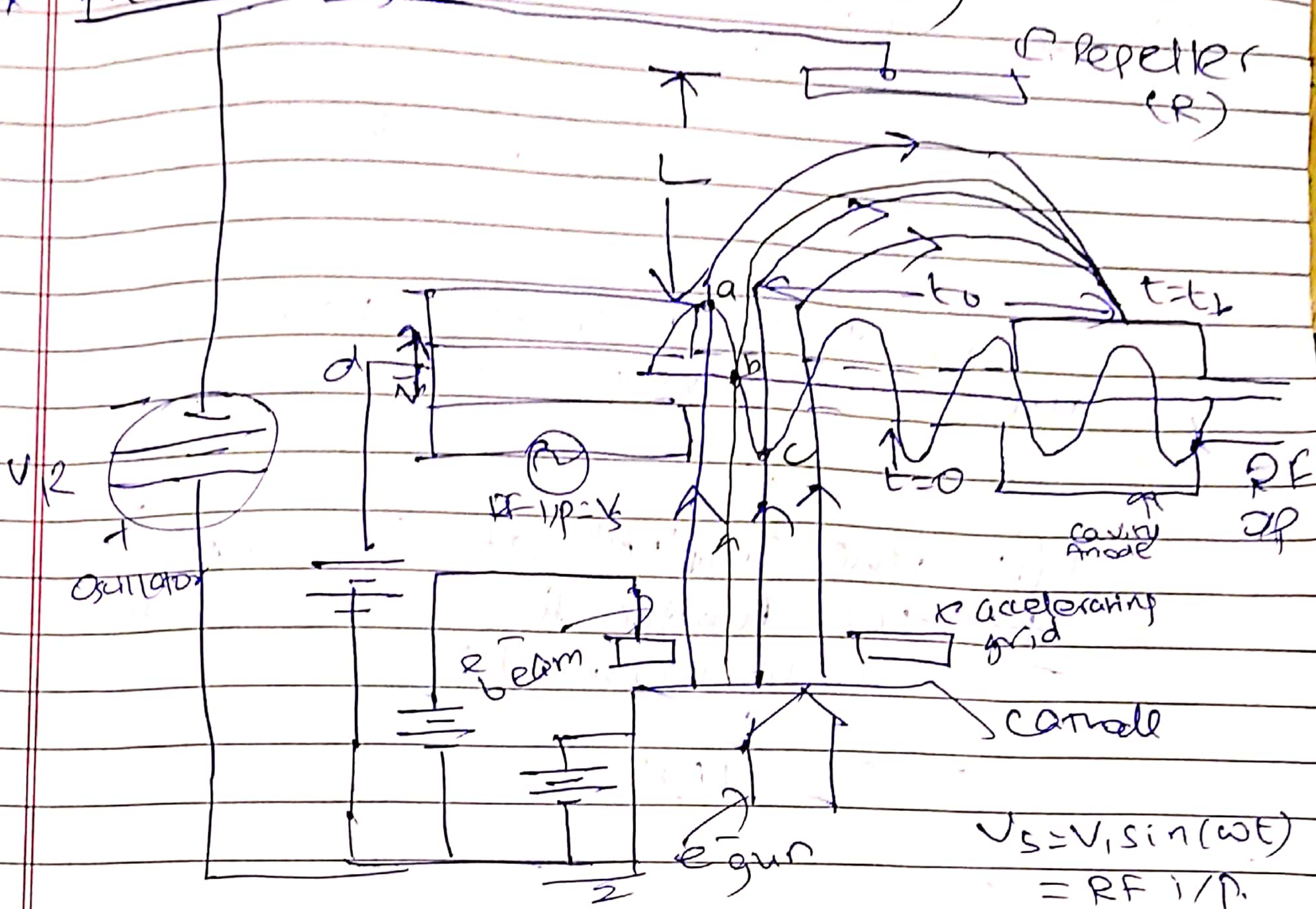
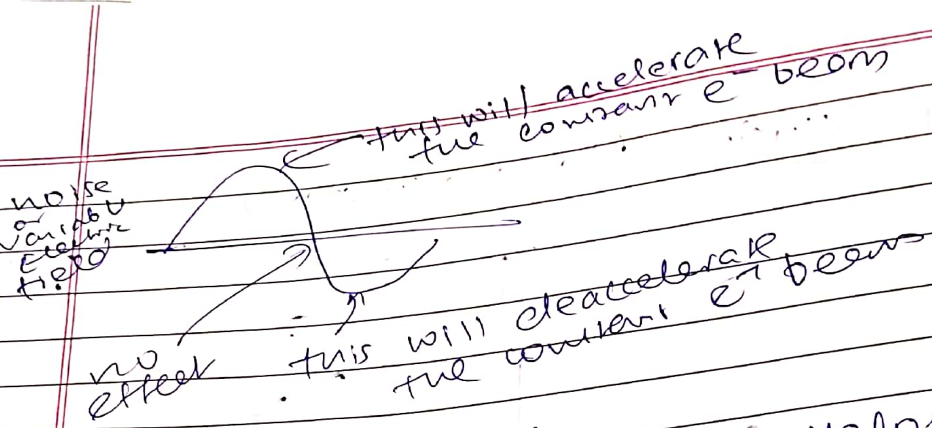
* Reflex Klystron (acts as oscillator)



- The amplified e^- beam will be repelled by -ve voltage at repeller & inside cavity will either come back in phase & add to ~~velocity modulated~~ signal in cavity & if out of phase then subtracts with the ~~velocity modulated~~ signal in cavity.
- The phase of repelled signal will be decided by -ve voltage V_R at repeller of length L.
- accelerating grid to form bunch of e^- into an e^- beam
- d → dimension of reentrant cavity
- e^- gun produces constant d.c. Electric field & a variable electric field inside cavity interact.



so due to this interaction velocity modulated beam will exit cavity.

⟹ (So the amplifⁿ at first entry + (the positive feedback back into cavity (in phase)).

= Oscillation

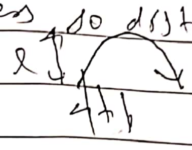
- as noise in cavity could be random so Pour, four tough to determine.
- RF o/p will be in GHz
- so RF i/p will be kept in KHz and will be kept sinusoidally periodic.

⟹ RAF ? ...

→ Tuning:
change P_{RF} or f_{out}

- Electronic tuning:
  - more V_R then repulsion more & dist. travelled by beam less.

  - less V_R repulsion less so dist. more



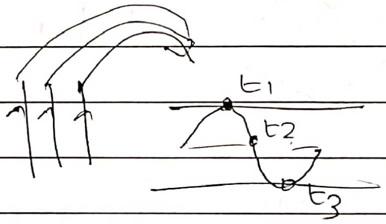
as dist. travelled by beam changes & $l \propto \lambda \propto \frac{1}{f}$

so f_{out} changed & thus electronically tuned.

~~me~~ To change P_{RF}: change the amp of e^- beam from e^- gun. & thus P_{RF} will change.

- mechanical Tuning:
  changing length (L) of Repeller & thus repulsion varies & thus as above f_{out} can be changed.

→



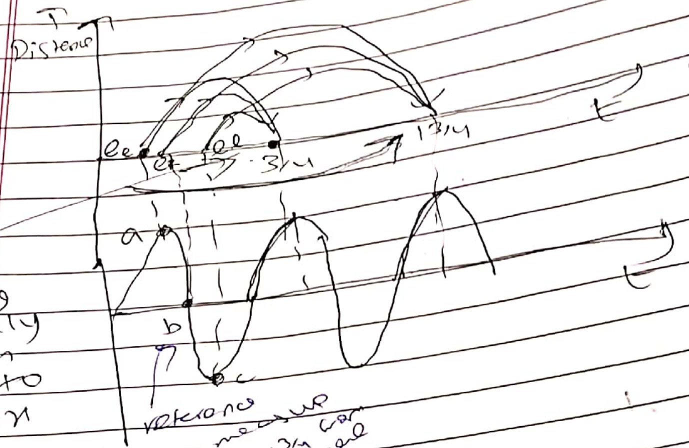
if e^- beam comes at t_1 then P_{max}
if e^- beam comes at t_3 then P_{min}

Conclusion: the e^- beam is allowed to come back inside cavity at t_1 instants for max. power, this is bunching.

Theory: The bunched e's can deliver max power to cavity at any instant corresponding to +ve peak of RF cycle.
i.e. $t_0 = (n + \frac{3}{4})T$ where $n = 0, 1, 2 \ldots$

→ Applegate graph for Reflex Klystron:

$N = n + \frac{1}{4}$



So bunching done only at 1/4 cycles to get max power

so measure 3/4 & 13/4 cycle

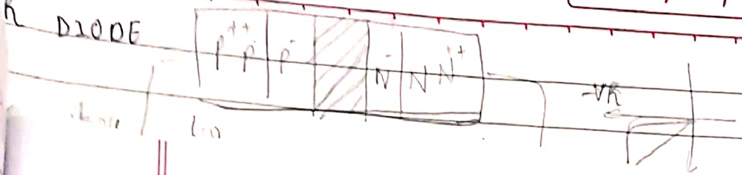
$$P_{OUT\ RF} = \frac{V_0 I_0 J_1(X)\,[V_0 + V_R]}{2\pi f_{out} L}$$

f_{out} → o/p freq.
V_0 → beam (cathode voltage)
V_R → repeller voltage
L → length of drift space.
X → bunching coeff.

$$X = \frac{\pi N \beta_1 V_1}{V_0} \quad ; N = n + \frac{1}{4}$$

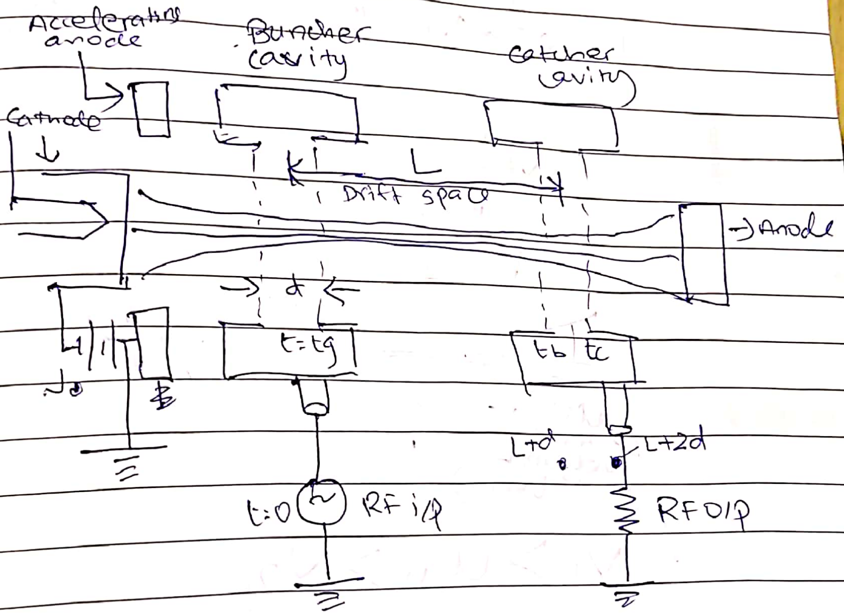
V_1 → peak amp. of RF voltage

R DIODE



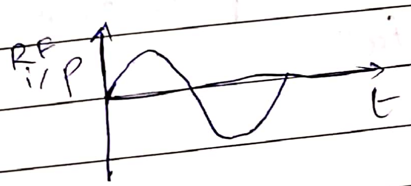
$$\boxed{f_{out} = \frac{[V_0 + V_R]\, N}{[\sqrt{V_0}\; 6.74 \times 10^{-2}]}} \text{ MHz}$$

