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Production of X-RAYS using X-RAY Tube

Sangeetha Prabhu[1,*], Divya Kumari Naveen[2], Sandhya Bangera[3] and Subrahmanya Bhat B[4]

[1,2,3]Research Scholar, College of Computer Science and Information Science, Srinivas University, Mangalore, India
[4]College of Computer Science and Information Science, Srinivas University, Mangalore, India

*Corresponding author e-mail: sangeethaprabhu96@gmail.com

Abstract: X-rays are usually the most common form of electric magnetic radiation. Technological developments in imaging have resulted in increasingly powerful and guided X-ray rays, and also growing use of visible light in adolescence microbial tissues and structural elements of materials like concrete. Since its discovery in 1895 X-ray has been commonly used in medication and some areas of technology, science and engineering. The X-ray tube is an essential component of each X-ray union, and in its early stages scientists and doctors utilized gas ion tubing. X-rays are generating because fast-moving electrons suddenly decelerate when they collision with the target anode and interact with it. Therefore, x-ray tube absorbs and dissipates a large heat charge in order to achieve adequate radiation output for digital radiology influencing the structure and function of a x-ray source. An x-ray tube's key components include electrode and counter electrode frames, rotor and stator, and tube cover. The X-rays generated have waveform features similar to other electromagnetic waves. As x-rays come across matter, the small wavelength of radiation defines their property. Most of the materials are transparent to the x-ray and radiation will not transmit lead and other dense materials. Throughout this paper, we discuss X-ray machine, characteristics and features of x-ray, X-ray source modules, x-ray applications in a broad range of domains to discuss x-ray background, manufacturing and x-ray identification.

1. Introduction

In 1894, Wilhelm Conrad Röntgen or Roentgen noticed that a high-voltage gas release creates penetrating radiation among electrodes at much reduced pressure that allows some substances to leak with visible light. He identified that radiation which he called x-rays can penetrate a hand, throwing shadows on the fluoresce display when the voltage is more than 30kV [1]. As it soon became apparent, electromagnetic radiation is expressed when electrodes (anodes) or tank walls clash as the negative (cathode) electrode of the release pipe is released and as the voltage is being applied is acceleration. Roentgen's work has had significant implications for physics. Six years ago, Hertz discovered electromagnetic radiation one million times longer than wavelength visible lights [1]. The research of Roentgen shows how electromagnetic radiation can be produced ten miles shorter by wavelength. These wavelengths are identical to the measurements of atoms. As a result, x-rays have become an essential model for examining the biochemical properties of the materials, and the groups of atoms. The detection and analysis of x-ray anomalies became a significant part of the growth of the scientific quantum theory of radiation and matter over the ensuing 30 years.

Coolidge is a reference of almost today's forms of x-ray tubing. Coolidge tube utilized the thermionic emission concept as the first kind of functional x-ray camera. A filament from tungsten is used as a cathode tube, while a current pass through it heated to incandescent during operation [2]. This leads to electrons being emitted in a rate depending on the filament temperature. With the high tube voltage, the electrons are then guided into the tube anode. When the anode hits, the electrons are delayed very quickly, mostly as warmth, and partly as radiation. Excessive kinetic energy is drained. The cathode filament is enclosed by the metal concentrate cup with significant negative potential that converges the beam on the anode into a small focal area to prevent the electrons from being scattered due to repulsive forces between electrons [2]. X-ray tubes are strong enough to pull electrodes through a tube voltage from the cathode before the Coolidge tube (so-called gas tubes) depends on its electron source. It was accelerated to anode and left the residual gas molecules deliberately in the tube which ionized molecules and caused the expulsion of more electrons. This created a sort of 'avalanche effect' on the electron beam that was required. However, in case of a collision with the anode, the number of electrodes generated within the beam and their energy focused on the sometimes stable and difficult to regulate gas pressure within the tube. In fact, the quantity of electrons is emitted in this way was relatively small compared to today 's guidelines and the intensity of x rays produced was also very low which led to very long exposure periods [2]. The Coolidge tube eliminated the residual gas reliance on the amount and energy of electrons in the electron beam in the same requirement as thermionic pollution for receiving a supply of electron. The Coolidge-tube made it possible to change the numbers of electrons generated and their energy separately and easily [2]. Because the number of electrons produced depends on current which was used over cathode filament as well as the tube voltage electrons. The heat emission also caused the number of electrons emitted to be significantly higher and therefore resulted in a dramatic decrease of exposure times.

