

# Bone Imaging

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# References and Acknowledgments

## BOOKS

- Cierniak R. *X-Ray Computed Tomography in Biomedical Engineering.* 2011
- Vitamin D

## JOURNAL ARTICLES

- Link T. *Osteoporosis Imaging: State of the Art and Advanced Imaging.* Radiology Apr;263(1):3-17, 2012

## PEOPLE

- Kerstin Müller, Rebecca Fahrig, Norbert Pelc, Andreas Meier
- Galateia Kazakia

# Studying the Bone

Biology

Biomechanics

Imaging

Bone

Bone Quality  
Assessment

Bone Fracture  
and Fixation

# Multi-Scale Approach to Bone Study

BODY  
LEVEL



[m - cm]

ORGAN  
LEVEL

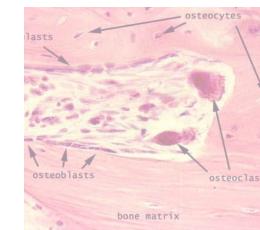


[cm - mm]

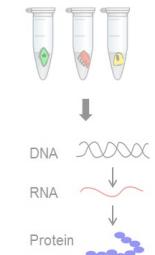
TISSUE  
LEVEL



CELLULAR  
LEVEL



MOLECULAR  
LEVEL



Biology

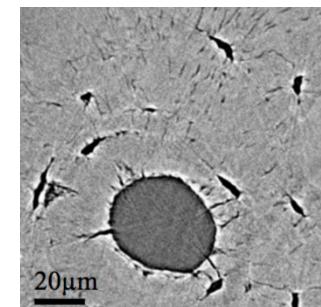
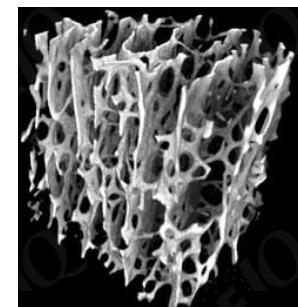
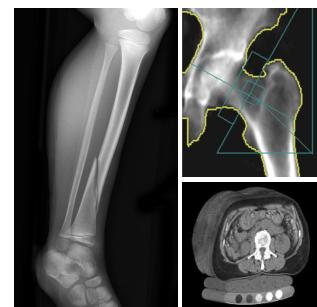
Biomechanics

