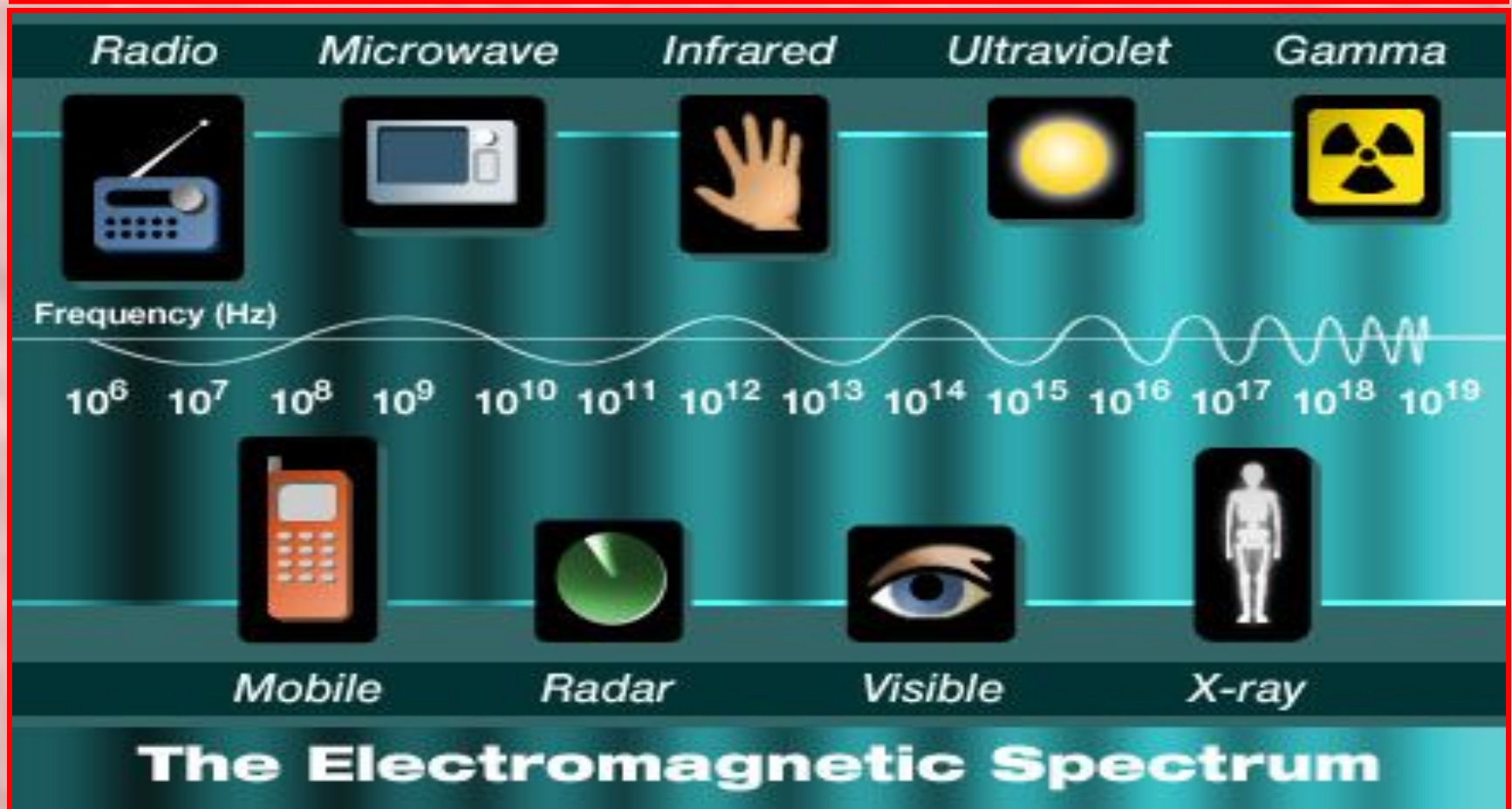


# MICROWAVE ENGG

- Microwaves
- Properties
- Advantages / Need
- Limitations
- Applications

# Electro Magnetic Spectrum



# Microwaves

- Microwaves are electromagnetic waves whose frequencies range from about 300 MHz – 300 GHz (1 MHz =  $10^6$  Hz and 1 GHz =  $10^9$  Hz) or wavelengths in air ranging from 100 cm – 1 mm.
- The word *Microwave* means *very short wave*, which is the shortest wavelength region of the radio spectrum and a part of the electromagnetic spectrum.

## Properties of Microwaves

1. Microwave is an electromagnetic radiation of short wavelength.
2. They can reflect by conducting surfaces just like optical waves since they travel in straight line.
3. Microwave currents flow through a thin outer layer of an ordinary cable.
4. Microwaves are easily attenuated within short distances.
5. They are not reflected by ionosphere

# Advantages/Need and Limitations

## **1. Increased bandwidth availability:**

- Microwaves have large bandwidths compared to the common bands like short waves (SW), ultrahigh frequency (UHF) waves, etc.
- For example, the microwaves extending from  $\lambda = 1 \text{ cm}$  -  $\lambda = 10 \text{ cm}$  (i.e) from 30,000 MHz – 3000 MHz, this region has a bandwidth of 27,000 MHz.

## **2. Improved directive properties:**

- The second advantage of microwaves is their ability to use high gain directive antennas, any EM wave can be focused in a specified direction (Just as the focusing of light rays with lenses or reflectors)

# Advantages and Limitations

## **3. Fading effect and reliability:**

- Fading effect due to the variation in the transmission medium is more effective at low frequency.
- Due to the Line of Sight (LOS) propagation and high frequencies, there is less fading effect and hence microwave communication is more reliable.

