**UNIT-V**

**MICROWAVE TUBES & MEASUREMENTS**

**Session - I**

Introduction:

* Microwave tubes - Linear beam- ‘O’type

Presentation & discussion:

* Need for microwave tubes

For amplification, oscillation

* Types

Cavity structure – two cavity klystron, four and multiple cavity, reflex klystron

Slow wave structure – TWT amplifier

* Significances

Oscillator and amplifier for high frequency

Presentation & discussion:-

High frequency limitations:

* Circuit reactance
  + Inter electrode capacitance
  + Lead inductance
* Transit time effects
* Cathode emission & plate heat dissipation area
* Power loss due to skin effect, radiation & dielectric loss
* Gain bandwidth product

Conclusion & Summary: recall by key words

* Cavity tube
* Slow wave structure
* Inter electrode capacitance
* Cathode emission
* Transit time effect
* Skin effect
* Plate heat dissipation area

**Session – II**

Introduction:

* Multi-cavity Klystron

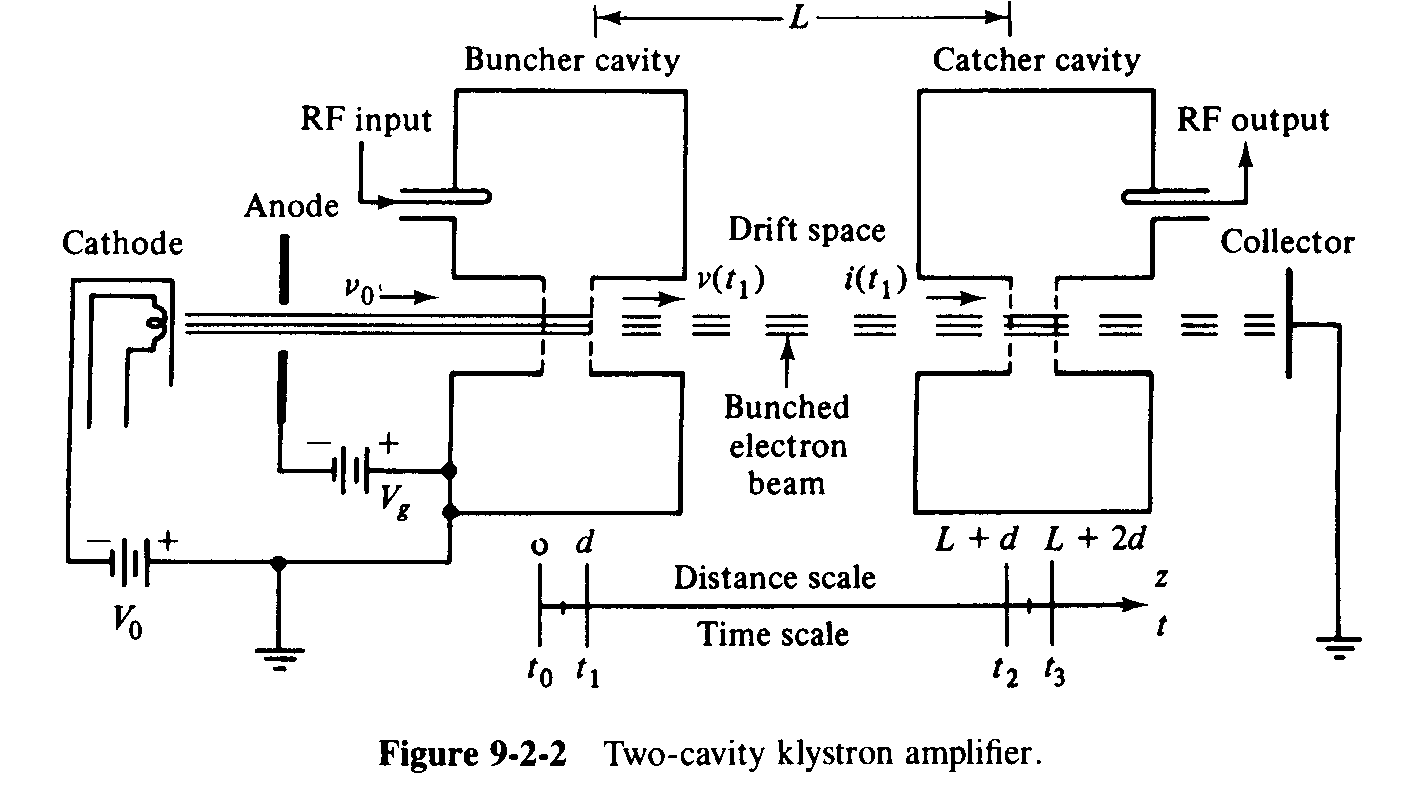
Two cavity, four cavity and multiple cavity structures