Rigid Object  
Models

Deformable Continuum  
Models

Statistical  
Models

Imaging



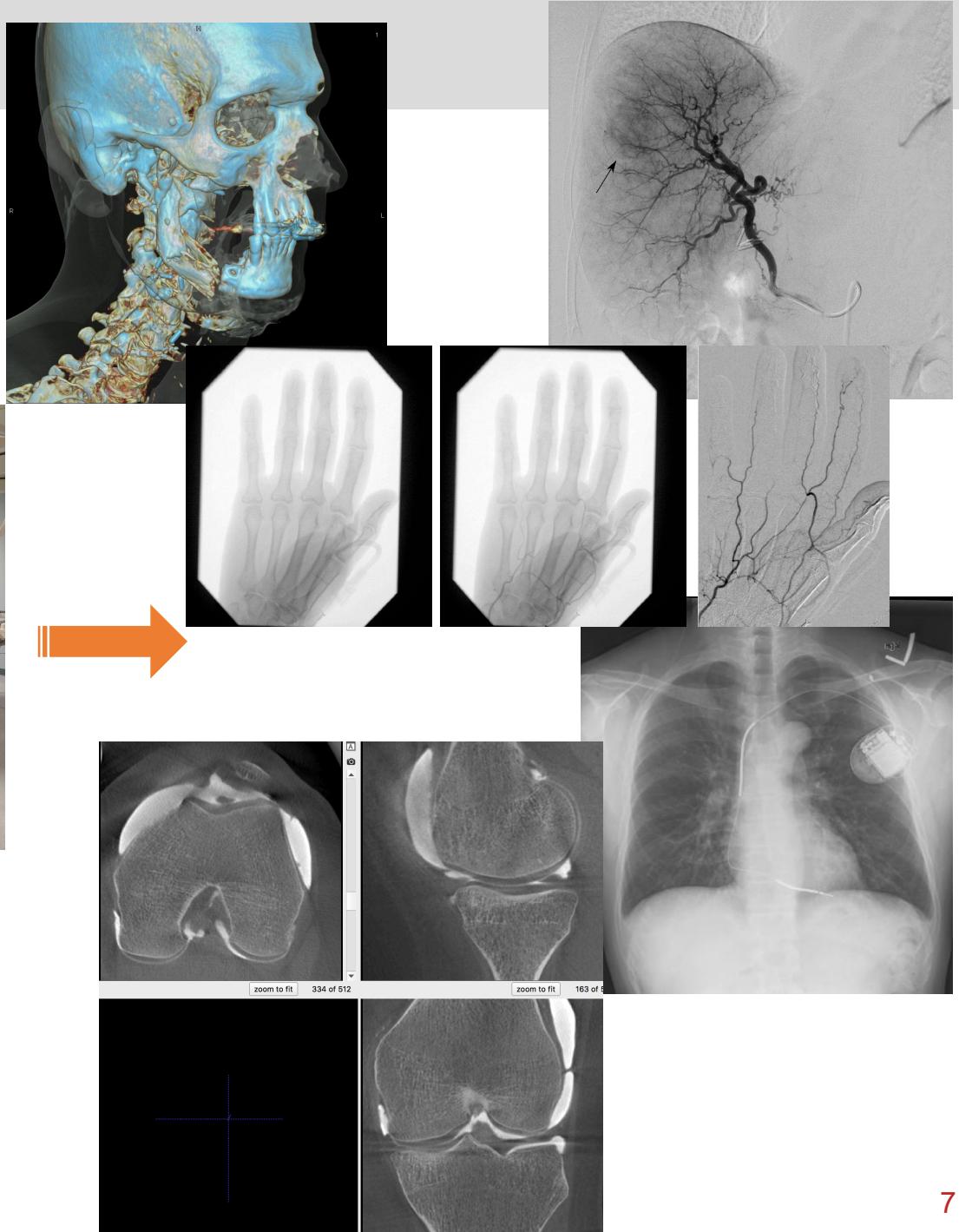
# Principles of X-ray Imaging

# Zeego Lab – S088

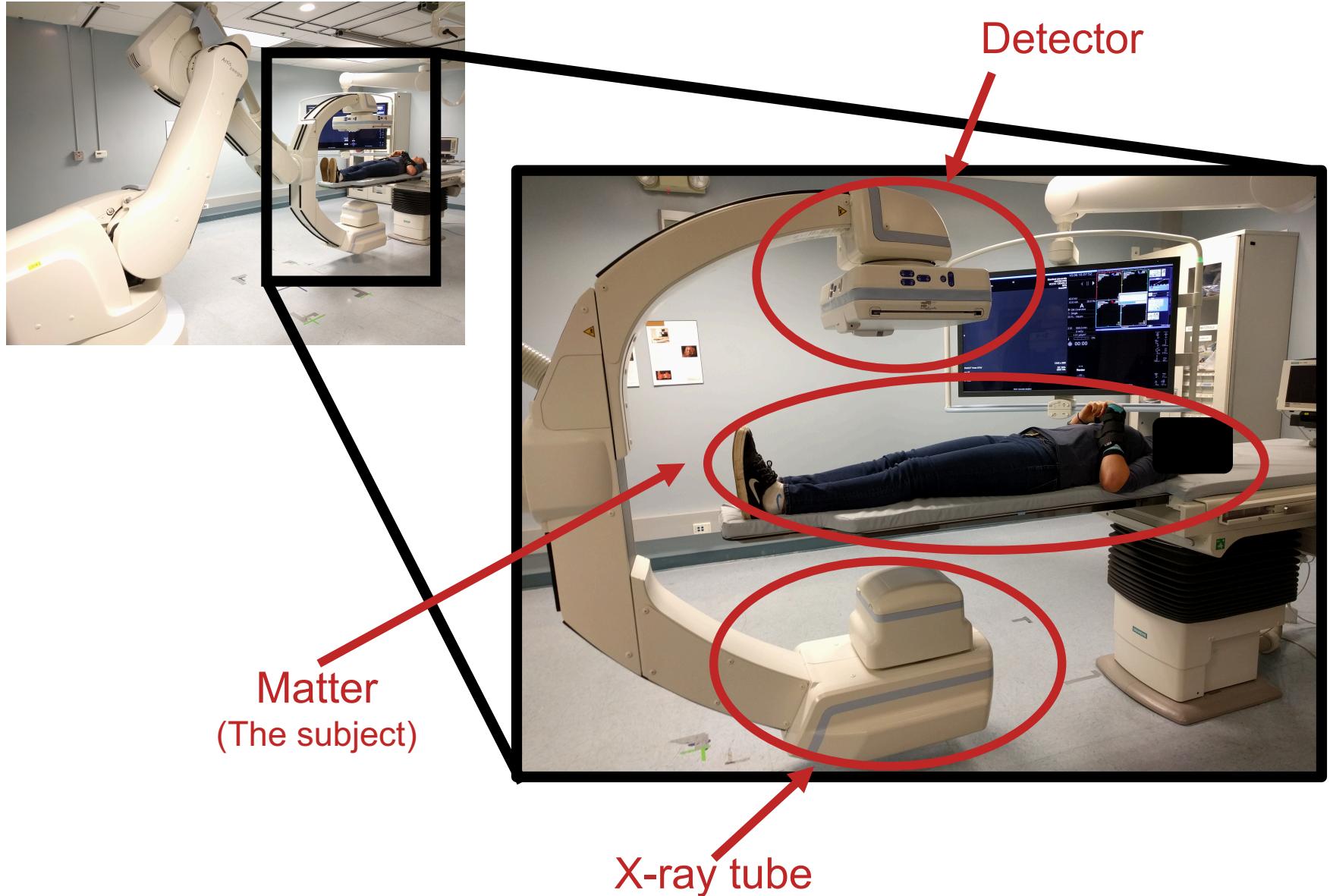


Cone-Beam Computed Tomography (CBCT)  
C-arm Computed Tomography (C-arm CT)