## **4. Power requirements:**

- Transmitter / receiver power requirements are pretty low at microwave frequencies compared to that at short wave band.

## Advantages and Limitations

### **5. Transparency property of microwaves:**

- Microwave frequency band ranging from 300 MHz – 10 GHz are capable of freely propagating through the atmosphere.
- The presence of such a transparent window in a microwave band facilitates the study of microwave radiation from the sun and stars in radio astronomical research of space.



# Applications

□ Microwaves have a wide range of applications in modern technology, which are listed below

1. **Telecommunication:** Intercontinental Telephone and TV, space communication (Earth – to – space and space – to – Earth), telemetry communication link for railways etc.
2. **Radars:** detect aircraft, track / guide supersonic missiles, observe and track weather patterns, air traffic control (ATC), burglar alarms, garage door openers, police speed detectors etc.



### 3. Commercial and industrial applications

- Microwave oven
- Drying machines – textile, food and paper industry for drying clothes, potato chips, printed matters etc.
- Food process industry – Precooling / cooking, pasteurization / sterility, hat frozen / refrigerated precooled meats, roasting of food grains / beans.
- Rubber industry / plastics / chemical / forest product industries
- Mining / public works, breaking rocks, tunnel boring, drying / breaking up concrete, breaking up coal seams, curing of cement.
- Drying inks / drying textiles, drying / sterilizing grains, drying / sterilizing pharmaceuticals, leather, tobacco, power transmission.
- Biomedical Applications ( diagnostic / therapeutic ) – diathermy for localized superficial heating, deep electromagnetic heating for treatment of cancer, hyperthermia ( local, regional or whole body for cancer therapy).

## Other Applications

4. Identifying objects or personnel by non – contact method.
5. Light generated charge carriers in a microwave semiconductor make it possible to create a whole new world of microwave devices, fast jitter free switches, phase shifters, HF generators, etc.

# Magnetron oscillator

- Magnetrons provide microwave oscillations of very high frequency.

## Types of magnetrons

1. Negative resistance type
2. Cyclotron frequency type
3. Cavity type

# Description of types of magnetron

## Negative resistance Magnetrons

- Make use of negative resistance between two anode segments but have low efficiency and are useful only at low frequencies ( $< 500$  MHz).

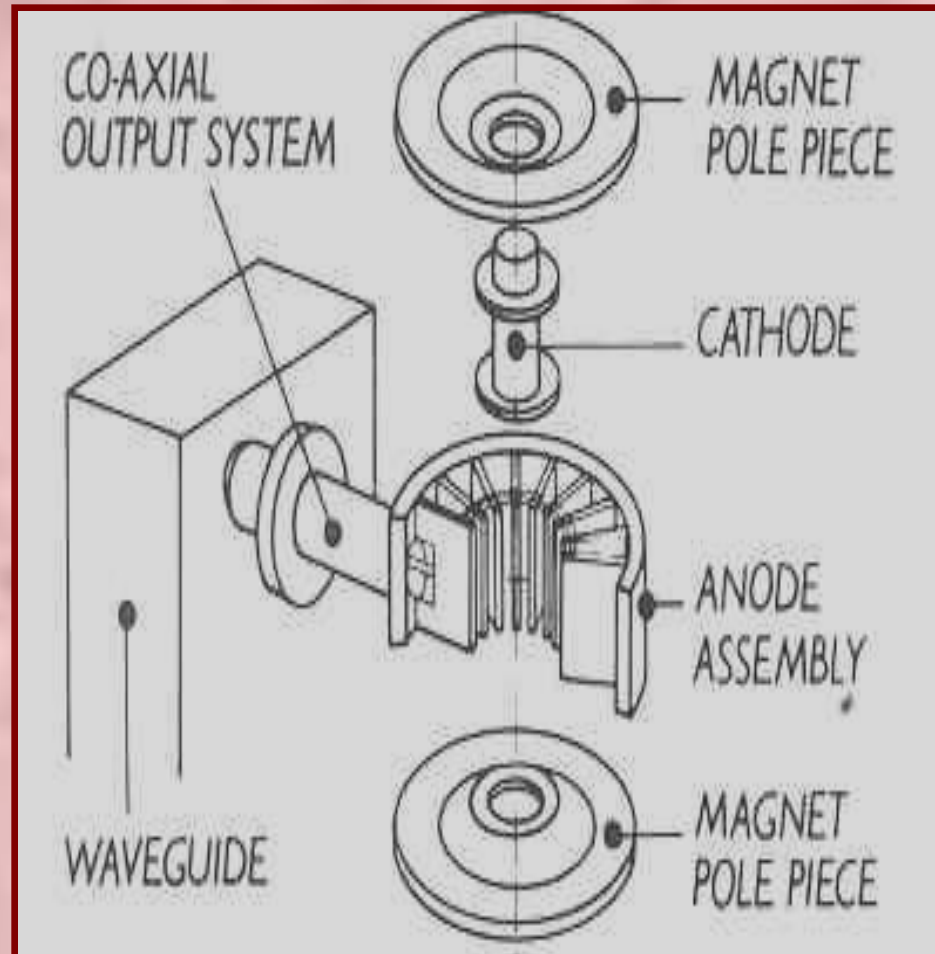
## Cyclotron frequency Magnetrons

- Depend upon synchronization between an alternating component of electric and periodic oscillation of electrons in a direction parallel to this field.
- Useful only for frequencies greater than 100 MHz.

