MAGNETRON

Dr. Gajanan G. Sarate
Head of Deptt,
Dept. of Electronics,
Government Polytechnic, Amravati

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

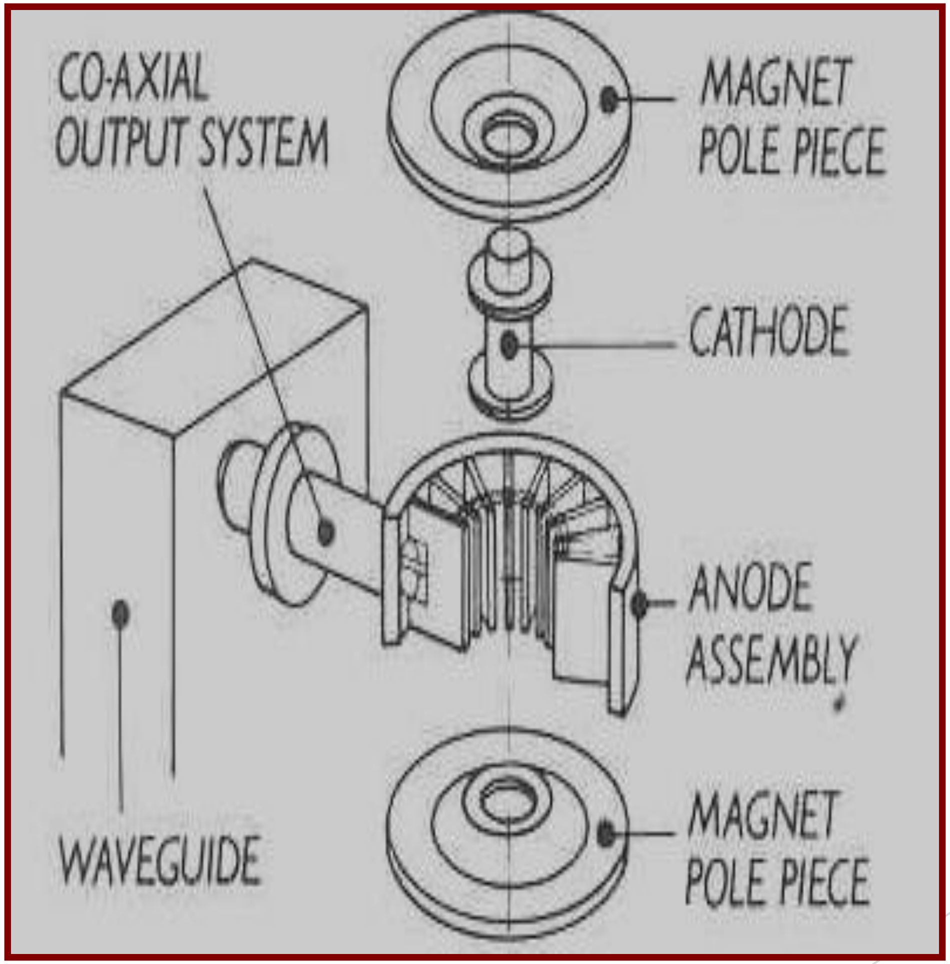
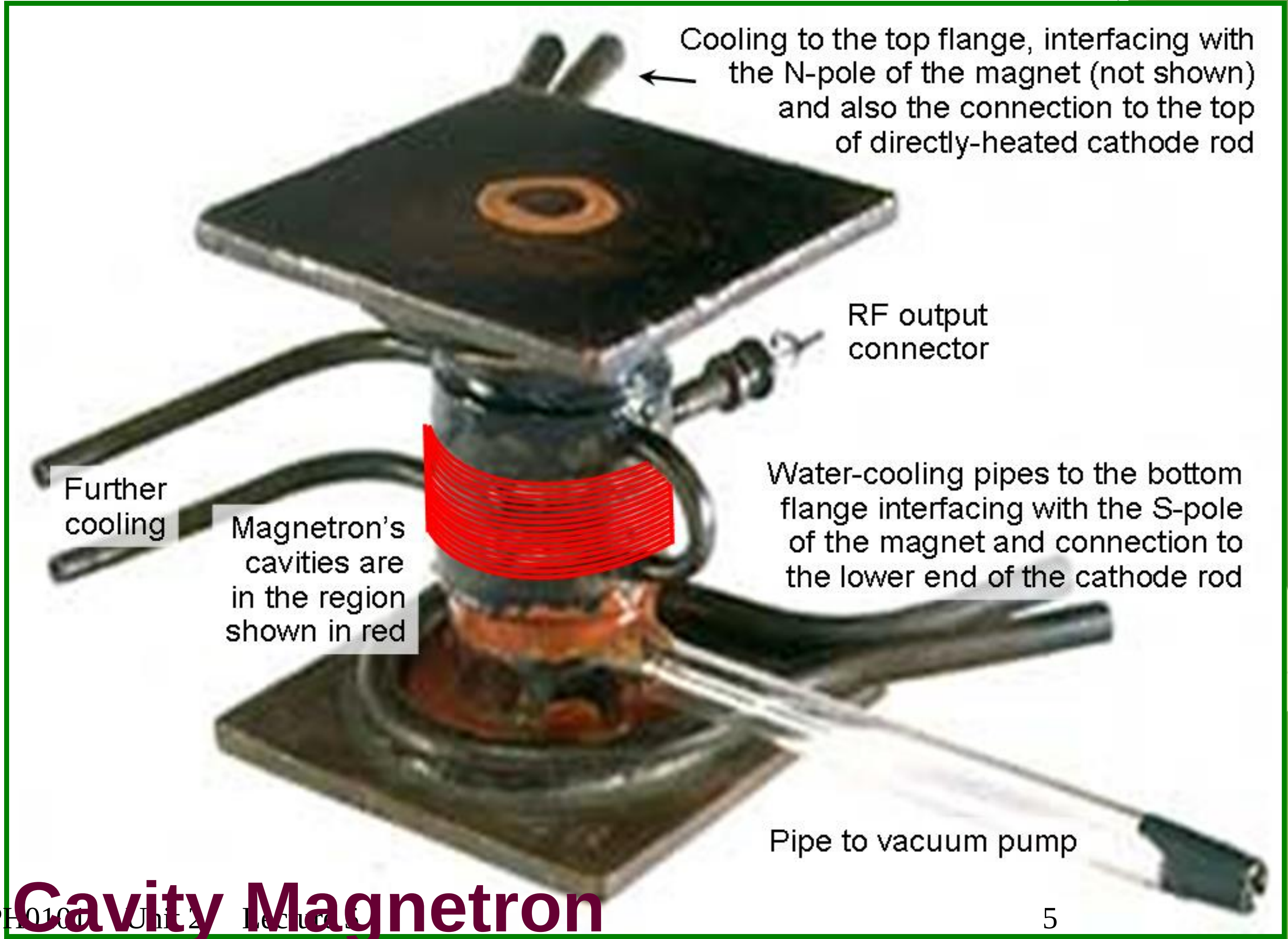
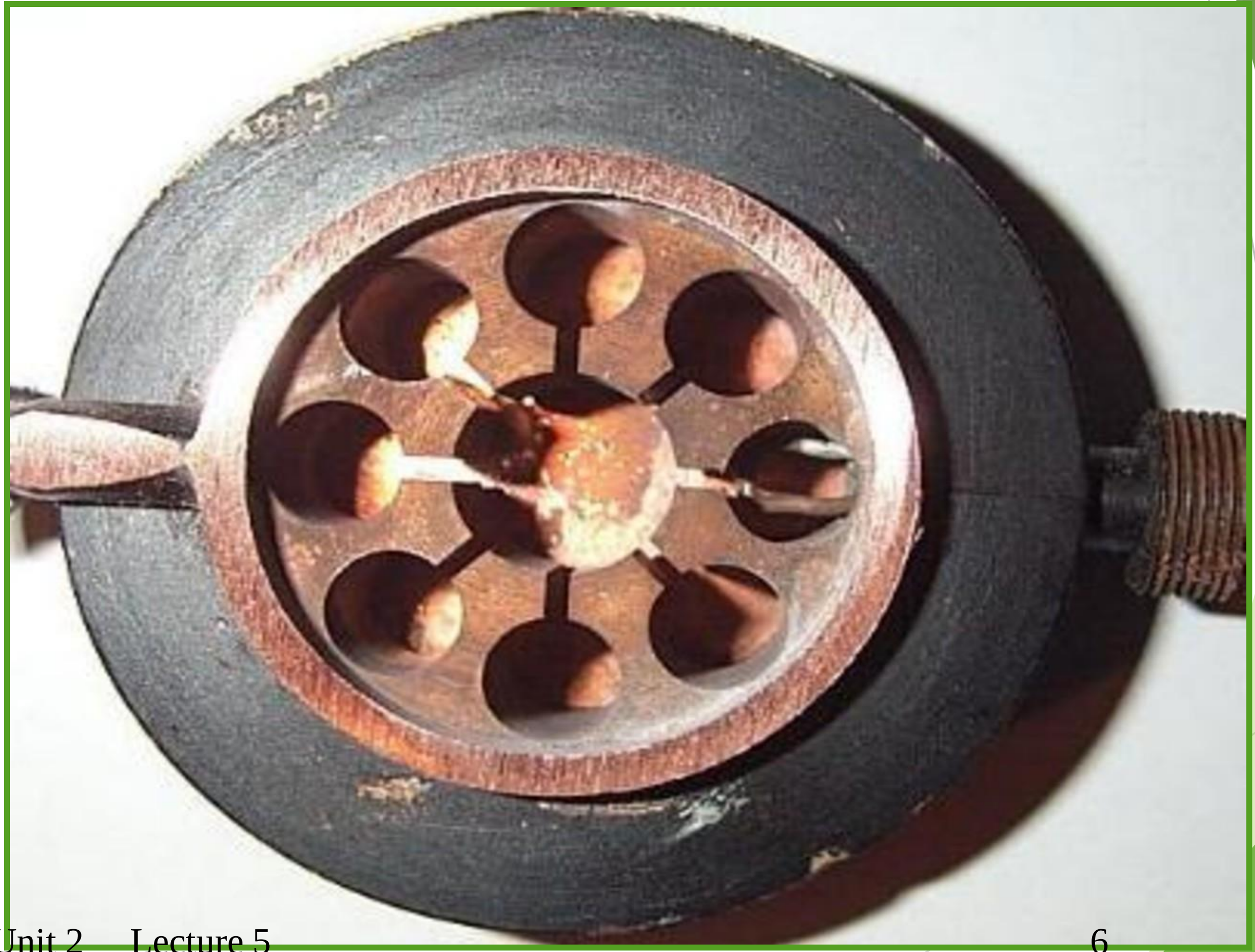