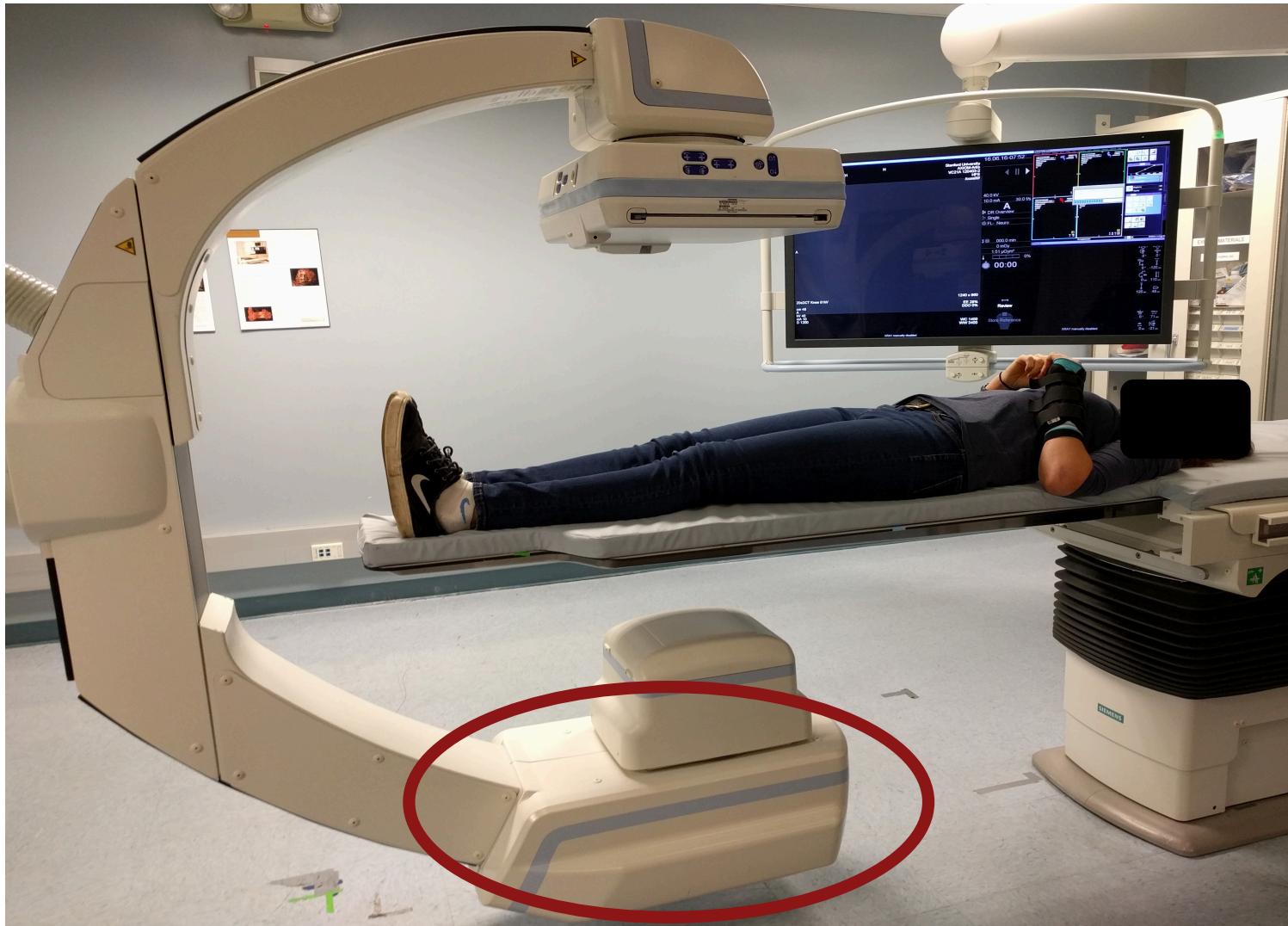
# Machine and Images



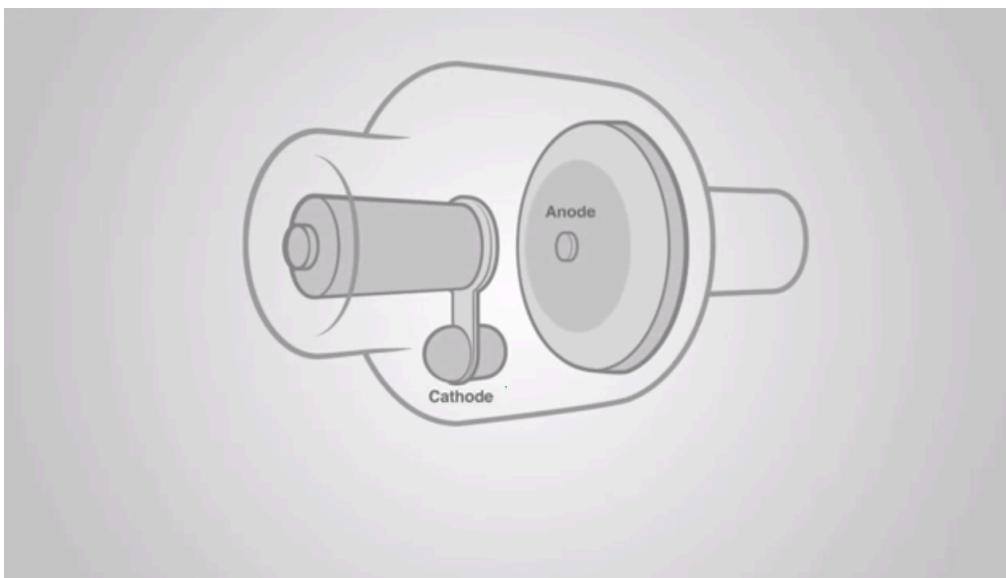
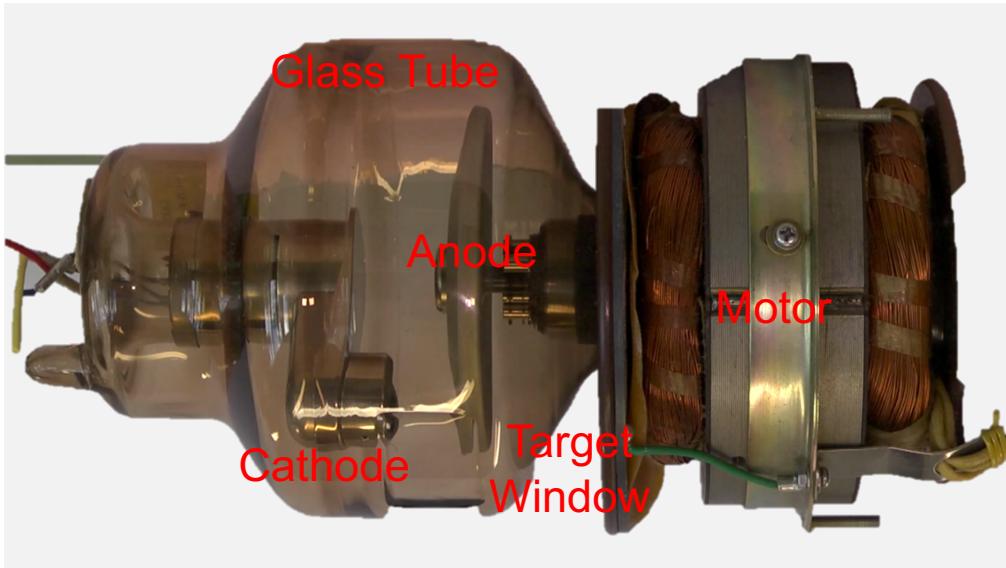
# The imaging system: X-ray Tube, Detector and Subject



# The X-Ray Tube

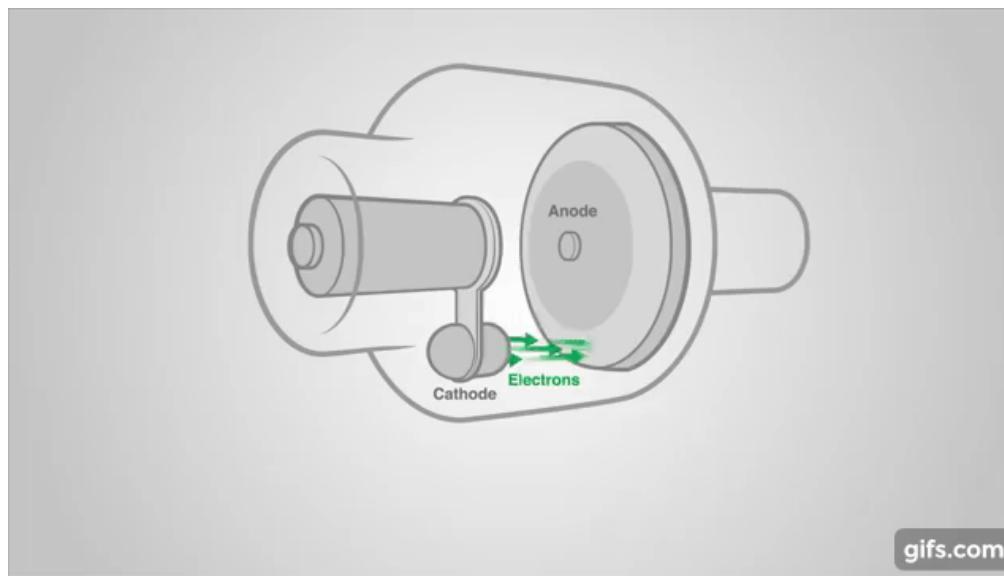
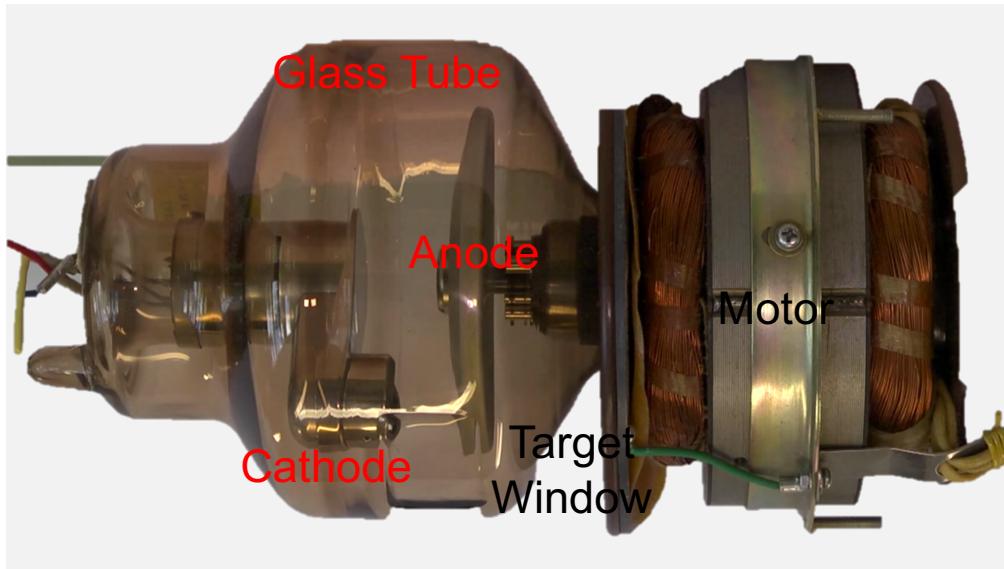


# The X-Ray Tube



[https://www.youtube.com/watch?v=3\\_bZCA7tlFQ](https://www.youtube.com/watch?v=3_bZCA7tlFQ)