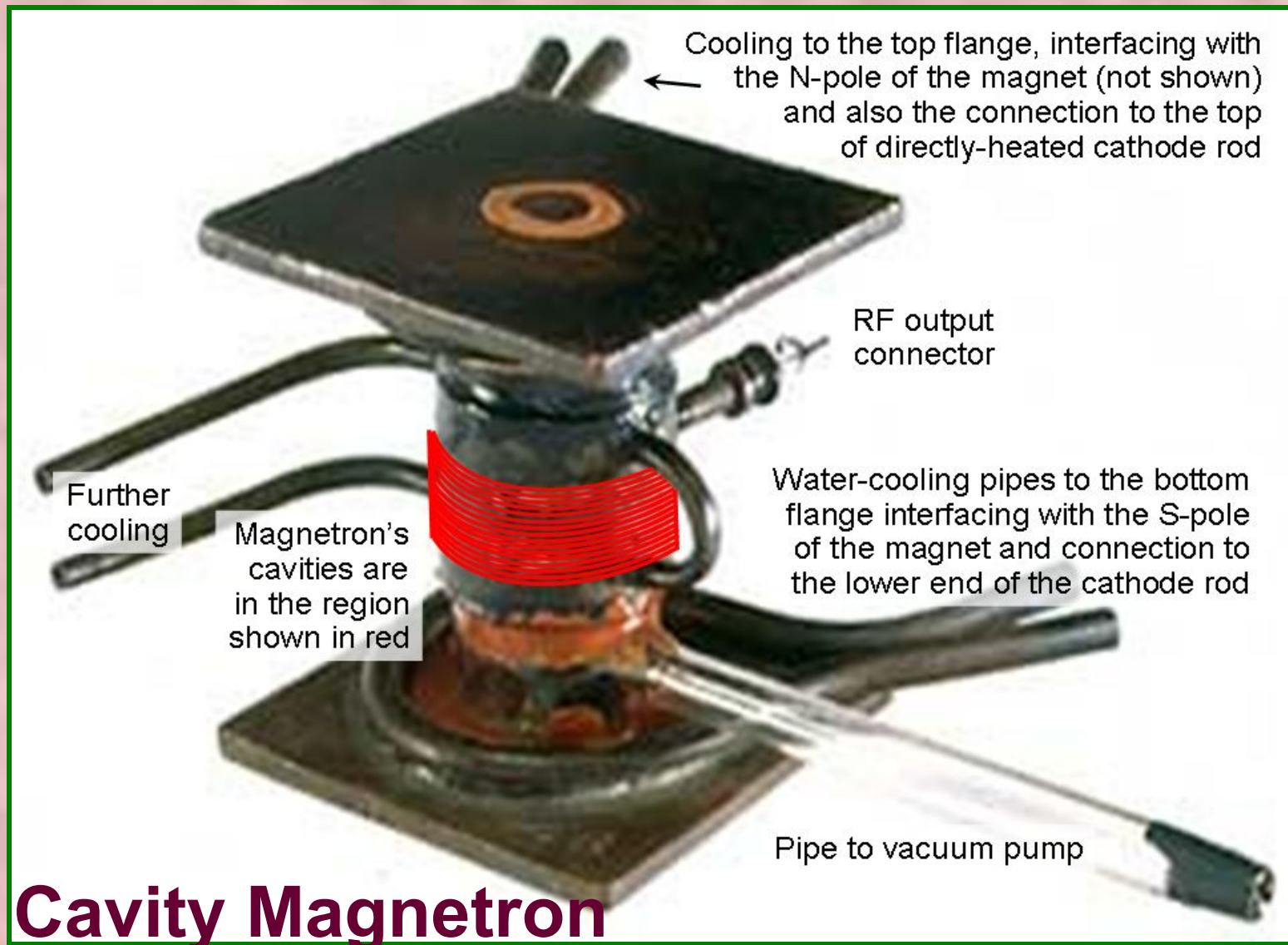
## Cavity Magnetrons

- Depend upon the interaction of electrons with a rotating electromagnetic field of constant angular velocity.
- Provide oscillations of very high peak power and hence are useful in radar applications