* Two / multi cavity Klystron: (amplifier)



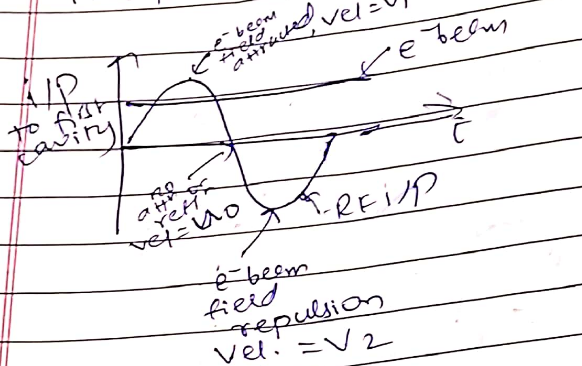
Both cavities act as amplifiers.

for buncher cavity, two i/ps RF i/p & beam will travel distance L to catcher cavity o/p of this where it gets amplified.

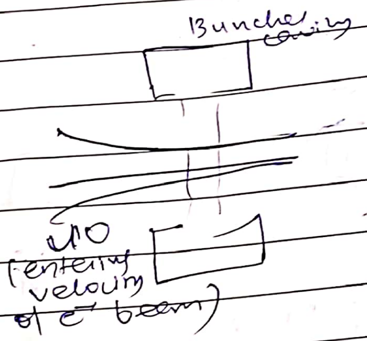


$$V_{av} = V_1 \beta_1 \sin\left(\omega t_1 + \frac{\theta_g}{2}\right)$$

The e^- beam has a constant DC level V_0.
The RF i/p is periodic



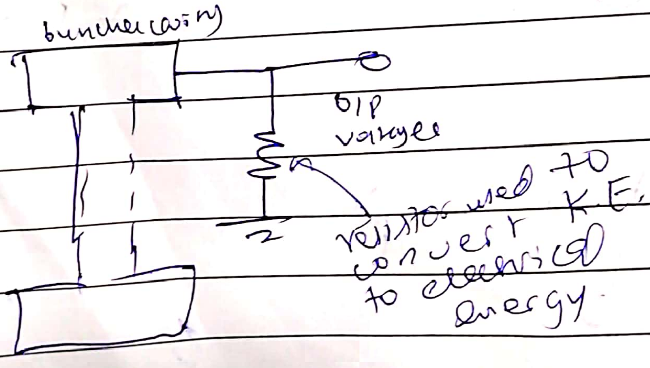
In each period first e's are slowed & the later e's speed up & thus in bunching



$$V_1 > u_0 > V_2$$

$$\therefore \frac{1}{2}mv_1^2 \quad \frac{1}{2}mu_0^2 \quad \frac{1}{2}mv_2^2$$

$\therefore$ Velocity mod^n occurs in first cavity on e^- beam caused by RF i/p. to be amplified & thus leads to amplific^n.



• Role of d:

$d = n\lambda$

↳ wavelength of RF i/p

$n \leq 5$

~~so~~ as if $n > 5$ then region of inter^n very high so e^- may dissipate and cause heating rather than amplifi^n.

• Accelerating anode:

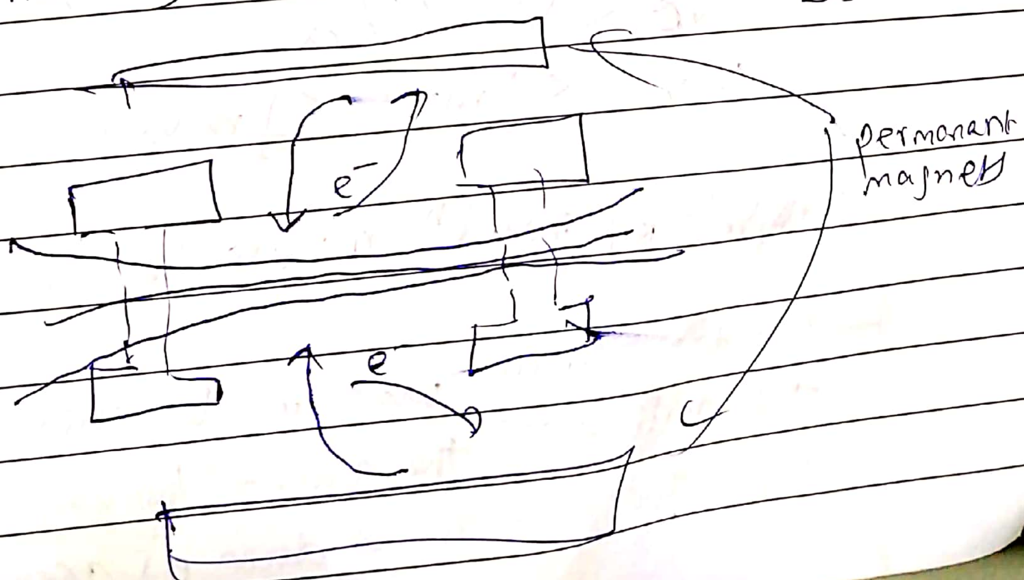
used to concentrate and bunch e^-s to a beam.

• Catcher cavity:

Two electric fields present, the constant DC level field due to original e^- beam & the velocity modulated beam ~~from~~ first cavity. This, acts as a second amplifier ~~and~~ as same inter^n as first buncher cavity/amplifier.

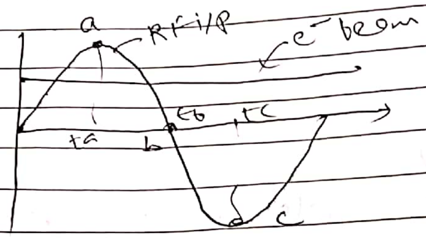
• Anode: used to collect any escaping e^-

• permanent magnets placed above & below cavities to beam. & helps to return the escaping e^-s & also inc. efficiency as no e^-s lost. prevent heating / thermal runaway.



Operⁿ:

- The e^-s are emitted in a continuous stream at cathode & accelerated and concentrated to a beam by accelerating anodes
- The buncher cavity has two i/ps : the RF i/p to be amplified & the e^- beam. RF i/p voltage is sinusoidally varying.



The e^-s in each period :

- the first e^-s are at $t = t_c$ are repelled by -ve RF voltage & thus slow down.
- the e^-s in middle at point $t = t_b$ are not affected.
- the e^-s entering last at $t = t_a$ are attracted by +ve RF voltage & thus accelerated & thus velocity increases.

$V_b = V_0$ (initial velocity)

$V_c < V_b < V_a$

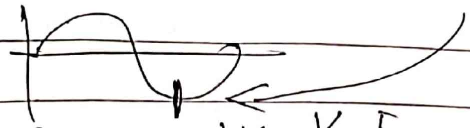
$\frac{1}{2}mv_c^2 < \frac{1}{2}mv_b^2 < \frac{1}{2}mv_a^2$

Thus, velocity modⁿ occurs in first cavity.

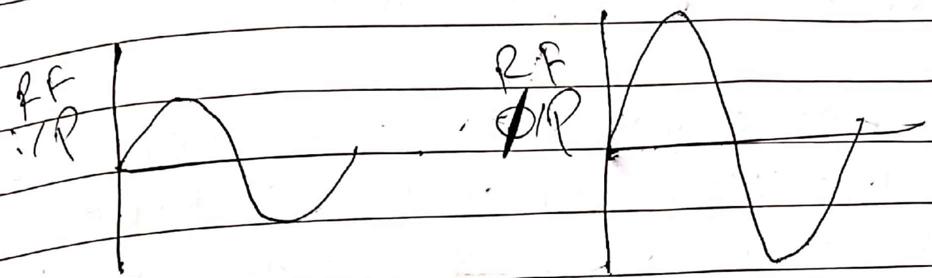
- Due to velocity modⁿ in buncher cavity over the drift space the accelerated last e^-s, middle unaffected e^-s & the first slowed down e^-s arrive at same time

at the catcher cavity in a bunch.
This is called bunching effect.

- In the catcher cavity the density modulated wave is then slowed down by



& thus loses its K.E. & this K.E. is ~~used up to~~ converted to P.E. & leads to amplific^n to produce amplified RF o/p



Bunching & vel. modl^n is analogous to amplific^n in directly coupled

Oper^n of Reflex Klystron:

- The e^- beam emitted from cathode is accelerated by anode towards the cavity.
- We assume an initial ac. field in cavity due to noise, etc. and causes velocity modulation

velocity modn

- The e^-s at a are accelerated due to +ve half cycle of RF field
- The e^-s at b travel at original velocity
- The e^-s at c will be retarded due to -ve half cycle of RF field

- The repeller plate having -ve voltage used to repel e^-s to cavity as +ve feedback

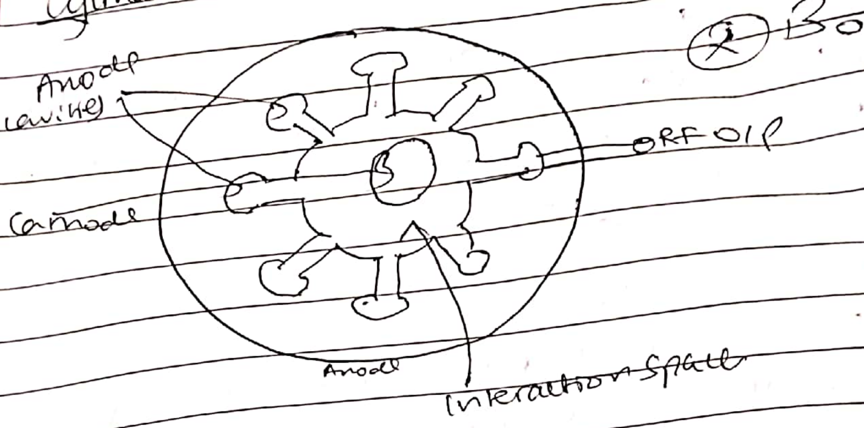
bunching

- The accelerated early electrons e_a have a long return time.
- The slowed down late electrons e_c have shortest return time to cavity.
- The electrons 'b' are reference e^-s e_b.

