4.2 Klystron amplifier

Module:4 Microwave Sources

Course: BECE305L – Antenna and Microwave Engineering

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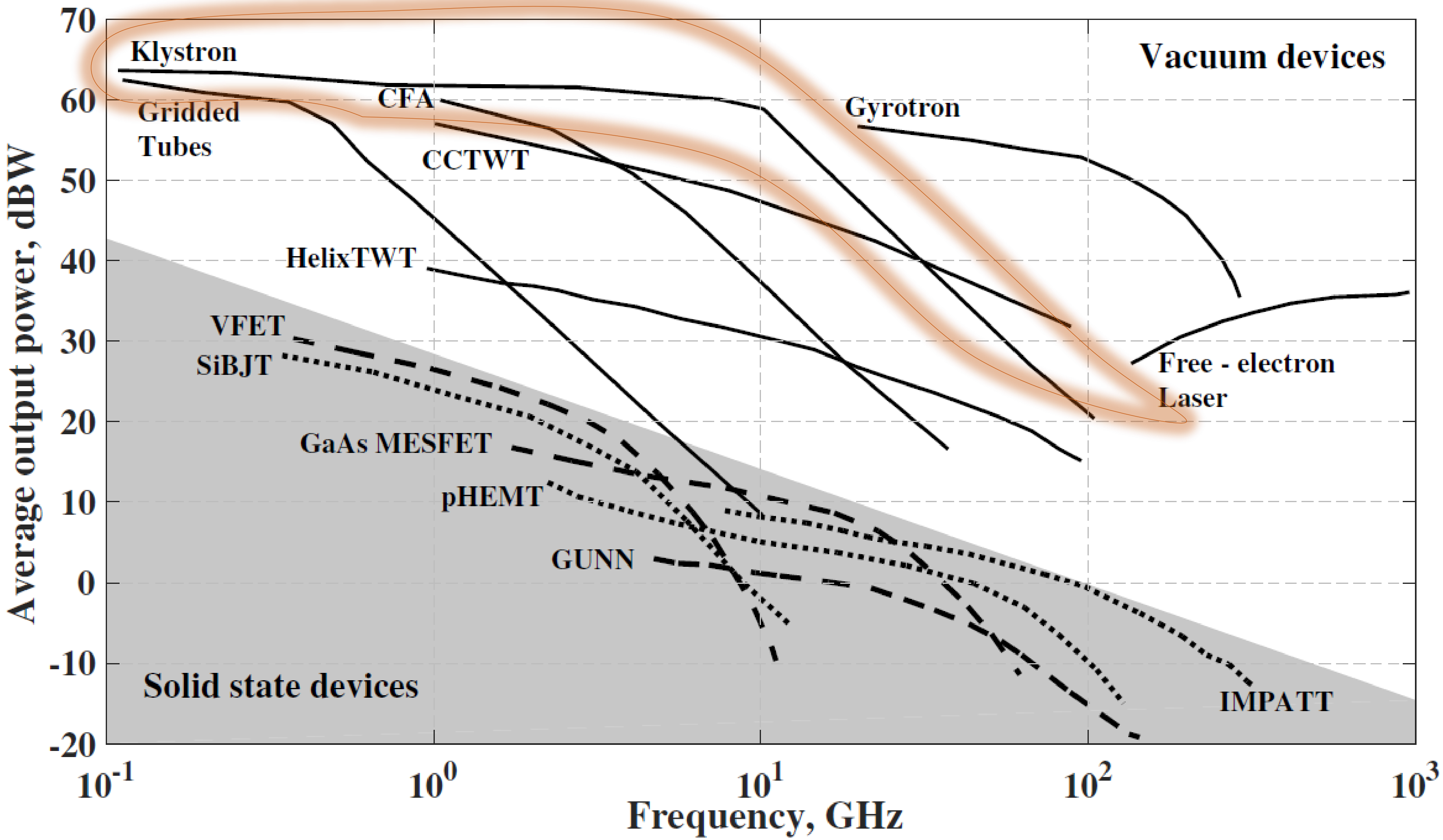
VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)
CHENNAI

Module:4 Microwave Sources 5 hours

- Microwave frequencies and applications, Microwave Tubes: TWT, Klystron amplifier, Reflex, Klystron & Magnetron. Semiconductor Devices: Gunn diode, Tunnel diode, IMPATT – TRAPATT - BARITT diodes, PIN Diode.

