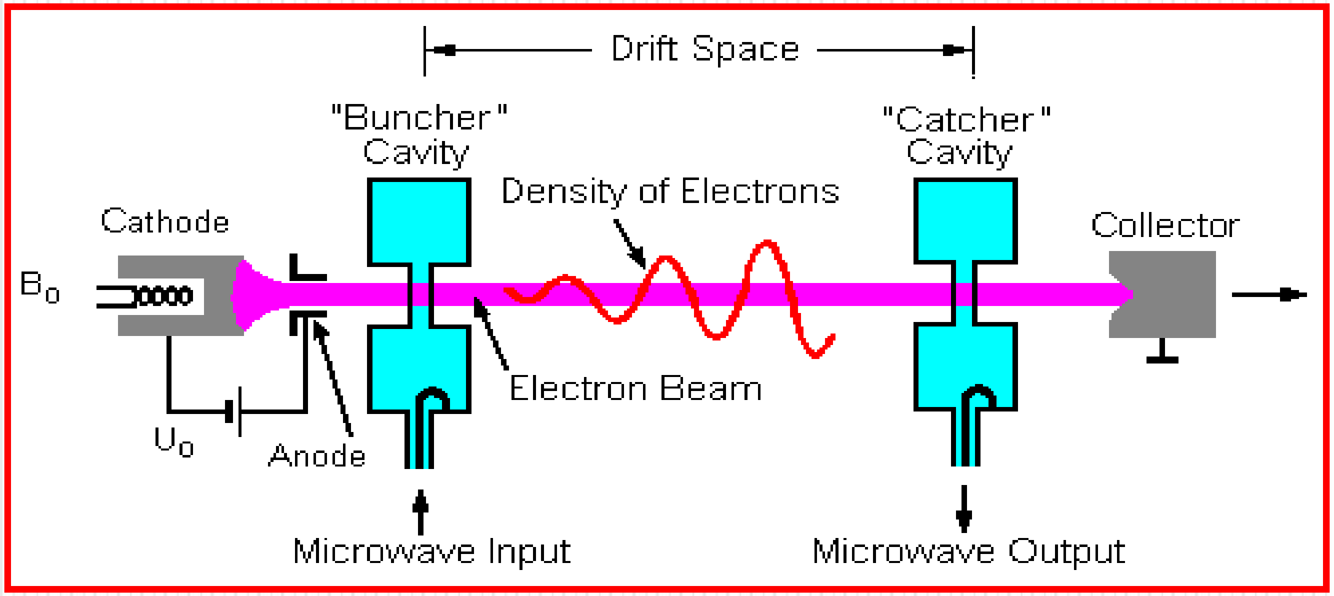
Chapter 4

- Klystron Oscillator
- Reflex Klystron
- Traveling Wave Tube
- Traveling Wave Magnetron

Klystron Oscillator

A klystron is a vacuum tube that can be used either as a generator or as an amplifier of power, at microwave frequencies.



Principles of Two-Cavity Klystrons

- The two-cavity klystron utilizes an electron source (heater), an anode, and a cathode like a conventional vacuum tube. It also utilizes a collector element at the end of the electron stream. The heater boils off electrons when heated and the electrons are ejected from the cathode and accelerate towards the anode due to the high dc potential between the two elements. A focused beam of electrons is thus produced.

- Operations

-All electrons are injected from the cathode arrived at the first cavity with uniform velocity .

-Those electrons passing the passing the first cavity gap at zeros of the gap voltage pass through with unchanged velocity .

-Those passing through the positive half cycle of the gap voltage

Undergo an increase in velocity while those passing through negative swing of the gap voltage undergo a decrease in velocity –The maximum bunching should occur midway between the second cavity grid . The electron emerge from the second cavity with reduced velocity and finally terminated in collector.

