

Fisica Medica



ASSOCIAZIONE ITALIANA
di FISICA MEDICA e SANITARIA
La Fisica al servizio della salute

Fisica Medica e Sanitaria si occupa di:

- Controlli di qualità
 - radiologia, medicina nucleare, radioterapia
- Piani di cura (radioterapia, ecc)
- Radioprotezione
 - Dosimetria (pazienti e ambienti di lavoro)
- Applicazione di sviluppi recenti della fisica in medicina (per la diagnosi o la terapia)
 - Radiazioni non ionizzanti (MRI, US), segnali elettrici (EEG)

<https://www.fisicamedica.it>

- <https://www.youtube.com/watch?v=pbGMJZKtKO0>
- <https://www.youtube.com/watch?v=o6jyXHLgGOA> (medicina nucleare)
- https://www.youtube.com/watch?v=ODCv4_nH6c (radioterapia)
- <https://www.youtube.com/watch?v=fAWnctwVQKI> (radiologia)
- <https://www.youtube.com/watch?v=JqcFTHBm4ww> (radioprotezione)

Fisica Medica

Aree interdisciplinari tra fisica, biologia e medicina:

- Biofisica

- Le cellule: come trasmettono i segnali, come reagiscono alle variazioni ambientali

- Neuroscienze

- Come funziona il cervello e il sistema nervoso centrale

- Radiobiologia

- Come i danni da radiazione ionizzante influenzano lo sviluppo delle cellule e come questi danni vengono “riparati”

Laboratorio di Fisica Medica

Laboratorio con i raggi X

Caratterizzazione del tubo (Fulvia Arfelli)

- Camere a ionizzazione (curve di saturazione)
- Misure flusso al variare della corrente del tubo
- Misure di flusso al variare del kV del tubo
- Misure di flusso al variare della distanza
- Misure di Half Value Layer (spessore di dimezzamento)
- Misure di spettri del tubo al variare dei parametri (con CdTe detector)

Caratterizzazione di un rivelatore digitale (Luigi Rigon)

- Risoluzione spaziale
- Contrasto e SNR delle immagini

■ **Libri di testo**

- Bushberg – The Essential Physics of Medical Imaging, Jerrold T. Bushberg, J. Anthony Seibert, Edwin M. Leidholdt, John M. Boone, Lippincott Williams & Wilkins (disponibile presso la Biblioteca Tecnico Scientifica di Ateneo)
- Handbook of Medical Imaging, Volume 1, J. Beutel, H.L.Kundel, R.L. Van Metter Editors, SPIE press
- Webb_The Physics of Medical Imaging
- The Physical principles of medical imaging, P. Sprawls
<http://www.sprawls.org/resources/>

Simulatore spettro tubo a raggi X

- <https://health.siemens.com/booneweb/index.html>

Laboratorio di Fisica Medica

Metodi di MonteCarlo in Fisica Medica

Seminario Francesco Longo

- GEANT e Gate: un toolkit di simulazione per l'interazione radiazione materia
- Geometria e Fisica: come costruire una simulazione
- Alcuni esempi di simulazione: hadrontherapy, brachitherapy, medical_linac, human_phantom etc

Laboratorio di Fisica Medica

Controlli di qualita' in Ospedale

presso il servizio di Fisica Sanitaria dell'azienda ospedaliero universitaria (ASUGI)

1CFU - maggio

- Radiologia (CT, Mammografia)
- Medicina Nucleare
- Radioterapia

Medical Physics

In radiology different form of energy are used to produce the image must be capable of penetrating tissues.

Visible light has limited ability to penetrate tissues at depth and is used mostly outside of the radiology department for medical imaging.

Visible light images are used in dermatology (skin photography), gastroenterology and obstetrics (endoscopy) and pathology (light microscopy).

