Imaging System Components

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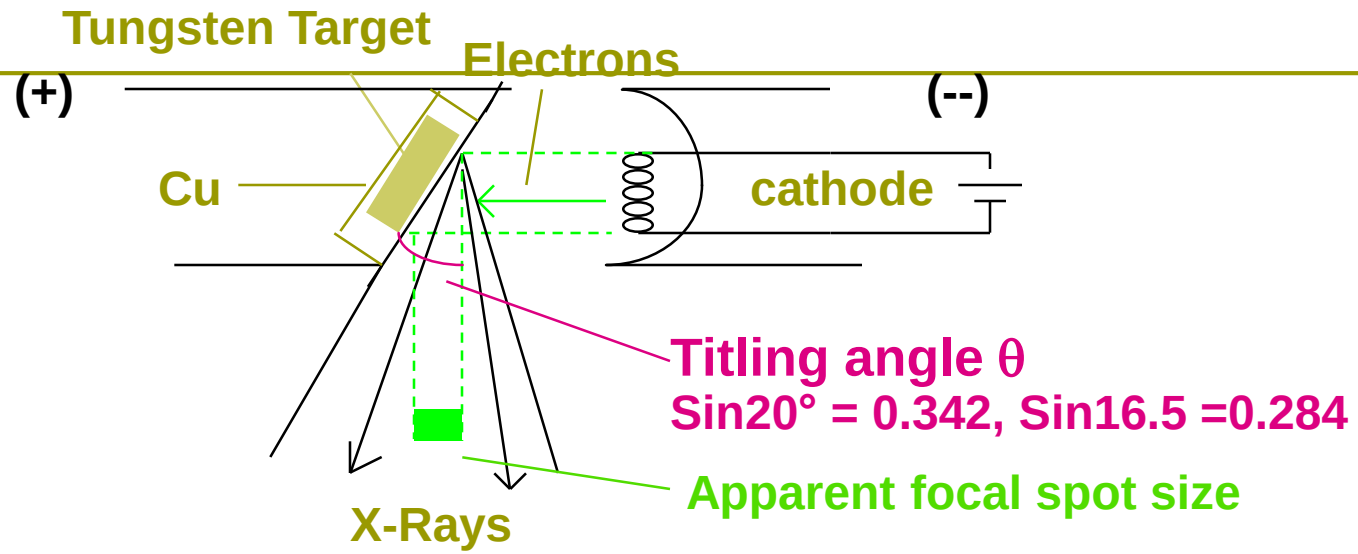
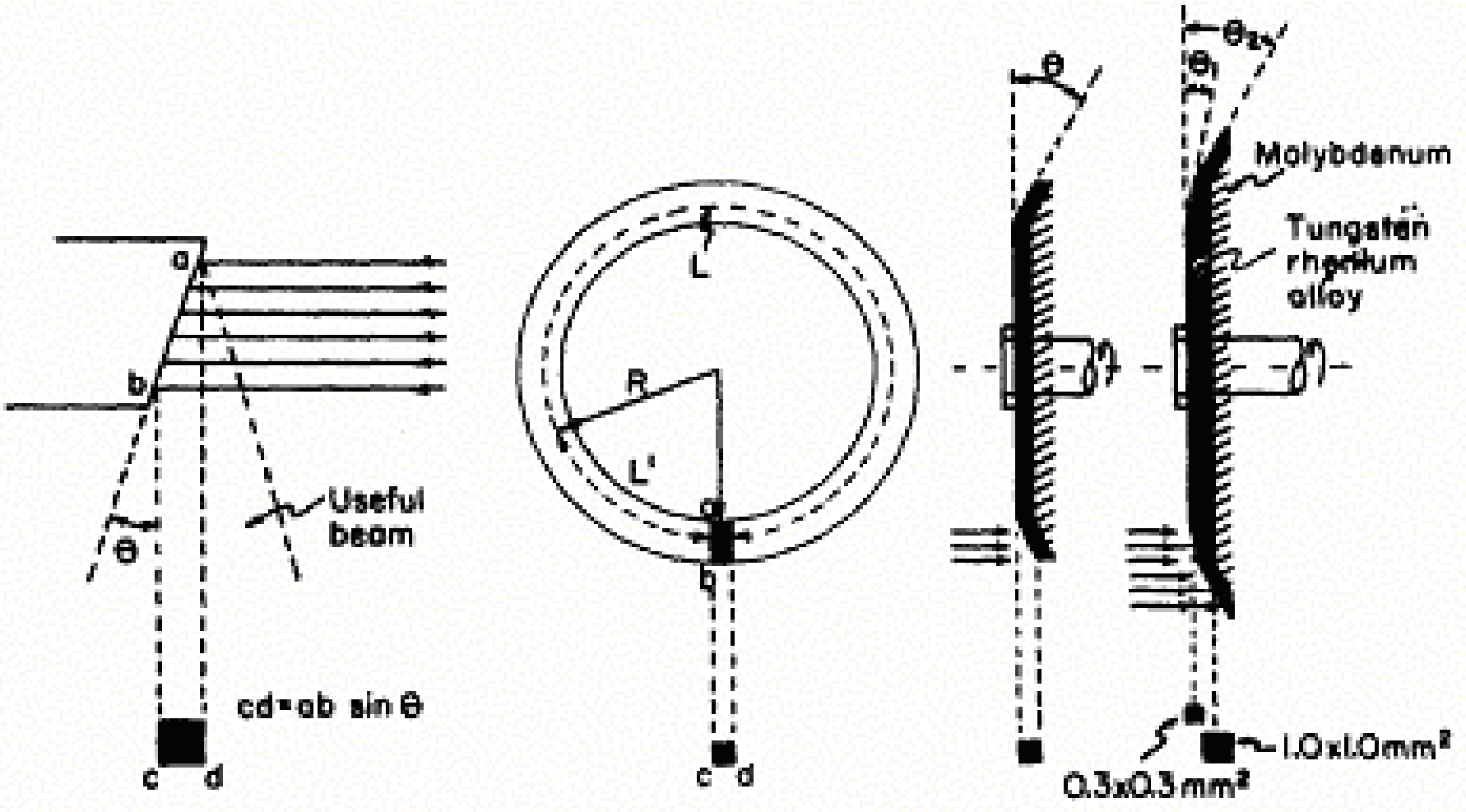