Thus, e^-s e_b catch up with e_a & e_c & thus reenter the cavity as a bunch

- The repeller distance L & voltages adjusted so that the e^- bunch are received on the +ve peak of cavity RF voltage cycle, & thus, the bunch loses its K.E.

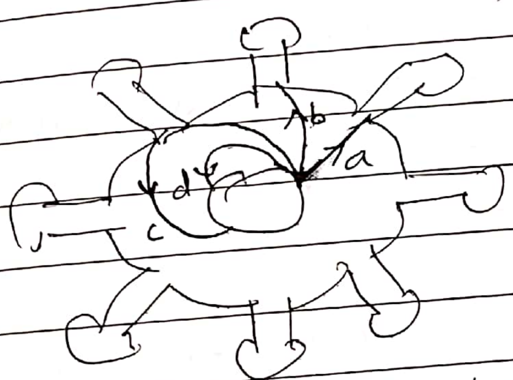
Cylindrical Magnetron:



- It consists of a cylindrical cathode at centre & thick cylindrical block of anode. The anode block has a no. of holes & slots which act as resonant cavity.
- The space b/w anode & cathode is interⁿ space
- Electric field produced by app. dc voltage b/w anode & cathode from anode to cathode
- The mag. field produced by permanent magnet & is vertical to plane region b/w anode & cathode
- The cathode emits electrons in interⁿ & interact with fields.

Operⁿ:

1.) With static electric & magnetic fields.



Case 1: If mag field absent i.e. B=0 then e⁻ will travel straight from cathode to anode due to radial force acting on it, as in trajectory (a)

Case 2: when $B < B_c$
It will exert a lateral force bending the path of e⁻s as indicated by trajectory b.
radius of path is:
$$R = \frac{mv}{eB}$$

Case 3: when $B = B_c$
The e^- will move into intern space & just graze around surface of anode (c)

Case 4: when $B > B_c$
The e⁻s experience a greater rotational force & may return back to cathode & cause heating of cathode

2.) With Active RF field: (Amplifⁿ)
~~Cas~~ " there are three kinds of e⁻s emmitted.

Case 1: when oscillations are present an e⁻ a is slowed down by tangential comp. of RF field
This e⁻ transfer their energy to RF field and are favored e⁻s.
- responsible for bunching.
- they spend a large time in interⁿ space & can orbit cathode several times before arriving at anode.

e⁻s at peak of RF field

Case 2: another e⁻ b, takes energy from RF field and is accelerated which cause it to bend more sharply, spend little time in interⁿ space.
- These are unfavoured e⁻s & do not help in bunching.
- Cause back heating of cathode

classmate

Date
Page

Vel. modⁿ occurs.

Note: type 'a' e⁻s spend more time in intern space than type 'b' e⁻s so more energy given to oscillations & thus oscillations are sustained. R F field so RF signal amplified

case 3). Bunching (Phase focussing)

+ve f/b:
→ E & H are altered so that the e⁻s take a complete circle and strike back at their origin point on cathode so 360° or 2π rotⁿ causes +ve f/b

so +ve f/b + amplifⁿ = oscillations

←
or this controlled

Velocity moduln.

Due to potential diff V_0 b/w anode & cathode, e's form a current density beam with velocity u_0

$$u_0 = \sqrt{2eV_0/m}$$

e = charge on e^-

m = mass of e^-

to change u_0 we have to change V_0

time taken by beam to cross cavity gap 'd' is transit time & angle through gap 'd' is

$$\text{Transit time} = t_2 - t_1$$
$$= t_g$$
$$= \frac{d}{u_0}$$

transit angle $= \theta_g = \omega t_g$

i/p given to buncher cavity is RF i/p

Avg. RF i/p in gap of buncher cavity is,

$$V_{av} = \frac{1}{t_g}\int_{t_1}^{t_2} V_1 \sin(\omega t)\, dt$$

$$= \frac{V_1}{\omega t_g}\left(\cos(\omega t_1) - \cos(\omega t_2)\right)$$

$$= \frac{V_1}{\omega t_g}\left[2\sin\left(\frac{\omega t_1 + \omega t_2}{2}\right)\sin\left(\frac{\omega t_1 - \omega t_2}{2}\right)\right]$$

$$= \frac{V_1}{(\omega t_g)/2}\left[\sin\left(\omega t_1 + \frac{\theta_g}{2}\right)\sin\left(\frac{\omega t_g}{2}\right)\right]$$

Let $\beta_1 = \frac{\sin(\theta_g/2)}{\theta_g/2}$ = buncher cavity beam coupling coefficient

Significance of β_1:

Note: if u_0 constant so $\frac{1}{2}mu_0^2$ is same for each e^- but

$\therefore V_{av} = V_1$

$\beta_1 \Rightarrow$ it re... that ... havi... & e... re...

Note: u_0 ... & also ...

Limits: V_0 ...

significance of β_1 :

Note: if u_0 constant so $\frac{d}{t}$ = constant thus, if θ inc. t inc. & the energy of e^- will start decreasing & thus total K.E. reduces & gain of amplifier decreases.

$\frac{1}{2}mu_0^2$ is same for each e^- but ~~amp. of~~ no. of e^-s in bunch of e^- decreases with inc. in θ. & so ~~total energy reduces~~ as total no. of e^- reaching end of cavity reduces.

$$\therefore V_{av} = V_1 \beta_1 \sin(\omega t_1 + \theta_g/2)$$

$\beta_1 \Rightarrow$ it tells us the number of electrons that are able to reach end of cavity having mass m and desired velocity. e^-s that dissipate their energy ~~and~~ cannot reach end of cavity they do not contribute to amplif^n.

Note: $u_0 \propto V_0$ so amplif^n depends on cathode voltage & also no. of e^-s emitted $\propto V_0$ so amplif^n

Limits: $V_{0\,min} \Rightarrow$ min V_0 required for all e^-s to reach from cathode to anode.

$V_{0\,max} \Rightarrow$ $u_0 = \frac{d}{t} = d \times f_{RF\,input}$

so $V_{0\,max}$ defined by freq. of RF i/p signal

& also $V_{0\,max}$ defined by thermal runaway as $V_0 \uparrow$ so no. of $e^- \uparrow$ so heating $\uparrow$ thus $V_{0\,max}$ restricted.

Let u_{av} = velocity of e^- at mid of gap

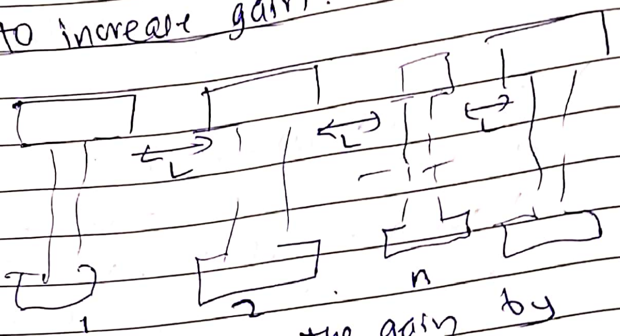
$$u_{av} = \sqrt{\frac{V_0 + V_{av}}{V_0}} = u_0 \sqrt{1 + \frac{V_1 \beta_1 \sin(\omega t_1 + \theta_g/2)}{V_0}}$$

Let $m = \frac{V_1}{V_0}\beta_1$ = depth of modulation

$$\boxed{u_{av} = \sqrt{1 + m\sin(\omega t_1 + \theta_g/2)}}$$

Now to increase gain:

acts as a cascaded amplifier



we can increase the gain by increasing no. of cavities

$\beta = \beta_1 \beta_2 \cdots \beta_n$

- but problem is that as ~~drift~~ no. of cavities increase the drift space b/w the cavities cause more no. of dissipated e's to cause heating & thus, thermal runaway

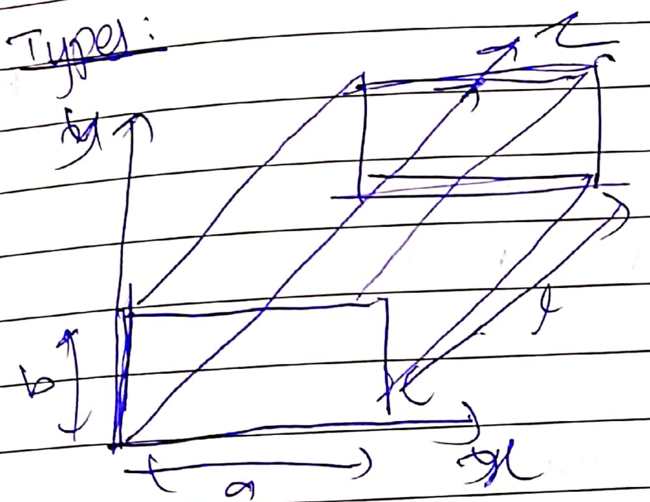
- as Gain × B.W. = constant
  so if Gain ↑ then B.W. ↓
  so puts a higher limit on no. of cavities.

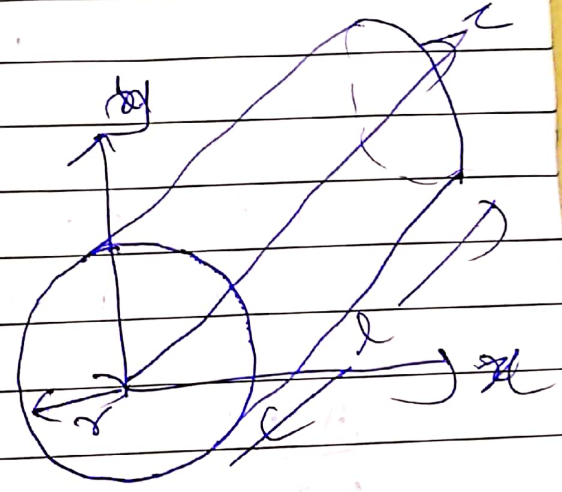
Thus, instead of increasing no. of cavities we can use multiple two cavity klystrons,
but limitⁿ is large no. of klystrons will need large area to install

Cavity Resonators :-

- A cavity resonator is a device that behaves like a resonant circuit.
- It is a hollow metallic enclosed tube that exhibits resonance behaviour when excited by EM fields in microwave range.
- Freq range (> 3GHz)
- At microwave frequencies resonant circuit with ordinary inductors and capacitors connected by wires cannot be used as for resonance very low valued inductance and capacitance needed & very difficult to obtain high Q also at μwave range small physical dimensions needed.
- A hollow conducting box which is essentially a segment of waveguide with closed end faces in which the end faces are shorted metal plates so as to reflect waves from both ends to form standing waves at resonant frequency in cavity.