Fig (i) Major elements in the Magnetron oscillator



Cavity Magnetron

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

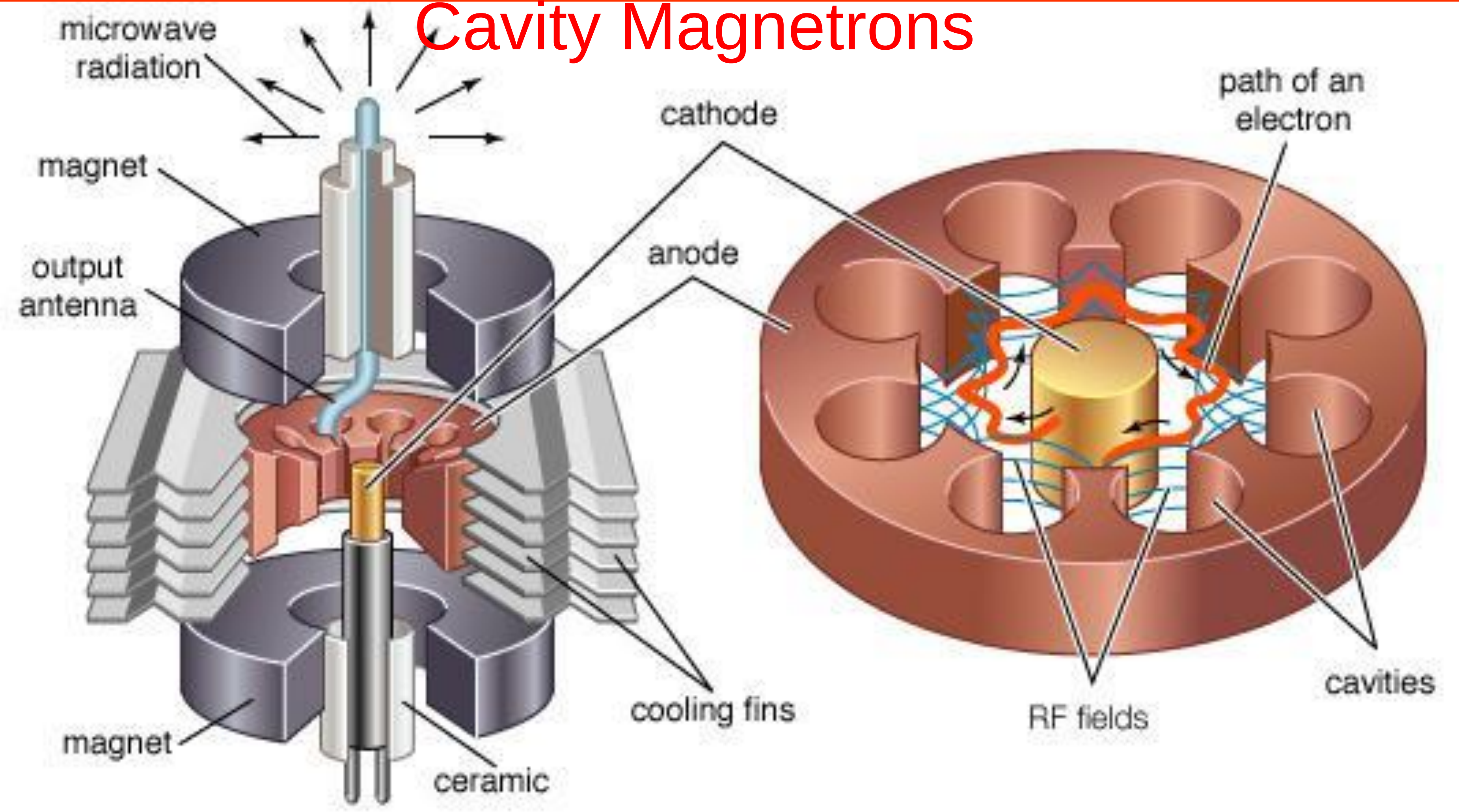
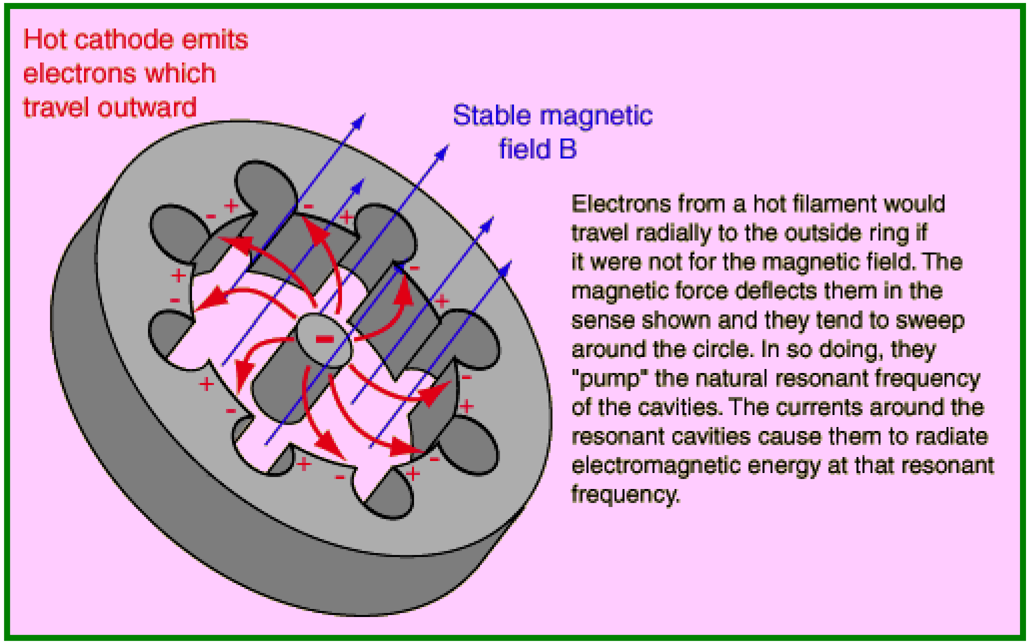