Velocity Modulation

-The variation in electron Velocity in the drift space

$Vo = (0.593 \times 10^6)\,Sqrt(Vodc)$ m/s

Where Vodc= DC Beam Voltage

Vo= electron Velocity

Gap Voltage :

$Vg = V1 \sin(2\pi ft) = V1 \sin(wt)$

V1= Amplitude of the Signal

- Average Transit Time

$S = d/V_o = T_1 - T_o$

- Average Gap Transit Time

$\O_g = WS = w(T_1 - T_o) = wd/V_o = 2\pi f d/V_o$

- Maximum Input Voltage

$V_1(Max) = V_o(3.68)/(\beta_i \O_o) \quad = 2XV_o/(\beta_i \O_o)$; $X = Kr$

Bessel Functions

Where $\beta_i = (\sin(\O_g/2))/(\O_g/2)$

$\O_o = wT_o = 2\pi f L/V_o$

Where L= Spacing between Cavities

Vo=Electron Velocity

Øo=DC transit Angle in Drift Space

ßi= Beam Coupling Coeficient of input Cavity

- Problem 1

A two cavity Klystron amplifier has the following parameters

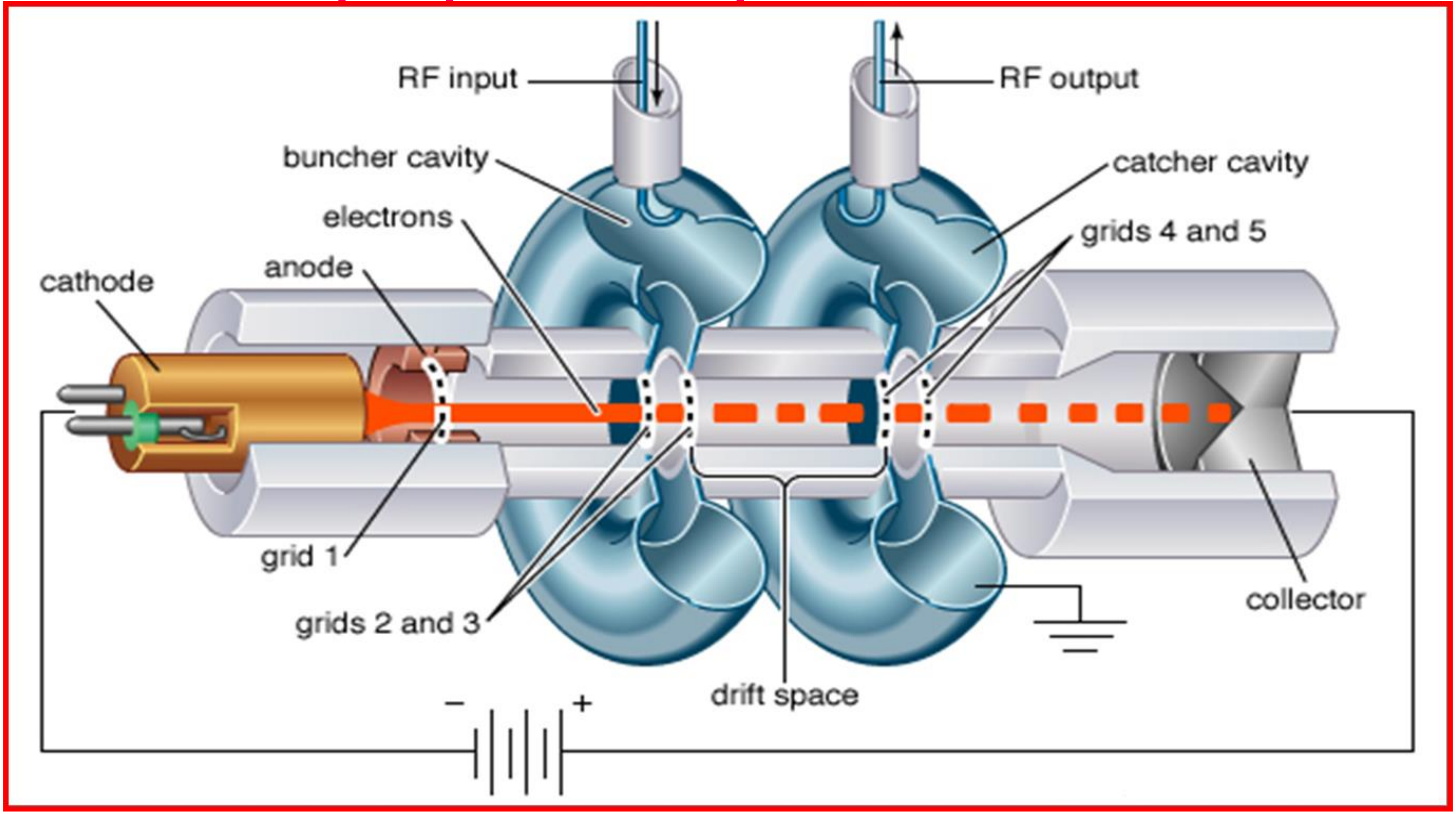
Beam Voltage = 1 KV , Beam Current =30mA , Frequency =8 GHz, Gap Spacing in either Cavities = 1mm , Spacing between Center of Cavities 4 cm, Effective Shunt Impedance =40 Kohms .

