Acceleration and Phase Stability

Second Chapter
First Class

August 30, 2004
Types of Accelerators

- **DC Accelerators:**
  - Get DC beams of low energy and narrow energy spread
  - Cockcroft-Walton
    - Charge Capacitors in Parallel
    - Discharge in Series
    - ~750 keV
    - Front ends on high energy accelerators until RFQs
  - Tandem Van de Graaff
    - Transport charges on insulating belt to high voltage terminal
    - ~15 MeV
    - Limited by high voltage breakdown
    - Can double the voltage with stripper foil – tandem
  - Can’t make circular DC accelerator - \( \nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \)
Types of Accelerators

- **AC Accelerators:**
  - **Induction Accelerators**
    - **Induction linear accelerators (linacs)**
      - High Intensity
      - Up to a few MeV
  - **Betatron**
    - Get constant orbit radius
    - Energy limited by monotonic increase of flux
  - **RF Accelerators**
    - **RF linacs**
      - Highest energy electron accelerators
      - Preacceleration for synchrotrons
  - **Cyclotrons**
    - Big magnets
    - Split RF cavities called “Dee”s
    - Spiral orbit
    - Energies to several hundred MeV
  - **Synchrotrons**
    - Strong focusing
    - Highest energies for protons - TeV
    - Electron light sources

\[ \dot{\Phi} = 2\pi r^2 B \]
RF Cavities

- RF Cavities are highly metallic conducting cavities that can support an infinite number of electromagnetic wave solutions.

- The boundary conditions for these solutions are approximately conducting walls.

- Although there are an infinite number of solutions, we want a low order solution with strong E_z, where the beam travels in the z direction. A good choice is the TM_{010} mode.

- There are a few figures of merit that are used to describe RF cavities:
  - The transit time factor relates the actual energy boost to the energy boost from a fixed (in time) field
  - The Q of the cavity relates the loss rate due to resistivity of the walls to the energy stored in the fields inside the cavity.
  - The shunt impedance relates the energy gain per unit charge in the beam to the resistive loss rate.

- For proton or ion synchrotrons, it is usually necessary to adjust the cavity frequency as the beam is accelerated.
Accelerating Structures

• There is a variety of ways to arrange cavities into individual or multicell accelerating structures.

• Accelerating structures can be driven independent RF sources for each cavity, or a single source can drive multiple cavities.

• The relationship between phases in successive cavities is of critical importance – the fields are time varying and they must be aligned with the beam as it passes through.

• Because the cavity fields vary in time, it is necessary to use bunched, rather than continuous, beams.

• In electron linacs, traveling waves are used to accelerate the beam. It is necessary to slow their phase velocities, which are greater than c, using disks inserted into the waveguide.
Homework:
Assignment due Tuesday, 09/14/2004

- Read Edwards and Syphers, Chapter 2 through page 41.

- Problems, due Tuesday, 09/14/2004:
  - 2.1
  - 2.2
  - 2.3
  - 2.4
  - 2.5
  - 2.7