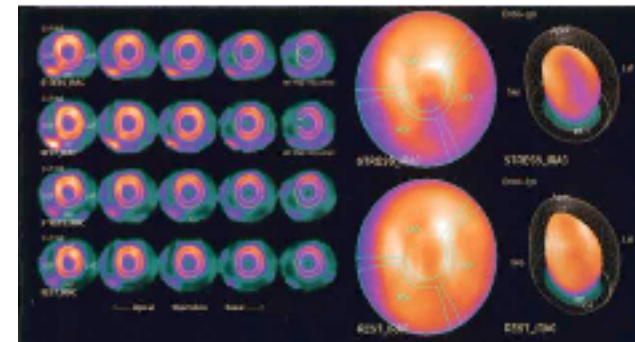
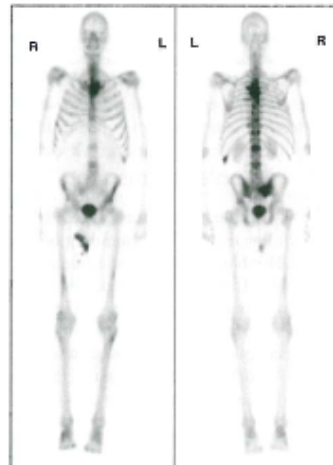
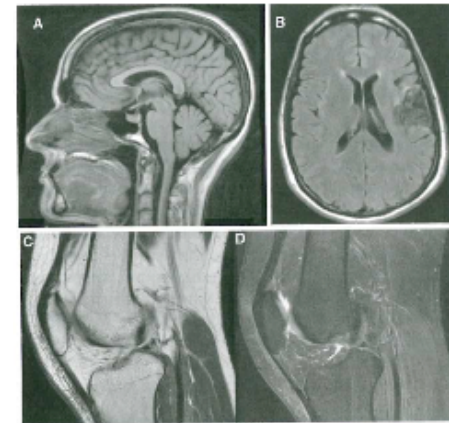
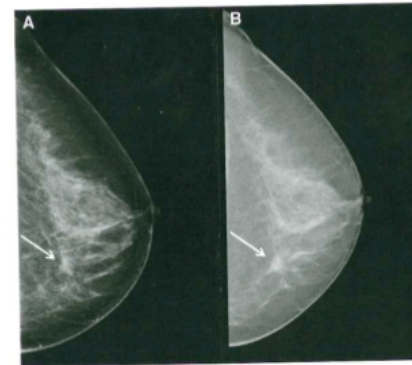
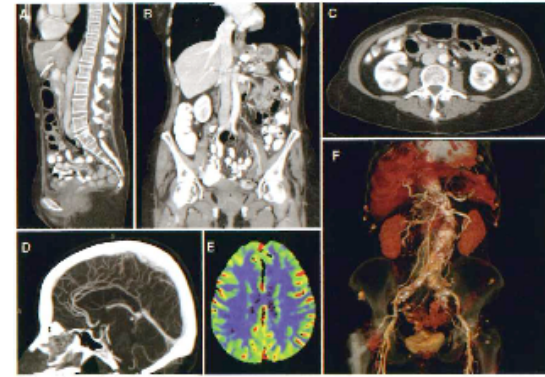
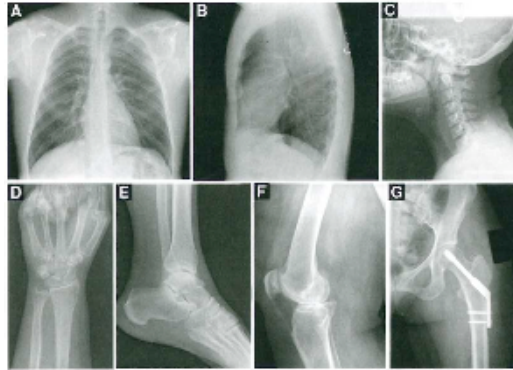
In diagnostic radiology, the electromagnetic spectrum outside the visible light region is used for medical imaging, including x-ray mammography and computed tomography (CT), radiofrequency (RF) in magnetic resonance imaging (MRI) and gamma rays in nuclear medicine.

Energy, in form of high-frequency sound waves, is used in ultrasound imaging.