# Cavity Magnetrons



**Fig (i) Major elements in the Magnetron oscillator**





# Anode Assembly





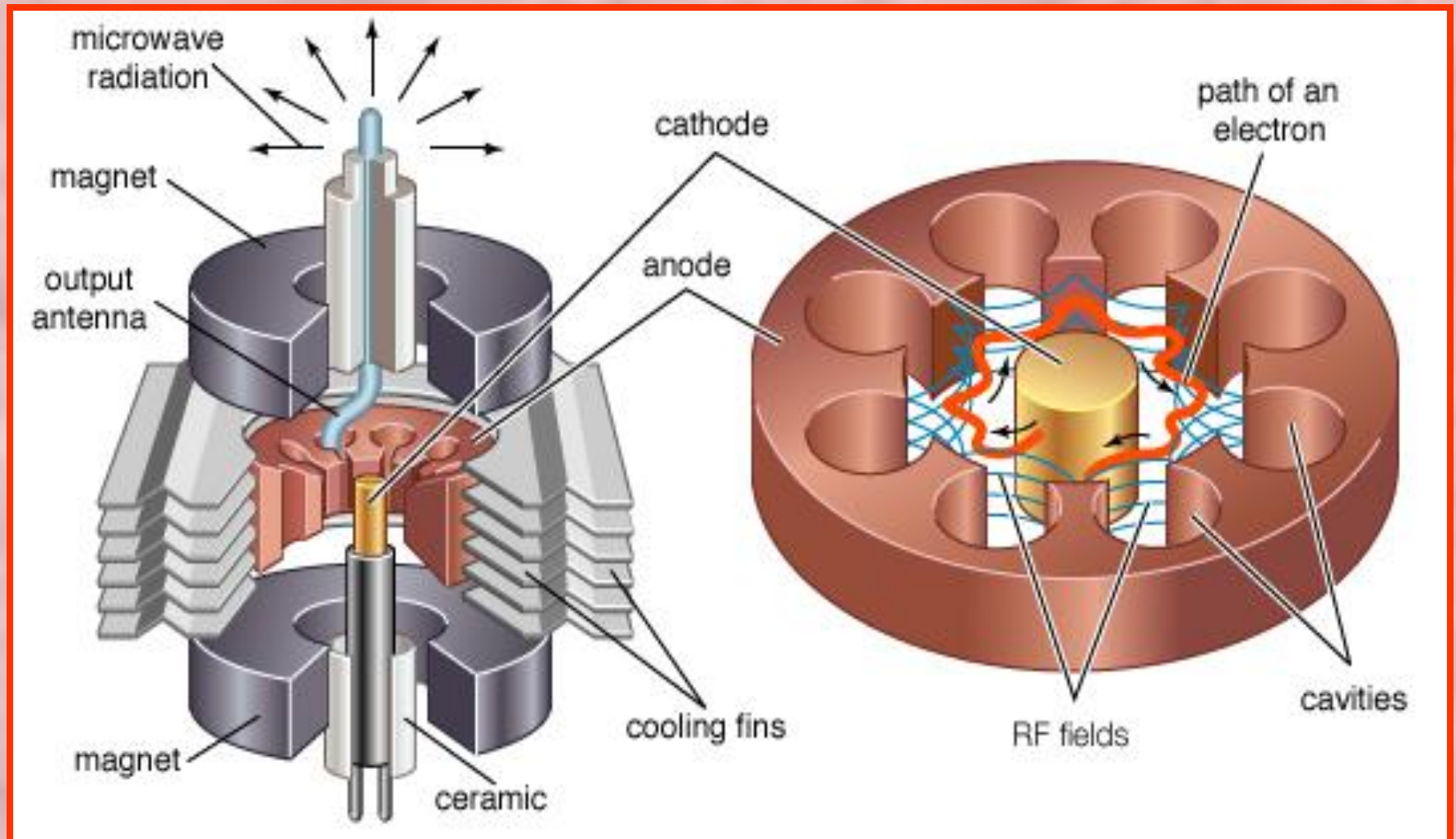
# Construction

- Each cavity in the anode acts as an inductor having only one turn and the slot connecting the cavity and the interaction space acts as a capacitor.
- These two form a parallel resonant circuit and its resonant frequency depends on the value of  $L$  of the cavity and the  $C$  of the slot.
- The frequency of the microwaves generated by the magnetron oscillator depends on the frequency of the RF oscillations existing in the resonant cavities.