# The X-Ray Tube

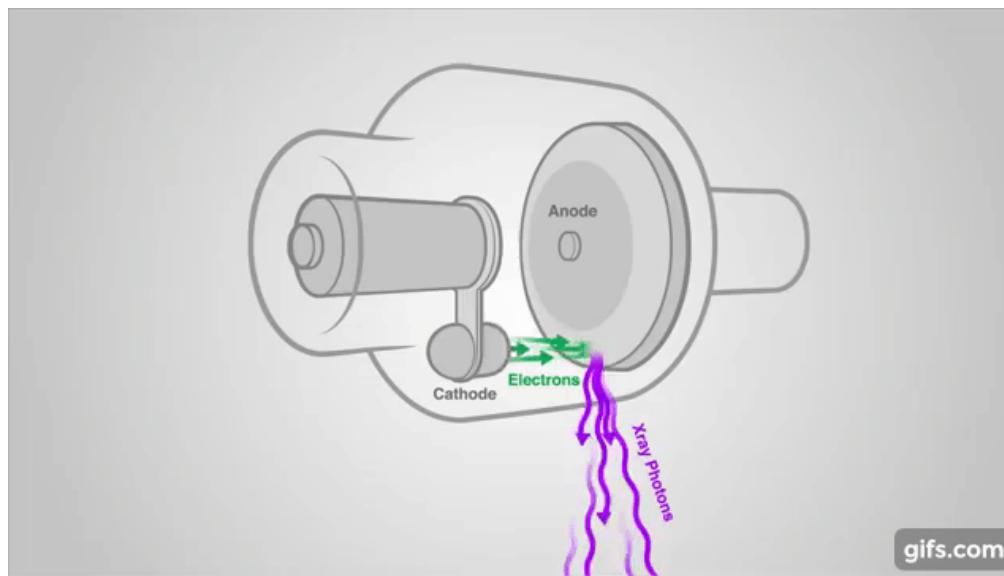
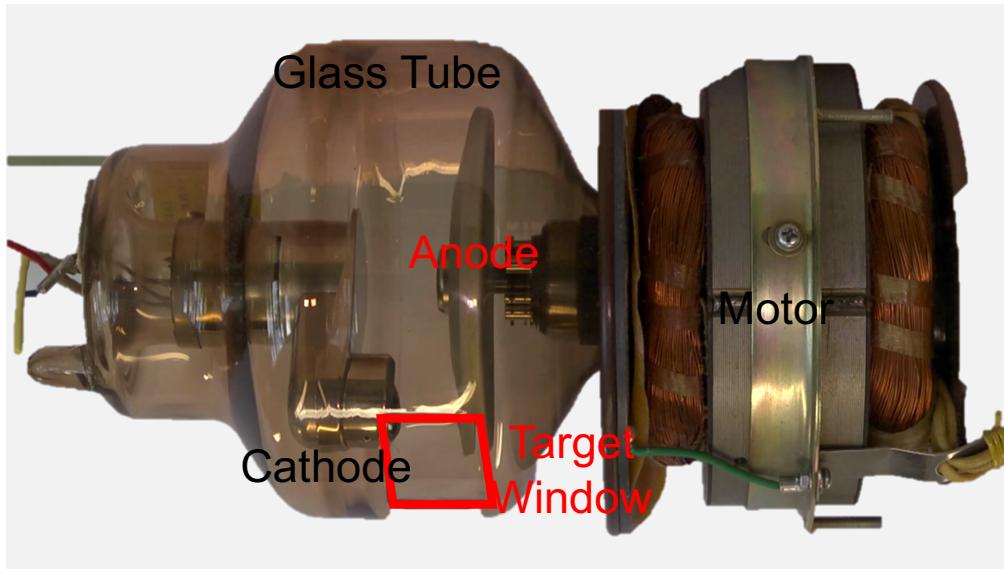


- Accelerating voltage:
  - 20-150 kVp
- Electron current:
  - 0.1-1.0A
- Vacuum in glass tube to avoid collision with air particles

gifs.com

[https://www.youtube.com/watch?v=3\\_bZCA7tlFQ](https://www.youtube.com/watch?v=3_bZCA7tlFQ)

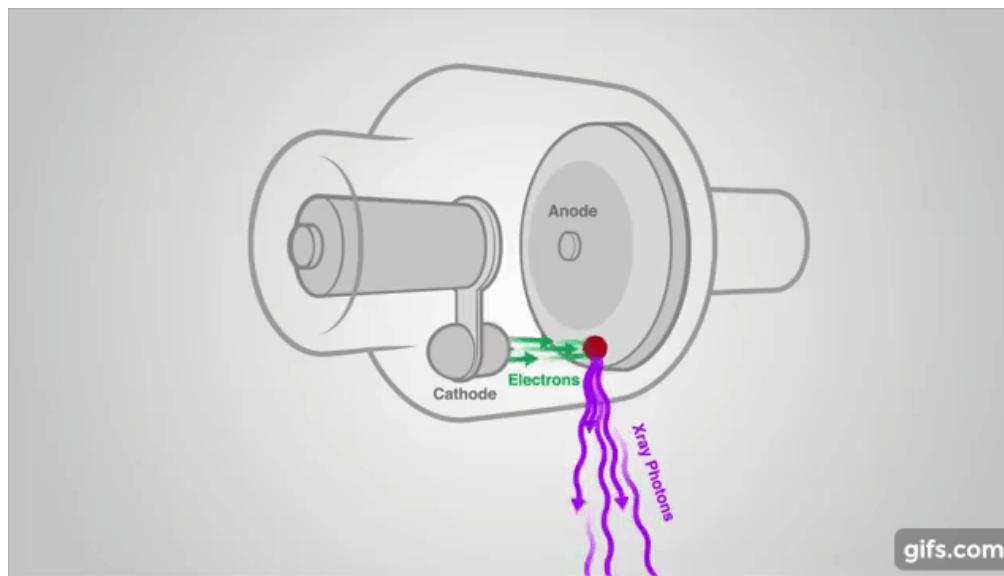
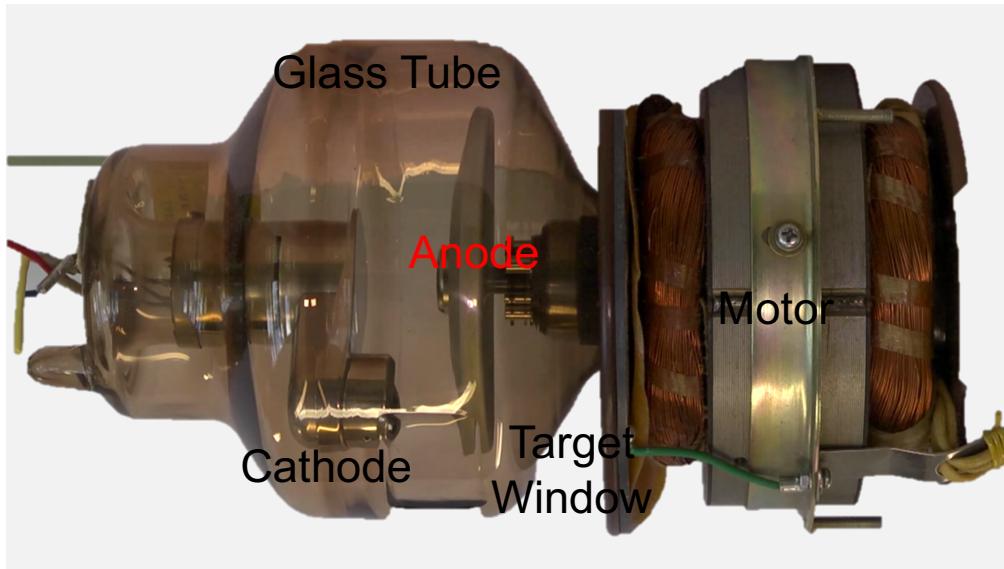
# The X-Ray Tube



- The angle of the anode directs X-rays towards target window
- 1% of  $e^-$  energy becomes X-rays

[https://www.youtube.com/watch?v=3\\_bZCA7tlFQ](https://www.youtube.com/watch?v=3_bZCA7tlFQ)