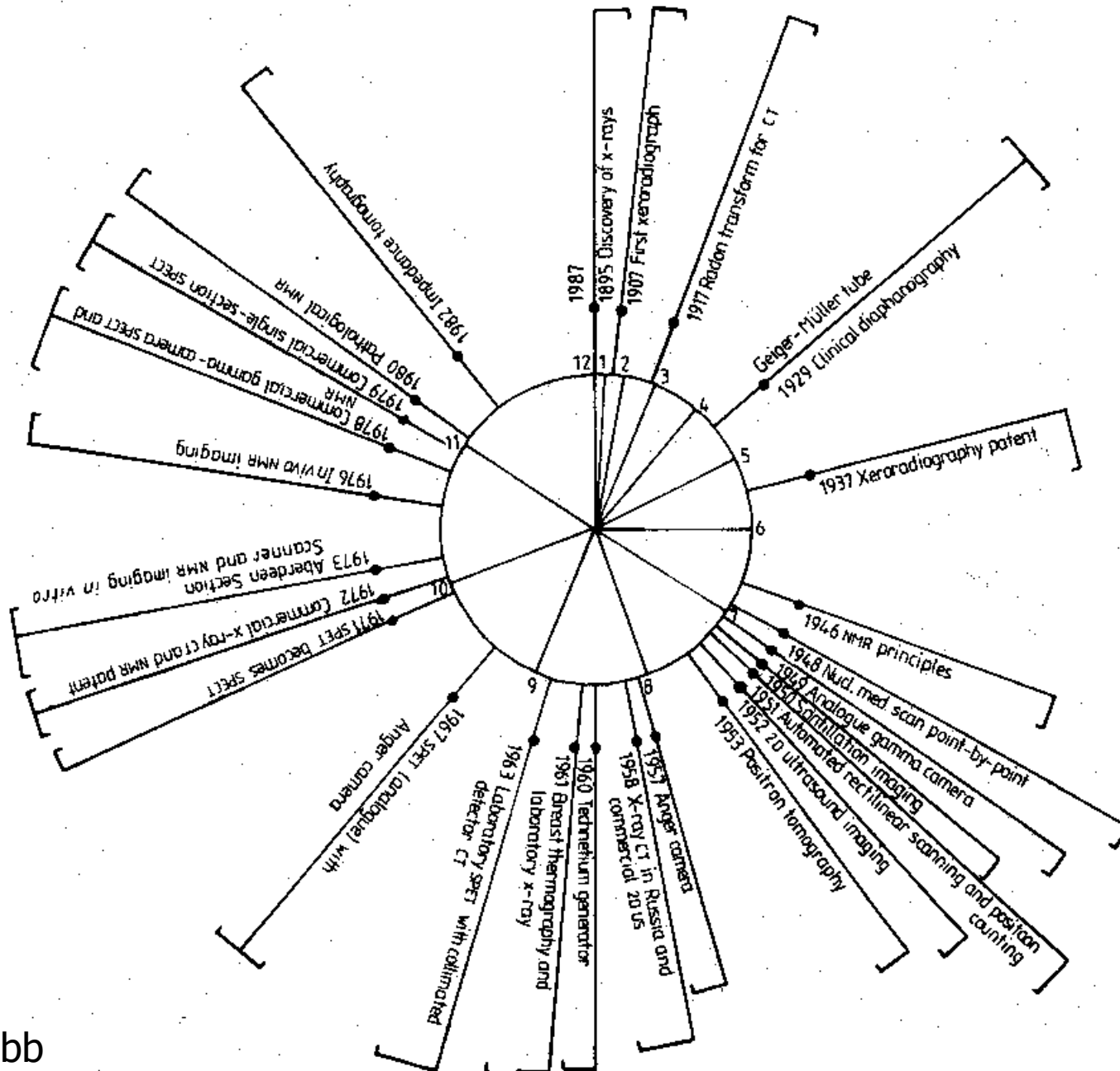
- Radiography
- Fluoroscopy
- Mammography
- Computed Tomography
- Magnetic Resonance Imaging
- Ultrasound Imaging
- Nuclear medicine Imaging

Nuclear medicine planar Imaging
Single Photon Emission Computed
Position Emission Tomography

