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 increse of flux**

$$\dot{\Phi} = 2\pi r^2 B$$

  - **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**

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