**Ministry of Higher Education and Scientific Research**

**Al-Ma'moun University College**

كليــة المــأمون الجامعــة

للعام الدراسي (2023–2024)

# Physics of Computed Tomography

Lecture (5,6&7)

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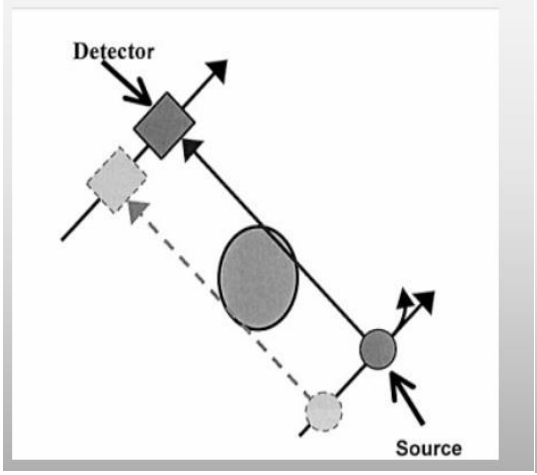
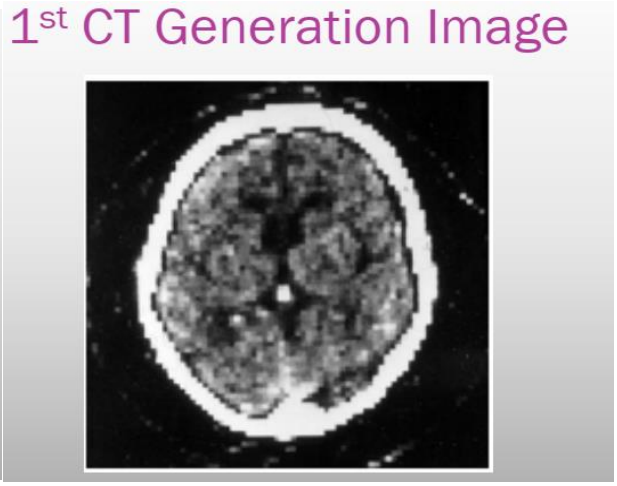
# Physics of Computed Tomography

- Computed tomographic images are reconstructed from a large number of measurements of x-ray transmission through the patient. The resulting images are tomographic “maps” of the x-ray linear attenuation coefficient.
- The first practical CT instrument was developed in 1971 by DR. G. N. Hounsfield in England and was used to image the brain.
- The projection data were acquired in approximately 5 minutes, and the tomographic image was reconstructed in approximately 20 minutes. With technological development, projection data are typically acquired in approximately 1 second, and the image is reconstructed in 3 to 5 seconds.

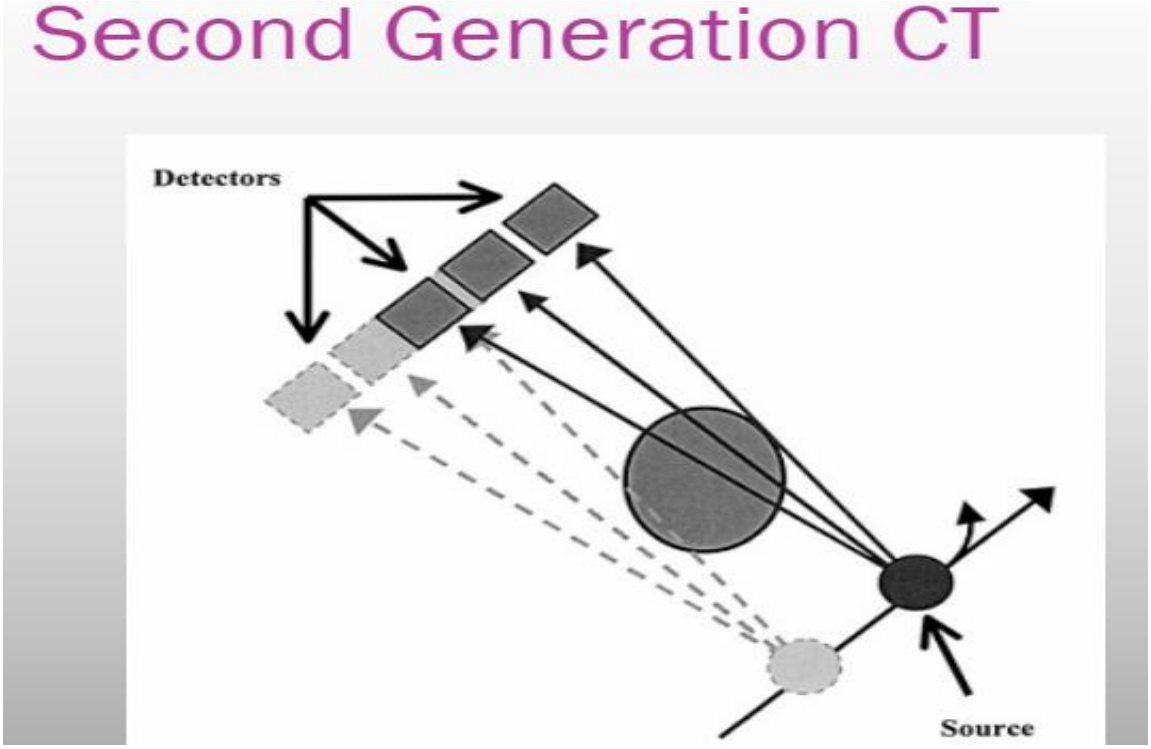
- First Generation: Parallel-beam geometry is the simplest technically and the easiest with which to understand the important CT principles.
- The beam is translated in a linear motion across the patient to obtain a projection profile.
- The source and detector are then rotated about the patient by approximately 1 degree, and another projection profile is obtained.
- This translate-rotate scanning motion is repeated until the source and detector have been rotated by 180 degrees.