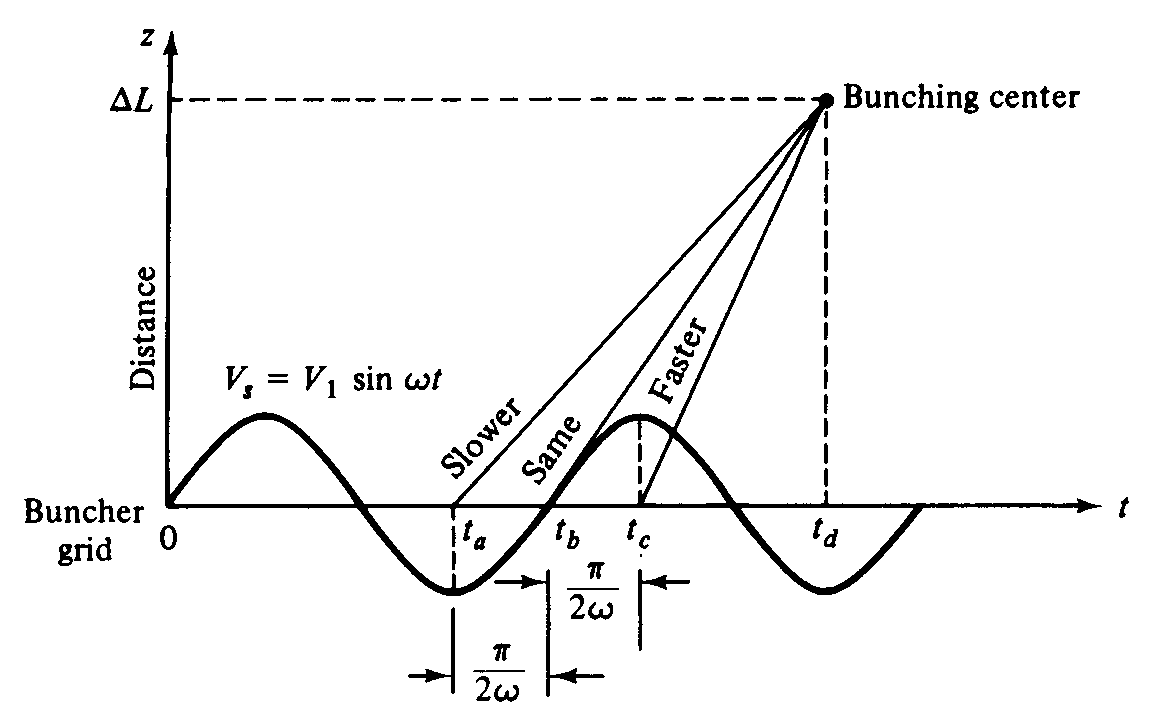
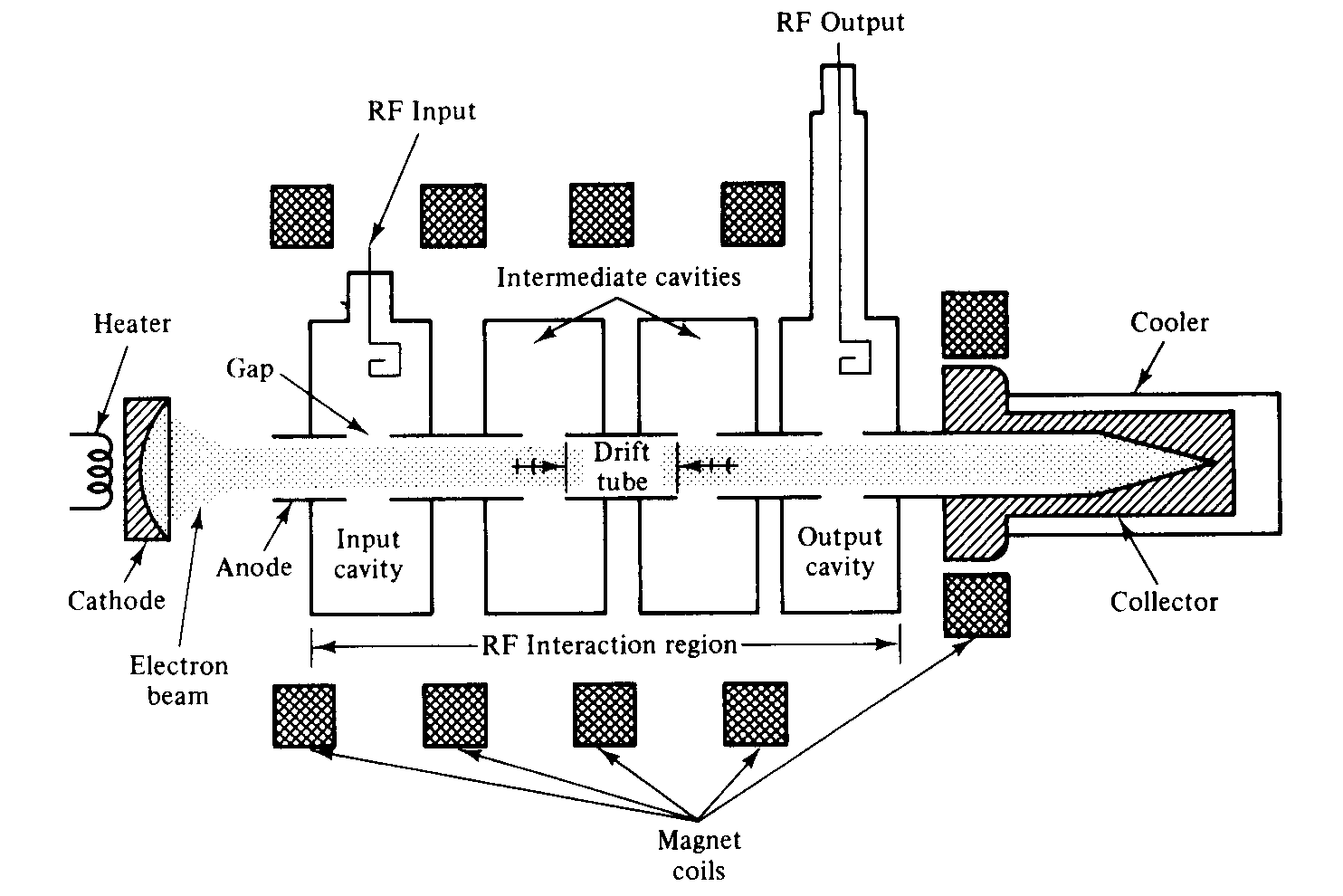
Presentation & video:-