Types:



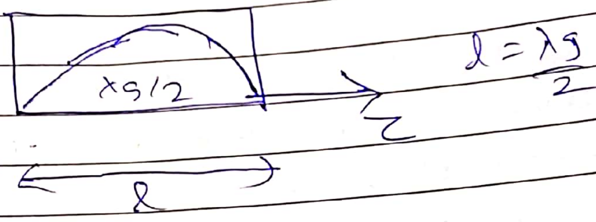


- General modes in cavity resonator are TE_{mnp} or TM_{mnp}

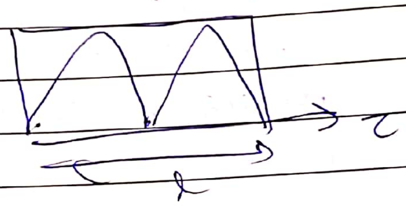
where m corresponds to dimension a, n corresponds to b, p corresponds to l.

For a signal propagating along z dirⁿ for standing wave pattern to form the incident & reflected waves from both ends must be in phase & for this the length of reflector must be $n\left(\frac{\lambda g}{2}\right)$

For resonance to occur we need standing pattern.
If signal propagating along z direction to have a standing pattern the length of resonator must be a multiple of half of guided wavelength so that the incident & reflected waves are in phase and thus form a standing wave. Reflections occur at both ends to form standing waves.



$l = \frac{\lambda g}{2}$



$l = 2\left(\frac{\lambda g}{2}\right)$

& so on for resonance.

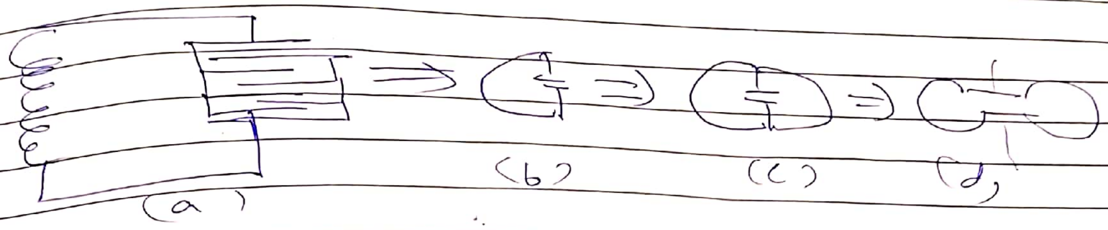
Condⁿ for resonance:

$$l = n\left(\frac{\lambda g}{2}\right) \quad n = 1, 2, 3 \ldots$$

Adv:
- dimensions simplicity
- very high quality factor (Q)
- very high impedance

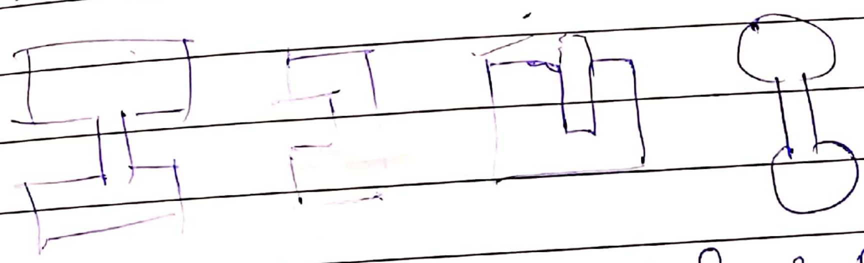
Appⁿs:
- high frequency tubes like klystrons, magnetrons
- wavemeters to measure frequency.

Reentrant cavities:



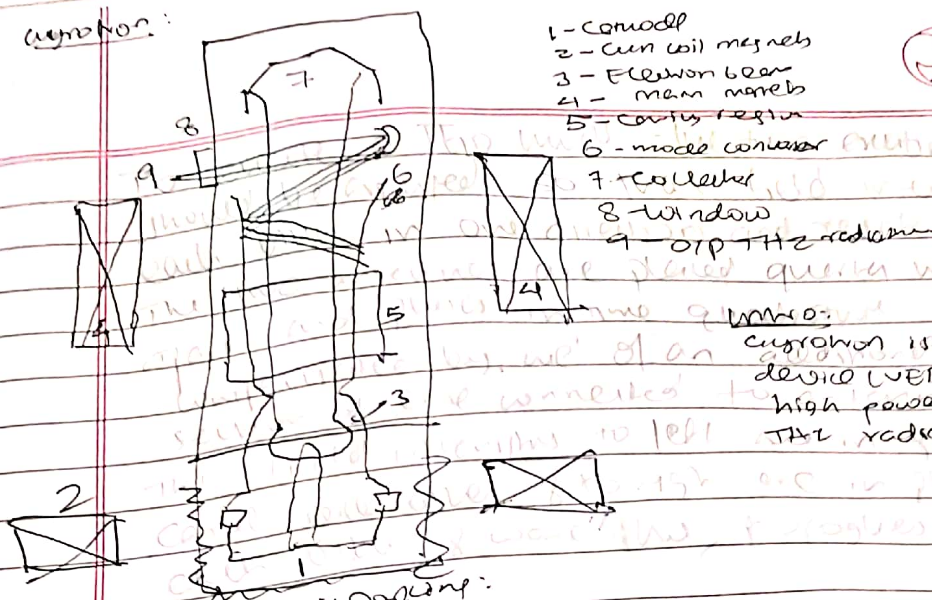
- At freq. well below microwave range cavity resonators can be represented by lumped resonator circuit
- As freq ↑ the L & C must be reduced for resonance & so the multiturn inductors & multiplate capacitors replaced by (b) a single half turn & single pair capacitor plates
- On further inc. freq. the capacitance reduced by increasing plate spacing and adding inductors in parallel.
- With addn of many parallel inductors the inductor portion becomes a hollow toroid in which magnetic fields are concentrated & electrical energy in central capacitive region.
- Resonance occurs by back & forth waves b/w toroidal & central capacitive region.

Diff. shapes of reentrant cavities



It is possible to pass a low power e beam through centre region by replacing capacitor plates with parallel grids

Gyrotron:



Intro: Gyrotron is a vacuum electronic device (VED) capable to generate high power, high frequency THz radiation.

Gyrotron: Working:

- Magnetron & Klystron requires resonant cavities to support EM field that interacts with e^- beam. TWT requires a SWS. These structures have dimensions proportional to wavelength. So in µwave range f very high so the dimensions of structures have to be reduced. & so it can leads to low power o/p & can cause overheating / breakdown. power handling capacity of structure

Gyrotron does not rely on such structures & so can produce very large o/p (in kW range) at µwave large frequency ranges.

Oper^n:

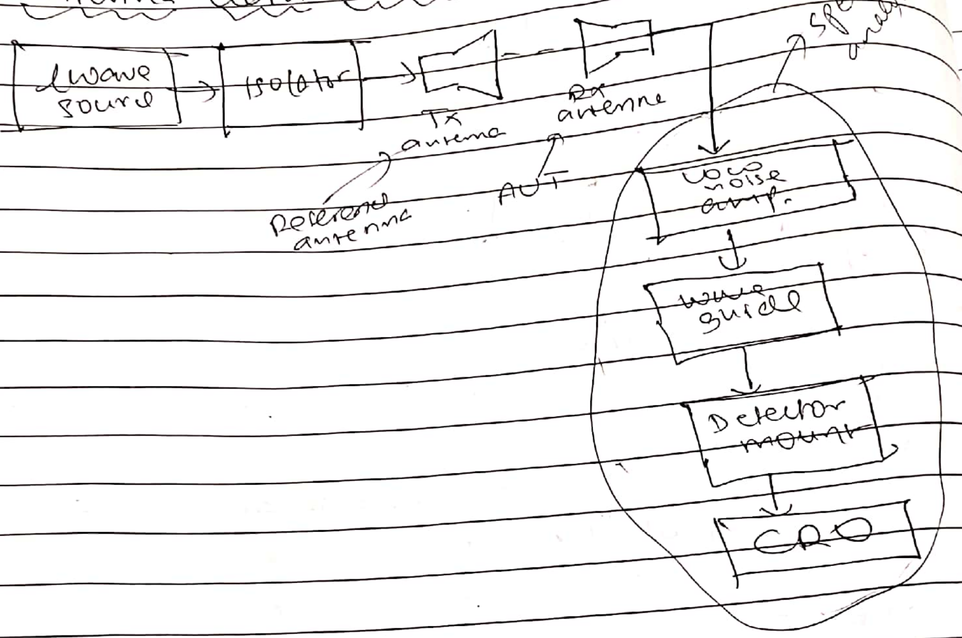
used to cause thermionic emission from cathode and ~~the electrons are~~

- A hot fillament which are accelerated by a high voltage anode an annular shaped beam of e^-s
- The beam travels through a resonant cavity structure where strong magnetic feed created by superconducting magnets around the tube finish.
- Due to intense magnetic field e^-s start to gyrate at a specific freq. and so e^-s move helically in tight circles around magnetic field lines as they travel axially through tube.
- In the cavity at the pos^n where magnetic field strength is maximum e^-s radiate RF waves in a dir^n $\perp$ to axis of tube at their cyclotron resonance frequency close to RF field frequency
- These radiation forms standing waves in tube (which acts as an open ended resonant cavity), which ~~is f~~ using a mode convertor used to form a free-gaussian beam that leaves gyrotron through a window & is coupled to a waveguide.
- The spent e^- beam is absorbed by the collector.