2. Aims and objectives of study

This is basic paper based on the production x-ray using x-ray tube. The paper deals with the following aim and objectives:

1. To learn how x-rays are produced.
2. To know the properties and characteristics of X-ray.
3. To learn about the objects of X-ray machine.
4. Knowing X-ray technologies in diverse fields.

3. History of X-RAY

- 1895 - While working on cathode light in a glass tube, Wilhelm Roentgen the German physicist detects X-rays [3].
- 1896 - Inspired by Roentgen x-ray monitor is invented by Thomas Edison.
- 1906 - Charles Barkla, British physicist demonstrates that light beams can skew X-rays too. This gives valuable proof that X-rays are actually light waves with various wavelengths and frequencies [3].
- 1912 - Max von Laue discovered that he can calculate the strength of x-rays with crystallites and primarily embraces x-rays in atomic radioactivity and wavelength [1].
- 1913 -14 - Lawrenz Bragg and William Henry Bragg discovered that wavelength of x-rays could be used to examine atomic divergence in crystals as well as the x-ray field [4].
- 1913 - William David Coolidge is developing the practical X-ray machine. This is a large glass container with a beam of electron and metal in a tube named the Coolidge. As the beam fires at the mark, the X-rays are released. Increased voltage produces higher frequency and shorter range, stronger and more intense X-rays. His invention of Coolidge patents in 1916[4].
- 1922 - Arthur H. Compton tests the absorption of highly polished glass X-rays, and very precisely measures the duration. He describes a mechanism known as the Compton Effect the dispersed X-rays are less strong than particulate matter in the initial beam.
- 1953 - James D. Watson and Francis Crick developed the DNA structure using the X-ray

diffraction images from Rosalind Franklin [5].

- 1972 - Godfrey Hounsfield, the British electronics scientist, invents a CT scanner, utilizing thin X-ray beams to create 3D images of a person's body.
- 1999 - The Chandra X-ray Telescope has been designed by Space Shuttle as the most powerful x-ray telescope ever.
- 2000 - In order to enhance airport baggage screening safety, CT X-ray scanners are used.
- 2009 - The strongest source of radiation in the nation is developed by California's SLAC National Accelerator Laboratory [5].
- 2018 - New Zealand researchers create a diagnostic scanner that can display the human body's 3D color X-rays.
- 2019 - Singapore scientists demonstrate that perovskite particles can produce enhanced X-ray sensors [6].

4. Production of X-RAY

X-rays are released if the electrons in motion interact with matter. In the x-ray tube electrons interact with a target and a part of kinetic energy of the electrons are converted into x rays or electromagnetic energy.

The simplified electrical x-ray tube system defined in Figure 1 demonstrates the basic process of using a radiographic tube to generate x-ray. The potential gap of 20-150kV is generated between anode and cathode of x-ray tube by the x-ray machine [7]. A current through a filament at the cathode side is generated by a separate low voltage circuit. The thermionic emission effect, which is the current in the filament, causes the filament to heat up and expel the electrons. The considerable potential gap among anode and cathode produces electron. The movement of electrons between anode and cathode is considered as tube voltage and the energy of electron in the cathode filament is called voltage of the filament. Bremsstrahlung process and characteristic x-ray production are the two ways of transforming the energetic electrons to x-rays at the anode side. X-rays escapes from the tubes in both dimensions but constrained bylead boxes and collimators to the correct beam size and interact finally with the individual and the sensor for a realistic image.