Principle :

* Electrons drift with velocity along the field free space b/w two cavities
* Effect of velocity modulation produces bunching of electron beam (or) current modulation
* Electrons passing at Vs=0, have unchanged velocity
* Electron passing at positive half cycle have travels faster than at Vs=0
* Electron passing at negative half cycle travels slower than at Vs=0
* At distance ΔL, along the beam from the buncher cavity, the beam electrons have drifted into dense clusters

Structure –Operation:

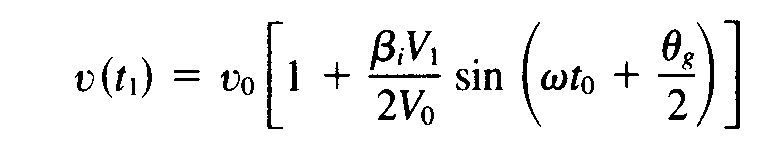
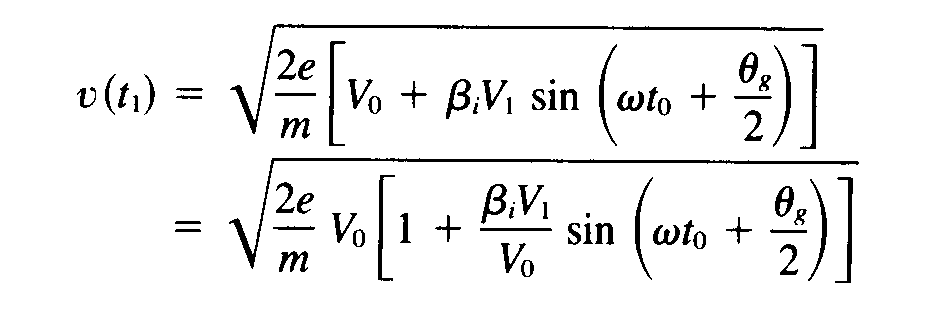