Scanned by CamScanner

Module 5:

- Antenna Gain measurement:



Reference tx antennas are horn antennas with known gain

Rx antenna – microstrip antenna

Spectrum analyser used at rx to measure Pr(dB).

f	Pr(dB)

By Friss formula,

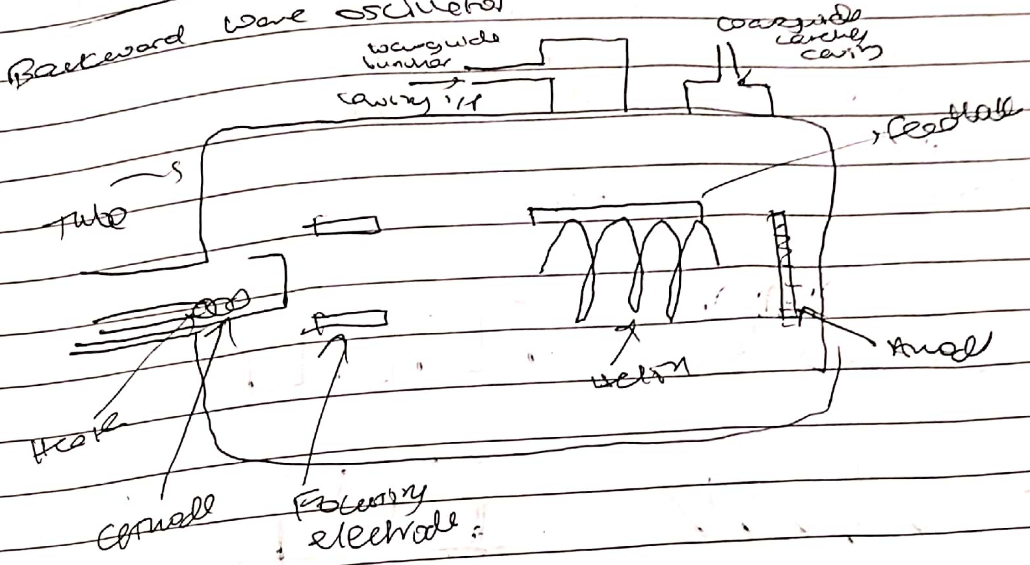
$$P_r = \frac{P_t \lambda_0 G^2}{(4\pi S)^2}$$

S → dist. b/w antennas

$$\therefore G = \frac{4\pi S}{\sqrt{\lambda_0}} \sqrt{\frac{P_r}{P_t}}$$

• Radⁿ pattern:
same set-up as before, the AUT is rotated in its plane & the radⁿ strengths noted in diff. dirⁿs & final radⁿ pattern plotted.

Backward wave oscillator



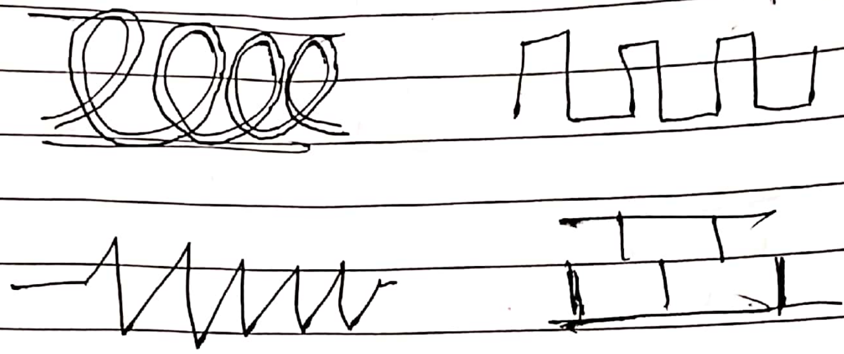
working:
① when i/p signal applied to buncher cavity the waveguide buncher cavity will excite. This will induce voltage at i/p end of helix.
② As induced voltage in helix is A.C. signal it will have +ve & -ve half cycles.
③ If we consider -ve half cycle of input, the electrons emitted from cathode will be repelled back at input of helix which will form a bunch. (bunch that was repelled so ... moves)
④ For a +ve half cycle these electrons (bunch) will speed up & induce voltage in next ring of helix. This induced voltage will be stronger than previous one.
⑤ Finally at o/p of helix the i/p voltage will be ~~stro~~ so strong that it will excite catcher cavity
⑥ The o/p ~~of~~ will be obtained at catcher cavity with help of loop coupling.
Feedback used to reduce damping & maintain oscillation.

- In two cavity klystrons if we inc. no. tubes then gain ↑ but for resonant structures like klystrons gain × B.W. = const so BW ↓ which is not wanted
so we use **non-resonant structures** so that the structures can inc. gain by vel. modn & non-resonant property will maintain the B.W.

⇓

→ Slow wave structure:

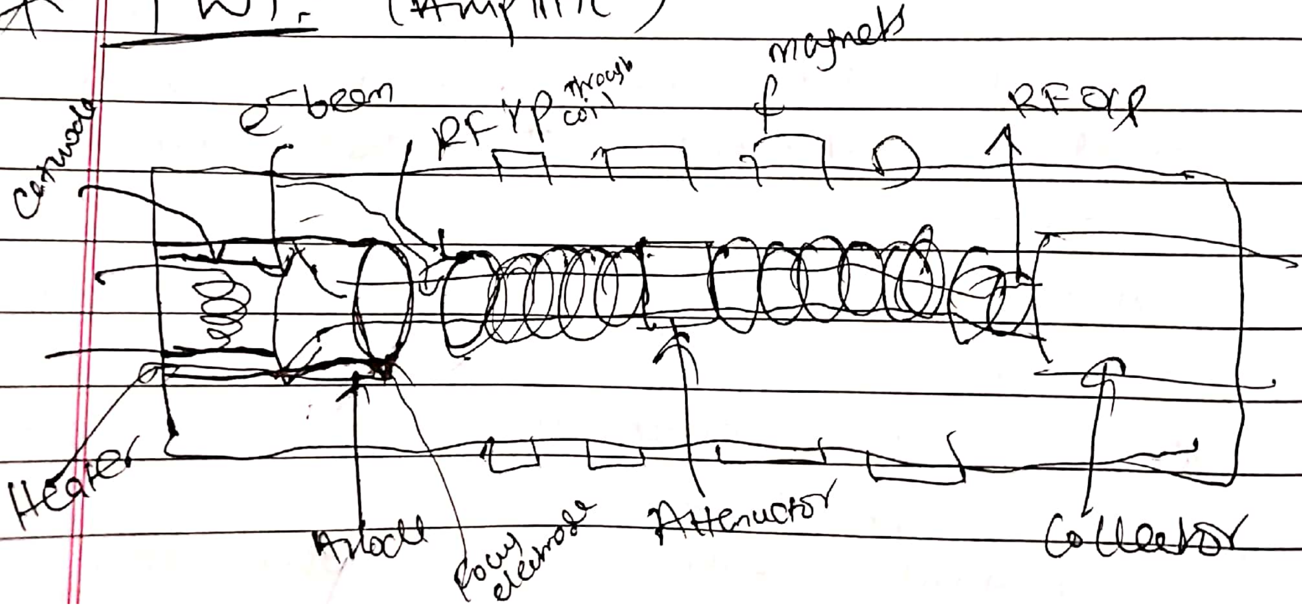
There are simple metallic wires



- This structure slows down the wave as dist. increases so for a constant vel., d∝t

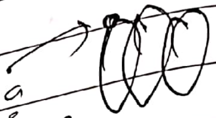
High BW ⇒ As simple metallic wires so at high μwave freq not able to store energy & very low L&C so non-resonating structures.

✳ TWT: (High Amplific^n)



One end of helical sws connected to RF i/p & to other end RF o/p taken.

When RF i/p passes through helical coil it generates sinusoidal electric field.
At any time instant as helical structure we don't know if field max or min at a point



here at t=a maybe RF i/p min & at t=b RF i/p max ~~at t=~~

~~when~~ inside structure ~~interⁿ b/w e^- beam & RF i/p~~ occurs inside helixes & cause vel. modⁿ.

Step ①: Through one helix e^- beam attracted by +ve point & repelled by -ve part of helix & by vel. modⁿ ~~vel.~~ K.E. increases

Step ②: In second helix again vel. modⁿ occurs on already velocity modulated beam & K.E.

Step ③: At each coil vel. keeps increasing so each coil/helix acts as amplifiers in cascade.

Thus entire structure acts as amplifiers in cascade & each is non-resonant
So Gain ↑ & BW ↑

Restrictⁿ on no. of turns:
- thermal runaway may occur
- if any feedback/signal reflected & if reflected & incident signal will be in phase then oscillations start occurring so to prevent it we use attenuator to attenuate energy after fixed no. of turns.

In klystron RF field stationary & e^- beam travels
In TWT both travel at nearly same velocity

attenuator is directional in nature so no attenuation of incident signal

if reflected signal then attenuation occurs

magnets used to focus escaped e^-s back to structure so as to avoid heating & dissipation.

Adv:

- High B.W. & amplifier so to be used for RADAR appl^ns, unmanned vehicles, unlike klystrons.

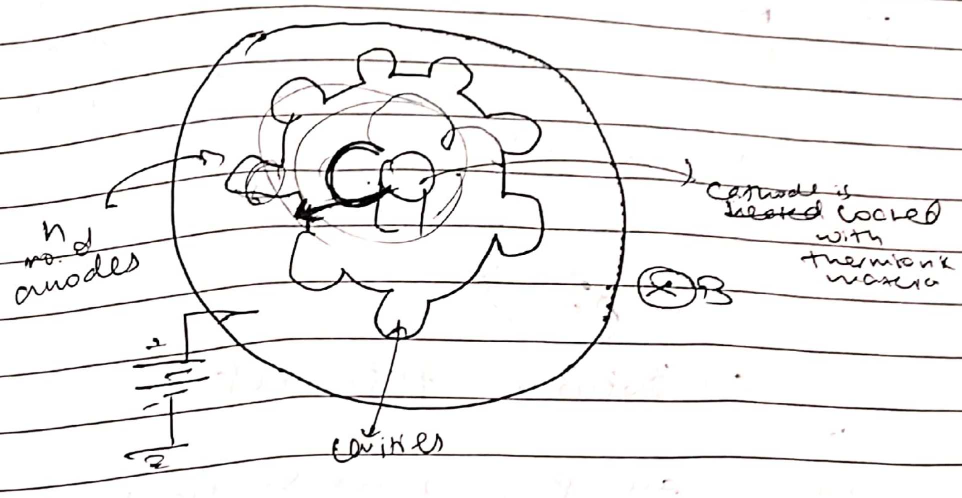
SWS are used through which the RF i/p signal is passed. RF in general travels at speed of light so this SWS is used to slow down the propag^n of RF to match it to propag^n speed of e^- beam so as to increase interaction between them. As v = const so $d \propto t$, as d inc t inc. so value to SWS ~~delivers~~

Op^n: RF signal to be amplified applied to TWT & its velocity is speed of light but due to SWS it produces electric field along axis of helix which propagates along axis of helix with phase velocity $V_p = c\sin\psi = \frac{cP}{2\pi a}$ P → pitch of helix, $2\pi a$ → circumference of helix

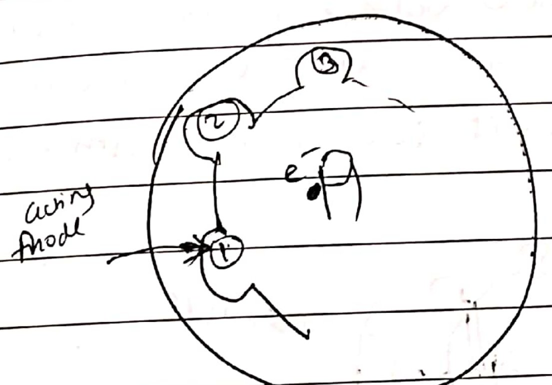
- In each turn the axial electric field interacts with e^-s.
The e^- entering helix at zero field are not affected, e^-s entering at +ve cycle of RF field are attracted & thus accelerated, the e^- entering helix at -ve cycle of RF field & are repelled & decelerated. Thus velocity modulation takes place & bunching of electrons occurs.
- The i/p for next helix is e^- beam & velocity modulated wave & same process occurs & further amplification occurs.
- This entire structure acts as amplifiers in cascade.