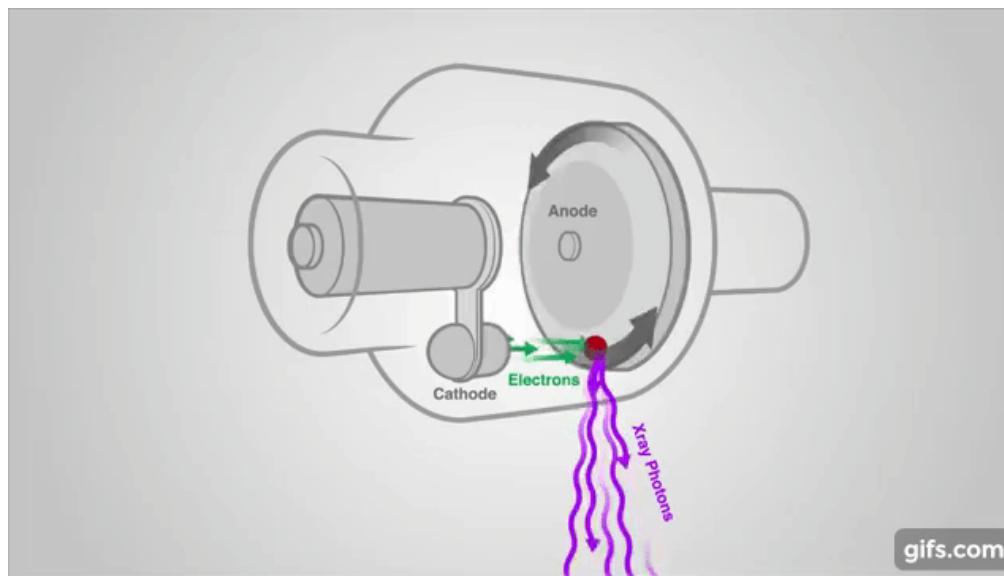
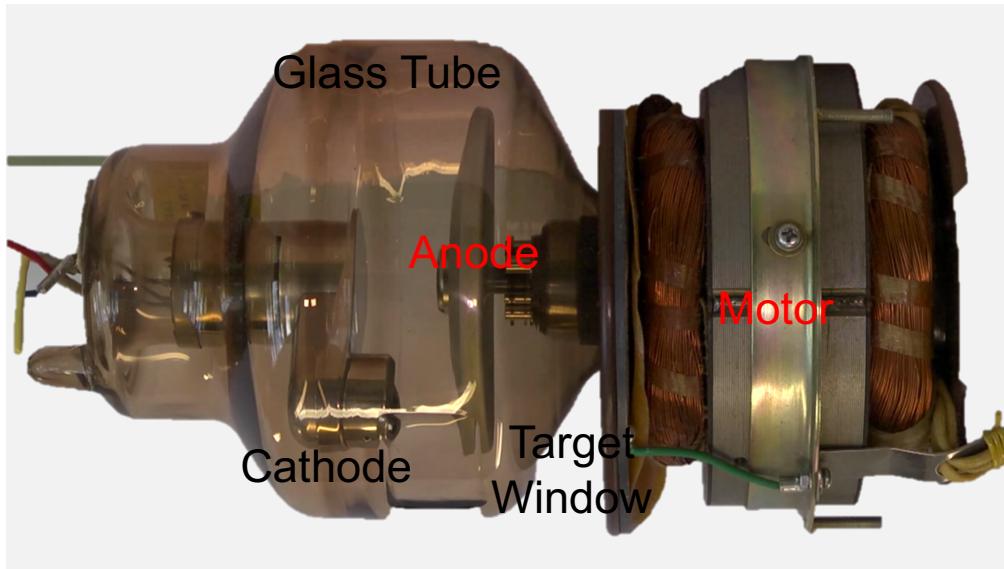
# The X-Ray Tube



• 99% of  $e^-$  energy is converted to heat

[https://www.youtube.com/watch?v=3\\_bZCA7tlFQ](https://www.youtube.com/watch?v=3_bZCA7tlFQ)

# The X-Ray Tube

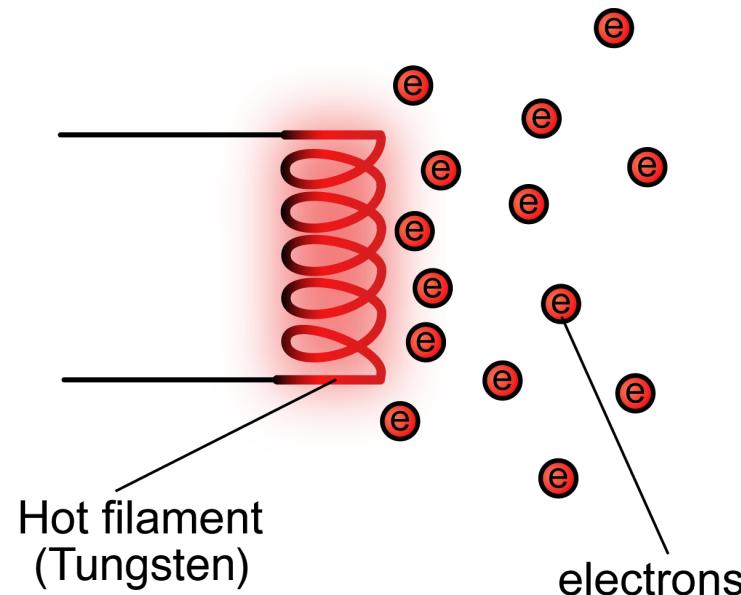
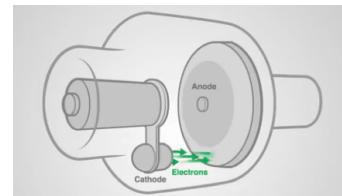


- The motor rotates the anode to change hit spot

[https://www.youtube.com/watch?v=3\\_bZCA7tlFQ](https://www.youtube.com/watch?v=3_bZCA7tlFQ)

# What Happens at the Cathode?

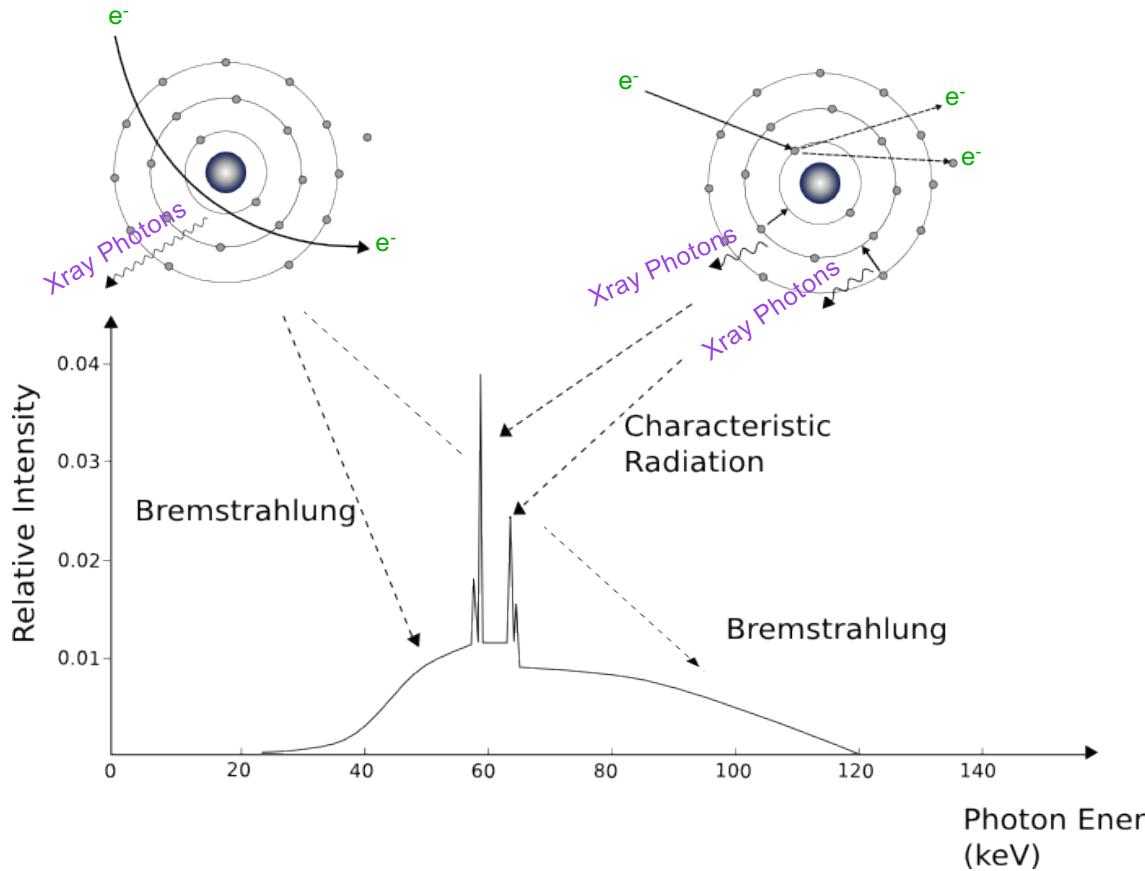
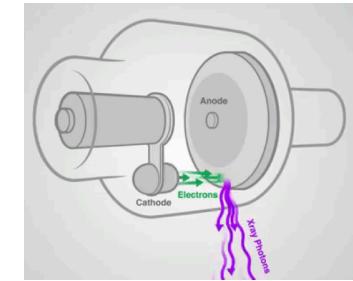
- $e^-$  production!
- How? Thermionic emission