- The highly collimated beam provides excellent rejection of radiation scattered in the patient; however, the complex scanning motion results in long (approximately 5-minute) scan times.



- Second Generation: Fan Beam, Multiple Detectors Scan times were reduced to approximately 30 s with the use of a fan beam of x-rays and a linear detector array.
- A translate-rotate scanning motion was still employed; however, a larger rotate increment could be used, which resulted in shorter scan times.
- The reconstruction algorithms are slightly more complicated than those for first-generation algorithms because they must handle fan-beam projection data.

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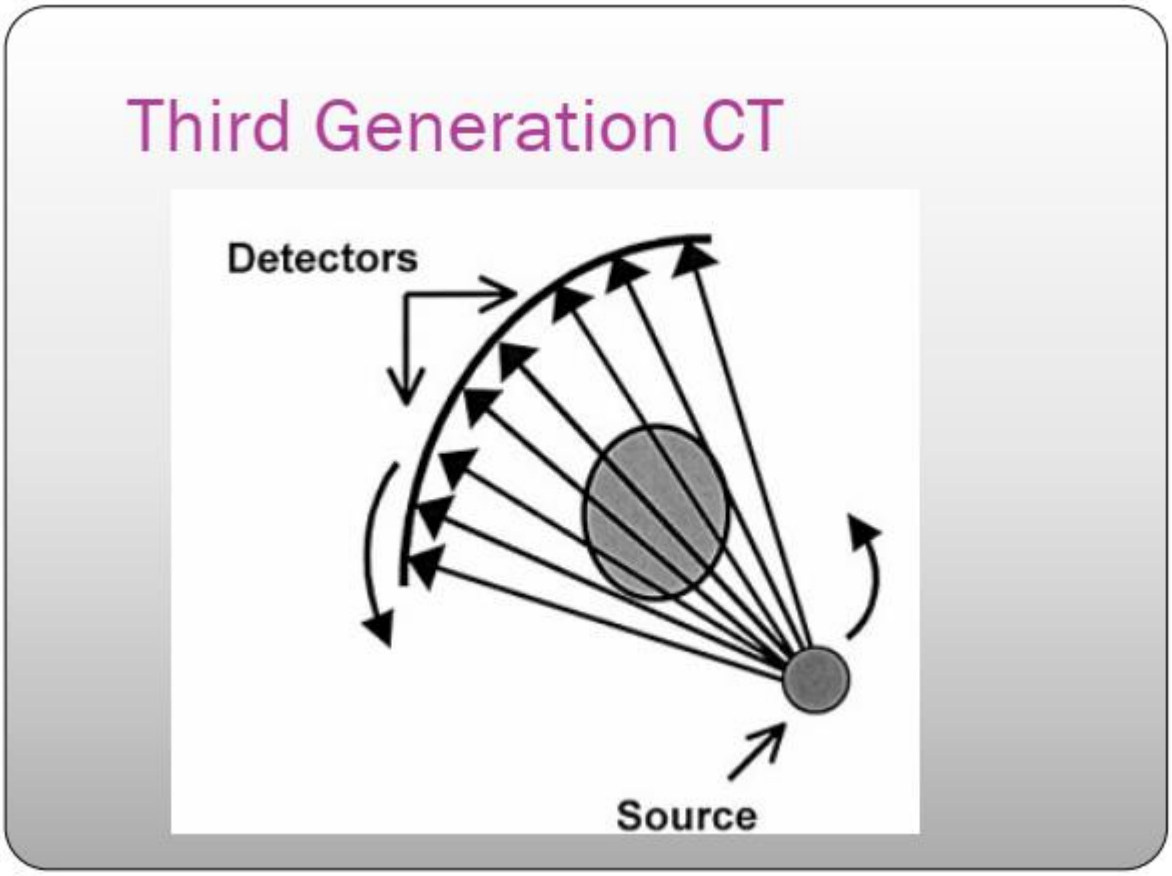
- Third Generation: Fan Beam, Rotating Detectors Third-generation scanners were introduced in 1976.
- A fan beam of x-rays is rotated 360 degrees around the isocenter.