- Combined Imaging Modalities



Medical imaging development



Radiography

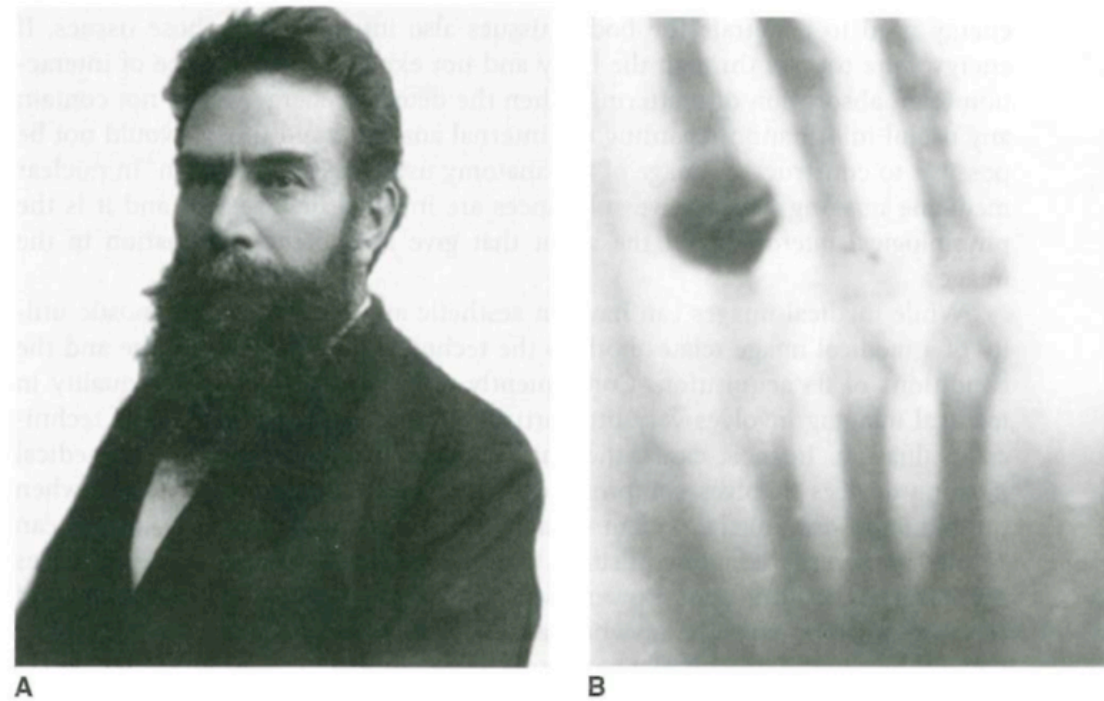


FIGURE 1-1 Wilhelm Conrad Roentgen (1845–1923) in 1896 (A). Roentgen received the first Nobel Prize in Physics in 1901 for his discovery of x-rays on November 8, 1895. The beginning of diagnostic radiology is represented by this famous radiographic image, made by Roentgen on December 22, 1895 of his wife's hand (B). The bones of her hand as well as two rings on her finger are clearly visible. Within a few months, Roentgen had determined the basic physical properties of x-rays. Roentgen published his findings in a preliminary report entitled "On a New Kind of Rays" on December 28, 1895 in the Proceedings of the Physico-Medical Society of Wurzburg. An English translation was published in the journal *Nature* on January 23, 1896. Almost simultaneously, as word of the discovery spread around the world, medical applications of this "new kind of ray" rapidly made radiological imaging an essential component of medical care. In keeping with mathematical conventions, Roentgen assigned the letter "x" to represent the unknown nature of the ray and thus the term "x-rays" was born.

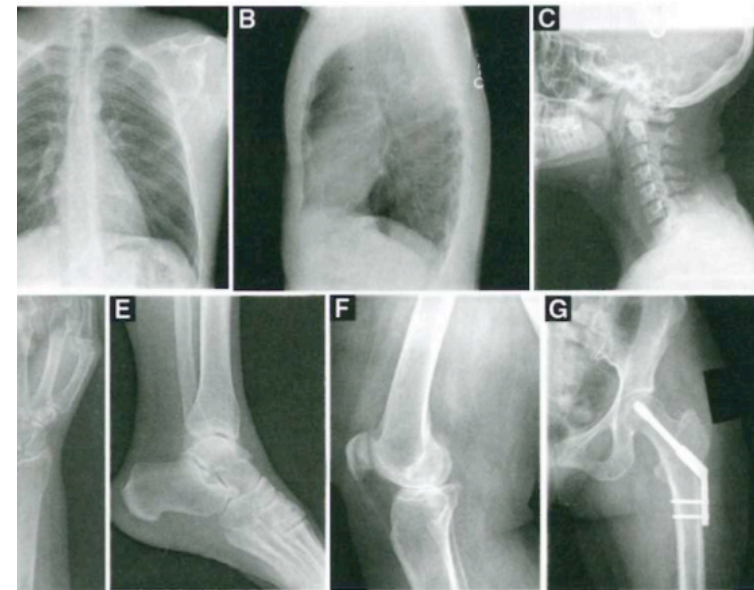
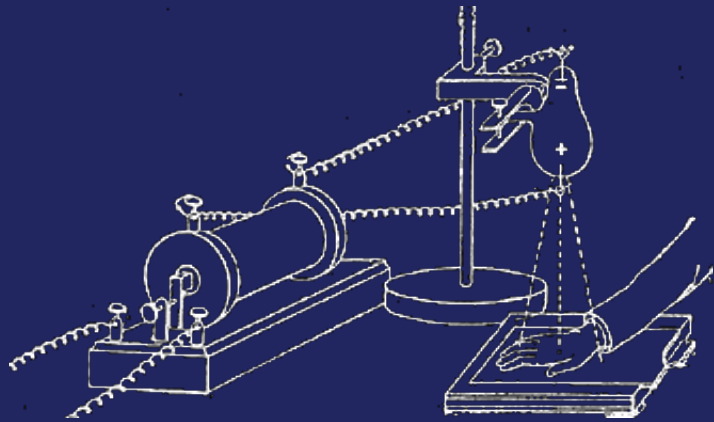