Calculate the electron velocity and the input voltage for maximum output voltage

Example 2

- Two cavity klystron amplifier operates at 4 GHz with DC Beam Voltage of 1 KV , Io=22mA , Cavity gap 1mm , Drift Space 3 cm .Calculate coupling coeficient , DC transit angle in the drift space and the input cavity voltage magnitude for maximum output voltage .

Two cavity Klystron Amplifier



Applications

- **As power output tubes**
  1. in UHF TV transmitters
  2. in troposphere scatter transmitters
  3. satellite communication ground station
  4. radar transmitters
- **As power oscillator** (5 – 50 GHz), if used as a klystron oscillator

Reflex Klystrons

- The reflex klystron has been the most used source of microwave power in laboratory applications.

REFLEX KLYSTRON

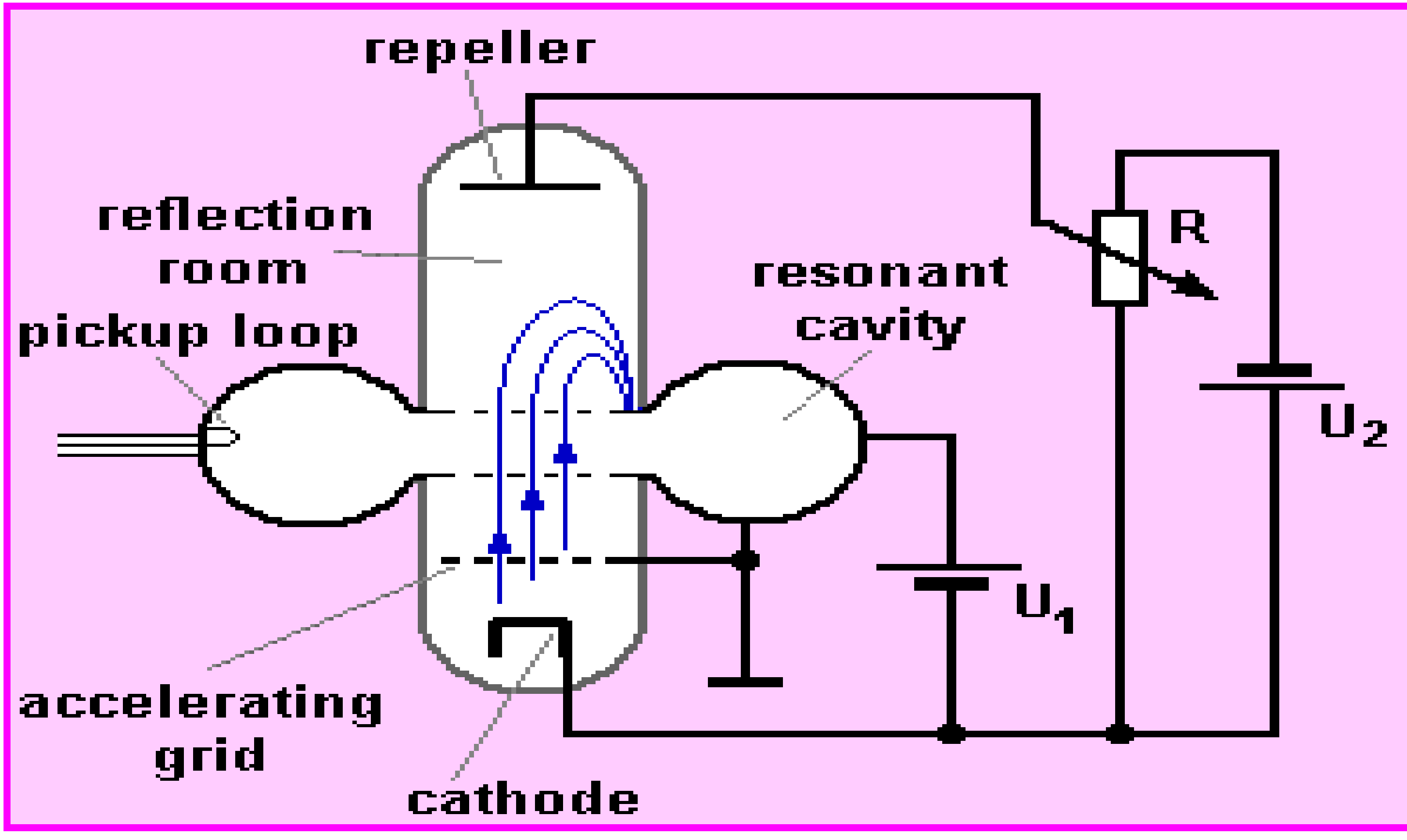
Construction

- A reflex klystron consists of an electron gun, a cavity with a pair of grids and a repeller plate as shown in the above diagram.
- In this klystron, a single pair of grids does the functions of both the buncher and the catcher grids.
- The main difference between two cavity reflex klystron amplifier and reflex klystron is that the output cavity is omitted in reflex klystron and the repeller or reflector electrode, placed a very short distance from the single cavity, replaces the collector electrode.

Working

- The cathode emits electrons which are accelerated forward by an accelerating grid with a positive voltage on it and focused into a narrow beam.
- The electrons pass through the cavity and undergo velocity modulation, which produces electron bunching and the beam is repelled back by a repeller plate kept at a negative potential with respect to the cathode.
- On return, the electron beam once again enters the same grids which act as a buncher, therby the same pair of grids acts simultaneously as a buncher for the forward moving electron and as a catcher for the returning beam.

Reflex Klystron oscillator



Working

- The feedback necessary for electrical oscillations is developed by reflecting the electron beam, the velocity modulated electron beam does not actually reach the repeller plate, but is repelled back by the negative voltage.
- The point at which the electron beam is turned back can be varied by adjusting the repeller voltage.
- Thus the repeller voltage is so adjusted that complete bunching of the electrons takes place at the catcher grids, the distance between the repeller and the cavity is chosen such that the repeller electron bunches will reach the cavity at proper time to be in synchronization.
- Due to this, they deliver energy to the cavity, the result is the oscillation at the cavity producing RF frequency.

Performance Characteristics

1. Frequency: 4 – 200 GHz
2. Power: 1 mW – 2.5 W
3. Theoretical efficiency : 22.78 %
4. Practical efficiency : 10 % - 20 %
5. Tuning range : 5 GHz at 2 W – 30 GHz at 10 mW