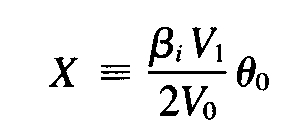
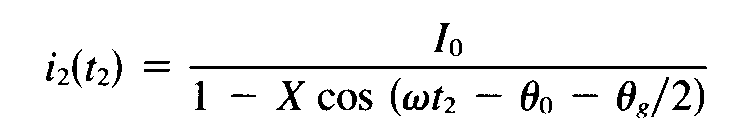
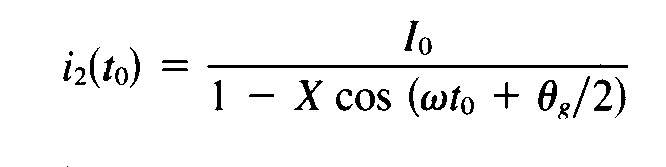


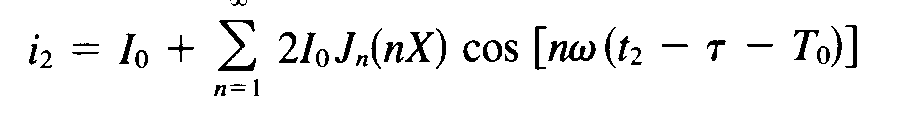
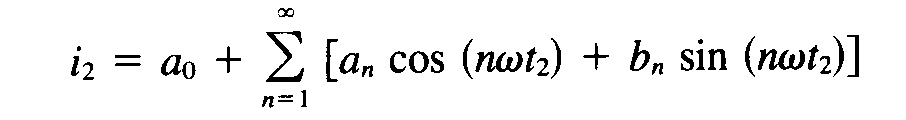
* Video presentation of working concept
* <http://www.youtube.com/watch?NR=1&feature=endscreen&v=tXfdv37gTU8>
* <http://www.youtube.com/watch?v=TsBTI3tO5-8&feature=related>

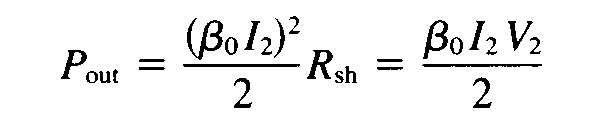
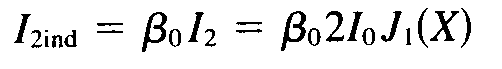
Derivation:

* Beam current density – output current – power









Conclusion & summary: list by key words

* Velocity modulation
* Buncher cavity
* Catcher cavity
* Current modulation
* Power output
* Oscillator & amplifier

**Session – III**

Introduction:

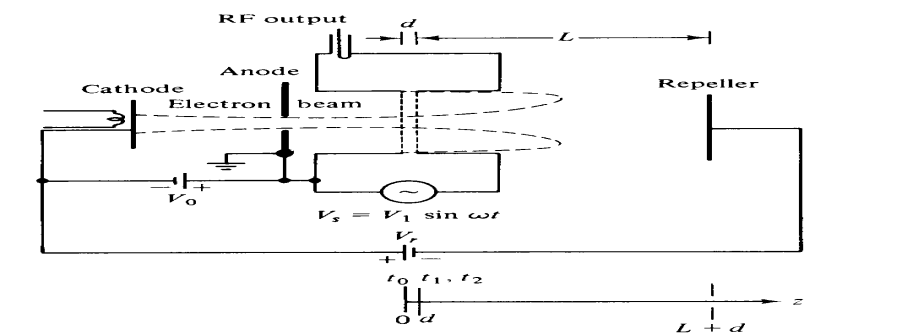
* Reflex Klystron

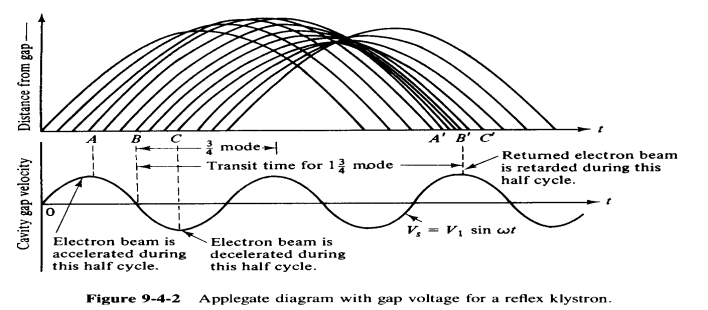
If a fraction of output power is fed back to input cavity,

loop gain is maintained as unity

phase shift of multiple of 2π

Then klystron will oscillate.