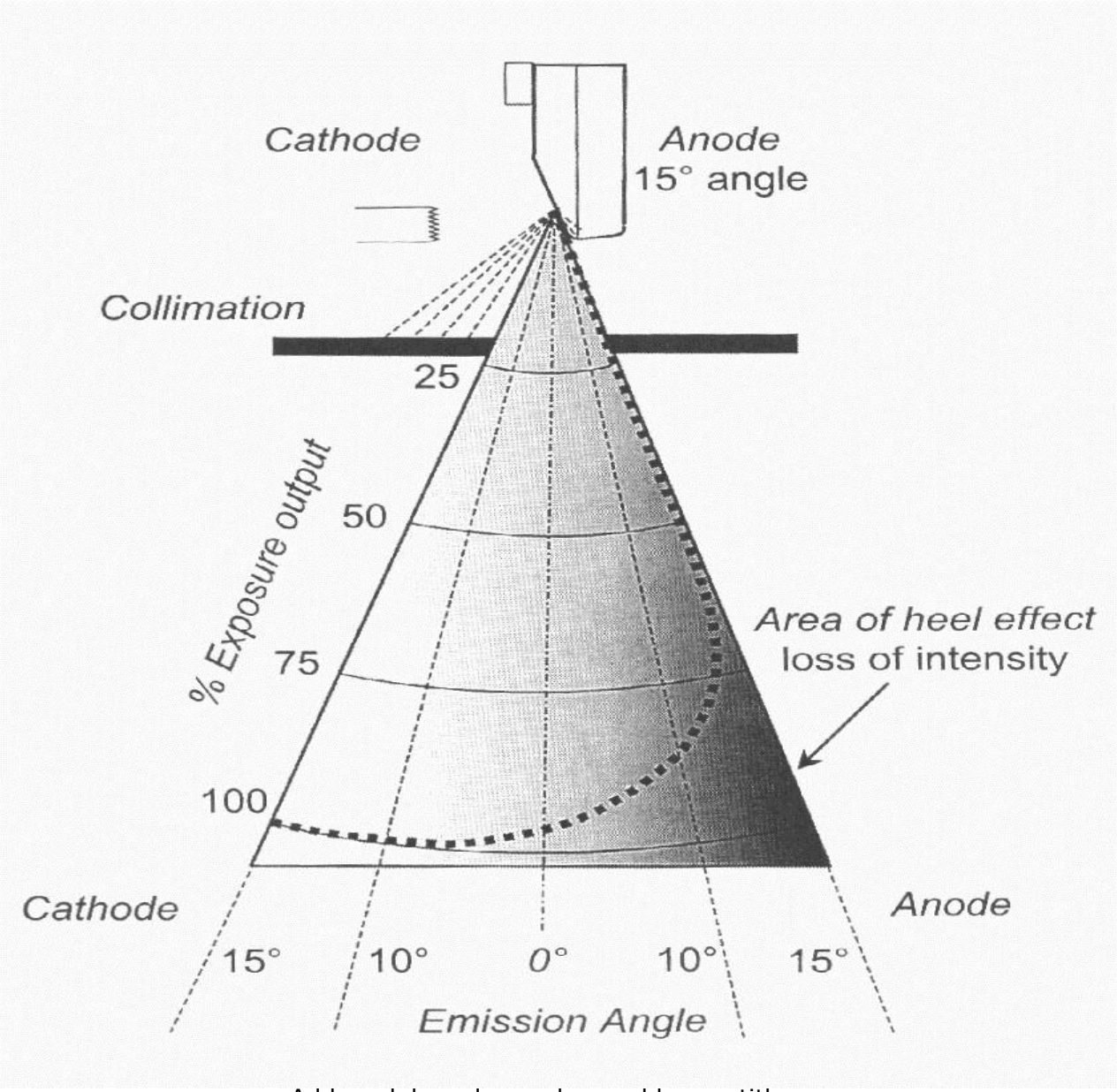
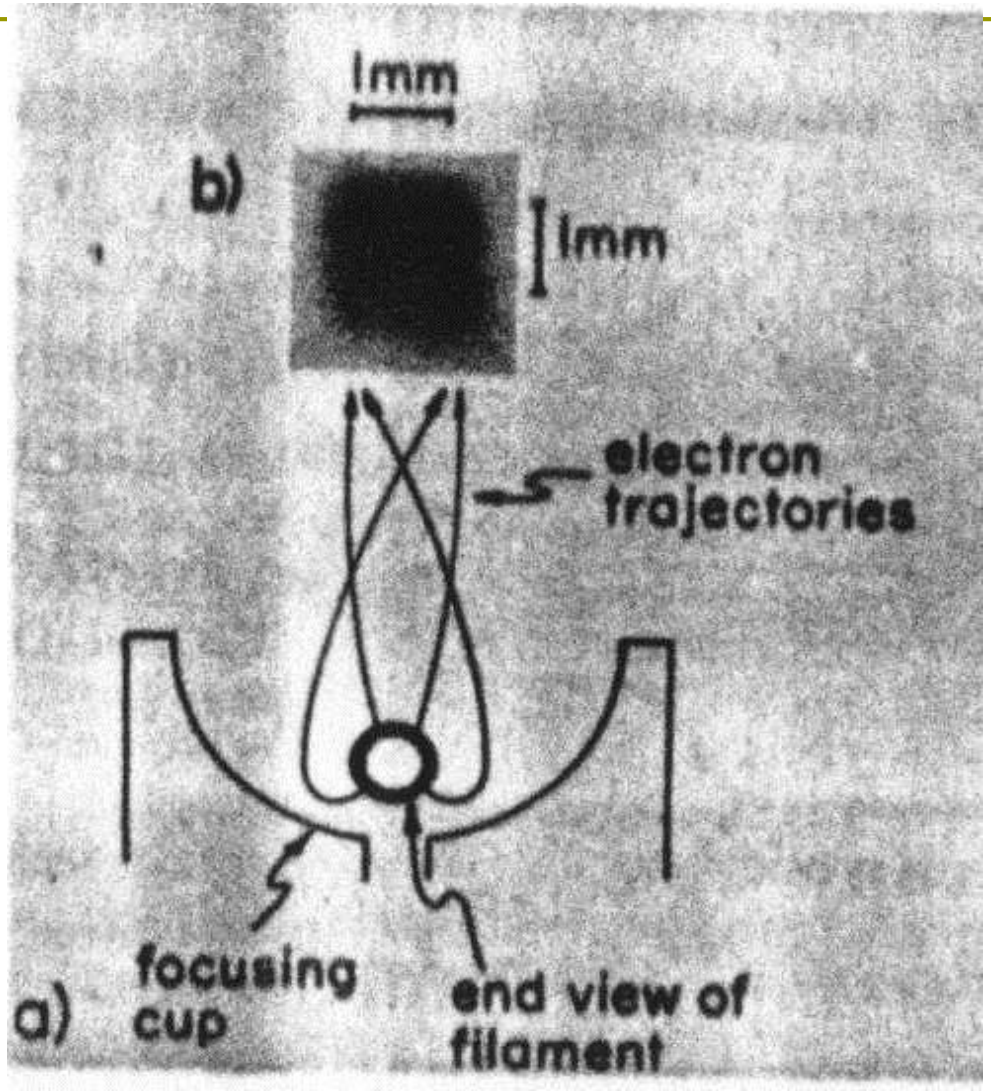