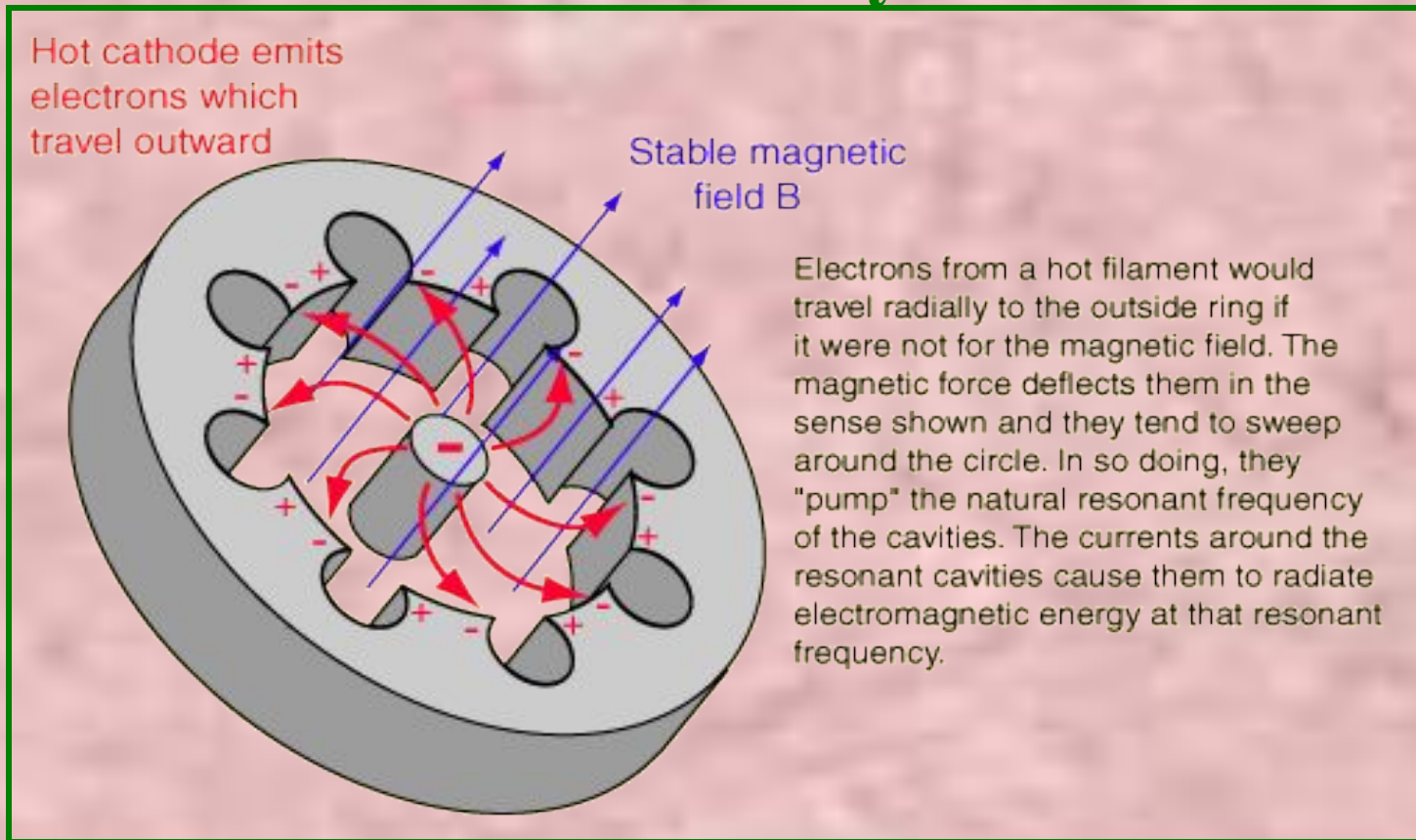
## Description

- Magnetron is a cross field device as the electric field between the anode and the cathode is radial whereas the magnetic field produced by a permanent magnet is axial.
- A high DC potential can be applied between the cathode and anode which produces the radial electric field.
- Depending on the relative strengths of the electric and magnetic fields, the electrons emitted from the cathode and moving towards the anode will traverse through the interaction space as shown in Fig. (iii).
- In the absence of magnetic field ( $B = 0$ ), the electron travel straight from the cathode to the anode due to the radial electric field force acting on it, Fig (iii) a.