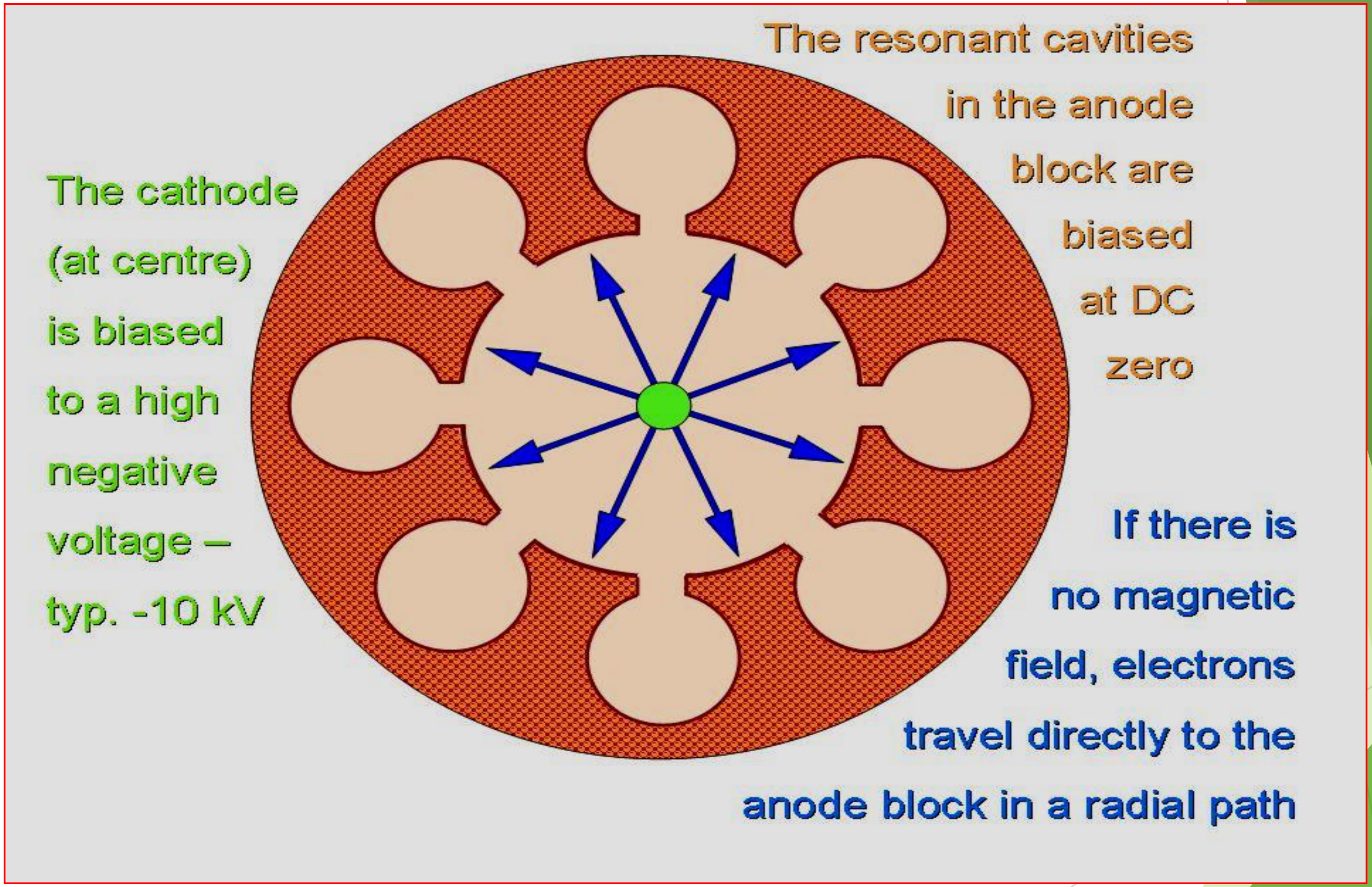
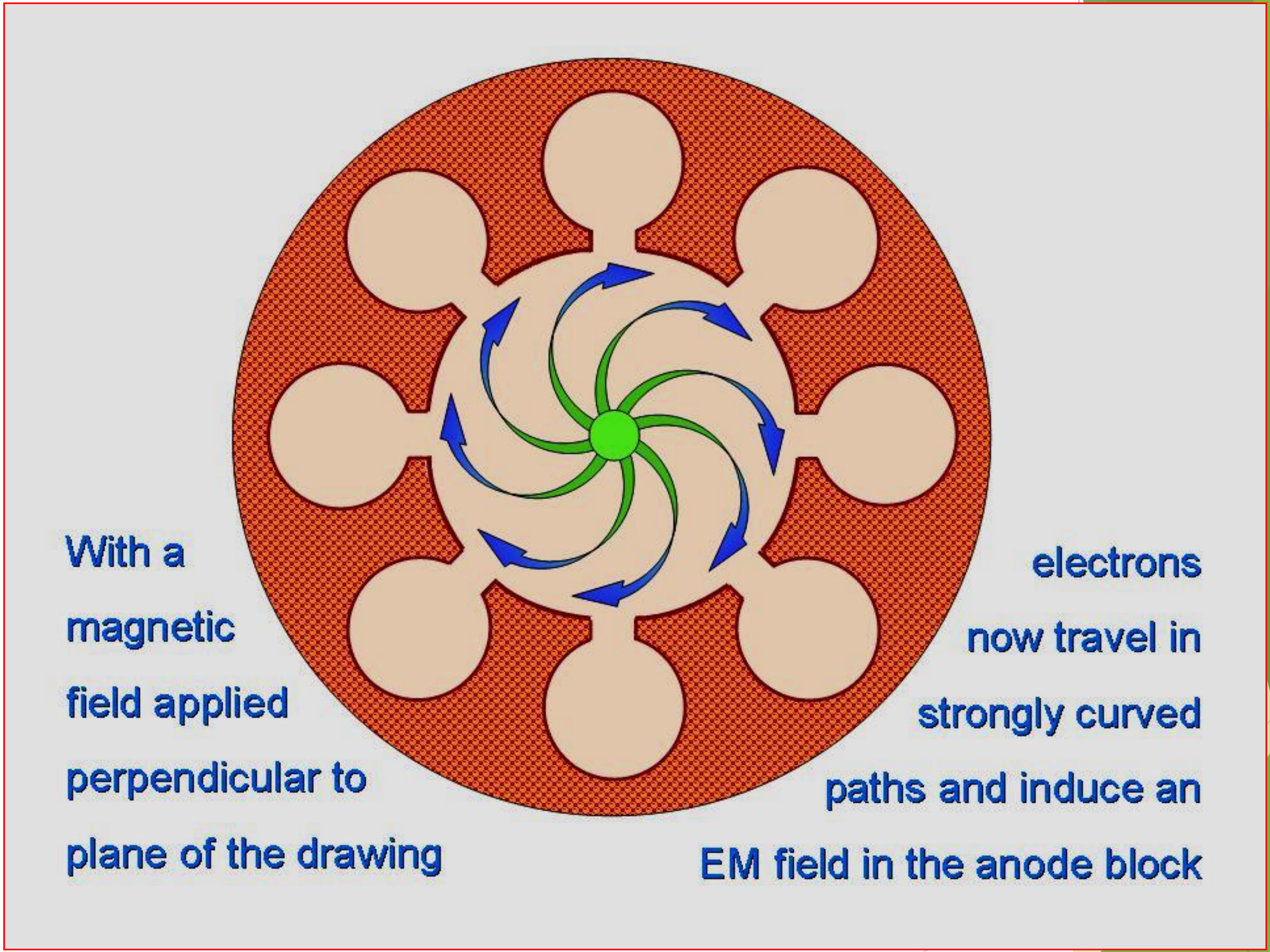