No translation motion is used; however, the fan beam must be wide enough to completely contain the patient. A curved detector array consisting of several hundred independent detectors is mechanically coupled to the x-ray source, and both rotate together. (Larger array Of detectors)

– (300-700 detectors, usually circular)

- As a result, these rotate-only motions acquire projection data for a single image in as little as 1 s.
- Third-generation designs have the advantage that thin tungsten septa can be placed between each detector in the array and focused on the x-ray source to reject scattered radiation

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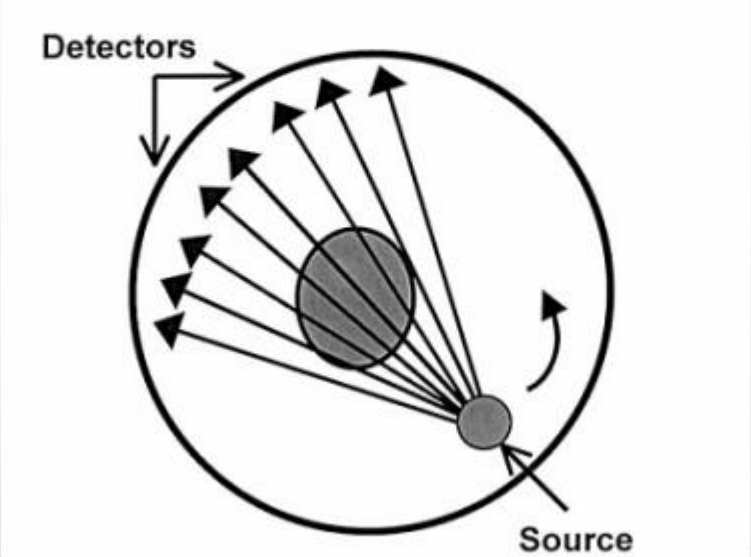
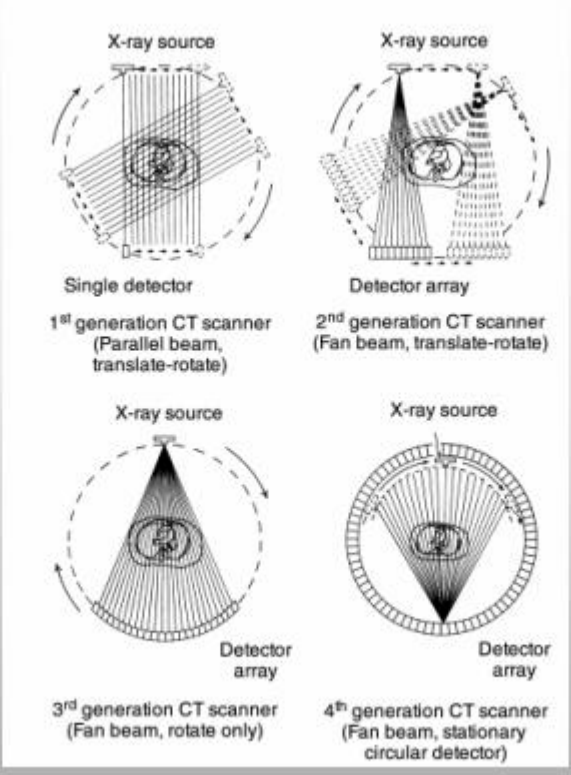
- Fourth Generation: Fan Beam, Fixed Detectors In a fourth-generation scanner, the x-ray source and fan beam rotate about the isocenter, while the detector array remains stationary.
- The detector array consists of 600 to 4800 (depending on the manufacturer) independent detectors in a circle that completely surrounds the patient.
- Scan times are similar to those of third-generation scanners. The detectors are no longer coupled to the x-ray source and hence cannot make use of focused septa to reject scattered radiation.