Applications

- The reflex klystrons are used in

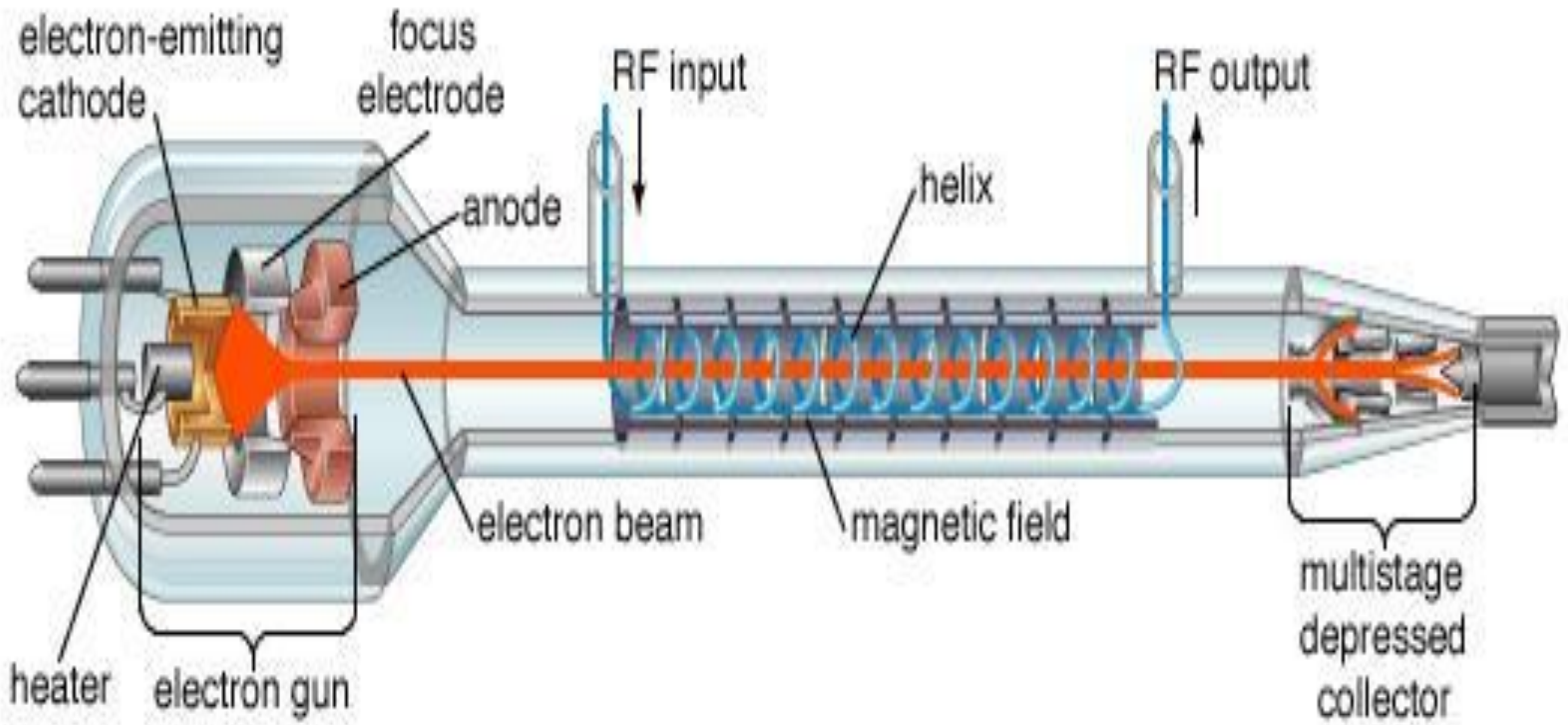
1. Radar receivers
2. Local oscillator in microwave receivers
3. Signal source in microwave generator of variable frequency
4. Portable microwave links
5. Pump oscillator in parametric amplifier

Traveling Wave Tube

- Traveling Wave Tube (TWT) is the most versatile microwave RF power amplifiers.

- The main virtue of the TWT is its extremely wide band width of operation.

Basic structure of a Traveling Wave Tube (TWT)



Basic structure

- The basic structure of a TWT consists of a cathode and filament heater plus an anode that is biased positively to accelerate the electron beam forward and to focus it into a narrow beam.
- The electrons are attracted by a positive plate called the collector, which has given a high dc voltage.
- The length of the tube is usually many wavelengths at the operating frequency.
- Surrounding the tube are either permanent magnets or electromagnets that keep the electrons tightly focused into a narrow beam.

Features

- The unique feature of the TWT is a helix or coil that surrounds the length of the tube and the electron beam passes through the centre or axis of the helix.
- The microwave signal to be amplified is applied to the end of the helix near the cathode and the output is taken from the end of the helix near the collector.
- The purpose of the helix is to provide path for RF signal.
- The propagation of the RF signal along the helix is made approximately equal to the velocity of the electron beam from the cathode to the collector

Functioning

- The passage of the microwave signal down the helix produces electric and magnetic fields that will interact with the electron beam.
- The electromagnetic field produced by the helix causes the electrons to be speeded up and slowed down, this produces velocity modulation of the beam which produces density modulation.
- Density modulation causes bunches of electrons to group together one wavelength apart and. these bunch of electrons travel down the length of the tube toward the collector.