1. Introduction: Microwave Devices



2. Classification of microwave devices

1) **Electron beam interaction**:

Forward wave tubes: fundamental harmonic of forward propagating wave interacts with the electron beam as in TWTs. [21]

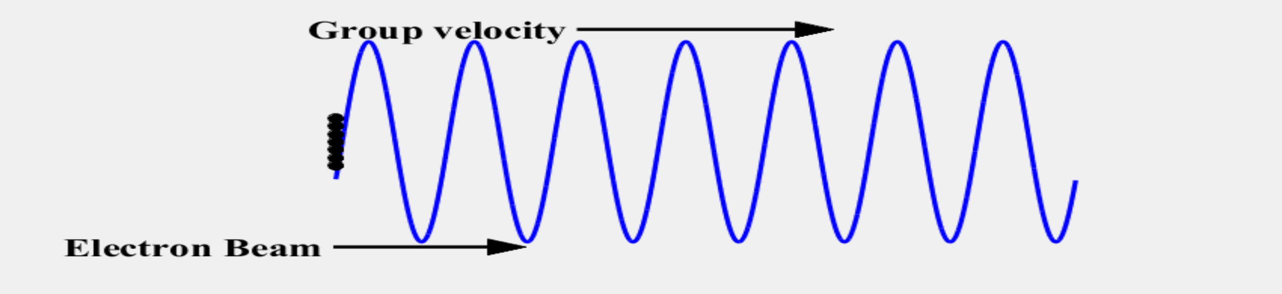


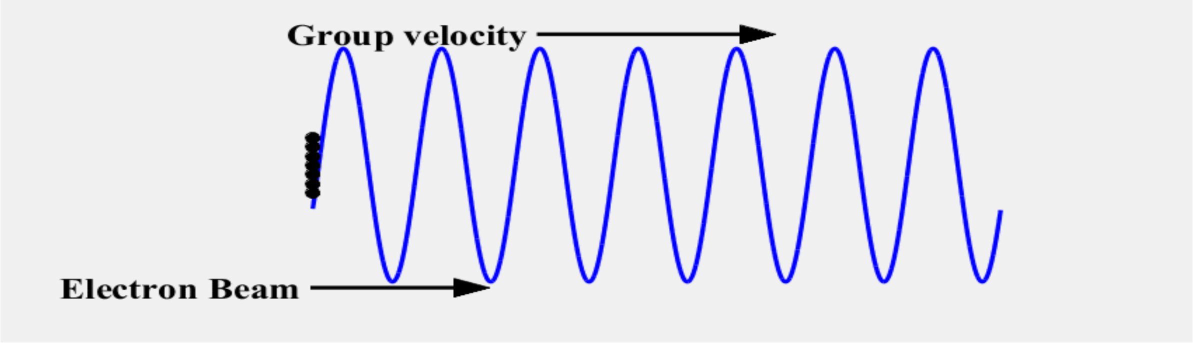
Fig. 2a. BWI in forward wave tubes

2. Classification of microwave devices

2) Static magnetic field direction

O-type devices: Longitudinal component – for rectilinear electron beam focusing [21]

