ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY
AUTONOMOUS INSTITUTION
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DEPARTMENT OF BIOMEDICAL ENGINEERING

VII Semester

OBT357 BIOTECHNOLOGY IN HEALTH CARE

UNIT- 5 BASICS OF IMAGING MODALITIES

5.1. Diagnostic X-rays

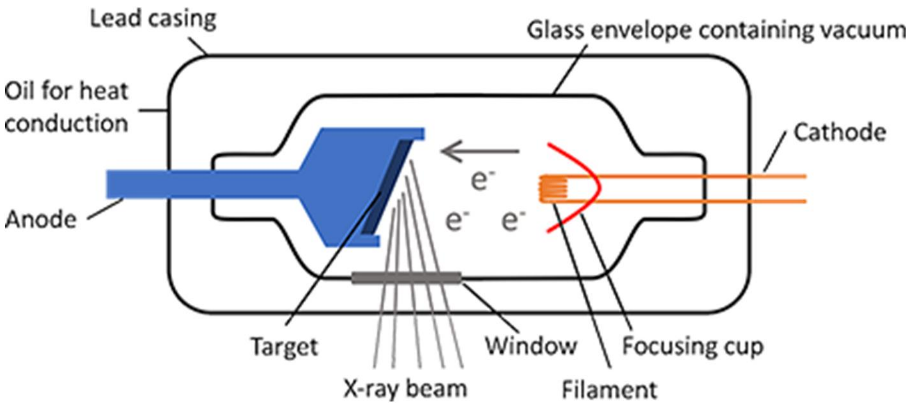
- X-ray imaging works by passing X-rays through the body, which are absorbed or scattered differently by tissues of varying densities.
- Dense materials like bone absorb more X-rays, appearing white, while softer tissues absorb less, appearing darker on the resulting image. Common X-ray modalities include projection radiography (a single static image), fluoroscopy (real-time X-ray video), and computed tomography (CT) (cross-sectional images created from multiple X-rays).
- These images are captured by detectors and processed by a computer to create diagnostic views of internal structures.
- The main components of a **diagnostic X-ray imaging system** can be grouped into
    1. X-Ray Tube
    2. High-Voltage Power Supply
    3. Collimator and Filters
    4. Image Receptor (Detector)
    5. Control Console

1. X-Ray Tube:

Components of the X-ray Tube

1. **Lead Casing**:
    - A protective shield surrounding the tube to absorb stray X-rays, ensuring safety for patients and operators by minimizing radiation leakage.
2. **Oil for Heat Conduction**:

A cooling medium surrounding the tube to dissipate the intense heat generated during X-ray production, preventing damage to the tube `



X-ray Tube

3. **Anode**:
   - A positively charged electrode, typically made of tungsten or molybdenum, with a target area where electrons strike to produce X-rays.
4. **Glass Envelope Maintaining Vacuum**:
   - A sealed glass or metal casing that maintains a vacuum inside the tube, preventing electron collisions with air molecules and ensuring efficient X-ray generation.
5. **Cathode**:
   - A negatively charged electrode that emits electrons when heated, consisting of a filament.
6. **Filament**:
   - A coiled tungsten wire that, when heated by an electric current, emits electrons via thermionic emission.
7. **Focusing Cup**:
   - A negatively charged structure around the filament that directs the emitted electrons into a narrow, focused beam toward the anode.
8. **Target**:
   - The specific area on the anode where the electron beam strikes, generating X-rays through energy conversion.

9. **Electron Beam**:
    - The stream of electrons accelerated from the cathode to the anode under high voltage.

Working Principle of the X-ray Tube

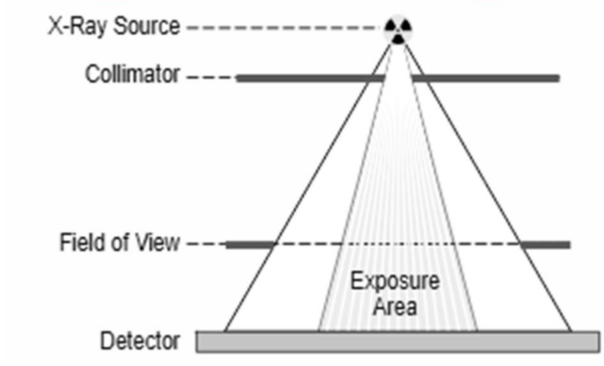
The X-ray tube generates X-rays through a series of physical processes, as illustrated in the diagram:

1. **Electron Emission**:
    - An electric current heat the filament in the cathode, causing thermionic emission. This releases electrons from the filament surface due to the high temperature.
2. **Electron Acceleration**:
    - A high voltage (typically 20–150 kVp) is applied between the cathode (negative) and anode (positive), creating a strong electric field. This accelerates the electrons from the cathode toward the anode at high speed.
3. **X-ray Production**:
    - When the high-energy electrons strike the target on the anode, their kinetic energy is converted into X-rays:
        - **Bremsstrahlung Radiation**: Electrons decelerate upon hitting the target, releasing energy as a broad spectrum of X-rays.
        - **Characteristic Radiation**: Electrons dislodge inner-shell electrons from the target material, and as outer electrons fill these vacancies, they emit X-rays at specific energies unique to the target material (e.g., tungsten).
    - Only about 1% of the energy becomes X-rays; the rest is converted to heat, managed by the oil cooling system.
4. **Beam Formation and Exit**:
    - The focusing cup shapes the electron beam to ensure it hits the target accurately.
    - The generated X-rays exit the tube through a window (not shown in the diagram but typically made of beryllium) and are directed toward the patient via a collimator (external to the tube).