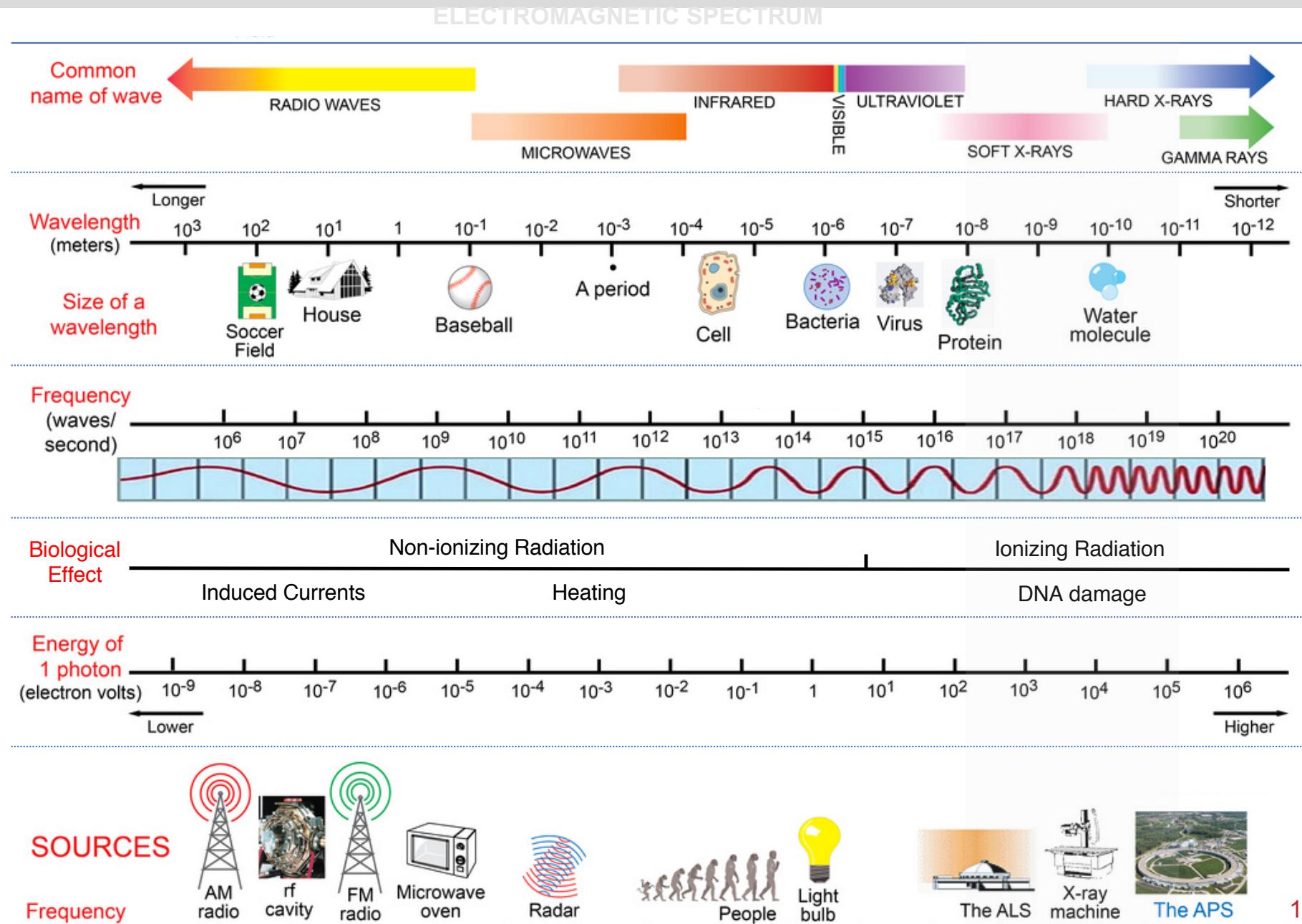
# What Happens at the Anode?



- X-ray production!
- How? Bremstrahlung and Characteristic Radiation



# Characteristics of X-rays



Adapted from [https://c1.staticflickr.com/7/6142/5940581568\\_1db150f055\\_b.jpg](https://c1.staticflickr.com/7/6142/5940581568_1db150f055_b.jpg)

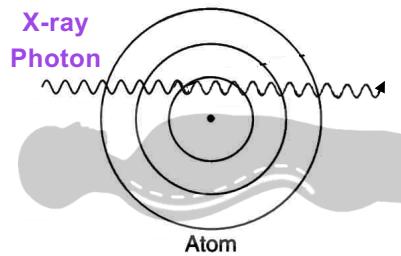
# Interaction with Matter – The Subject



# X-ray Interaction with Matter

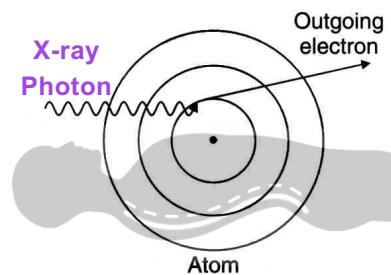


## 1. TRANSMITTED PHOTONS



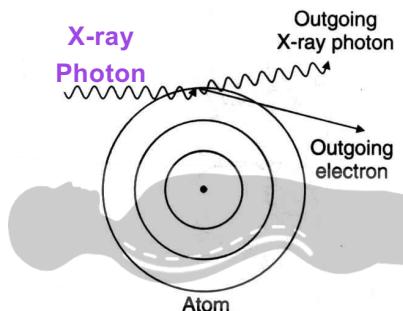
- Photon does not interact with matter and goes to detector

## 2. PHOTOELECTRIC ABSORPTION



- Photon absorbed in body
- Electron scatters again until it loses all its energy  
→ free radicals → DNA damage