FIGURE 1-2 Chest radiography is the most common imaging procedure in diagnostic radiology, often acquired as orthogonal posterior-anterior (A) and lateral (B) projections to provide information regarding depth and position of the anatomy. High-energy x-rays are used to reduce the conspicuity of the ribs and other bones to permit better visualization of air spaces and soft tissue structures in the thorax. The image is a map of the attenuation of the x-rays: dark areas (high film optical density) correspond to low attenuation, and bright areas (low film optical density) correspond to high attenuation. C. Lateral cervical spine radiographs are commonly performed to assess suspected neck injury after trauma, and extremity images of the (D) wrist, (E) ankle, and (F) knee provide low-dose, cost-effective diagnostic information. G. Metal objects, such as this orthopedic implant designed for fixation of certain types of femoral fractures, are well seen on radiographs.

Discovery of X-rays



Roentgen 1895



A New kind of rays

First radiograph
Mrs. Roentgen's
hand Autumn 1895

First medical device
commercially
available Spring 1896

Improvements in

- source
- detector



Fuji 1995
flat panel system



Contrast and Spatial resolution

Medical imaging makes use of a variety of physical parameters as the source of image information. The mechanism for generating contrast and the spatial resolution properties differs amongst the modalities, providing a wide range of diagnostic tools for physicians.

Contrast manifests as difference in the grayscale values in the image.

A uniformly gray image has no contrast, while high contrast arises from high transition from dark gray and light gray.

The various imaging modalities generate contrast using a number of different forms of energy which interact within the patient's tissues based on different physical properties.

Each imaging modality has also different abilities to resolve fine details in the patient. **Spatial resolution refers to the ability to see small details** and an imaging system has higher spatial resolution if it can demonstrate the presence of smaller object in the image. The limiting spatial resolution is the size of the smallest object that an imaging system can resolve.

Contrast

The contrast in x-ray transmission imaging (radiography, fluoroscopy, mammography, and CT) is produced by differences in tissue composition, which determine the local x-ray absorption coefficient, which in turn is dependent upon the density (g/cm^3) and the effective atomic number. The energies of the x-ray photons in the beam (adjusted by the operator) also affect contrast in x-ray images.

CT's contrast is enhanced over other x-ray imaging modalities due to its tomographic nature. The absence of out-of-slice structures in the CT image greatly improves its image contrast.

Nuclear medicine images (planar images, SPECT, and PET) are maps of the spatial distribution of radioisotopes in the patient. Thus, contrast in nuclear images depends upon the tissue's ability to concentrate the radioactive material.

Contrast in MR imaging is related primarily to the proton density and to relaxation phenomena (i.e., how fast a group of protons gives up its absorbed energy).

Contrast in ultrasound imaging is largely determined by the acoustic properties of the tissues being imaged. The difference between the acoustic impedances (tissue density $\times$ speed of sound in tissue) of two adjacent tissues or other substances affects the amplitude of the returning ultrasound signal. Hence, contrast is quite apparent at tissue interfaces where the differences in acoustic impedance are large.

Spatial resolution

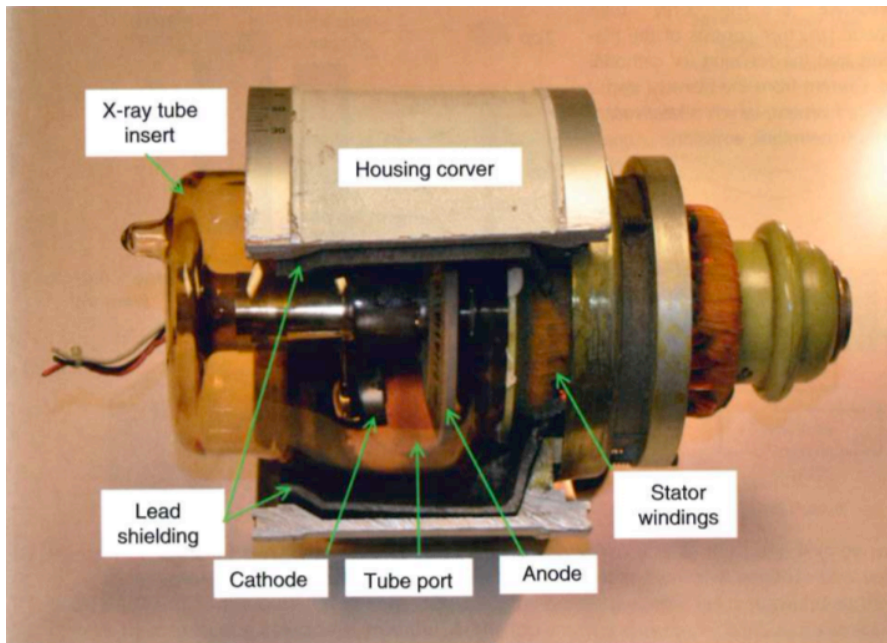
Table 1-1 lists the limiting spatial resolution of each of the imaging modalities used in medical imaging. The wavelength of the energy used to probe the object is a fundamental limitation of the spatial resolution of an imaging modality. For example, optical microscopes cannot resolve objects smaller than the wavelengths of visible light, about 400 to 700 nm. The wavelength of x-rays depends on the x-ray energy, but even the longest x-ray wavelengths are tiny—about 1 nm. This is far from the actual resolution in x-ray imaging, but it does represent the theoretical limit on the spatial resolution using x-rays. In ultrasound imaging, the wavelength of sound is the fundamental limit of spatial resolution. At 3.5 MHz, the wavelength of sound in soft tissue is about 500 μm . At 10 MHz, the wavelength is 150 μm .