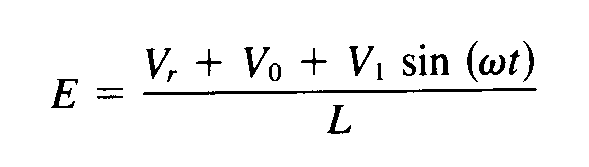
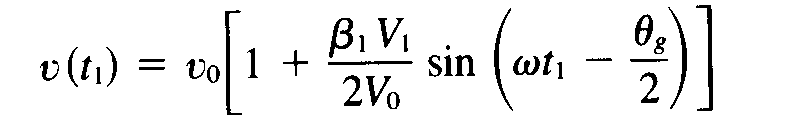


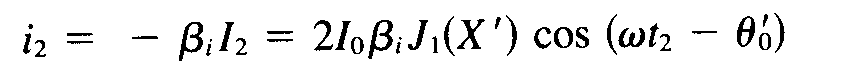
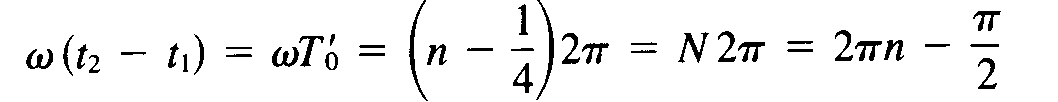
Video Presentation:

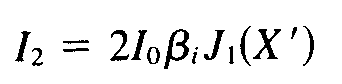
* Animated video of Principle & operation & velocity modulation of Reflex Klystron oscillator

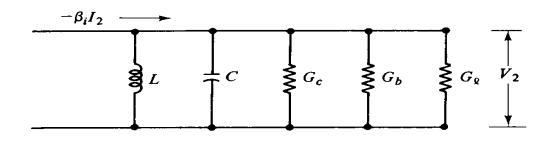
Derivation:

* Output power – efficiency – electronic admittance









Conclusion & summary: recall by key words

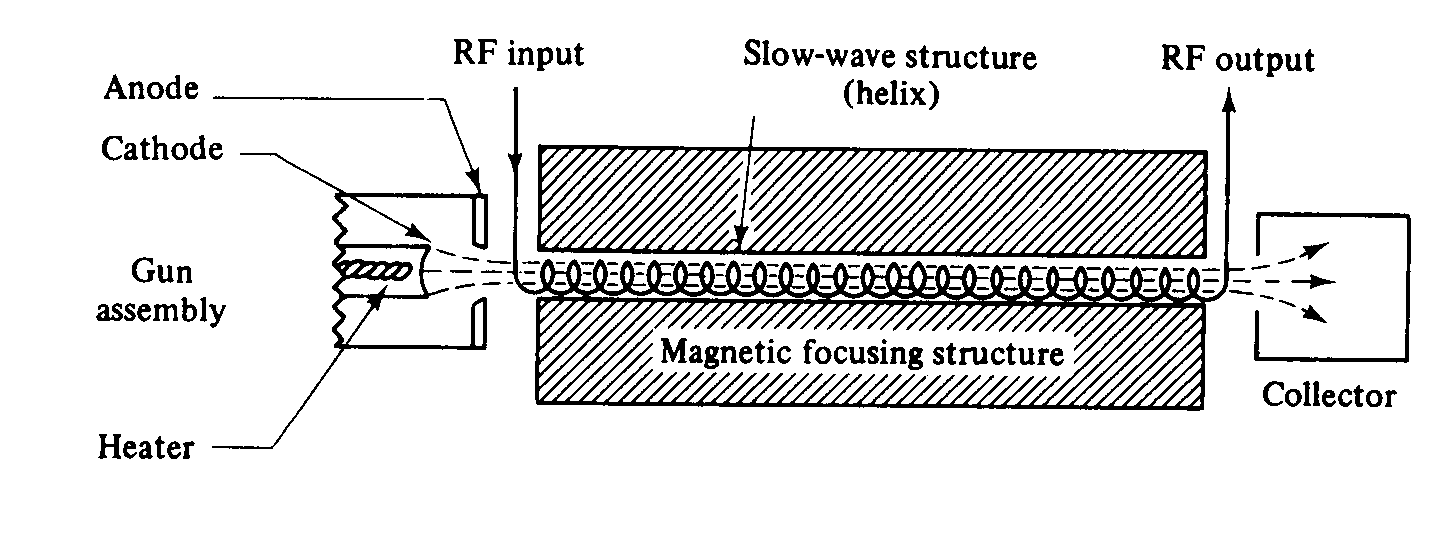
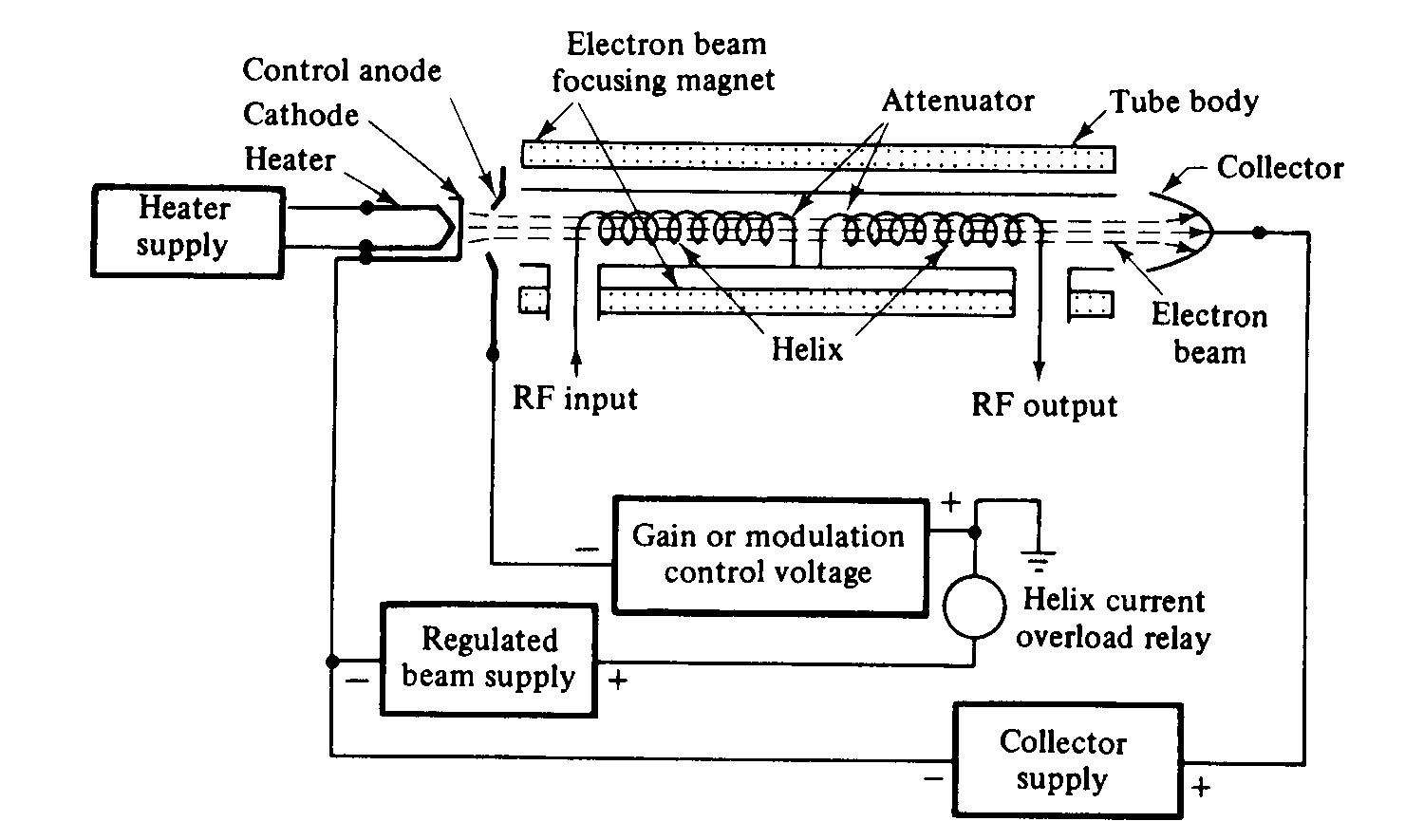
* Electronic admittance
* Velocity modulation
* Cavity gap
* Bunching parameter
* Round trip dc transit time, applications

**Session – IV**

Introduction:

* Travelling wave tube (TWT)
* Uses slow wave structure of non-resonant
* Helix TWT is widely used for broadband applications
* For high average power purpose like radar transmitter, coupled cavity TWT is widely used

Video Presentation:



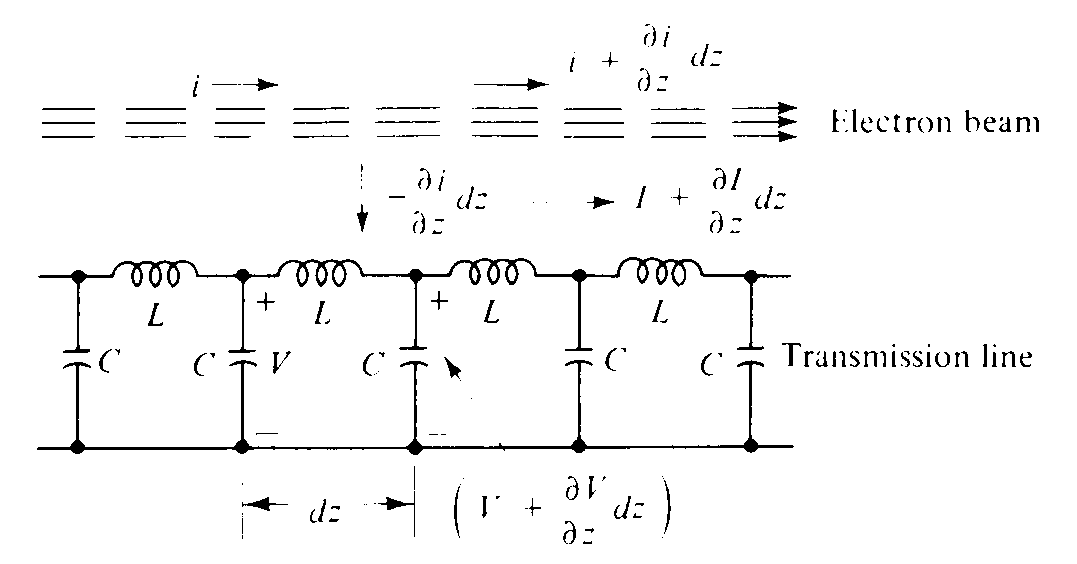
* Animated video of Amplification process & convention current

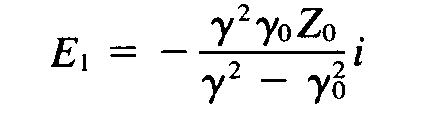
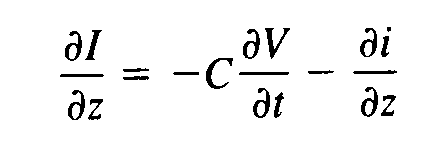
<http://www.youtube.com/watch?v=BLa9e2sz5L8>

<http://www.youtube.com/watch?v=0m7r2J4jj6o>

Derivation:

* Axial electric field – wave modes – gain





Conclusion & summary: List by key words

* Slow wave structure
* Comparison b/w klystron & TWT
* Frequency pulling & pushing
* FWO, BWO
* Difference b/w TWT & klystron
* Applications

**Session –V**

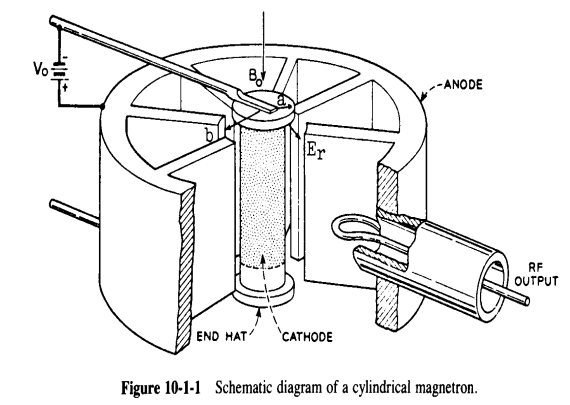
Introduction:

Cylindrical magnetron oscillator:-

* Crossed field tube devices(M-type)
* DC electric field & DC magnetic field are perpendicular to each other
* It is high power microwave oscillator

Presentation:

* Principle - operation



* Cylindrical cathode of finite length of radius “a” at centre
* Cylindrical anode of radius “b”
* Anode is a slow wave structure
* Anode consisting of several reentrant cavities equi-spaced around the circumstance and coupled together through anode cathode space by means of slots
* Dc voltage Vo b/w cathode & anode establishes radial electric field
* Dc magnetic flux(Bo) is maintained by means of permanent magnet(or) an electromagnet
* Electron from cathode try to travel to anode but due to crossed field of E & H, it experience a force F=-eE-e(vxB) & takes curved path
* Due to excitation b/w anodes, electron are accelerated during it motion & transfer energy into cavity to grow output oscillation
* Featured animated video presentation from Simtel.