# Cavity Magnetrons

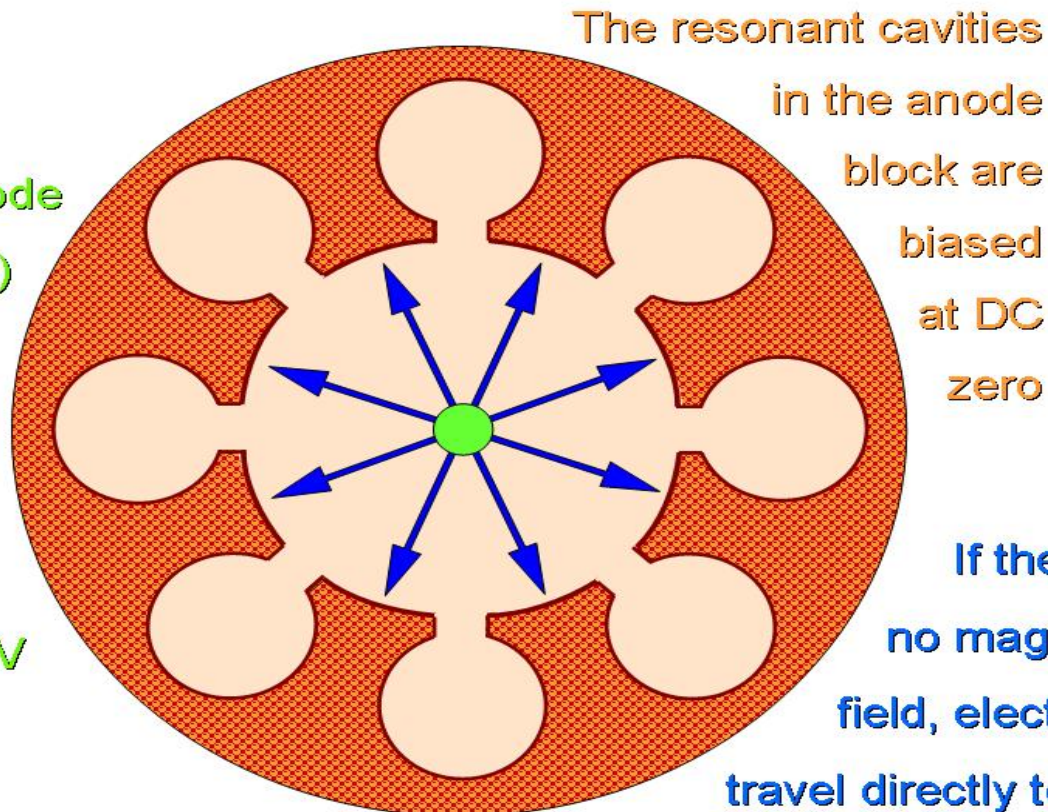


## Fig (ii) Cross sectional view of the anode assembly



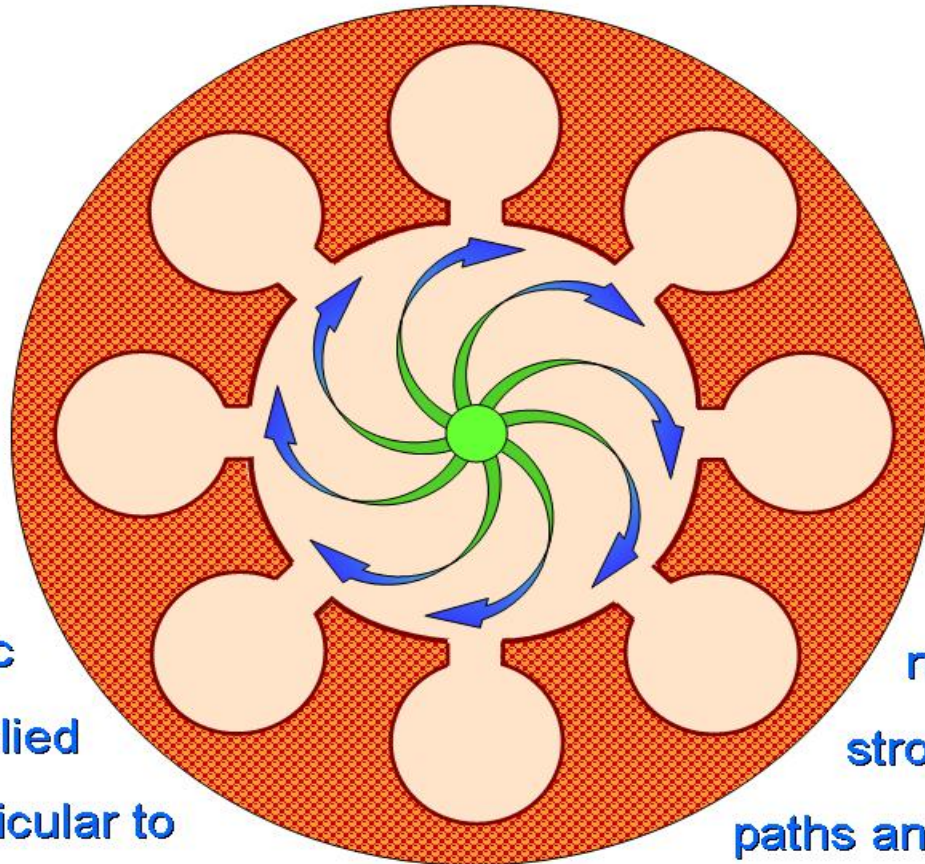


The cathode  
(at centre)  
is biased  
to a high  
negative  
voltage –  
typ. -10 kV



If there is  
no magnetic  
field, electrons  
travel directly to the  
anode block in a radial path

With a  
magnetic  
field applied  
perpendicular to  
plane of the drawing



electrons  
now travel in  
strongly curved  
paths and induce an

EM field in the anode block

## Description

- If the magnetic field strength is increased slightly, the lateral force bending the path of the electron as given by the path '*b*' in Fig. (iii).
- The radius of the path is given by, If the strength of the magnetic field is made sufficiently high then the electrons can be prevented from reaching the anode as indicated path '*c*' in Fig. (iii)),
- The magnetic field required to return electrons back to the cathode just grazing the surface of the anode is called the critical magnetic field ( $B_c$ ) or the cut off magnetic field.
- If the magnetic field is larger than the critical field ( $B > B_c$ ), the electron experiences a greater rotational force and may return back to the cathode quite faster.



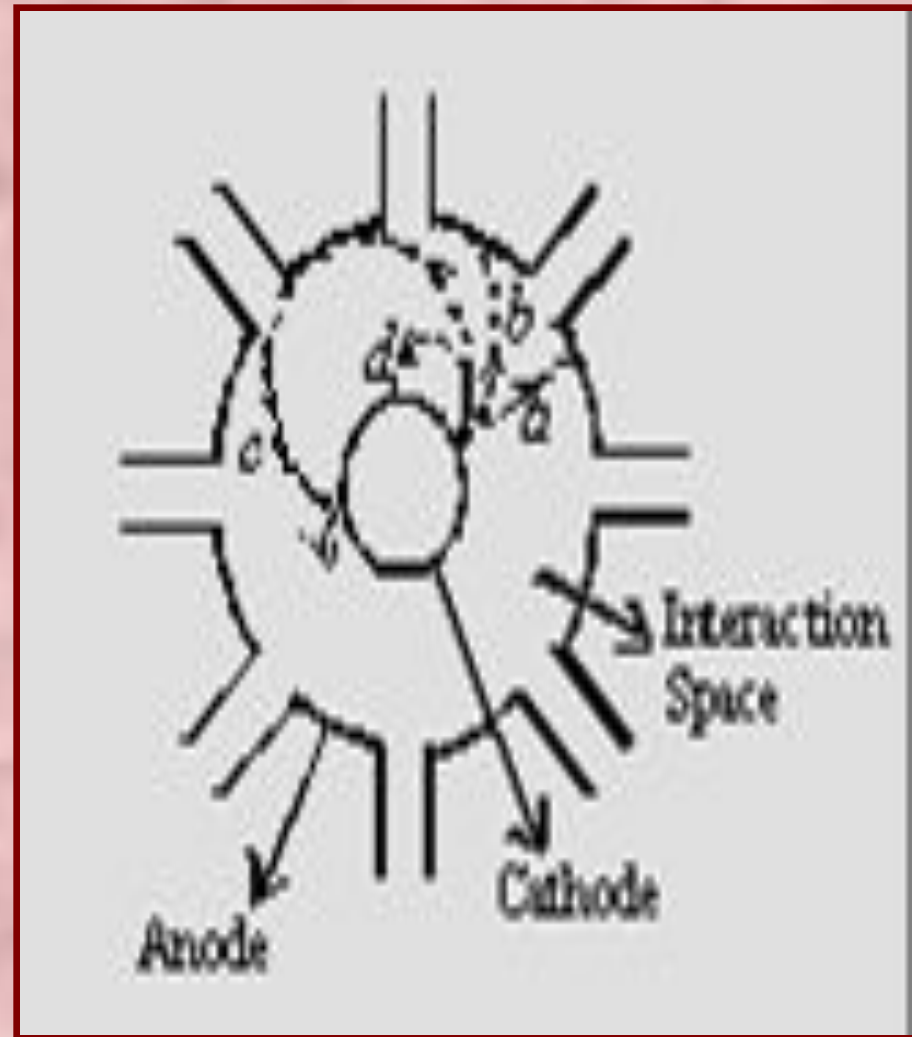
**Fig (iii) Electron trajectories  
in the presence of crossed  
electric and magnetic fields**