TABLE 1-1 THE LIMITING SPATIAL RESOLUTIONS OF VARIOUS MEDICAL IMAGING MODALITIES. THE RESOLUTION LEVELS ACHIEVED IN TYPICAL CLINICAL USAGE OF THE MODALITY ARE LISTED

MODALITY	SPATIAL RESOLUTION (mm)	COMMENTS
Screen film radiography	0.08	Limited by focal spot size and detector resolution
Digital radiography	0.17	Limited by size of detector elements and focal spot size
Fluoroscopy	0.125	Limited by detector resolution and focal spot size
Screen film mammography	0.03	Highest resolution modality in radiology, limited by same factors as in screen film radiography
Digital mammography	0.05–0.10	Limited by same factors as digital radiography
Computed tomography	0.3	About ½ mm pixels
Nuclear medicine planar imaging	2.5 (detector face), 5 (10 cm from detector)	Spatial resolution degrades substantially with distance from detector
Single photon emission computed tomography	7	Spatial resolution worst towards the center of cross-sectional image slice
Positron emission tomography	5	Better spatial resolution than the other nuclear imaging modalities
Magnetic resonance imaging	1.0	Resolution can improve at higher magnetic fields
Ultrasound imaging (5 MHz)	0.3	Limited by wavelength of sound

Produzione dei raggi X

La produzione dei raggi X avviene solitamente



Alternative possibili:

- i generatori basati sui laser

- le macchine di luce di sincrotrone.

Radiographics 1997 17:1259-1268

Radiographics 1997 17:1533-1557

I controlli di qualità in radiologia

- Sono un mezzo per mantenere alta la qualità dell'imaging lavorando per minimizzare la dose per i pazienti e per lo staff sanitario.
- Occorre misurare un insieme di parametri fisici che determinano la qualità delle immagini, verificare la loro stabilità nel tempo.

S.Webb ed. The physics of Medical Imaging, 1988 IOP(UK)

I controlli di qualità' in radiologia X

- Tensione applicata
 - Influenza contrasto e dose depositata
- Tempo di esposizione
- Output (mGy)
 - Si misura con IC calibrate
- Spessore di dimezzamento
- Dimensione del focal spot
- Allineamento della luce di posizionamento
 - Per i mammografi
- Risoluzione spaziale e in contrasto