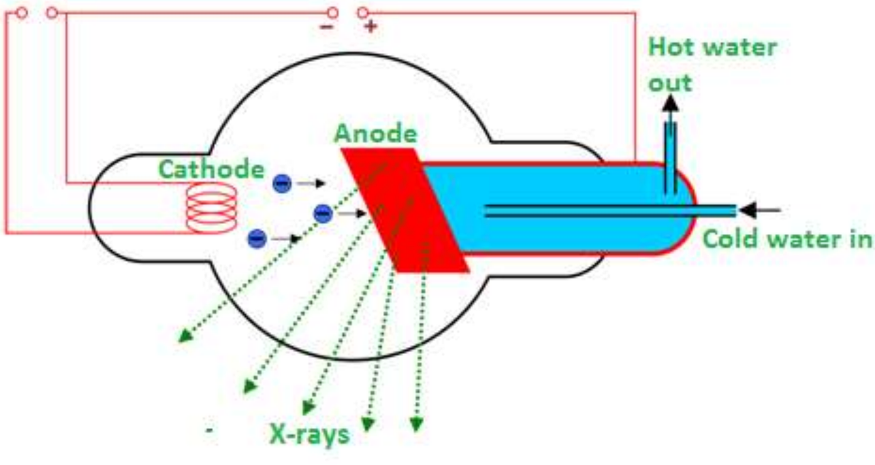

Figure 1. Basic x-ray production process.

4.1 X-RAY generator

Providing sufficient energy to the machine to generate x-rays is the purpose of x-ray machine. To maintain the current of the tube a sufficient current is supplied to the x-ray tube while transmitting the x-rays. During fact, any voltage variability happens through an application to x-rays, a phenomenon known as "voltage ripple". The current is defined as time to be the waveform of the voltage. The user estimates the generator-generated high voltage (20-150 kV) and tests the effective strength of the resulting x-rays. To produce the filament, current the generator will have specified low voltage around 10V [7]. The operator should choose the filament voltage, which reflects the excess of electrons produced by the filament, and therefore the electrons needed to move to the anode, which effectively defines the tube 's current. The changes in the filament current by 1% high will affect on more than 10% reduction in tube current. To get the x-ray output the operator can set the exposure time that is at what time the high current should be applied.

4.2 Bremsstrahlung process

The energy used by the electron is measured by the immediate contact of the electron path to the nucleus, and therefore by the frequency of the respective x-ray. By generating a range of radiographic energies at various wavelengths through nuclei the electrons were guided towards the target. When an electron eventually enters a nuclear reactor and releases all its kinetic energy as an x ray, it produces the maximum potential x-ray energy. Figure 2 indicates the energy spectrum for the braking radiation [8]. The total amount of energy the electron gives up is dictated by the closeness of electron path and the nucleus, this result in the intensity of the x-ray. As electrons migrate at varying speeds through the target surface, they pass into the nucleus, producing a range of x-ray energy. Since the distance between the target nucleus is relatively wide relative to the nucleus width, low-energy x-rays are released than x-rays having high energy, this occurs only when the electrons travel through nucleus. If an electron comes into contact directly with the nucleus and gives all of its energy then maximum potential x-ray power is emitted. Figure 2 shows a spectrum of energy from bremsstrahlung. The energy emitted on an unfiltered spectrum by a bremsstrahlung x-rays vary from 0 to a peak value calculated by the engine's KV peak setup. It is favorable to use a target material with a high atomic number hence a nucleus with a considerably stronger energy to optimize bremsstrahlung x-ray efficiency; this method leads to more effective electrostatic diversion of the streaming electron beams. The melting point and atomic number of tungsten is high, so it is used as common target [8].

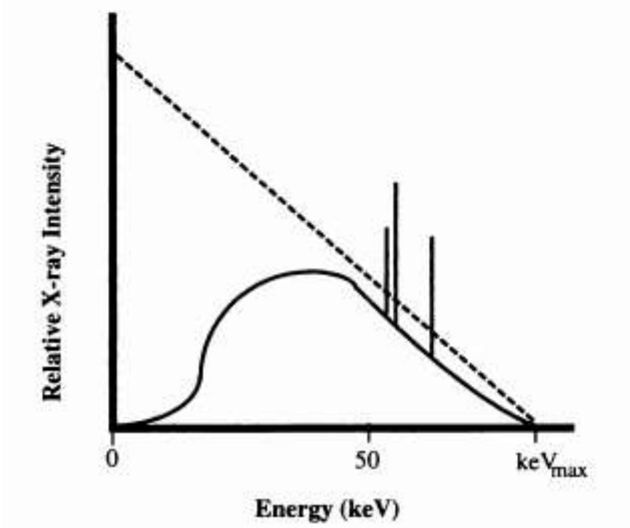

Figure 2. Spectrum of emission to a tungsten target.