Derivation:

* Equation of electron motion – cyclotron angular frequency
* At zero magnetic field, electron take straight path from cathode to anode
* If Vo increased, electron take curved path
* At critical value of magnetic field Bc, electron take curved path (teach the anode)& return back to cathode
* If magnetic field greater than critical value, then electron return to cathode without reaching of anode
* Value of Bc is called as cut-off magnetic flux density

Conclusion & summary: recall by key words:

* Phase focus effect
* Strapping
* Cyclotron angular frequency
* Cross field tubes, Resonant cavities

**Session –VI**

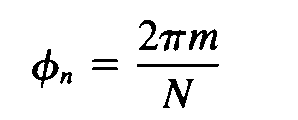
Recap:

* Magnetron

Resonant modes:

* Each anode acts as resonant cavity

Phase shift b/w two adjacent cavity is



* It has opposite phase in successive cavities, excitation is maximum at 0, called as π mode

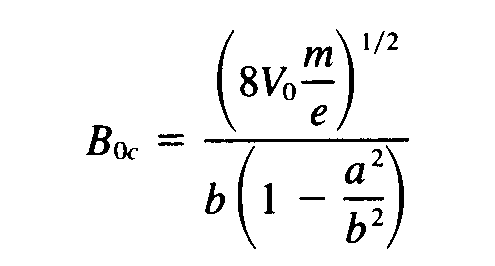


Mode separation:

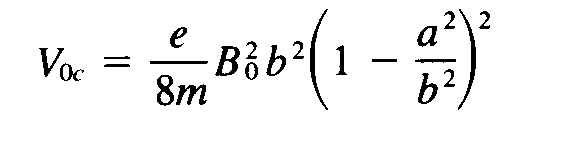
* Each mode corresponds to different frequencies
* Separation of π mode from other mode is done by strapping method in which one ring is connected to even numbered anode & other connected to odd numbered anode
* Magnetron usually designed to operate in π mode

Derivation:

* Power output – efficiency
* Hull cut off magnetic equation is



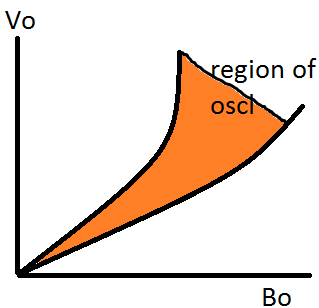
Hull cut off voltage is



* For oscillation in π mode Beam voltage is Voh = {2 πf (b2-a2)Bo}/ N

called as **Hartree Voltage**

* A plot b/w Hull cut off voltage (or) Hartree voltage Vs Bo gives region of oscillation



Presentation:

Types :-

* (i) Coaxial magnetron
* (ii) Voltage –tunable magnetron
* (iii) Inverted coaxial magnetron
* (iv) Frequency – agile tunable magnetron
* Magnetron can deliver a peak power output of 40MW with dc voltage of 50KV at 10GHz
* Average power is 800KW
* Efficiency is 40-70%
* Application:
* Radar transmitter
* industrial heating
* microwave ovens

Conclusion & summary: list by key words

* Hull cutoff voltage
* Hartee voltage
* Hull cutoff magnetic equations
* Π mode
* Average drift velocity
* Applications

**Session –VII**

Brainstorming & introduction:

* Impedance – Standing Wave Ratio(SWR)

Presentation:Measurement of impedance

* Slotted line method
* Reflectometer method

Presentation: Measurement of SWR

* VSWR is important as it determine the degree of impedance matching
* When ZLǂZo, standing waves arise
* VSWR is measured by detecting Vmax&Vmin

**Low VSWR:-**

* Probe moved from the load until peak voltage is obtained, adjust gain control meter to read at 1.0 or 0 dB – gives Vmax
* Move probe toward sending end until minimum voltage is obtained, thus VSWR meter gives direct reading of VSWR=Vmax/Vmin
* Repeated with other set of frequencies for average

**High VSWR:-**

* Probe moved to voltage minimum point and probe depth & gain control is adjusted to read 3 dB in VSWR.
* Probe is moved to either sides of minimum to read 0 dB in meter. Position x1 & x2 are noted
* Succesive voltage minimum point is noted = (λg/2)

S = λg / π(x1-x2)

Possible errors

* Probe thickness & depth of penetration produce reflection
* Mechanical slope may cause different values of VSWR
* Reduction in sharpness for 1KHZ signal

Conclusion & summary: list by key words

* VSWR
* ISWR
* Vmax&Vmin
* Tunable detector
* SWR & reflection coefficient
* Possible errors