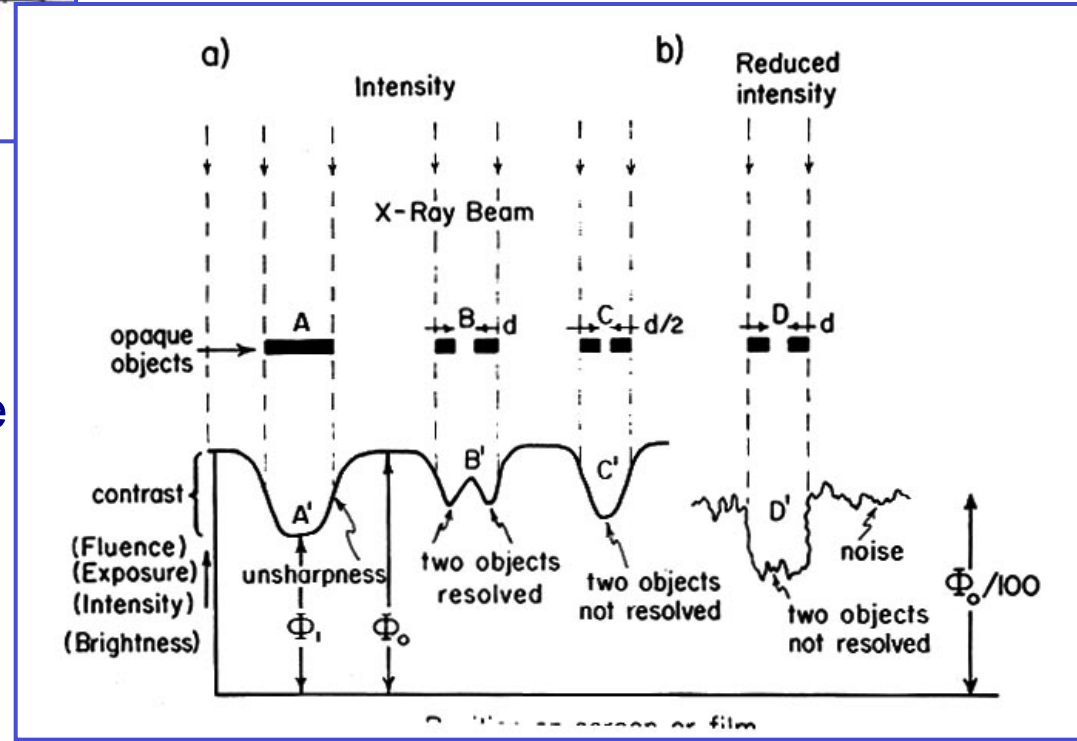
Definizione delle immagini & risoluzione spaziale

effective
focal spot

object

detector

Blurred object edges



Risolvere i dettagli dipende da:

- Dimensione della sorgente
- Risoluzione spaziale del rivelatore
- Rapporto S/N

Unita' radiologiche

- Fluenza: detector "photon counting"
- Intensità': detector ad integrazione di carica
- Esposizione: camere a ionizzazione
- Dose e kerma: dosimetri calibrati

Table 6
Radiologic Units

Quantity	Description	Conventional Unit*
Fluence	Number of photons per unit area	1/centimeter ² [1/meter ²]
Flux (fluence rate)	Fluence per unit time	1/(centimeter ² · second) [1/(meter ² · second)]
Intensity (energy fluence)	Number of photons times photon energy per unit area	kiloelectron volt/centimeter ² [joule/meter ²]
Exposure (X)	Charge produced per unit mass of air from x and gamma rays	roentgen [coulomb/kilogram] [†]
Kerma (K)	Kinetic energy released in matter per unit mass	rad [joule/kilogram or gray] [‡]
Dose (D)	Energy absorbed per unit mass	rad [joule/kilogram or gray] [‡]

*SI units are given in brackets.

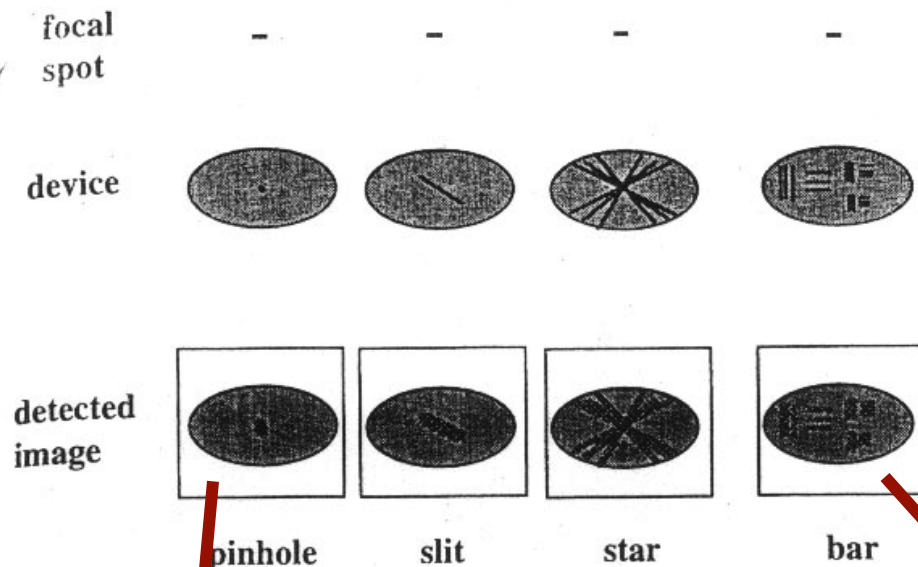
[†] 1 roentgen = 2.58×10^{-4} coulomb/kilogram.

[‡] 100 rad = 1 gray.

Misura della macchia focale

Le dimensioni effettive della macchia focale vanno misurate.