The dotted line which can be seen in fig.2 is the unmediated portion of the x-ray spectrum generated from bremsstrahlung label. After escaping from the x-ay tube the full spectrum of x-rays are represented in clear line format. The x-ray tube emitted rays are represented by vertical straight lines. The overall scope of pollutants contains both bremsstrahlung and signature radiation.

4.3 Characteristic X-RAY production

Unless the velocity of energetic particles through the target is significant enough, x-ray will be founded on the basis of a accelerated electron reacting in the material surface with normal physiological atomic nucleus. Orbital particles of the target material are connected with nucleus at different energy levels. When the electrons energy exceeds the binding force then by keeping unused shell the internal shell electron be ejected. The top surface electron then reaches the vacuum creating an x-ray of radiation equal to the difference of the unifying theme between both the external and internal shells.

Table 1. Energies of X-ray in various levels [9]

Target	Orbital Transition	Energy (keV)
Tungsten	L to K	59.3
Tungsten	M to K	67.2
Molybdenum	L to K	17.4
Molybdenum	M to K	19.6

While various variations in potential can occur, some characteristic x-rays in pharmacy and genetics derive from defects inside K's innermost shell, that is filled by electrons from neighboring M and L levels. Figure 1 illustrates the frequency of x-rays at various energy levels applied to the wavelengths of x-ray tube. By x-ray tubes overall power 20% will be converted as characteristic radiation and remaining 80% will be as bram-ray cycle [9]. The speed of an energetic particles will surpass that of attaching K-shell strength of a material surface, in order to generate characteristic x rays.

5. Components of X-RAY tubes

Anode, cathode, stator, rotor and tank housing are the key components of the x-ray tube [10]. The tubing wrapping is called the surface of the tubing, as well as the components inside it. When an x-ray tube splits, it typically just requires fixing the patch. The tube enclosure is extracted and the space between both the shell as well as the casing is loaded with oil to help cool the tube as well as provide electrical shielding.

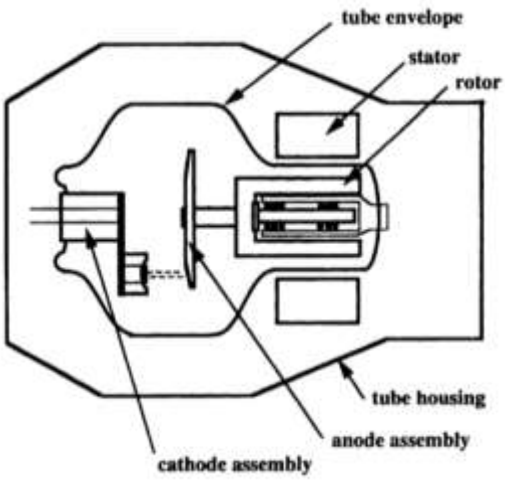

Figure 3. X-ray tube elements

5.1 Cathode Assembly

The cathode unit is in the middle of electrodes for a x-ray source (fig.4), a low voltage x-ray generator generates a voltage through tube filament. A focusing cup have a tungsten filament coil wire with 2-5cm in diameter and 10-20mm in length[8]. Filament electrons are boiled off tungsten wire. The higher voltage generates the anode-cathode electric current. The electrical field and filament arrangement form an electrical lens that determines the electron pathways and their region of influence and the region pointed to as the focal point.