Fig (ii) Cross sectional view of the anode assembly




The resonant cavities in the anode block are biased at DC zero
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.

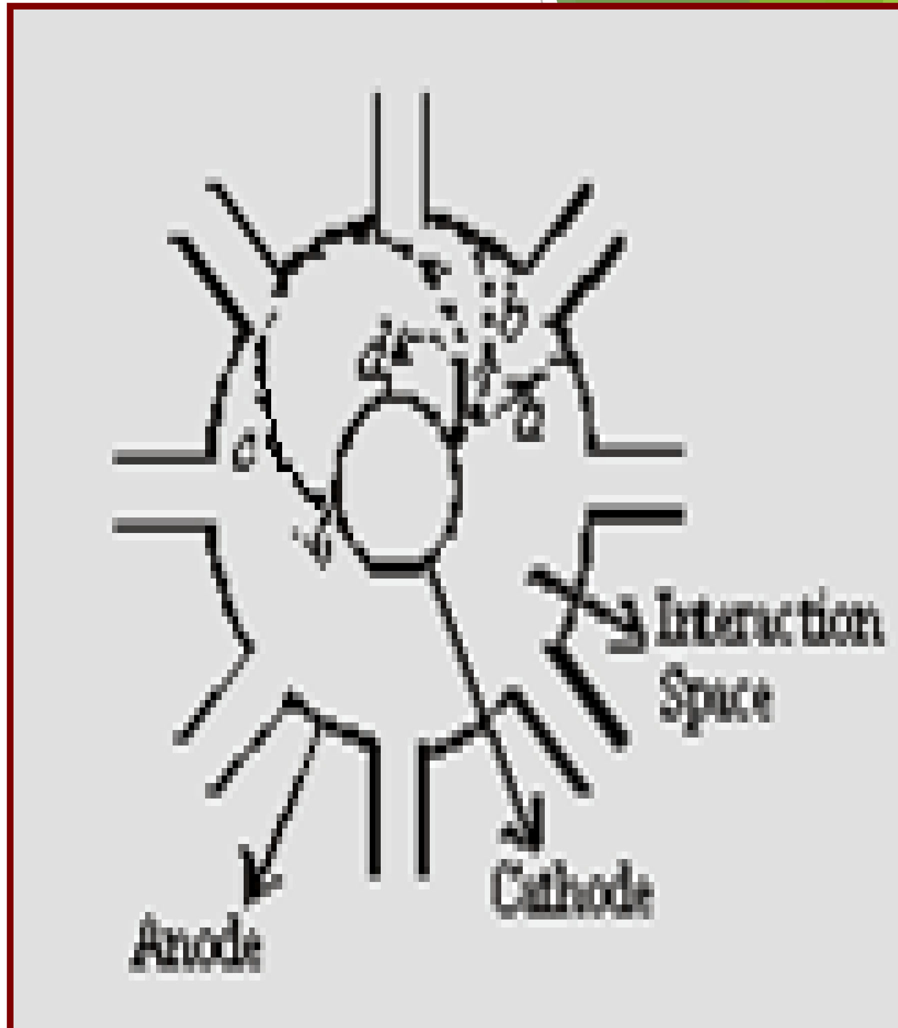
Fig (iii) Electron trajectories in the presence of crossed electric and magnetic fields