* Magnetron:

- works as Oscillator
- It is a cross field device (E & H fields are not linear but are ⊥ to each other)



cathode heating done & emits e^-s in all dirn
e^-s move only in horizontal plane as e^-s from cathode surface attracted to the anode & two magnets perpendicular to cathode.
The electric field in horizontal dirn & mag. field in ⊥ dirn act simultaneously on an e^- emitted by cathode and so due to these cross fields circular motion occurs.



W/O. B: case ①: if E is strong enough to attract e^-s straight to it & will combine to anode terminal ①

with B: case ②: if E not strong, B also acting enough then it follows circular path & will go to anode ② case ② - - : If E & H fields further adjusted that e⁻ ~~goes~~ follows circular path to anode ;

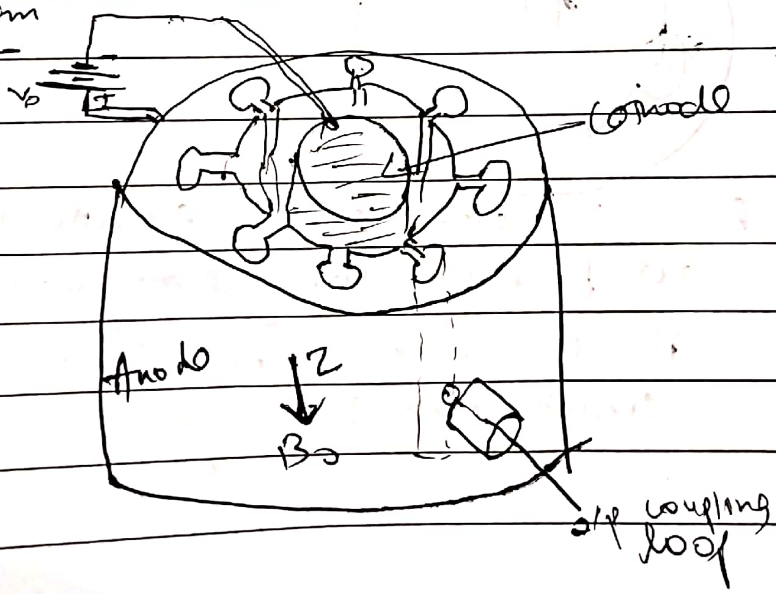
case: Now if E & H adjusted so that the e⁻ follows a circular path & completes a circle back to its original pt. to cathode

so positive feedback.

∴ E & H fields are properly set, so that instead of just going straight to anode ① it is accelerated to follow a circular path & then due to acc. velocity changes so vel. modulⁿ & then amplifⁿ occurs & further due to full 360° circular path +ve f/b occurs hence oscillations occur.

∴ have to vary anode voltage so that instead of e⁻ going straight to anode the e⁻ should come back to cathode & not combine with anode.

Diagram



e⁻ will try to escape but adjust E & H so that circular path maintained

Back hea

During

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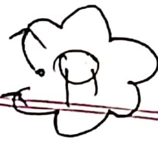
e⁻ will try to escape but adjust E&H so that circular path maintained

Path:



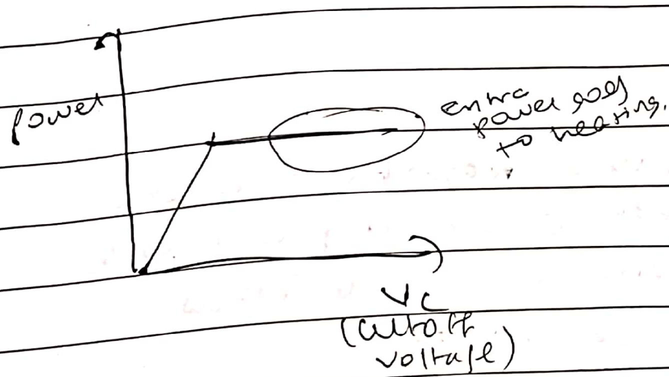
- Back heating:

B > B_c the e⁻s return to cathode at random pts.

- During circular motion if cathode voltage is insufficient to cause repulsion then the e⁻ will strike back to cathode at a random point & lead to heating of overall structure

- The potentials or E&H fields just sufficient to cause circular motion are Hull-cutoff voltages
  $V_{HL} - B$ (voltage to magnets)
  $V_{HL} - E$ (voltage to electrodes)

If V ↑ then acceln inc. so O/P power inc. upto saturation.



So limits on potential:
min — ~~above~~ required to just maintain circular motion
max — point at which we get const. power

Tuning:

- Freq. depends on:
  - no. of cavities: min ~~no.~~ decided by min. accelern needed to make e⁻ complete a full circular path & hence the RF to be generated.
    max no. depends on freq. required
  - anode voltage: as it ↑ so force of attn ↑ so e⁻ attracted more then moves back so dist ↑ & v = const so t ↑ & freq. changes.

$v = \frac{d}{t} = \infty$

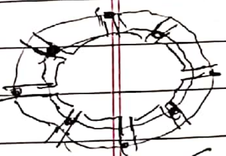
~~to avoid mode jumping~~

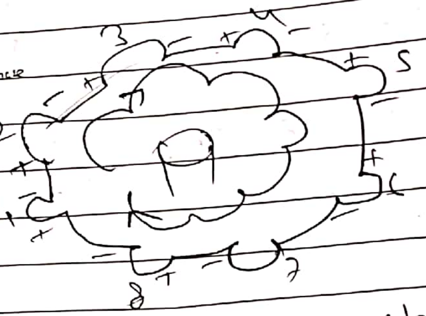
- freq. tuning: (Strapping)

freq. tuning/variⁿ can be done by changing no. of anode cavities.

so

we use two rings of heavy gauge wire connecting alternate anode poles as alternate poles should be in phase for π mode



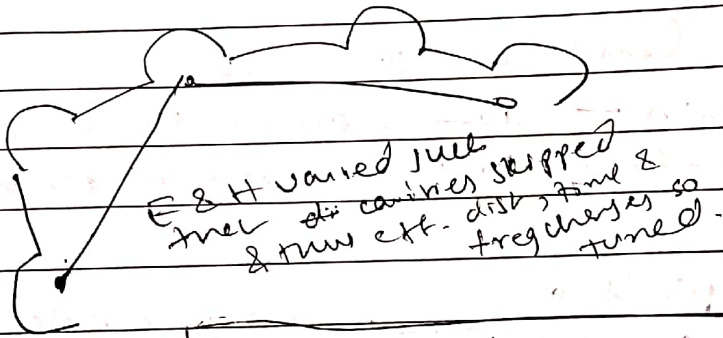


eg. So by strapping can short (1&2), (3&4), (5&6), (7&8) so effectively 4 cavities & so freq. changes.

- mode Jumping:

by adjusting external magnetic or electric potential so that e^- can jump cavities & thus change distance travelled & thus, frequency can be changed.

also as oscillating freq. for diff. mode are diff. so a 3cm π mode could spurious become a 3.05cm which 3π/4 mode produces oscillations of reduced power



Self consistent oscillation can occur only if phase diff. b/w adjacent anode poles is ~~nπ/4 when n=4 is used~~

App's:

- μwave oven
- industrial drying

MODULE 04 – Solid State Devices

Q) Why normal semiconductor devices can be used at µwave range:

Ans) • cannot we Si or Ge at µwave freq.

as $V_D = d \times f$ & V_D very low for these materials so if f very ~~low~~ high than the V_D won't cope up so we use GaAs, InP as V_D very high

• as f very high so physical size very low

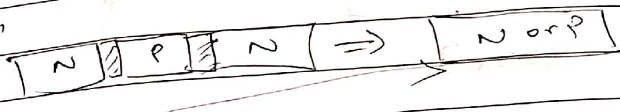
• length of depl^n region $\propto \frac{1}{f}$

so ideally at µwave freq. depl^n region $\simeq 0$

so current can't flow as all holes & e's recombine.

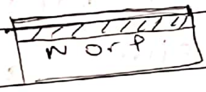
which means NPN device becomes only N or only P type device

so,



soln:

∴ • Bulk devices used which are coated with metallic layer & assuming a very thin depl^n region we assume a depl^n layer b/w bulk semiconductor & metallic conductor

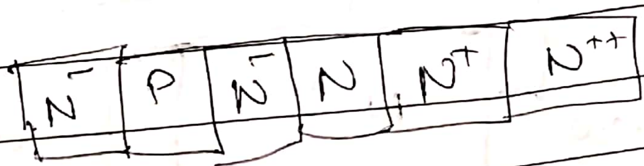


we used ~~N type~~ devices

• ~~avalanche devices~~

instead of using bulk we can introduce a gradual/exponential change in doping level so that we get a controllable variable depl^n region. These are

avalanche devices.

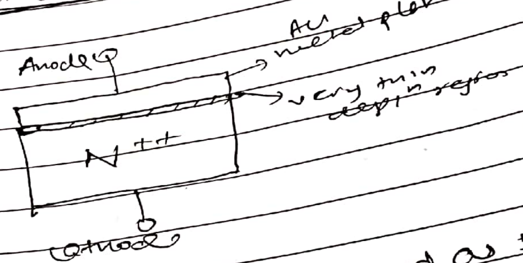


* Types of Bulk device.

• Gunn Diode:

→ construction:

we use heavily doped N type bulk device and also carrier density is very high (in ~~less~~ area large no. of elec. are accumulated



• A gold sheet connected ~~and~~ as it is best metallic conductor.

• The metal will have large no. of holes so anode taken out from it

• The semiconductor will have large no. of electrons as majority charge carrier so cathode taken from it.

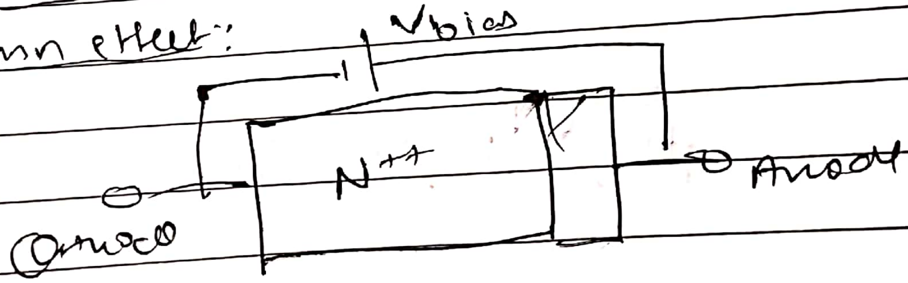
• An extremely thin depletion layer will form between them.