Functioning

- The electron bunches induce voltages into the helix which reinforce the voltage already present there. Due to that the strength of the electromagnetic field on the helix increases as the wave travels down the tube towards the collector.
- At the end of the helix, the signal is considerably amplified. Coaxial cable or waveguide structures are used to extract the energy from the helix.

Advantages

1. TWT has extremely wide bandwidth. Hence, it can be made to amplify signals from UHF to hundreds of gigahertz.
2. Most of the TWT's have a frequency range of approximately 2:1 in the desired segment of the microwave region to be amplified.
3. The TWT's can be used in both continuous and pulsed modes of operation with power levels up to several thousands watts.

Performance characteristics

1. Frequency of operation : 0.5 GHz – 95 GHz
2. Power outputs:

   5 mW (10 – 40 GHz – low power TWT)

   250 kW (CW) at 3 GHz (high power TWT)

   10 MW (pulsed) at 3 GHz
3. Efficiency : 5 – 20 % (30 % with depressed collector)

Applications of TWT

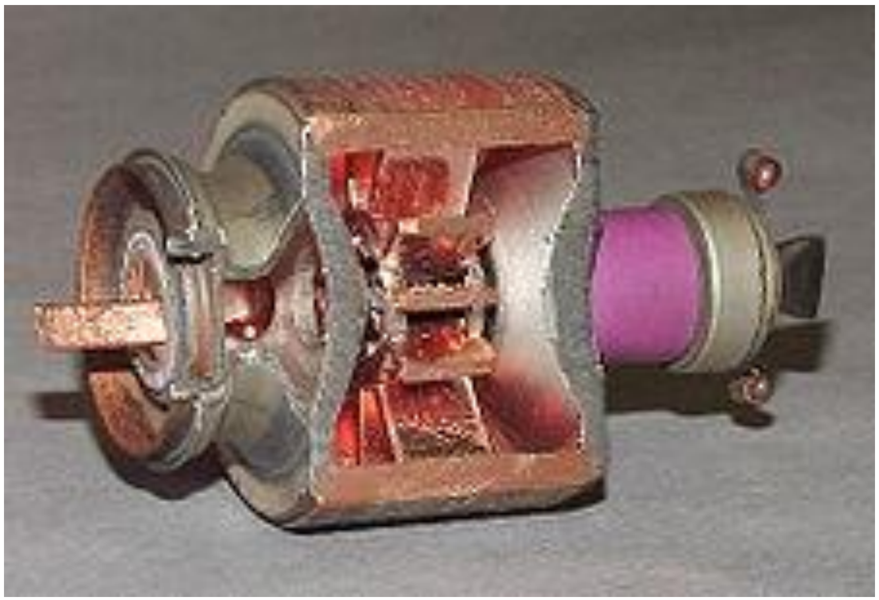
1. Low noise RF amplifier in broad band microwave receivers.
2. Repeater amplifier in wide band communication links and long distance telephony.
3. Due to long tube life (50,000 hours against ¼th for other types), TWT is power output tube in communication satellite.
4. Continuous wave high power TWT's are used in troposcatter links (due to larger power and larger bandwidths).
5. Used in Air borne and ship borne pulsed high power radars.

INTRODUCTION

- **A magnetron** is a high-powered vacuum tube that generates non consistent microwaves with built-in resonators or by special oscillators or solid-state devices to control the frequency.

- The electromagnetic energy created from a magnetron can travel at the speed of light and is the same type of energy used in radio and television broadcasting.