2. **High voltage power supply:**
   - The **high-voltage power supply** in X-ray equipment is a critical component that provides the electrical energy needed for X-ray production.
   - It generates and regulates the high potential difference (typically 30–150 kVp) between the cathode and anode of the X-ray tube, which accelerates electrons from the filament toward the target anode.
   - When these high-speed electrons strike the anode, X-rays are produced. The power supply must deliver a stable, ripple-free output to ensure consistent image quality and minimize patient dose.
   - It also includes circuits for filament heating (low-voltage, high-current supply) and exposure timing, making it essential for both the efficiency and safety of diagnostic X-ray imaging systems.

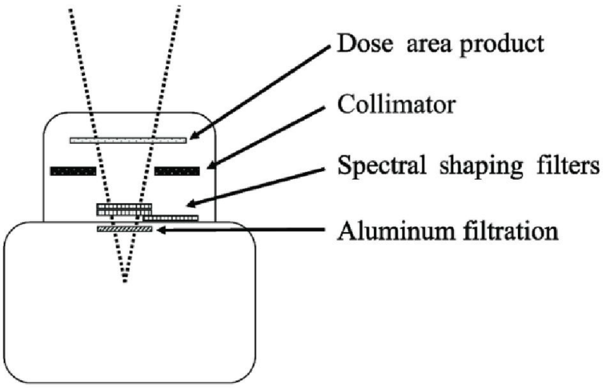
3. **Collimators and Filters:**

   Collimators:
   - Collimators in X-ray imaging systems shape and restrict the X-ray beam to the area of interest, reducing scatter radiation and unnecessary exposure.
   - Made of dense materials like lead or tungsten, they use adjustable plates or slits and often include a light field system for accurate positioning.
   - By limiting beam size, collimators improve image contrast and lower radiation dose, making them essential in both portable outpatient units and inpatient imaging.



   Filters:
   - Filters in X-ray imaging remove low-energy X-rays that add to patient dose without improving image quality.
   - Made from materials like aluminum, copper, or rare-earth compounds, they are placed between the X-ray tube and patient, often in a rotating wheel with variable thickness.

- By absorbing soft X-rays, filters harden the beam, reduce scatter and skin dose, and preserve diagnostic quality, making them valuable in both quick outpatient exams and high-precision inpatient imaging.

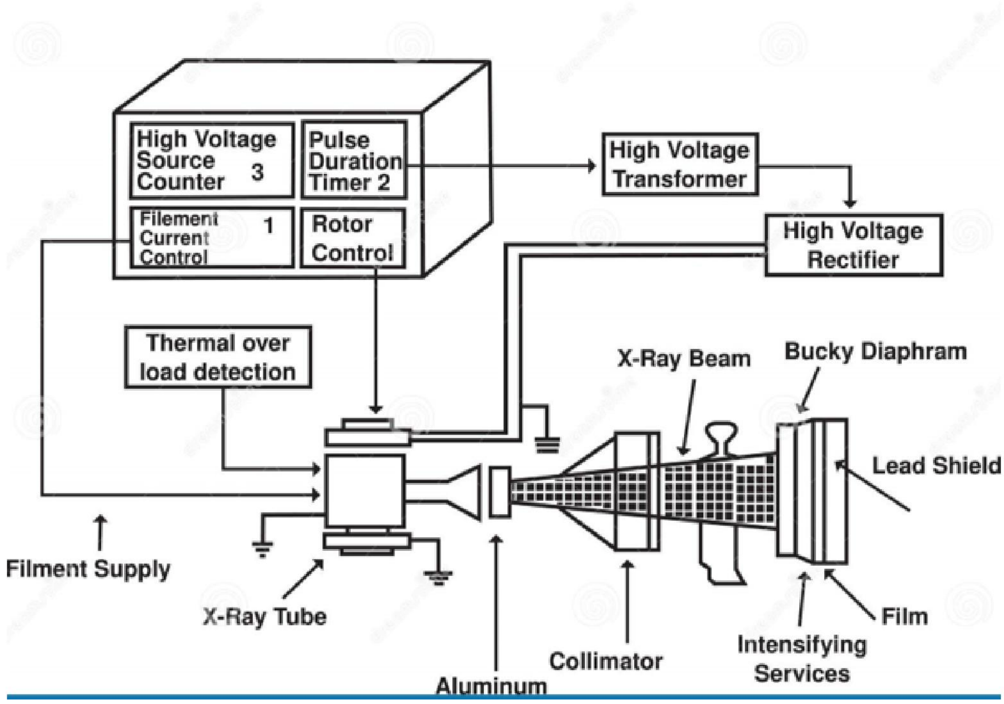


X-ray tube assembly

4. Image Receptor (Detector): -Film Based

- In film-based X-ray imaging, the beam passes through the patient and interacts with silver halide crystals on the film, forming a latent image by reducing silver ions to metallic silver.

BLOCK DIAGRAM OF X-RAY MACHINE



- ❖ Intensifying screens (calcium tungstate or rare-earth phosphors) boost efficiency by converting X-rays to light. During processing, the developer reduces exposed crystals to black silver, the fixer removes unexposed halide, and washing/drying finalizes the image.
- ❖ The result is a negative image where dense tissues appear dark. Films must be handled under safelights to prevent fogging, and silver recovery from used films offers economic and environmental benefits

5. Control Console:

- ❖ **Radiation Safety and Control Systems** minimize exposure using lead shielding, dose monitoring devices, and automatic exposure control (AEC), which adjusts output to tissue density. Biotechnology contributes with advanced radiation-sensitive materials and real-time dosimetry for safer imaging.
- ❖ **Control Console** enables technologists to set exposure parameters (kVp, mA, time) via user-friendly panels or touchscreens. Biotechnology enhances this with AI-driven interfaces that recommend optimal settings tailored to patient needs.

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