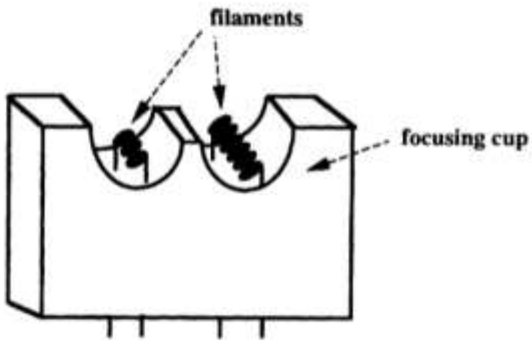

Figure 4. Two filaments of a simpler cathode assembly.

Cathode assembly is composed of the filament of a tungsten wire inside a focus point cup. A cathode mounting device of two filament dimensions is used for standard x-ray tubes. The big filament (right side) is used when short high intensity presentations are needed. When resolution is necessary or movement blasted (due to longer exposure), the smaller filament (left) is employed (figure 4). It is desirable to have a focal point as small as possible to fix fine detail in a radiograph. The focusing point's size is directly linked to the filament's size. The focus point size is decreased by a relatively higher heat flow charge on the destination. Thus, it is important to reduce the highest permissible power (the tube current kilovolt peak) [11]. As a consequence, the tube will also give a decrease in maximal x-ray pressure. In short exposure period, the criterion for an appropriate radiological strength defines minimum possible configuration for filament thickness. When period of exposure is too long, the picture can be movement fluttered. A cathode unit typically consists of two filaments: (1) a wider filament to accommodate high X-ray tube power applications over the short term of exposure; and (2) Smaller filament for devices with minimal resolution capacity and where the phase blurring will not be a matter of concern.

5.2 Anode Assembly

There are usually two types of anode: fixed and rotating. Originally, a tungsten reference material in a fixed copper block was used as a fixed anode. The low thermal ability reduced its strength of x-rays (i.e., radiation). The development of a revolving anode (objective) architecture allowed a significant input in x-ray intensity feasible. The instantaneous heat loaded in the middle of accelerated electrons is dispersed with a rotating anode across a much broader region. To optimize the efficiency of the split radiation, the target components utilized in an X-ray anode should be heavily radioactive, either fixed or rotating. Substantial heat charge is maintained by target material. Tungsten is used as modeling tool for x-ray source because of its high thermal conductivity, low viscosity and high atomic number. Usually to raise the thermal distortion power of rhenium by 10% tungsten is used because of its elastic and flexible nature [12]. Usually on molybdenum surface tungsten is used even though it is not a great conductor but it has high-quality sight, and on a copper substructure as a thin pattern too.

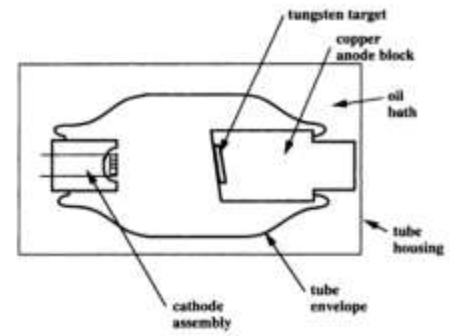

Figure 5. A tube with fixed x-ray anode.

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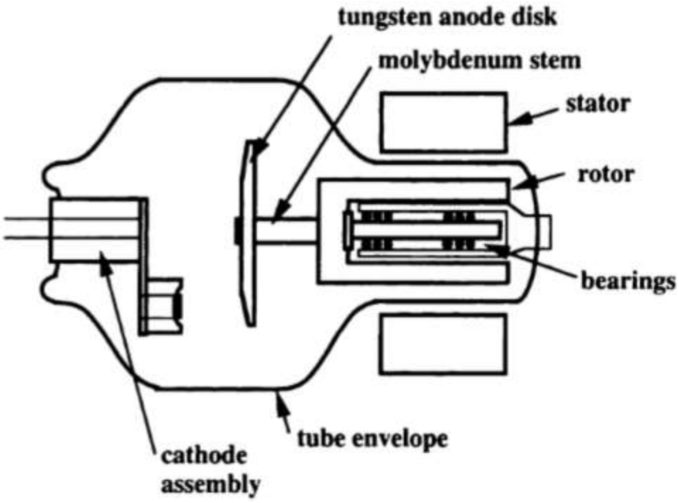

Figure 6. A tube with revolving x-ray anode.