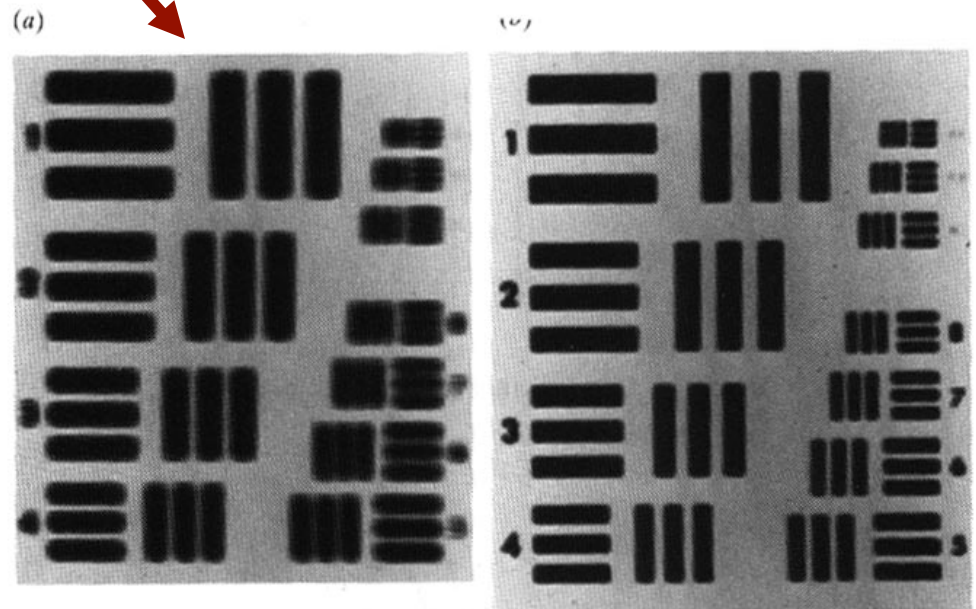
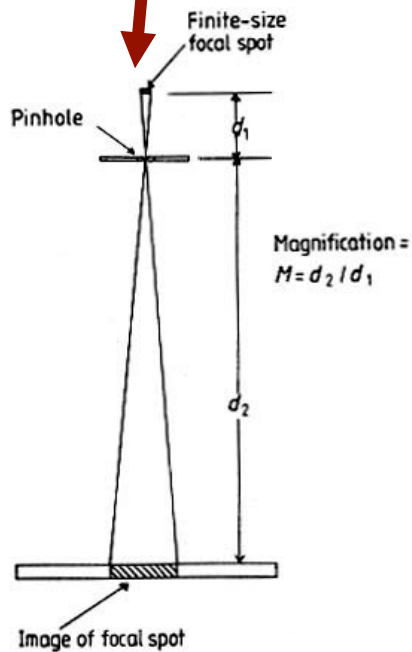
Possono deteriorarsi



Bar pattern
Macchia focale

1.3x1.5 mm²

0.6x0.6 mm²



Laborator

Utilizzo del tubo per i raggi X

- Annotare sul logbook data e valore del contatore posto sull'generatore di alta tensione, valore da registrare anche a fine lavoro (Nel "mobiletto" sotto il tubo)
- Accendere il generatore
 - Se non parte verificare che l'interruttore a muro sia aperto
- Aprire il circuito di raffreddamento
- Selezionare power ON sul pannello frontale
- Posizionare il collimatore meccanico all'uscita del tubo.
- Verificare:
 - la chiusura corretta delle ante a vetro schermanti (inter lock)
 - la pressione nel circuito di raffreddamento
 - la posizione al minimo delle regolazioni di mAs e kV
- La luce X-Ray deve essere "ready" e si puo' quindi premere ON
 - Luce rossa
- Impostare mAs, kV e kW in base alle esigenze
- Aprire lo shutter
- Per operare nello spazio di fronte il tubo portare in OFF il pannello X-ray
 - ✓ Per ripartire: chiudere shutter e la posizione al minimo delle regolazioni di mAs e kV

Uso dell'amperometro Keithley

- Collegare la camera a ionizzazione PTW
- Accendere lo strumento
- Opzione Zero Check ON
- Scegliere la tensione di output a 300V
 - Se necessario entrare in CONFIG e aumentare il range di tensione
- Scegliere se leggere corrente, carica o tensione
- Scegliere il range di lettura
- Operate: ora la camera e' alimentata
- Zero Check OFF: la camera e' letta
- Prima di ogni manipolazione sui parametri mettersi in Zero Check ON
 - Sospende la lettura della camera ed evita quindi sbalzi