• Thus diode formed.

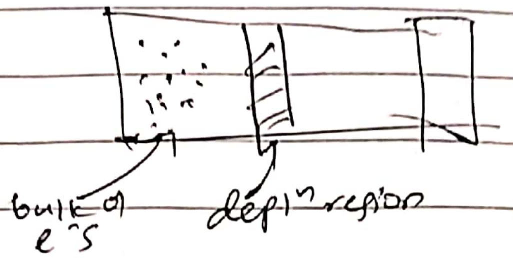
• It is mainly used as an oscillator.

→ Working:

• Gunn effect:

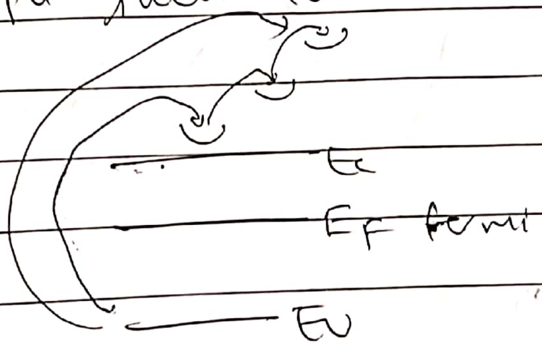


• diode is forward biased
• ~~due to~~ due to high doping & large carrier density so the electrons will start repelling each other
& so a bunch of e⁻s will form in one region of device & other area will be completely devoid / depleted of charge carriers



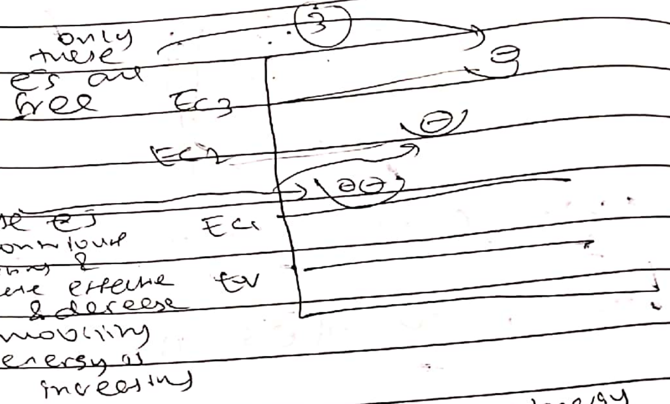
• we cannot control where both regions will form.
• This bunch of e⁻s is called domain of electron

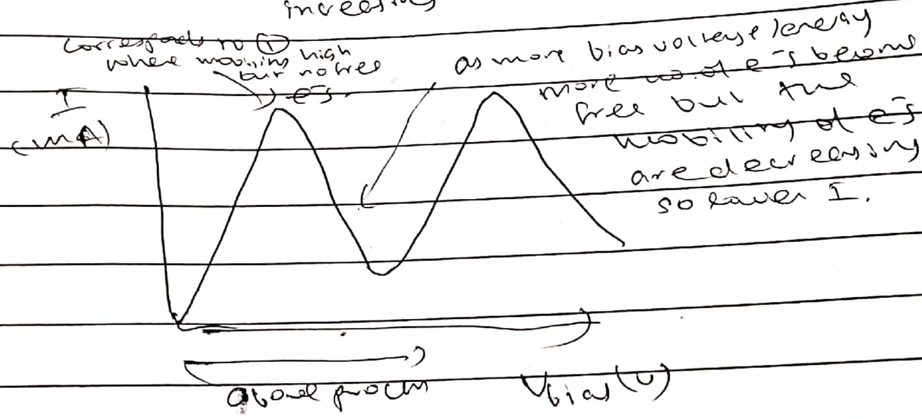
. doping is adjusted so that ~~one~~ single cond^n level divided into multiple such levels



e⁻s are free only in topmost cond^n level.
so on providing energy to e⁻s in ~~Eo~~ Ev will jump to topmost band & are free but if jump to intermediate cond^n level only two options ^ are to Ev or topmost so more energy given to promote to topmost Ec level & become free.

multivalley structure.





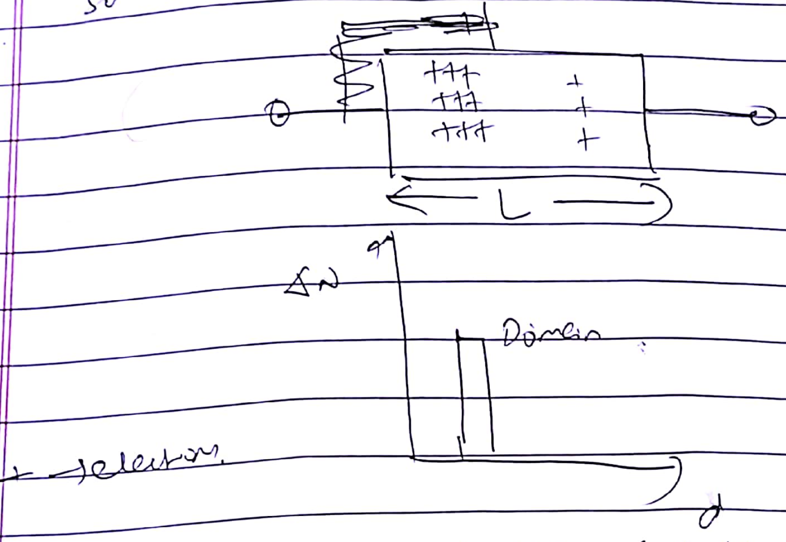
Due to doping, temp - decides distance b/w condⁿ levels

∴ with inc. in voltage/energy current decreases as mobility of e⁻s decreases

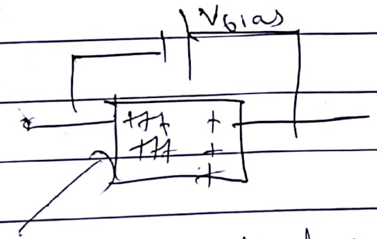
negative resistance

domain of e's : e's having same energy as only e's having same energy will not attract or repel each other

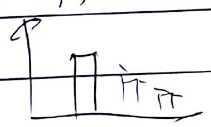
+ve resistance - dissipates power
-ve resistance - generates power
so -ve resistance a Gunn diode used for oscillation.



During manufacturing due to repulsion of e's domain formⁿ occur.
Now if f/w bias supply used



domain is repelled and as Vbias ↑ the domain is getting repelled which causes increase in electrons in domain & thereby increasing overall domain energy. The domain moves to other terminal and domain on reaching other end it collapses at +ve terminal.
As supply still on another bunch formed & again the new domain travels & collapses at +ve terminal.
The pulse travels along length of diode with decreasing energy



So dc bias voltage converted to ac signal

~~for~~ Pout is a fn of doping of bulk & amplitude of biasing voltage
four is a fn of length of ~~#~~ bulk & posn of domain ~~for~~ motion.
$V_D = L \times f_{out}$
$\therefore f_{out} \propto \frac{1}{L}$

Mode: to tune four :
1.) Transit time mode:
mode in which Gunn is operating naturally
so four $\propto \frac{1}{L}$

Disadv: cannot tune Gunn over a large range

2) Delayed mode:
domain transmitting velocity is reduced.
as time is varied four changes as
T ↑ four ↓
so ~~to~~ change operating freq. as compared to fabricated limit ~~[illegible]~~ Delayed mode used, as V_D & d cannot change so T changed. this delay caused by V_{bias} varying.
switching mechanism used in which external circuitry used to switch bias On & OFF regularly so interrupt occurs for domain & so more time taken

$V_D = \frac{d}{T}$ although V_D & d same but T changes.

3.) Quinched mode:
both Pout & four increased.
increase V_{bias} such that no. of e's in a domain increases simultaneously the velocity of
Pout ↑

domain increases
The higher limit
time so the
fabricated
4.) large space
doping
domain
taken
so
ampl
so
an

domain increases so $T_{out}\downarrow$ & $f_{out}\uparrow$.

The higher limit is doping done ~~before~~ at manufacturing time so the environment in which these gunns are fabricated is different.

4.) Large Space Accumulation (LSA) mode:

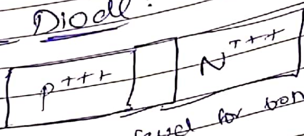
doping is adjusted such that multiple domains formed along the length. The time taken to reach the terminal will be different.

So many different pulses having diff. frequency and amplitude formed.

as no. of e's in each domain different.

So we get multi frequency o/p at different amplitudes.

* Tunnel Diode:



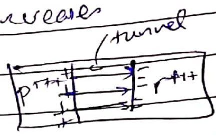
doping level for both materials is very high

triple + indicates no. of holes in p = no. of e^-s in n

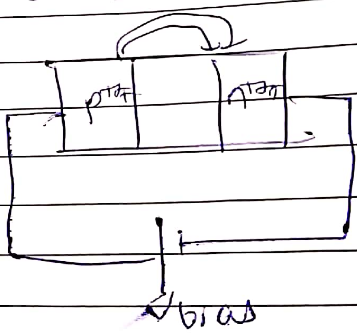
• as both semiconductor region heavily doped so width of depl^n region very small so holes just left to it & e^-s just right to it have very low difference.

W/O any bias voltage the majority charge carriers just on any side of depl^n region they don't need to jump over depl^n region for recombin^n on other side but can tunnel through depl^n layer as very thin. ~~& current flows~~

• due to tunneling effect recombin^n occurs & thus depl^n region width increases

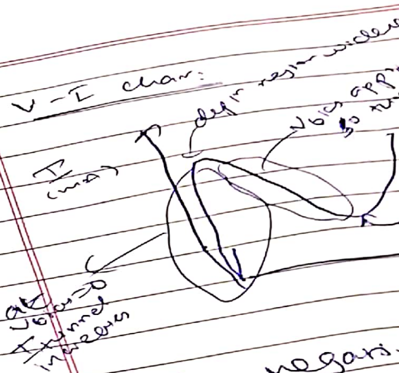


• so now for current flow we need bias voltage as cannot directly tunnel through depl^n region



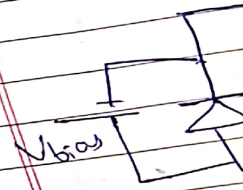
So now with V_{bias} the charge carriers will not tunnel through depl^n layer but will have enough energy to jump so tunnel current reduces & current due to V_{bias} increases & depl^n region becomes thinner.