To prevent spool thermal damage contributing to a common objective of radioactive fallout the molybdenum tubers are predicted to segregate the rotor from the radiation target. The x-ray tube anode appears in Figure 5. The target material of tungsten incorporated in the framework of a specified anode separates the tungsten anode. This same copper block pushes the temperature from the destination into the oil bath. The defined anode strip is used for relatively inexpensive applications, such as dentine X-ray or portable fluoroscopy, with the exception of its restricted heat power. The copper frame within the target is developed to capture heat from anode into oil bath across the tube cover. The target is built in. High-performance devices like dental X rays as well as handheld fluoroscopy lowered this kind of tube's temperature variation. The restricted x-ray range of the clamped anode structure resulted in the creation of revolving anodes (Figure 6). Use of a revolving anode enables enhancement of the targeted area's efficient heat capacity. Stator and rotor are elements of the anode rotating electrical induction engine during exposure to rays.

The efficacy of the target surface area is greatly improved (over 100 times) [12], causing the target to raise immediate heat load when the object is rotated rapidly during exposure. A power rise in effect enables a higher production of x-rays. A particular task for anode designers was how the anode can be rotated while keeping the vacuum in the tube container. It has been overcome with the use of an electric motor, which is shown in Figure 6. An A magnetic field varies inside the frame owing to the alternating current inside the stator windings (except for tube cover). As the magnetic field changes, the rotor (which is inside the envelope) rotates and rotates the attached destination disk.

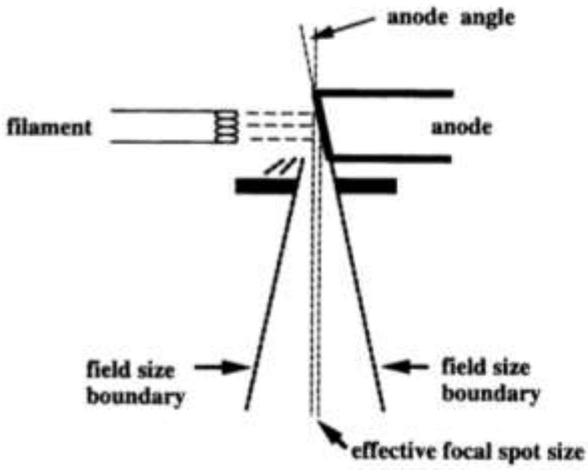

Figure 7. The association between the goal angle and the focus point distance.

The target is diverted with a slight angle from perpendicular anode-cathode axis in either a balanced anode and anode-rotating tube angle [13]. In all medical X - ray examinations the target is carried in a perpendicular axis at particular angle. The advantageous field measurements of the x-ray straight are augmented by the tube corner. The anode angle also reduces the efficient focal point size, which can lead to a lack of space in an image. The x-rays originate from target at such a wide angle which is reduced by target itself could be absorbed on the receiver section and limited by validation of the escaping port mostly on x - ray source on the back of a cathode. The successful emphasis is to project the direction of the electron from the detector to the target. For a better spatial resolution, a less effective focus point size is desirable. The tube architecture differs with a targeted angle, compensating between both the appropriate layer thickness and peak field size. This same x-ray-field size is higher with such a wider target angle, as well as the focusing area is much more efficient. The electrons can hit its target with a relatively barge region on the actual field, while the focal point projection from the detector is considerably lower whenever a wide anode angle pipe is installed. The consequence of this 'projection' is a line-oriented object which is seen in Figure 7. The anode angles are effectively focused in their actual size and sine. This theory only extends to the directions of the anode cathode. Many measurements are taken at a position perpendicular to a cathode anode axis which is similar to the positive scale [14].