**(a) no magnetic field**

**(b) small magnetic field**

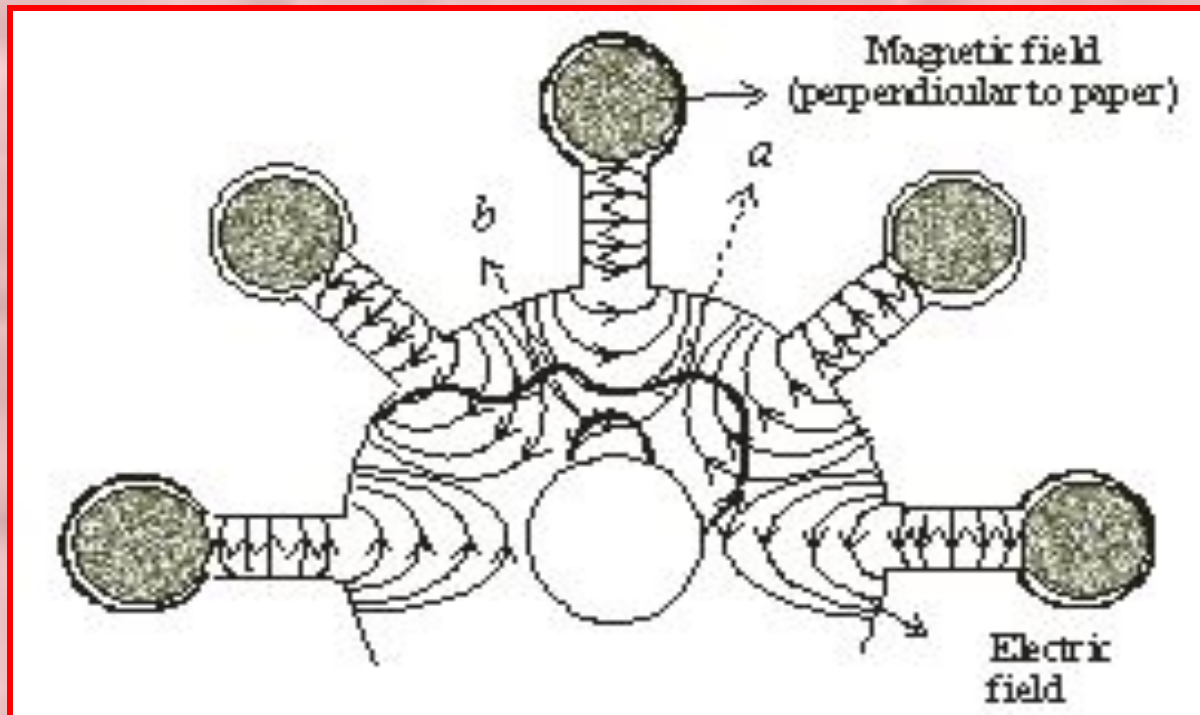
**(c) Magnetic field =  $B_c$**

**(d) Excessive magnetic  
field**



## Working

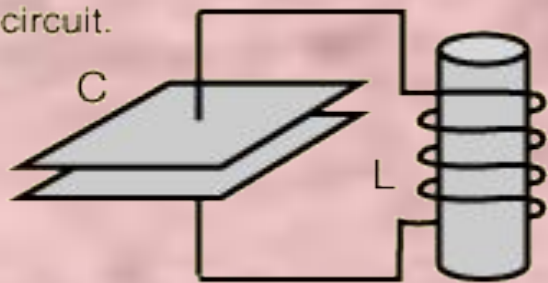
**Fig (iv) Possible trajectory of electrons from cathode to anode in an eight cavity magnetron operating in  $\pi$  mode**



## Working

- The RF Oscillations of transient nature produced when the HT is switched on, are sufficient to produce the oscillations in the cavities, these oscillations are maintained in the cavities reentrant feedback which results in the production of microwaves.
- Reentrant feedback takes place as a result of interaction of the electrons with the electric field of the RF oscillations existing in the cavities.
- The cavity oscillations produce electric fields which fringe out into the interaction space from the slots in the anode structure, as shown in Fig (iv).
- Energy is transferred from the radial dc field to the RF field by the interaction of the electrons with the fringing RF field.

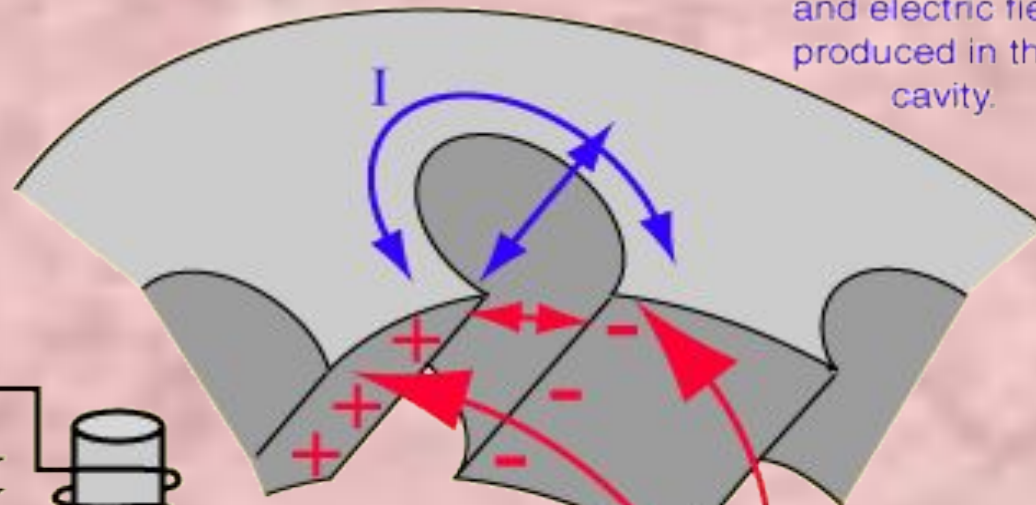
The cavity exhibits a resonance analogous to a parallel resonant circuit.



$$f_{\text{resonance}} \approx \frac{1}{2\pi} \sqrt{\frac{1}{LC}}$$

Current around the cavity plays the role of an inductor.

Oscillating magnetic and electric fields produced in the cavity.



Charge at ends of cavity plays the role of a capacitor.