MAGNETRON



CONSTRUCTION

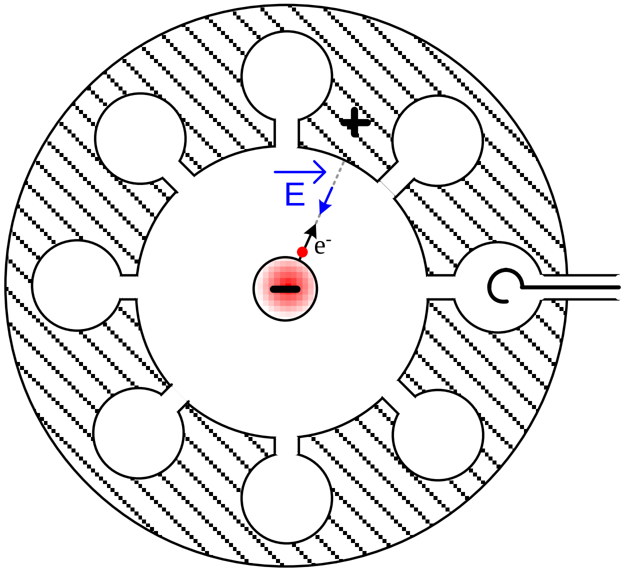
APPLICATIONS

APPLICATIONS

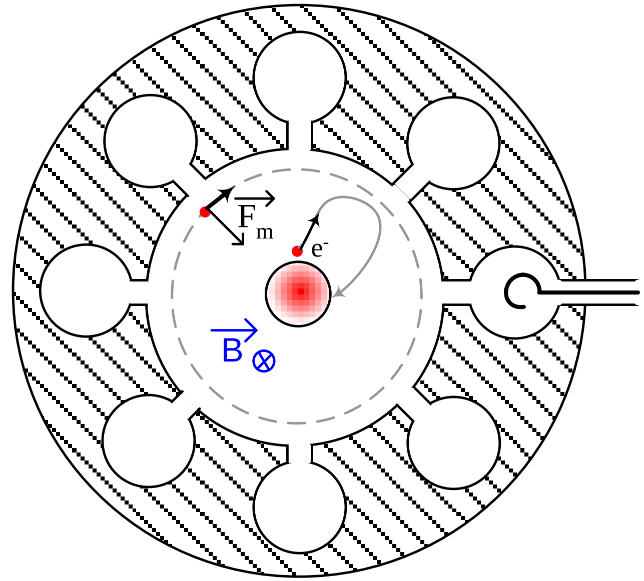
ADVANTAGES & DISADVANTAGES

CONCLUSION

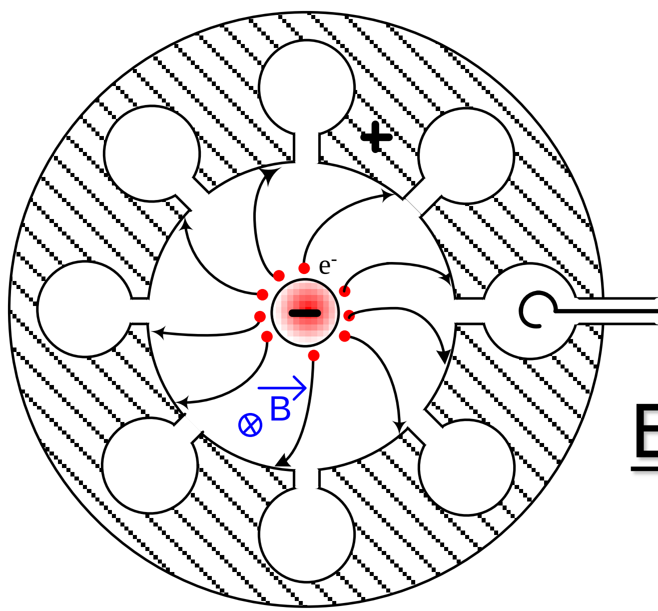
CONSTRUCTION & OPERATION



Effect of electric field



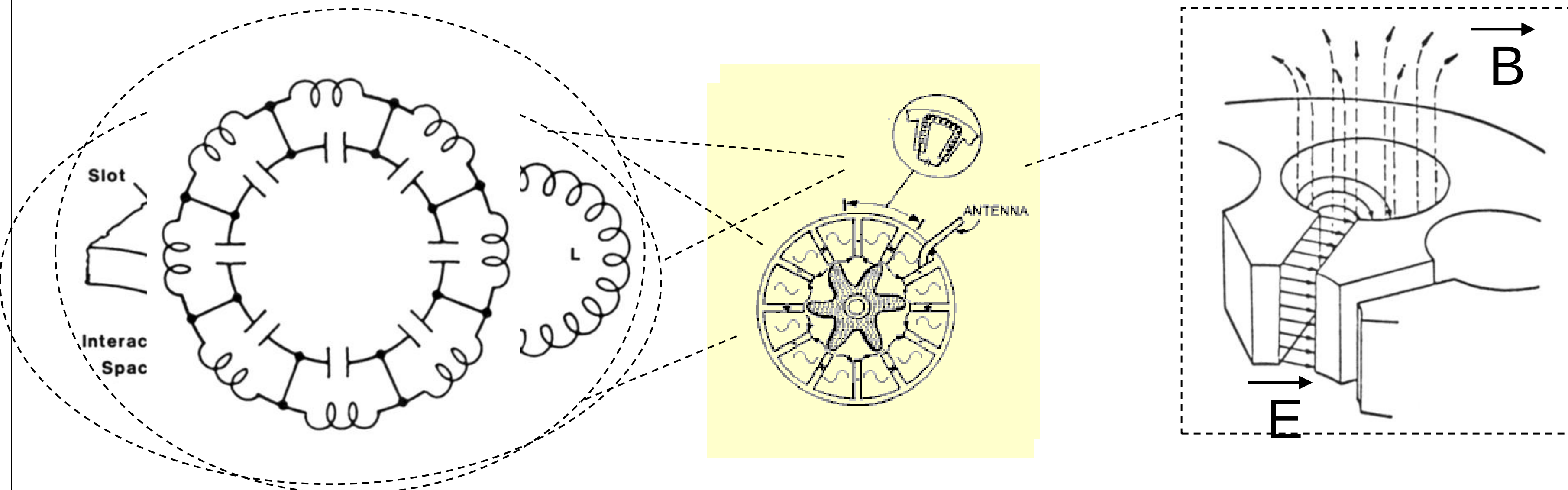
Effect of magnetic field



Effect of Crossed-Fields

CONSTRUCTION

- As shown in the figure, a cavity magnetrons consist of a hot filament (cathode) kept at, or pulsed to, a high negative potential by a high-voltage, direct-current power supply. The cathode is built into the center of an evacuated, lobed, circular chamber.
- A magnetic field parallel to the filament is imposed by a electro-magnet. The magnetic field causes the electrons, attracted to the (relatively) positive outer part of the chamber, to spiral outward in a circular path rather than moving directly to this anode.


Slot
L
Interac
Spac
ANTENNA
B
E

- Spaced around the rim of the chamber are cylindrical cavities. The cavities are open along their length and connect the common cavity space. As electrons sweep past these openings, they induce a resonant, high-frequency radio field in the cavity, which in turn causes the electrons to bunch into groups.
- A portion of this field is extracted with a short antenna that is connected to a waveguide (a metal tube usually of rectangular cross section). The waveguide directs the extracted RF energy to the load, which may be a cooking chamber in a microwave oven or a high-gain antenna in the case of radar.

Applications

- RADAR
- HEATING
- LIGHTING

APPLICATIONS

- RADAR