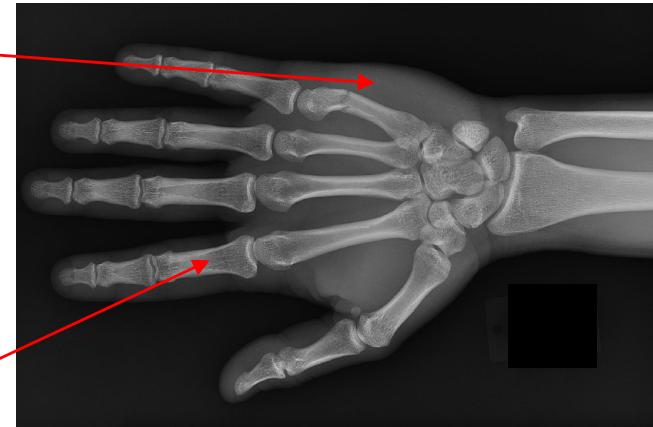
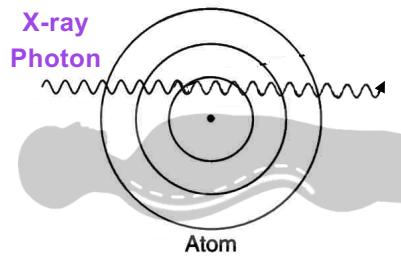
## 3. COMPTON SCATTERING



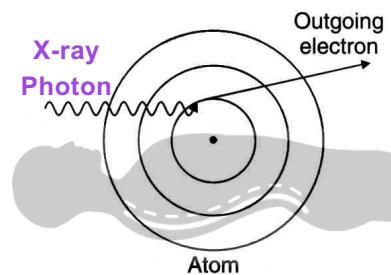
- Photon goes to detector (noise) or around (radiations for operators)
- Electron scatters again until it loses energy  
→ free radicals → DNA damage

# X-ray Attenuation

## 1. TRANSMITTED PHOTONS

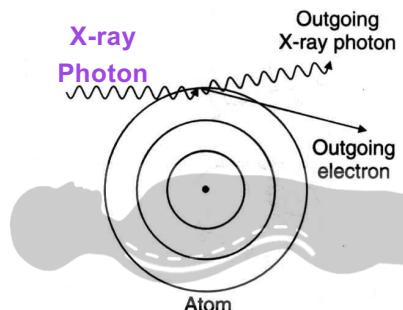


## 2. PHOTOELECTRIC ABSORPTION



[CONTRAST]

## 3. COMPTON SCATTERING



[NOISE]

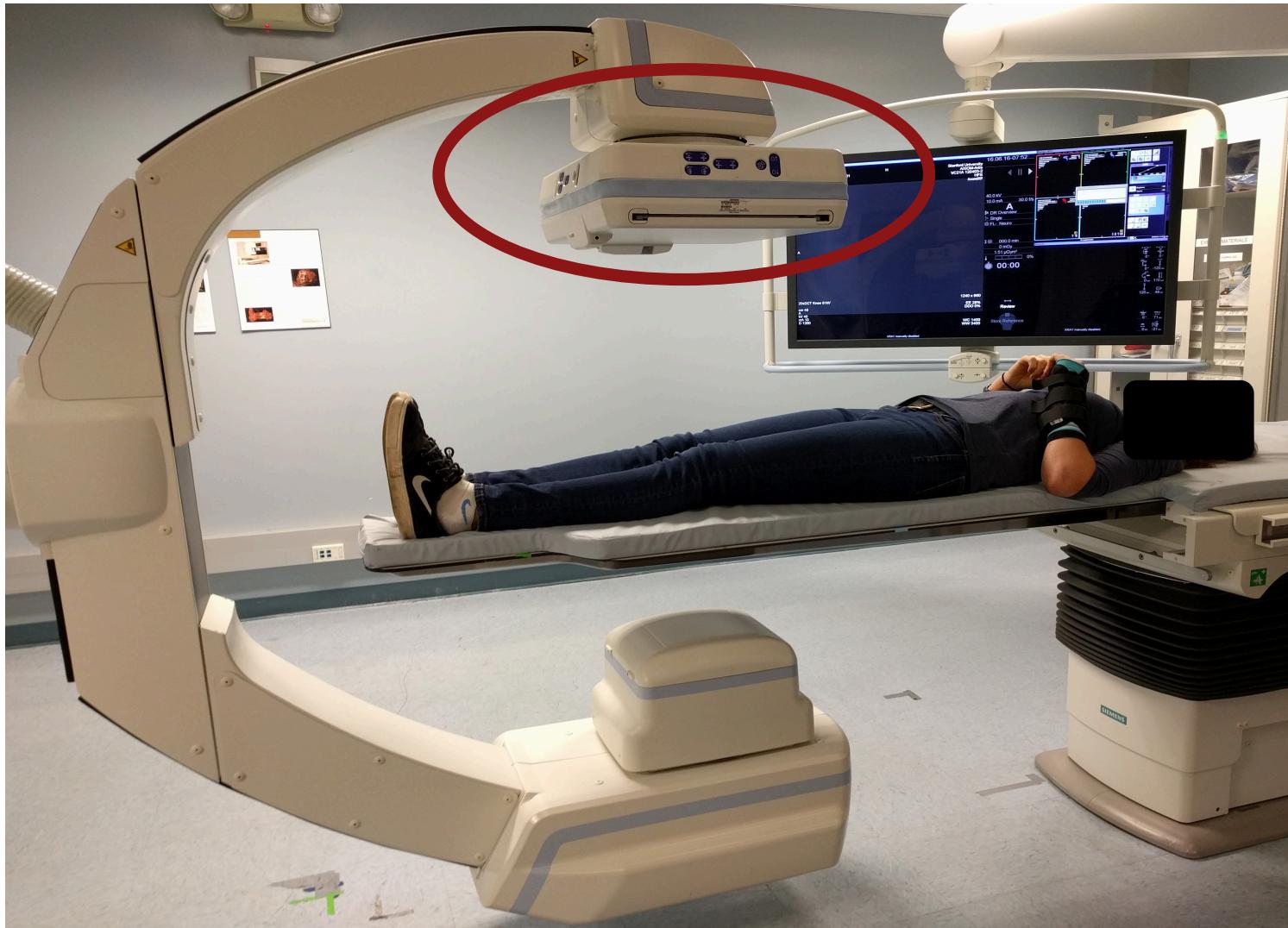
## ATTENUATION

Total reduction in number of X-rays  
in beam after passing through tissue

$$I = \int_0^{E_{max}} I_0(E) \cdot e^{-\int \mu dx} dE$$

[LAMBERT BEER'S LAW]