Electrons from the hot center cathode arriving at a negatively charged region tend to drive it back around the cavity, "pumping" the natural resonant frequency.

## Working

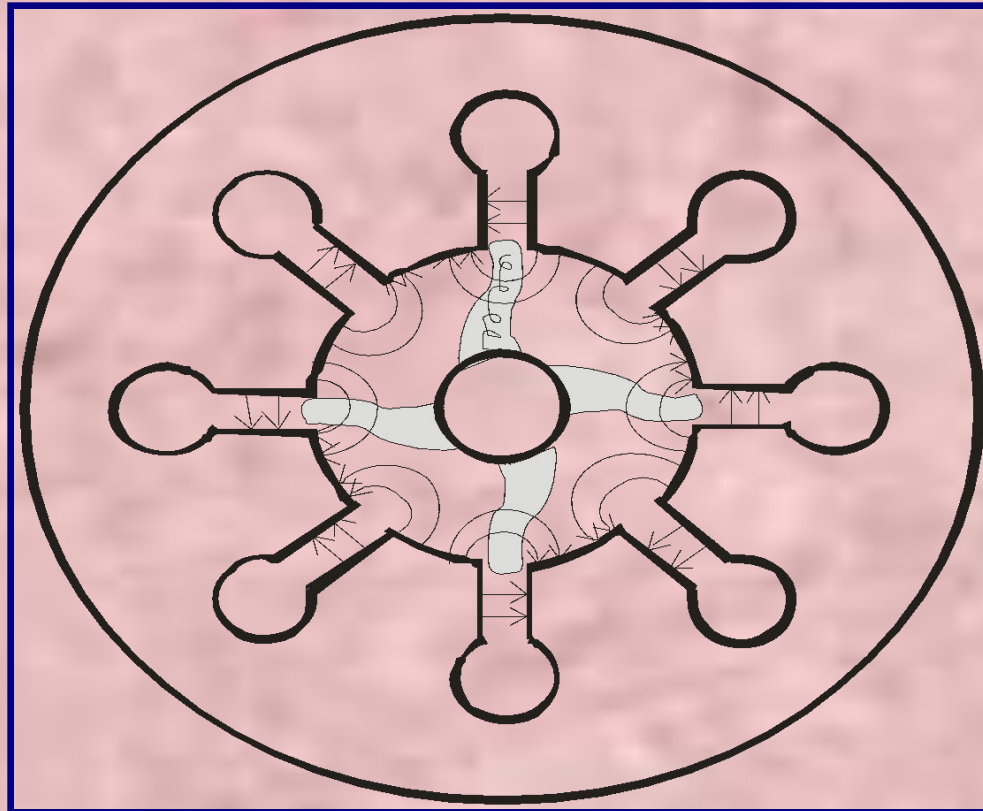
- Due to the oscillations in the cavities, the either sides of the slots (which acts as a capacitor) becomes alternatively positive and negative and hence the directions of the electric field across the slot also reverse its sign alternatively.
- At any instant the anode close to the spiraling electron goes positive, the electrons gets retarded and this is because; the electron has to move in the RF field, existing close to the slot, from positive side to the negative side of the slot.
- In this process, the electron loses energy and transfer an equal amount of energy to the RF field which retard the spiraling electron.
- On return to the previous orbit the electron may reach the adjacent section or a section farther away and transfer energy to the RF field if that part of the anode goes positive at that instant.



## Working

- This electron travels in a longest path from cathode to the anode as indicated by 'a' in Fig (iv), transferring the energy to the RF field are called as *favoured electrons* and are responsible for bunching effect and give up most of its energy before it finally terminates on the anode surface.
- An electron 'b' is accelerated by the RF field and instead of imparting energy to the oscillations, takes energy from oscillations resulting in increased velocity, such electrons are called *unfavoured electrons* which do not participate in the bunching process and cause back heating.
- Every time an electron approaches the anode "in phase" with the RF signal, it completes a cycle. This corresponds to a phase shift  $2\pi$ .
- For a dominant mode, the adjacent poles have a phase difference of  $\pi$  radians, this called the  $\pi$  - mode.

**Fig (v) Bunching of electrons in multicavity magnetron**





## Working

- At any particular instant, one set of alternate poles goes positive and the remaining set of alternate poles goes negative due to the RF oscillations in the cavities.
- AS the electron approaches the anode, one set of alternate poles accelerates the electrons and turns back the electrons quickly to the cathode and the other set alternate poles retard the electrons, thereby transferring the energy from electrons to the RF signal.
- This process results in the bunching of electrons, the mechanism by which electron bunches are formed and by which electrons are kept in synchronism with the RF field is called *phase focussing effect*. electrons with the fringing RF field.

## Working

- The number of bunches depends on the number of cavities in the magnetron and the mode of oscillations, in an eight cavity magnetron oscillating with  $\pi$  - mode, the electrons are bunched in four groups as shown in Fig (v).
- Two identical resonant cavities will resonate at two frequencies when they are coupled together; this is due to the effect of mutual coupling.
- Commonly separating the *pi mode* from adjacent modes is by a method called *strapping*. The straps consist of either circular or rectangular cross section connected to alternate segments of the anode block.

## Performance Characteristics

1. **Power output:** In excess of 250 kW ( Pulsed Mode), 10 mW (UHF band), 2 mW (X band), 8 kW (at 95 GHz)
2. **Frequency:** 500 MHz – 12 GHz
3. **Duty cycle:** 0.1 %
4. **Efficiency:** 40 % - 70 %

## Applications of Magnetron

1. Pulsed radar is the single most important application with large pulse powers.
2. Voltage tunable magnetrons are used in sweep oscillators in telemetry and in missile applications.
3. Fixed frequency, CW magnetrons are used for industrial heating and microwave ovens.

Have a nice day.