(a) no magnetic field

(b) small magnetic field

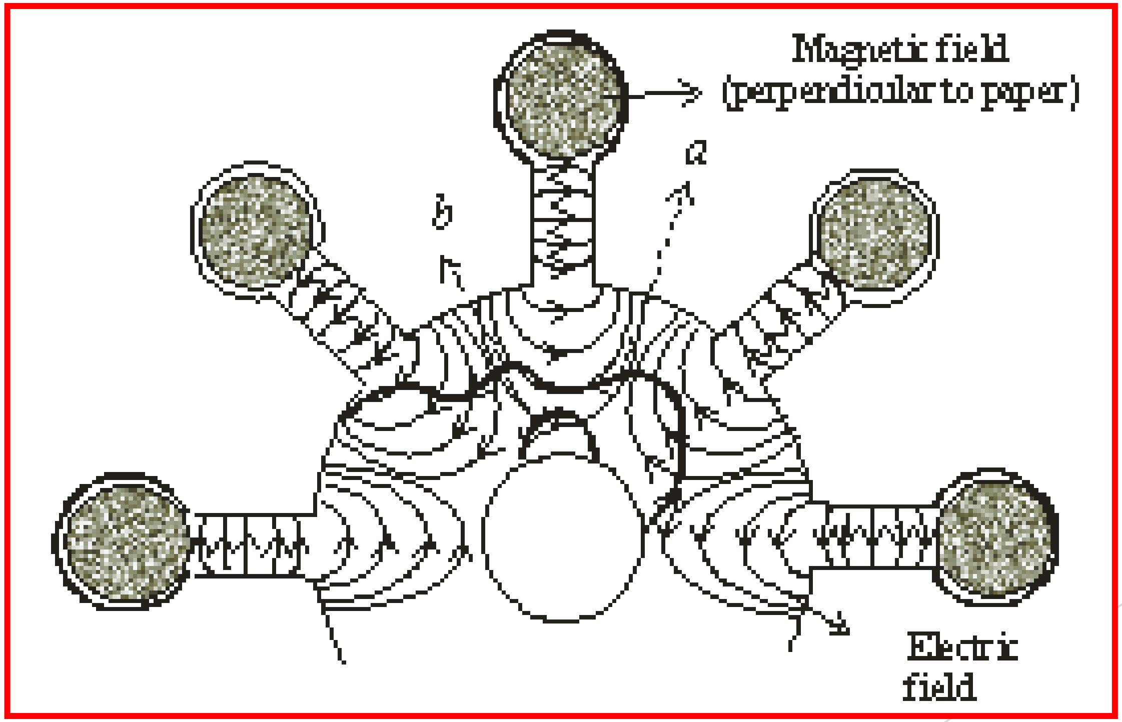
(c) Magnetic field = Bc

(d) Excessive magnetic field



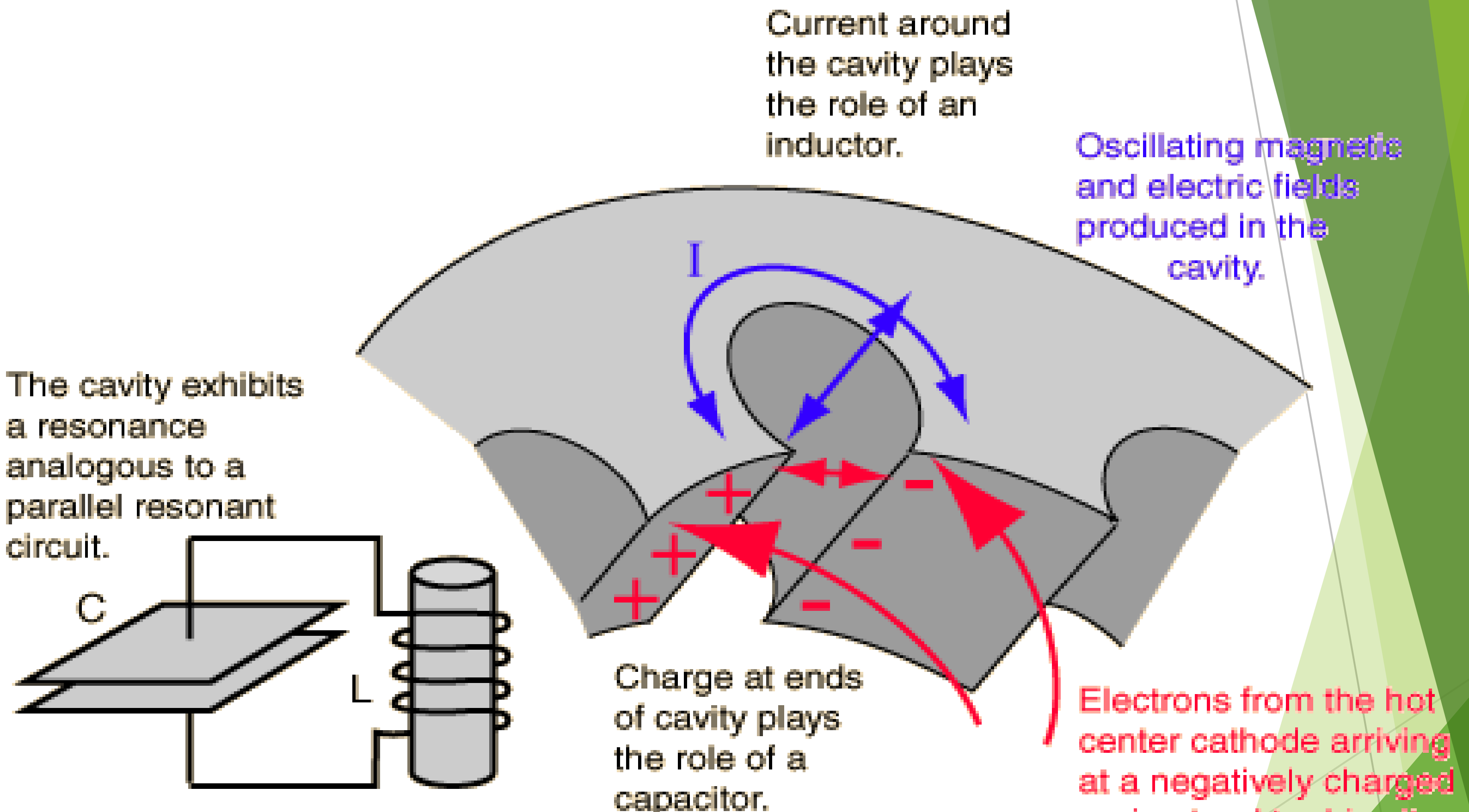
Working

Fig (iv) Possible trajectory of electrons from cathode to anode in an eight cavity magnetron operating in π 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.