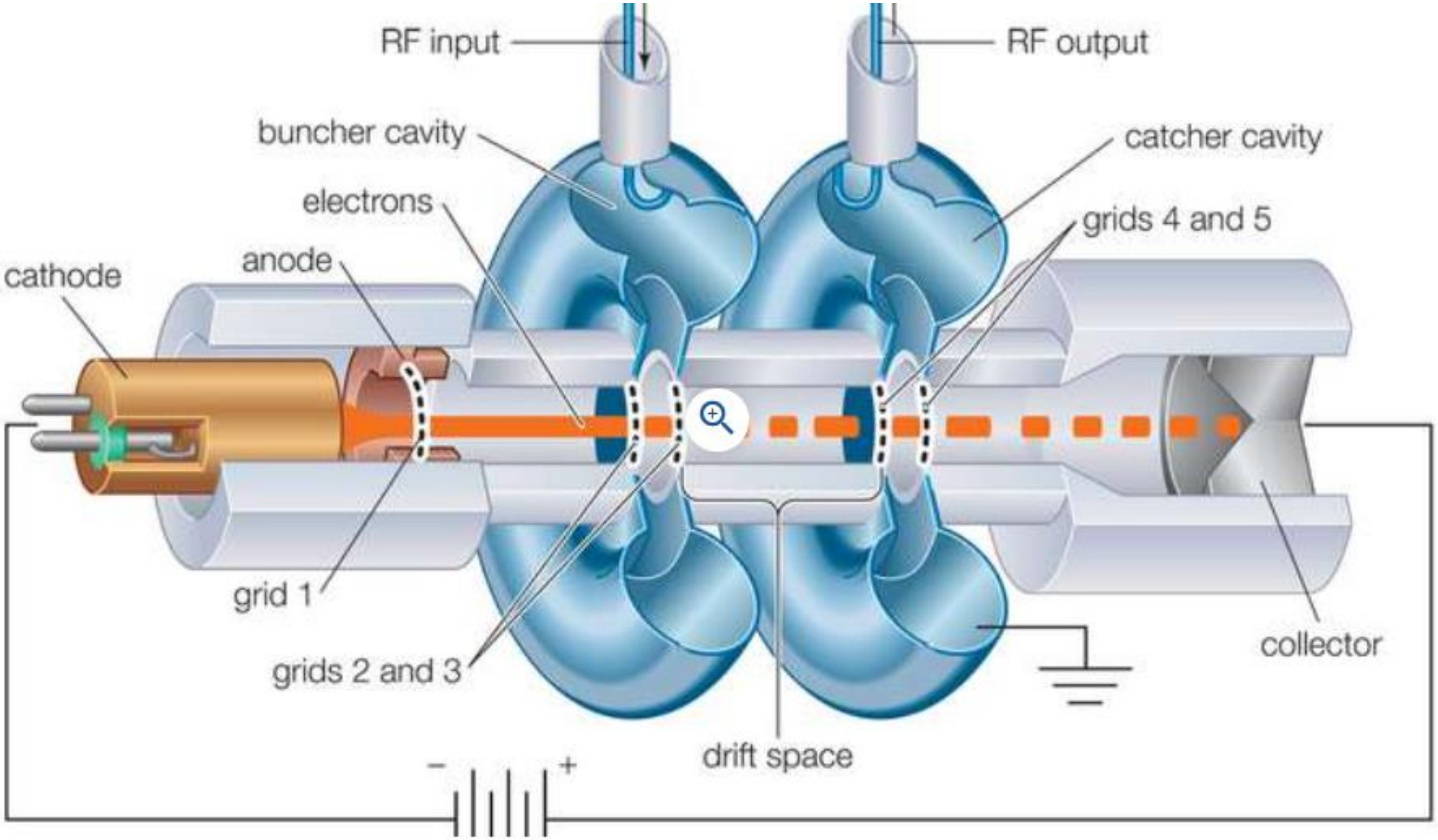
Fig. 3a. Electron motion in O-type devices



3.0 Features of Klystron amplifier

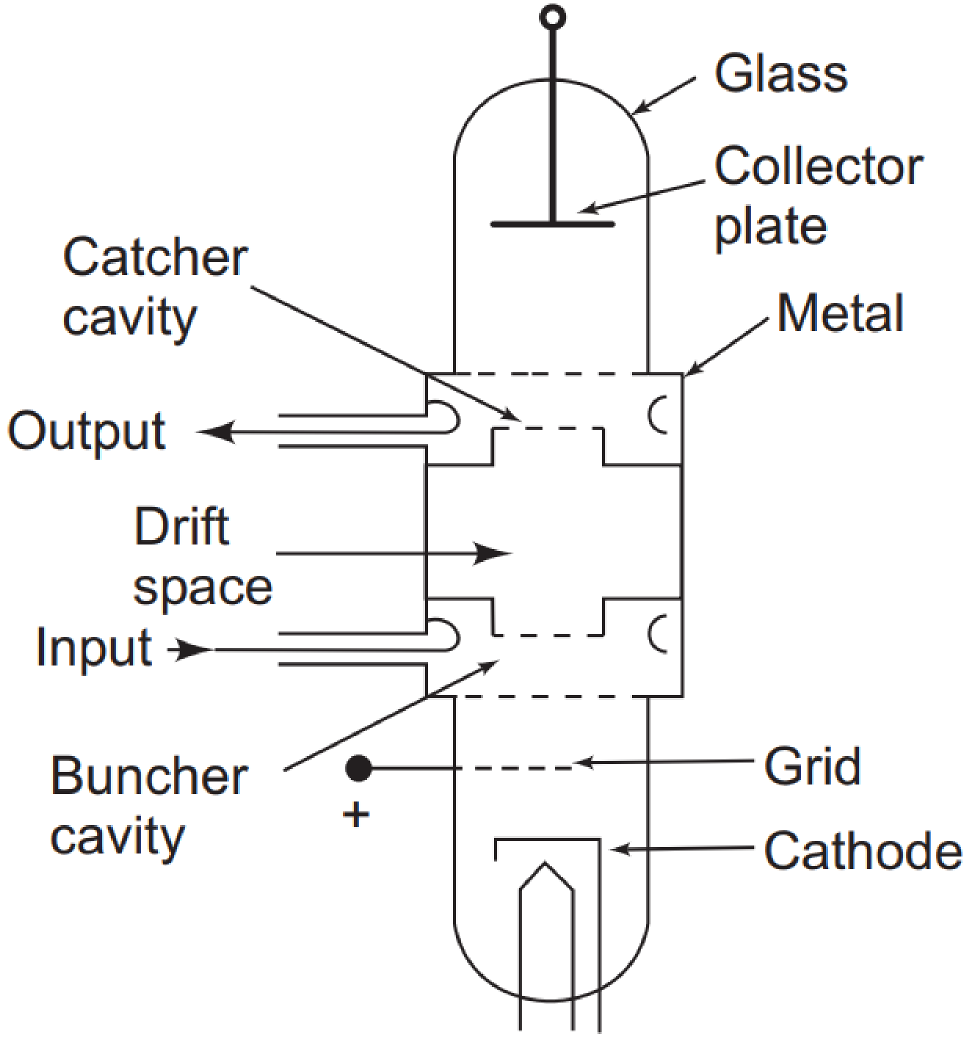
- High gain (>40dB) For input power of 0.01watt,
  output power will be over 100watts (few kW)
- Low noise (Noise floor <10dB)
- Narrow bandwidth