V-I char:

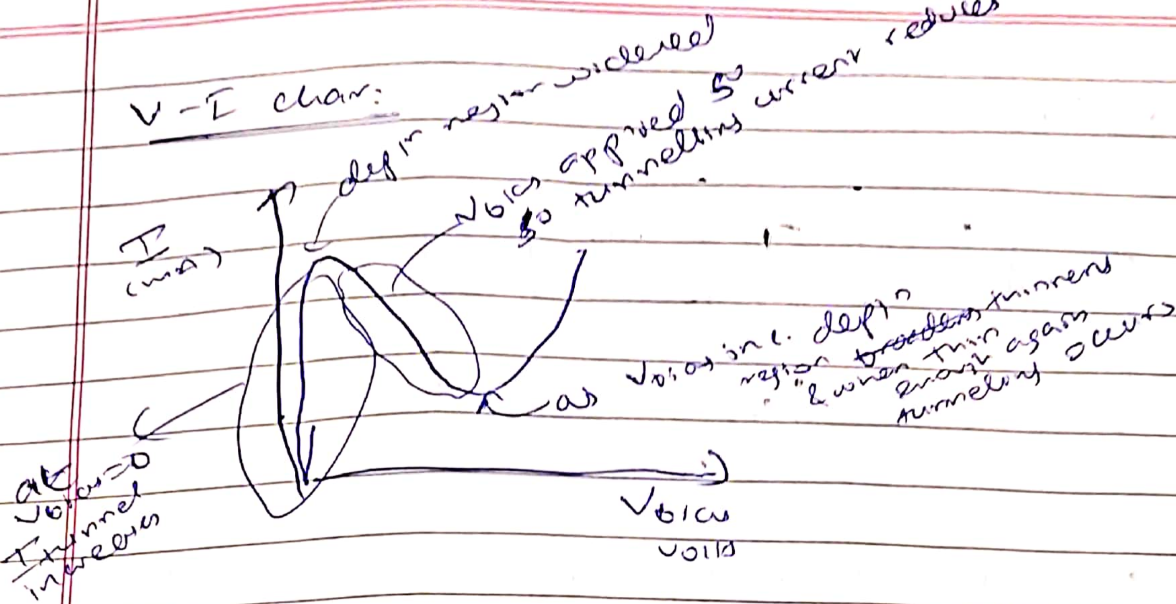


So negati...

Tunnel dio...

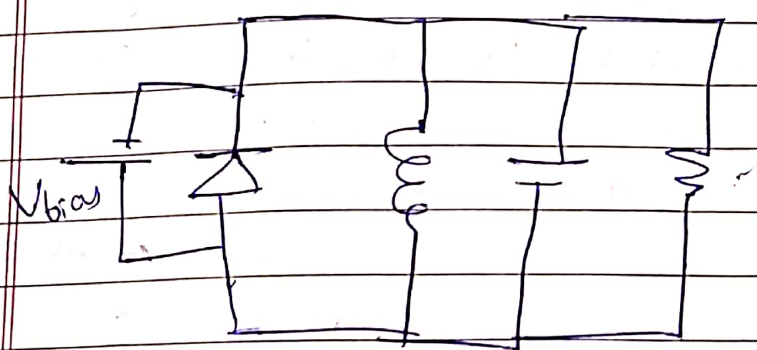


V-I char:

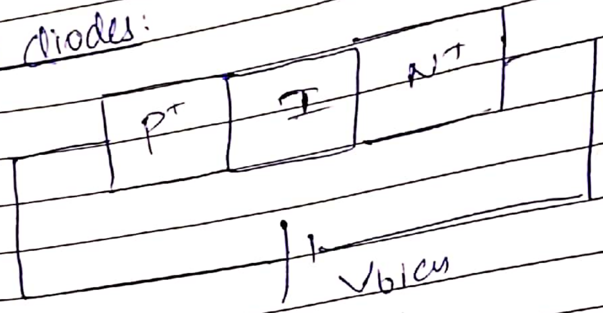


So negative resistance exhibited.

Tunnel diode used as an oscillator



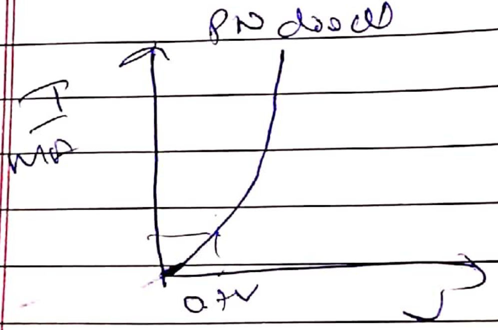
* PIN diodes:

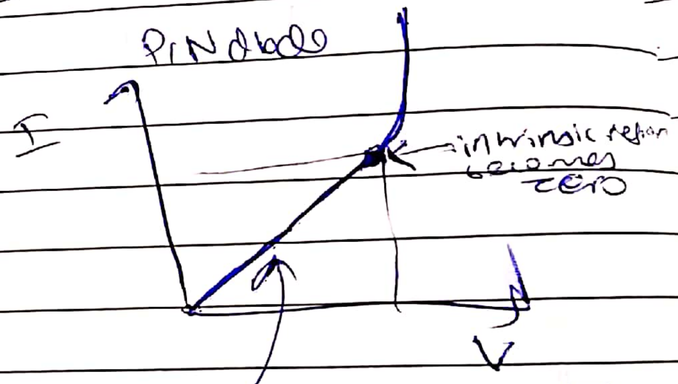


due to charge depleted intrinsic layer majority charge carriers cannot directly jump to other side for recombin^n.

~~Vbias = 0.7V : knee voltage~~

Normally in PN diodes after Vbias = 0.7V exponential increase but due to thick I layer flow current as Vbias inc. linear inc. in flow current upto a large range & at a very high Vbias exponential increase will occur ~~at the v.~~



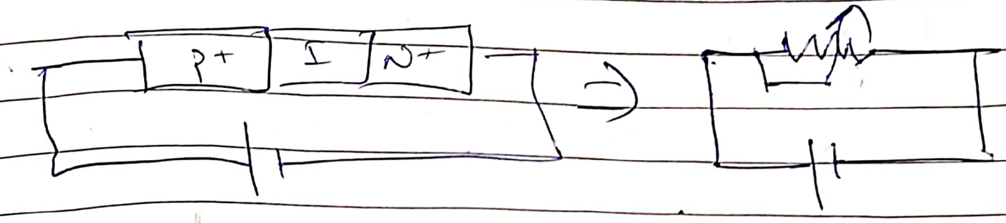


Redn in width of intrinsic layer is linear unlike exponential in normal PN diodes

• In linear region of PIN diode Ohm's law followed

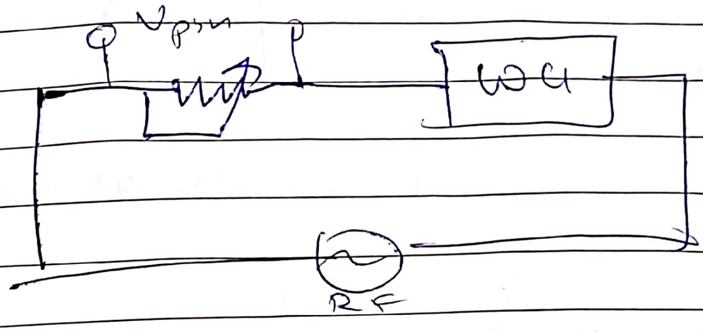
$\frac{V}{I} = R$ ~~[illegible]~~

∴ In linear region



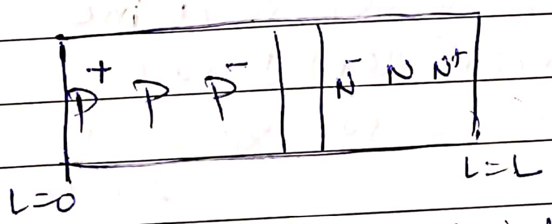
So it behaves as a variable resistor which changes with V_{bia}.

Appl^n:
used as a variable attenuator



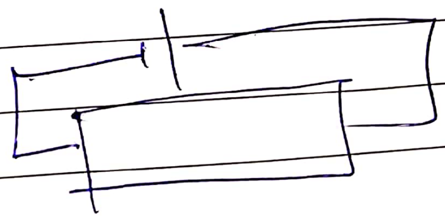
So Vpin changes as applied voltage changes so attenuation varied.

* **VARACTOR Diode:**
- It offers variable capacitive reactance
- doping changes exponentially along length of diode



This exponential change in doping can change length of depl^n region in abrupt manner.

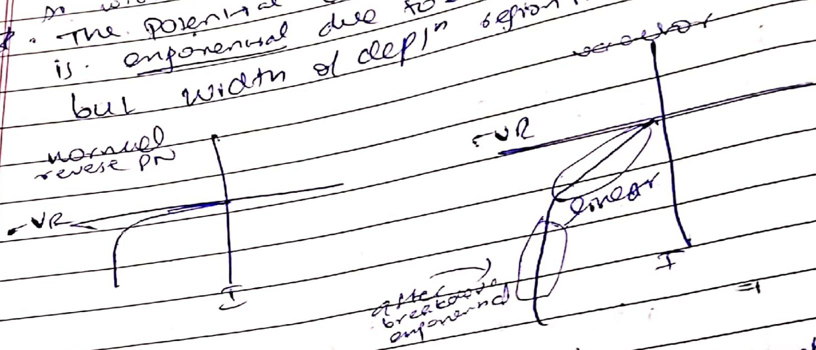
- It is operated in reverse bias



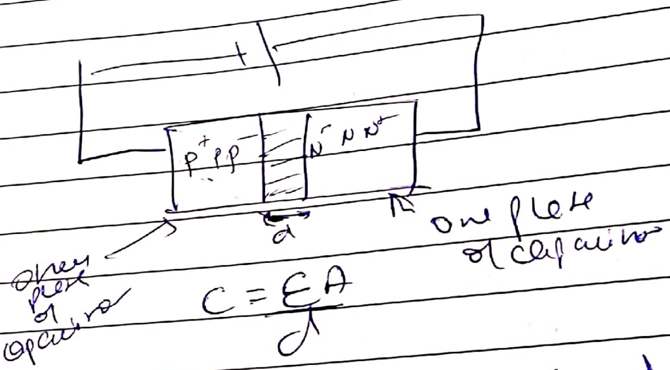
e⁻s attracted to +ve terminal, holes to -ve terminal

so width of depl^n region increases

8. The potential charge around depl^n region is exponential due to exponential doping changing but width of depl^n region increases linearly.



This current also increases linearly till breakdown.



$C = \frac{\epsilon A}{d}$

as V_{bias} changes so d inc. & A (area of plate) ↓ so C changes & so $X_C = \frac{1}{2\pi f C}$

changes