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

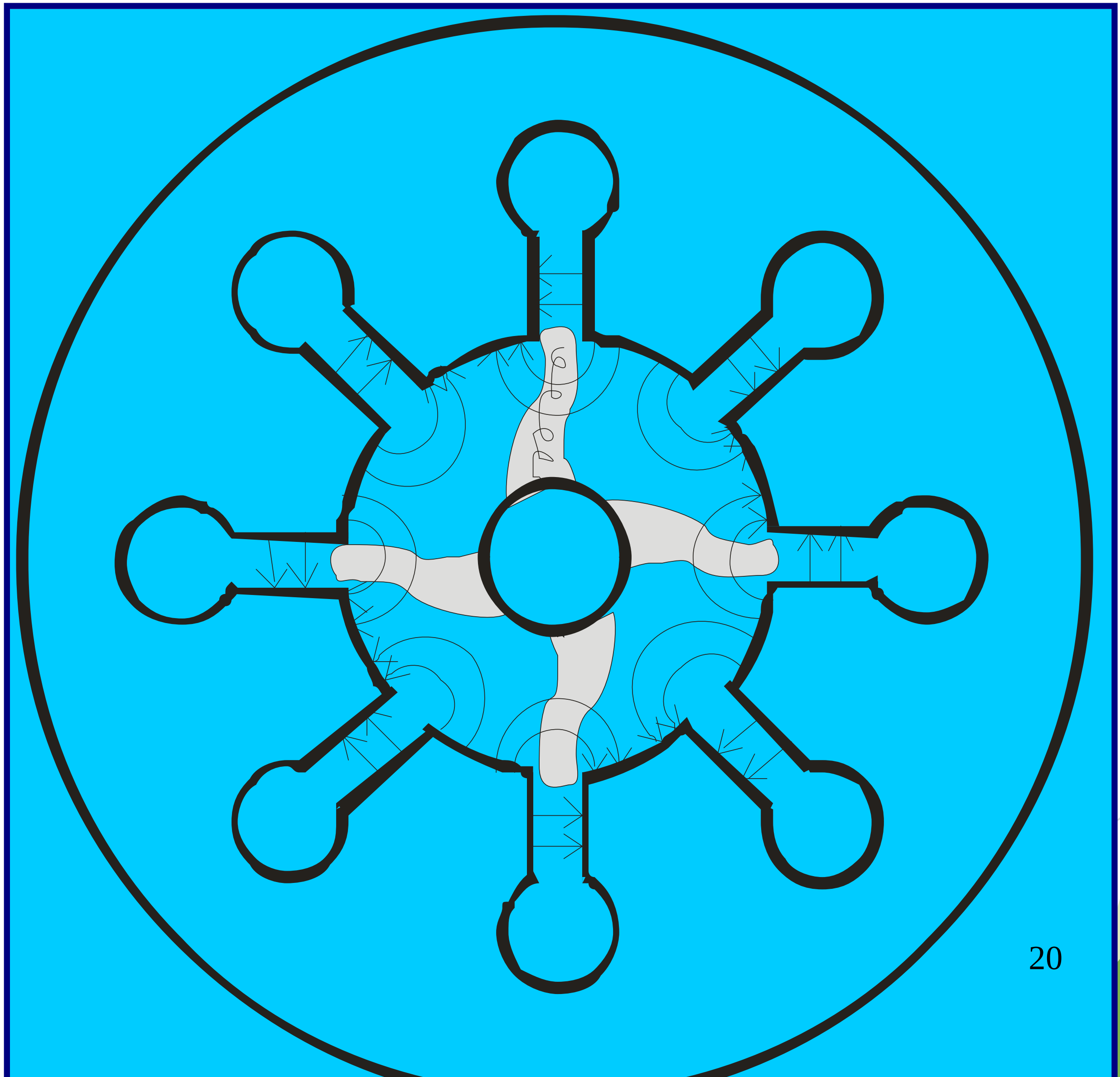
Working

- 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 2π.
- For a dominant mode, the adjacent poles have a phase difference of π radians, this called the π - 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 π - 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
  1. Magnetrons are widely used in radars with high output power.
  2. In satellite and missiles for telemetry.
  3. Industrial heating.
  4. Microwave ovens.
  5. In oscillators with great power and pulsed operation at 100 GHz and greater.

Thanks…