4.1 Structure



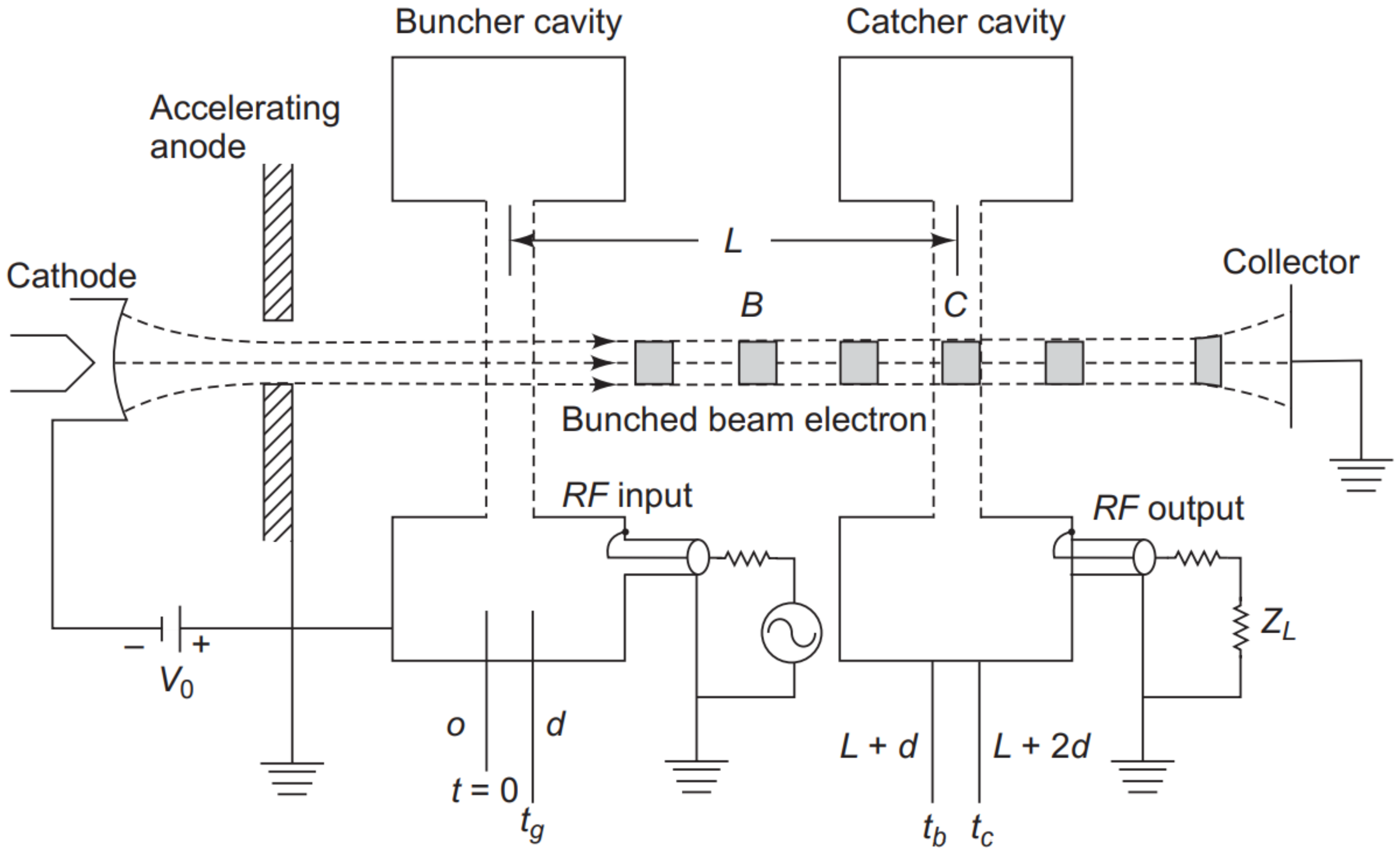
Source: https://www.britannica.com/technology/two-cavity-klystron