# Fourth CT


Detectors
Source


X-ray source
Single detector
1st generation CT scanner
(Parallel beam,
translate-rotate)
X-ray source
Detector array
2nd generation CT scanner
(Fan beam, translate-rotate)
X-ray source
Detector
array
3rd generation CT scanner
(Fan beam, rotate only)
X-ray source
Detector
array
4th generation CT scanner
(Fan beam, stationary
circular detector)

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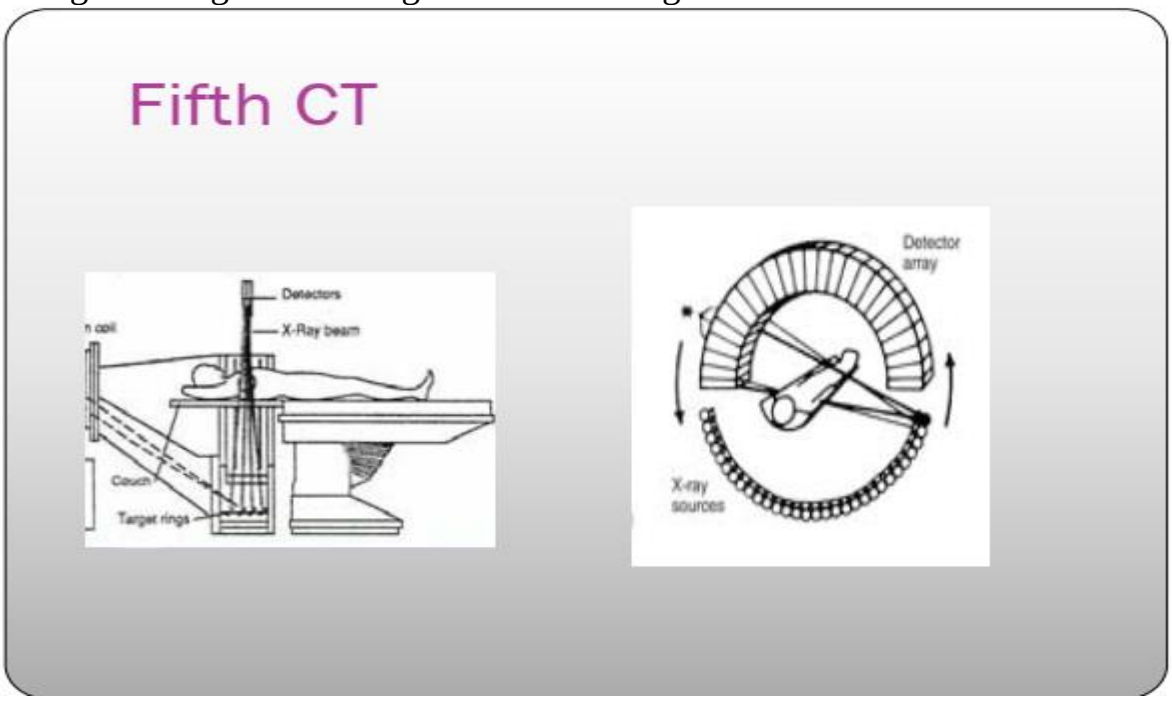
- Fifth Generation: Scanning Electron Beam Fifth-generation scanners are unique in that the x-ray source becomes an integral part of the system design. The detector array remains stationary, while a high-energy electron beams is electronically swept along a semicircular tungsten strip anode.
- X-rays are produced at the point where the electron beam hits the anode, resulting in a source of x-rays that rotates about the patient with no moving parts
- Projection data can be acquired in approximately 50 ms, which is fast enough to image the beating heart without significant motion artifacts.




- Alternative fifth-generation design, called the dynamic spatial reconstructor (DSR) scanner. This machine is a research prototype and is not available commercially.