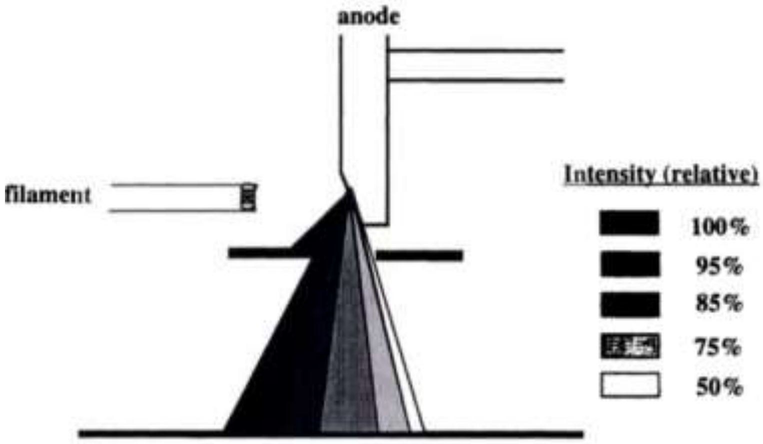

Figure 8. The difference in the distribution of x-ray strength over the heel effect x-ray region.

Ideally, the x-ray intensity distribution is the same throughout the radiation field [15]. The heel effect, which is defined as a decrease of the strength the beam has on the cathode anode axis along with the anode target, differs considerably due to the intensity of x-ray (Fig 8). Peer-absorption occurs if most of x-rays were emitted at a finite depth inside the target [14]. X-rays which lead to performance in the x-ray applied field anode continue to pass through a significant target stuff period, making the target more likely to hit. However, in the anode side the power of beam is lower. However, some heel behavior is found within the cathode anode axis in perpendicular direction [16]. The presence of a heel at the cathode of the x-ray field often implies that the x-ray tube irradiates from cathode side the most attenuating portion of the person's body.

5.3 Rotor and Stator

Alloy steels or molybdenum is used to made tip of the anode which connects anode ring to rotor. The stem prevents heat dissipation to a bobble, a frequent cause of loss of x-rays. The stator windings generate an alternating current that generates a magnetic field that changes the rotor region due to changes in the gravitational force of the metal rotor to create a related anode. In result of changes within gravitational flux the metal rotor moves to transform an anode connected to it. For such a high-speed anode the rotating frequency of anodes seems to be from 3,000 rpm to 10,000 rpm [15]. Alloy steels or molybdenum is used to made tip of the anode which connects anode ring to rotor.
The stem prevents heat dissipation to a bobble, a frequent cause of loss of x-rays.

5.4 X-RAY tube envelope
The shield which protects the evacuated atmosphere is the key element of a x - ray machine. If gas released from internal tube components or even the vacuum breaks, the gas tube is gassy, and the transfer of electrons through the cathode is stopped by gas particles. The filament in the cathode would also oxidize in such a case, resulting in a collapse of the pipeline. A tube shield requires a gap or an exit port, a region where the x rays emerge from its tube. A smaller region of glass and may have some other distinct material acts as escaping gate. X-ray coil window is made up of glass and beryllium product which is used in medical field [15]. Beryllium also has small molecular counts than quartz, which collects in mammograms lower efficient energy x-rays.

5.5 Properties and characteristics of X-RAY:
1. In an electronic, gravitational, or hybrid field, X-rays are electrically neutral; they have no interference or variation.
2. X-rays travels straight at light speed, which is characteristic for directing and focusing rays so that they can radiate the specific area of the studied body [17].
3. X-rays cause biological and chemical effects that could affect the organism through the production of ionization and/or cellular changes that can lead to disorders or additional mutations.
4. X-rays occupy a part of the continuum and not only have one but many wavelengths. These depend on the number of factors leading to radiation generation.
5. The human eye or body cannot detect X-rays and thus only machines and processing procedures can be detected [17]. In carrying out steps to secure the human body, that is an essential factor.
6. Radiographic images on photographic films, fluorescence on certain crystal types are produced by X-rays, both of which are used to produce x-rays on medically controlled monitoring films and fluoroscopes.
7. X-rays emits secondary radiation and dispersed radiation, meaning that a biological material receiving x-rays generates new rays with different characteristics in turn [17]. These rays are typically an optical issue, and therefore harmful to the health of those operating with x-rays.