4.2 Circuit equivalent



Source: Book by Annapurna Das

4.3 Cross sectional view



The loss of kinetic energy of the electrons on retardation process transfers RF energy to the output cavity continuously at signal cycle.

Source: Book by Annapurna Das

5.1 Analysis: Initial assumptions of 2 cavity klystron amplifier

1. The transit time in the cavity gap is very small compared to the period of the input RF signal cycle.

2. The input RF signal amplitude V1 is very small compared to the dc beam voltage V0 = The anode potential with respect to the cathode potential.

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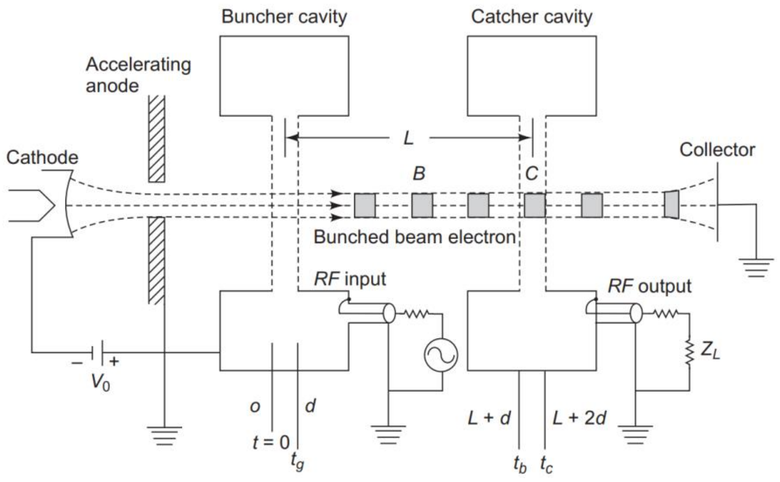
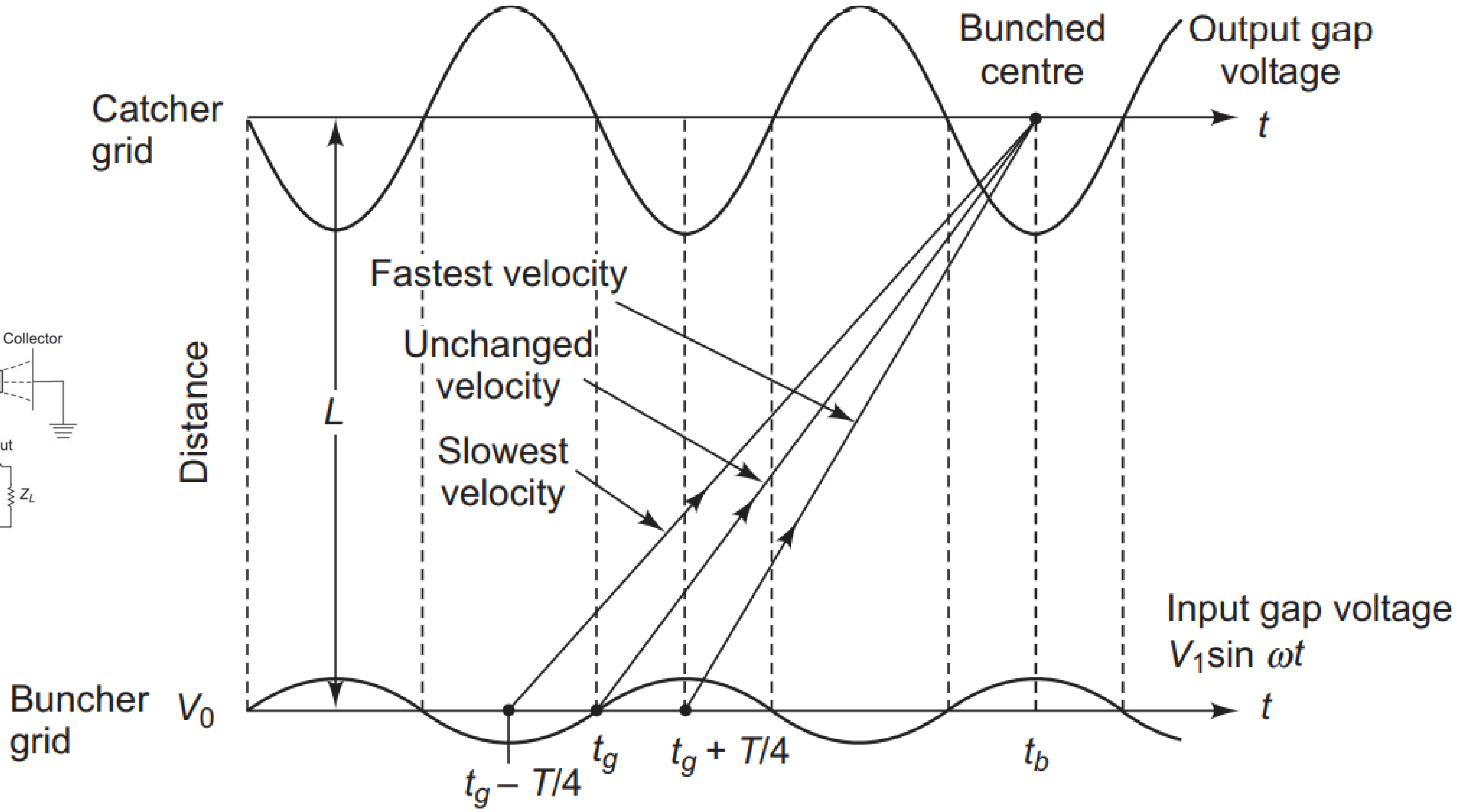
5. The RF fields are totally confined in the cavity gaps so that field is zero in the drift space L.