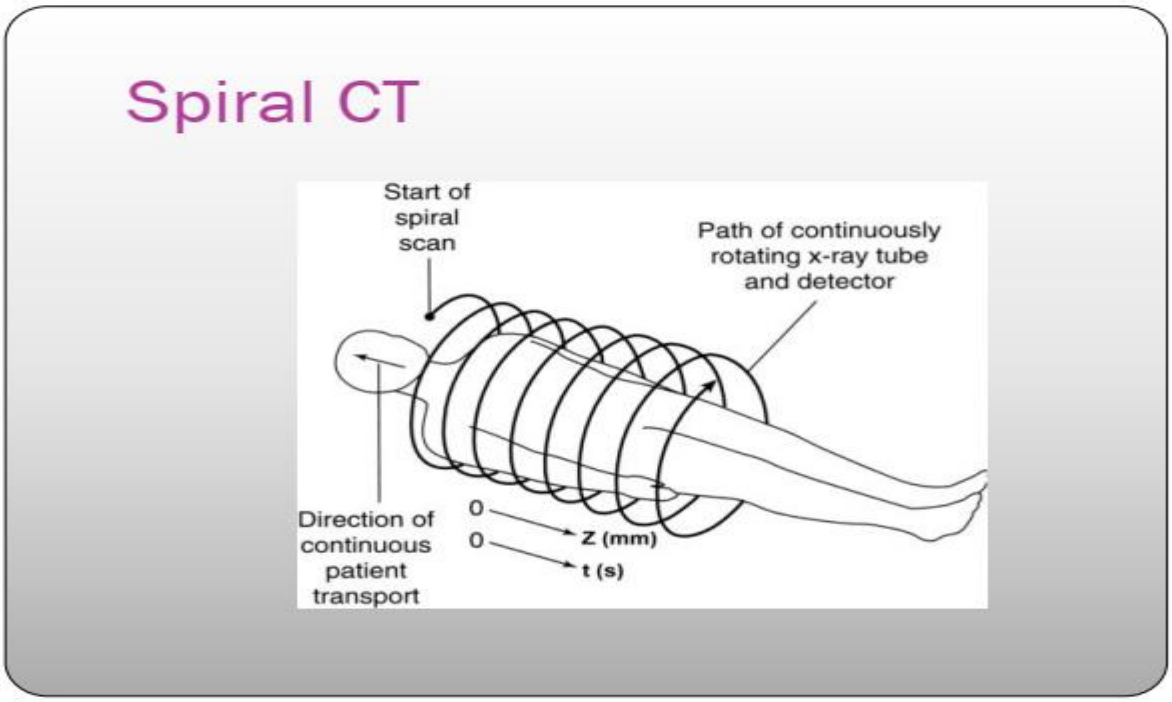
- It consists of 14 x-ray tubes, scintillation screens, and video cameras. Volume CT images can be produced in as little as 10 ms.

- Sixth-generation

- 1990,Significant advancement in technology

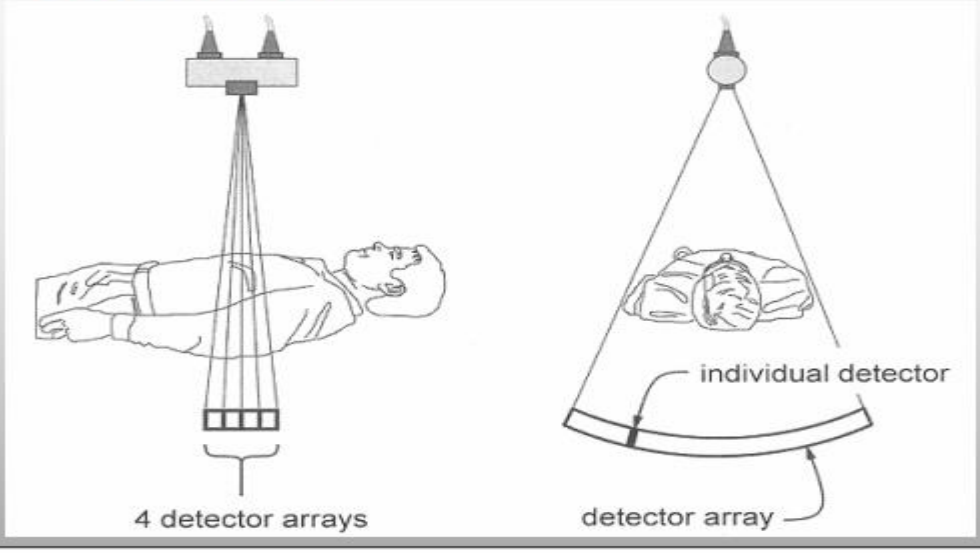
- Allowed 3D image acquisition within a single breath hold