6. Applications in various fields
1. For clinical medicine use of x-rays was especially important. X-ray pictures exploit the assumption that bones and teeth with greater quality are less visible to x-rays than in many parts of the body [18]. X rays are commonly used in these fields for diagnostic purposes. Examples include witnessing fractured bones and torn footballers' ligaments, identifying people in breast cancer, or finding cavities and damaged teeth of the intelligence.
2. Computerized axial tomography is a very new approach for utilizing x-rays in the field of pharmaceuticals, producing popular CAT scans. These scans produce a cross-section view of a portion of the body that is clearer than a standard X-ray. This is because a regular x-ray, obtained from the chest, also reveals superimposed organs and portions of the chest. In order to generate a CAT scan, a thin x-rays beam is sent from several different angles across the area of interest and the cross-sectional representation of the area is restructured using a computer [18].
3. Moseley found that different natural elements can be detected by calculating the strength of its signature x rays. This reality enables a valuable method of baseline analysis. If a sample with an unknown nature is affected by x rays with adequate intensity, the electrodes of the atoms of various sample components are shaken and the x rays are characteristic of such atoms. The energy analysis of these x-rays allows the elements found in the sample to be calculated. The method is called a study of fluorescence by x-rays. Chemists and law enforcement authorities use it frequently for a non-destructive primary examination because it is required to determine what elements are found in a hair or blood sample or some other substance that is used as proof in a forensic inquiry.
4. The X-rays can be used for sales in several other forms of manufacturing. For example, entire X-ray images/engine components can be made to recognize faults in a convenient manner [19].

Sections of the oil or gas tube lines may also be tested for holes or damaged welds. Airlines often use radiograph detectors in passenger luggage to search for weapons or unlawful objects. An interesting new X-ray source known as synchrotron radiation has been developed in recent years. Most particle accelerators accelerate charged particles, like the protons or electrons, by allowing them to travel in an accelerator along a circular path, by increasing their energy. Through this circular direction the element is protected by a circular ring of magnets. Every object traveling in a circular path has to travel to the middle of the circle, so charged particles traveling along those paths have to radiate and therefore lose energy [20]. Many years earlier, designers of nuclear physics accelerators treated the loss of energy as an inconvenience, but scientists slowly found that accelerators can be designed to take advantage of this intense radiation. Electrons are the most effective particulate in the use of electron synchrotron machines and now accelerators are constructed for the sole purpose of producing radiation that can be adapted from the visible region to x-ray region to produce radiation. With very strong atomic beams of almost 1 wavelength, this synchrotron radiation is particularly useful for biologists, chemists and physicists to consider the structure of atoms in specific compounds of interest [21].

5. One of the most significant industrial uses of synchrotron radiation is the x-ray lithography that is used in the electronics industry for high performance integrated circuits. The integrated circuit boards are introduced by etching successive types of electrical circuits onto a wafer of semiconductor material, like silicone. The specifics of the circuitry are determined by the shielding by a photographic resistant and dazzling light of a mask-like stencil of the wafer on the top [21]. The pattern of the electric circuits is cut into the mask, which can be easily washed away from the exposed photo resistance, leaving the circuit outline in the rest of the photo resistance. With the circuit elements, the shorter the wavelength, the smaller the circuit elements, the amplitude of the waves is shortened. When x rays are used instead of light, the circuits on a wafer can be significantly lowered, and a certain size wafer can be used to generate much smaller electronic equipment, such as computers.

7. Conclusion
Transformation of accelerated electrons into practical radiation beam is the main job of x-ray tube. This produces both the braking radiation as well as normal x rays. X-ray production is an extremely inefficient operation, and the heat produced controls components of the system as well as the tube. The main elements of a X-ray machine are cathode, anode, rotor, rotating stator and tube structure. These elements influence X-ray beam properties, for example the energy spectrum or the effective focus point size. Tubes for rapid exposure in cardio or vascular scanning, and also tubes split into different targets and filtering products to be used in cancer screening are key participants in x-ray tubing design.

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