6. The electrons leave the cathode with zero initial velocity.

5.2 Analysis: Applegate diagram





5.3 Analysis: Velocity modulation

- V_0: Potential difference between anode and cathode
- u_0: Axial electron beam velocity
- Equating the energies $\frac{1}{2}mu_0^2 = eV_0$
- $u_0 = \sqrt{2eV_0/m}$
- Signal voltage across the gap in buncher cavity: $V_1 \sin \omega t$
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- Transit time $t_2 - t_1 = t_g = d/u_0$
- Transit angle through buncher cavity: $\theta_g = \omega t_g$

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- Average RF voltage in the buncher gap: $V_{av} = \left(\frac{1}{t_g}\right)\int_{t_1}^{t_2} V_1 \sin \omega t = \frac{V_1}{\omega t_g}(\cos \omega t_1 - \cos \omega t_2)$

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Where $\beta_1 = \frac{\sin\left(\frac{\omega t_g}{2}\right)}{\frac{\omega t_g}{2}} = \frac{\sin\frac{\theta_g}{2}}{\frac{\theta_g}{2}}$ is buncher cavity beam coupling coefficient.

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- $M = \frac{\beta_1 V_1}{V_0}$ is the depth of velocity modulation
- At $t_1 + t_2$, when electrons enter field free drift space between two cavities, $u_a(t_2) \approx u_0 \left[1 + \frac{\mathrm{M}}{2} \sin\left(\omega t_2 - \frac{\theta_g}{2}\right)\right]$

5.4 Analysis: Transit time in the drift space

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- t_3: Time when bunched electrons are at catcher grid after traveling through drift space
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- Transit time in the drift space: $t_d = t_3 - t_2$

$$t_d = \frac{L}{u_0}\left[1 - \frac{\mathrm{M}}{2}\sin\left(\omega t_2 - \frac{\theta_g}{2}\right)\right]$$