- Finally the  Spiral/Helical Scanning The requirement for faster scan times, and in particular for fast multiple scans for three-dimensional imaging, has resulted in the development of spiral (helical) scanning systems.
- x-ray tube rotates as patient is moved smoothly into x-ray scan field
- Simultaneous source rotation, table translation and data acquisition
- Produces one continuous volume set of data for entire region
- Data for multiple slices from patient acquired at 1sec/slice

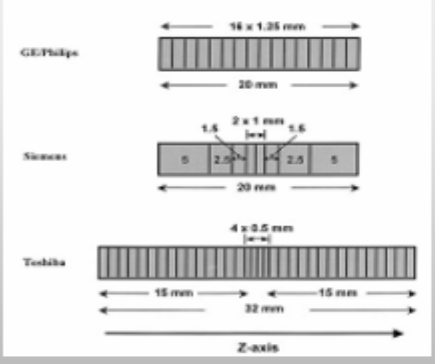



- Seventh Generation
- New Technology, single row had its limitation
- Design: multiple detector array
- The collimator spacing is wider and more of the x-rays that are produced by the tube are used in producing image data
- Opening up the collimator in a single array scanner increases slice thickness, reducing spatial resolution in the slice thickness dimension
- With multiple detector array scanners, slice thickness is determined by detector size, not by the collimator
- “turbo-charged” spiral
- Up to 8 rows of detectors
- 4 rows, large volume of patient scanned
- (thorax, abdomen, pelvis) at once
- Allows 1mm sections though chest in 20 sec

## Seventh CT

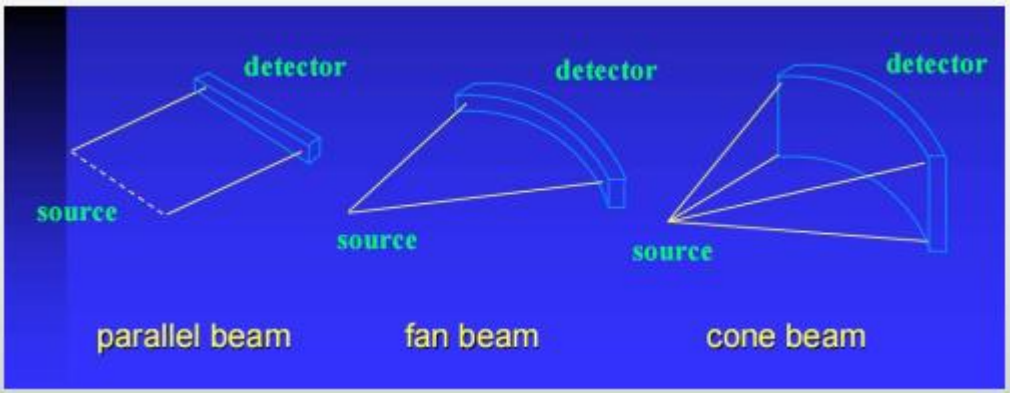



## Multiple Array Design




Combination of Section width

| GE*/Philips | Siemens† | Toshiba‡ |
|---|---|---|
| 4 × 1.25 | 2 × 0.5 | 4 × 0.5 |
| 4 × 2.5 | 4 × 1 | 4 × 1 |
| 4 × 3.75 | 4 × 2.5 | 4 × 2 |
| 4 × 5 | 4 × 5 | 4 × 3 |
| 2 × 10 | 2 × 8 | 4 × 4 |
| | 2 × 10 | 4 × 5 |
| | | 4 × 6 |
| | | 4 × 7 |
| | | 4 × 8 |



| Generation | Source | Source Collimation | Detector |
|---|---|---|---|
| 1st | Single X-ray Tube | Pencil Beam | Single |
| 2nd | Single X-ray Tube | Fan Beam (not enough to cover FOV) | Multiple |
| 3rd | Single X-ray Tube | Fan Beam (enough to cover FOV) | Many |
| 4th | Single X-ray Tube | Fan Beam covers FOV | Stationary Ring of Detectors |
| 5th | Many tungsten anodes in single large tube | Fan Beam | Stationary Ring of Detectors |
| 6th | 3G/4G | 3G/4G | 3G/4G |
| 7th | Single X-ray Tube | Cone Beam | Multiple array of detectors |

See Also animated CT generation

[Animated CT Generations [1st, 2nd, 3rd, 4th, 5th Gen CT] For Radiologic Technologists • How Radiology Works]

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