In radar devices the waveguide is connected to an antenna. The magnetron is operated with very short pulses of applied voltage, resulting in a short pulse of high power microwave energy being radiated. As in all radar systems, the radiation reflected off a target is analyzed to produce a radar map on a screen.

APPLICATIONS

- HEATING

In microwave ovens the waveguide leads to a radio frequency-transparent port into the cooking chamber. It is important that there is food in the oven when it is operated so that these waves are absorbed, rather than reflecting into the waveguide where the intensity of standing waves can cause arcing. The arcing, if allowed to occur for long periods, will destroy the magnetron.

APPLICATIONS

- LIGHTING

In microwave-excited lighting systems, such as Sulphur Lamps, a magnetron provides the microwave field that is passed through a waveguide to the lighting cavity containing the light-emitting substance (e.g. Sulfur, metal halides etc.)

ADVANTAGES

- The magnetron is a fairly efficient device. In a microwave oven, for instance, an 1100 watt input will generally create about 700 watts of microwave energy, an efficiency of around 65%.
- The combination of the small-cavity magnetron, small antennas, and high resolution allowed small, high quality radars to be installed in aircraft.

DISADVANTAGES

- They are costly and hence limited in use.

- Although cavity magnetron are used because they generate a wide range of frequencies , the frequency is not precisely controllable.

- The use in radar itself has reduced to some extent, as more accurate signals have generally been needed and developers have moved to klystron and systems for accurate frequencies.