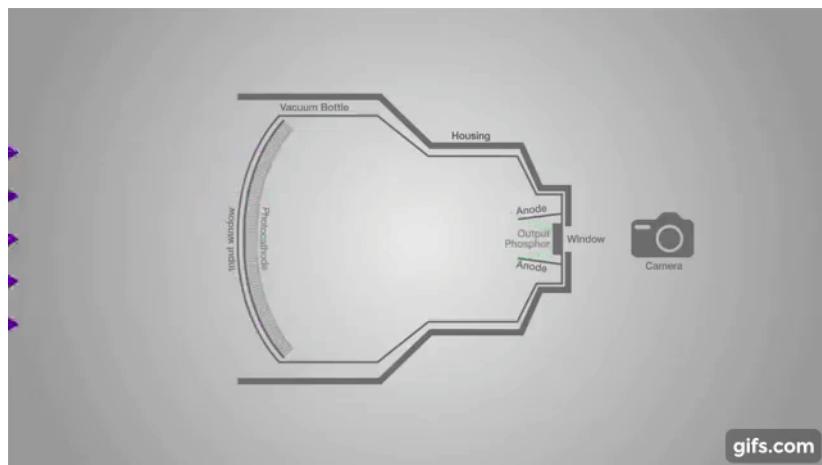
# The Detector



# Analog and Digital Detectors



## IMAGE INTENSIFIER

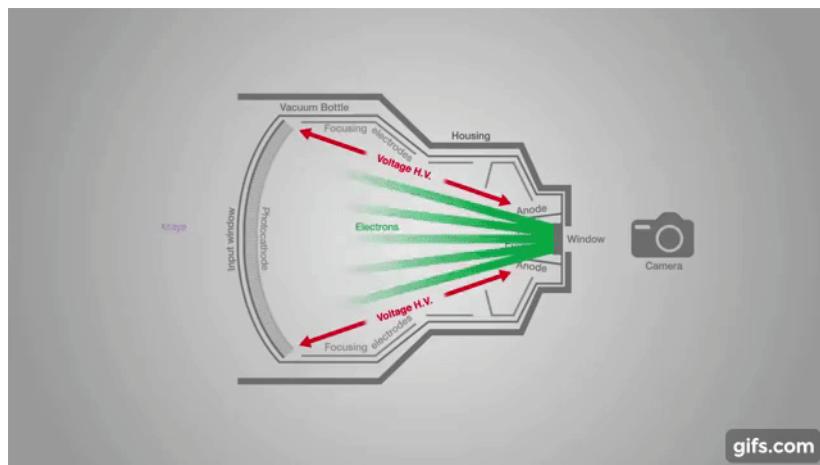


<https://www.youtube.com/watch?v=BQ0PZGnC334>

# Analog and Digital Detectors



## IMAGE INTENSIFIER

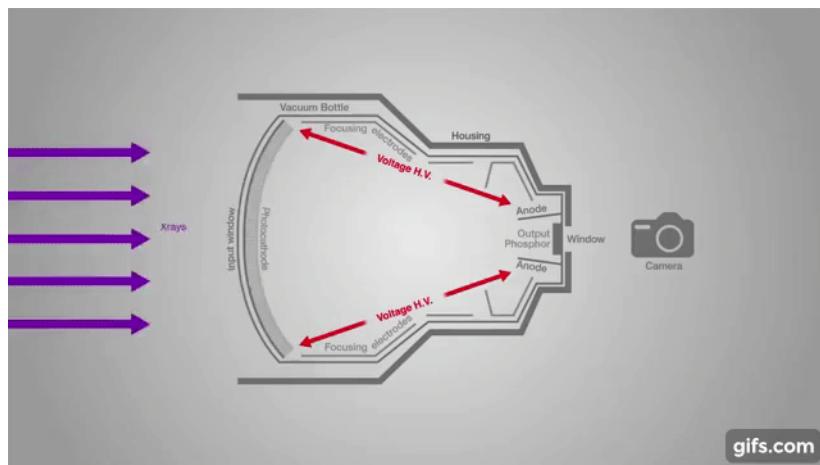


<https://www.youtube.com/watch?v=BQ0PZGnC334>

# Analog and Digital Detectors



## IMAGE INTENSIFIER

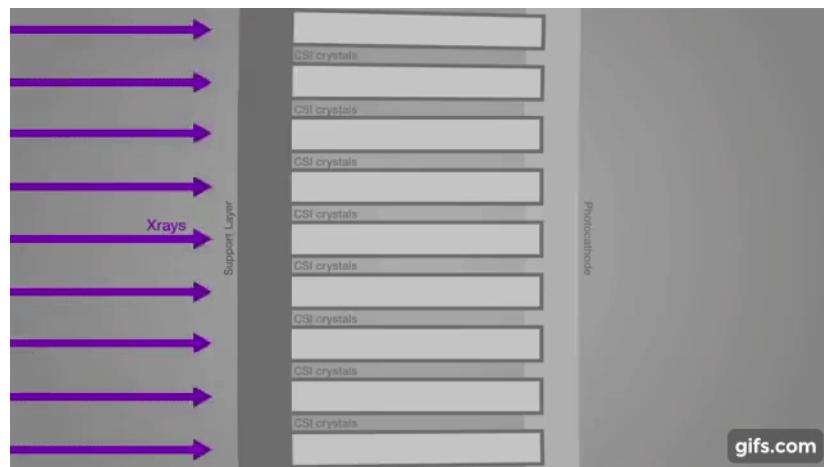


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# Analog and Digital Detectors

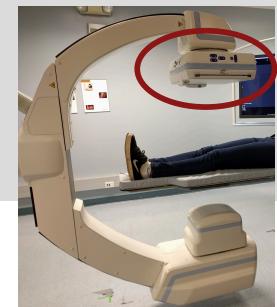


## IMAGE INTENSIFIER

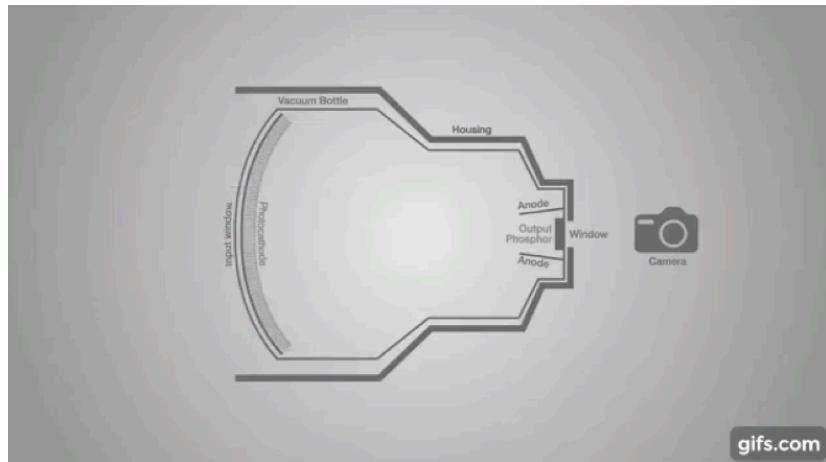


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# Analog and Digital Detectors



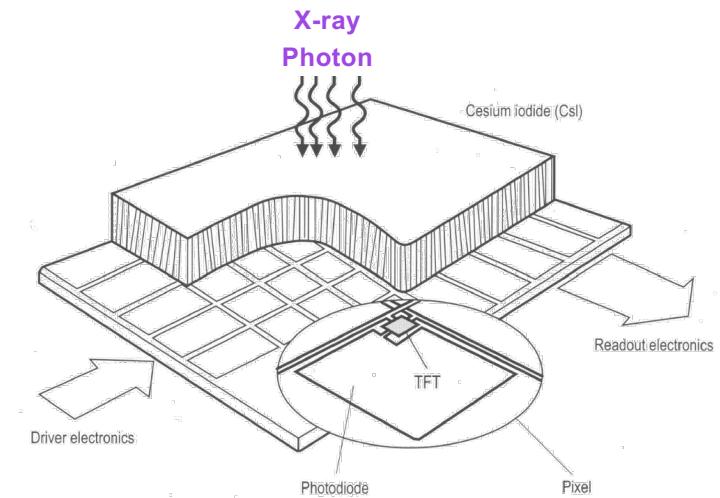
## IMAGE INTENSIFIER



<https://www.youtube.com/watch?v=BQ0PZGnC334>

- X-rays → Light → Electrons → Light → Image
- Introduced in the 1940s

## FLAT PANEL DETECTOR



- X-rays → Light → Electrons → Image
- Introduced in the 1990s
- Images are digitalized and thus easily viewed, shared, stored