Tungsten Target
Electrons
(+)
(--)
Cu
cathode
Titling angle θ
Sin20° = 0.342, Sin16.5 =0.284
Apparent focal spot size
X-Rays

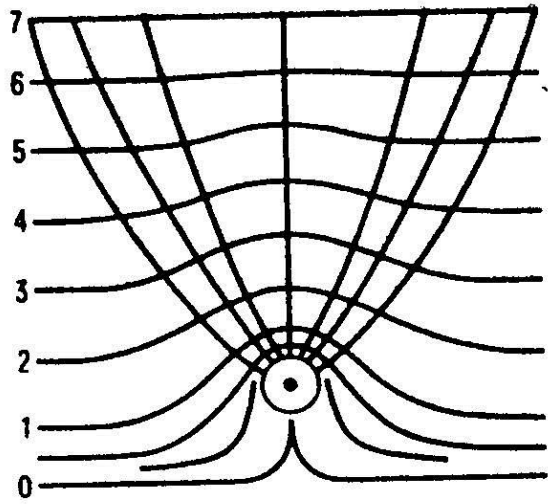
Focal Spot


a
b
θ
Useful beam
cd = ab sin θ
c
d
L
R
L'
a
b
c
d
θ
θ1
θ2
Molybdenum
Tungsten rhenium alloy
1.0x1.0mm²
0.3x0.3 mm²

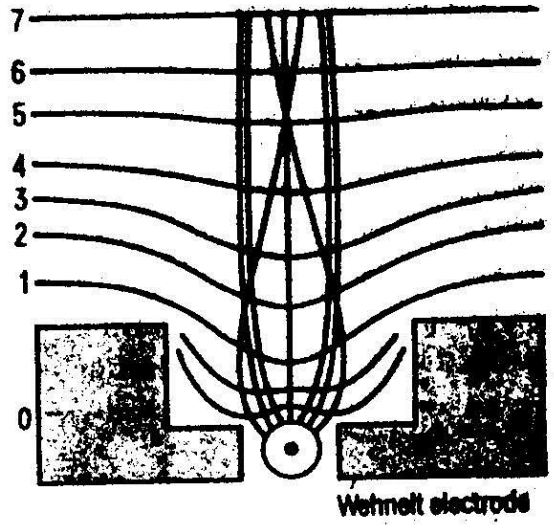

Cathode
Anode
15° angle
Collimation
25
50
75
100
% Exposure output
Area of heel effect
loss of intensity
Cathode
Anode
15°
10°
0°
10°
15°
Emission Angle

Focal Spot MTF

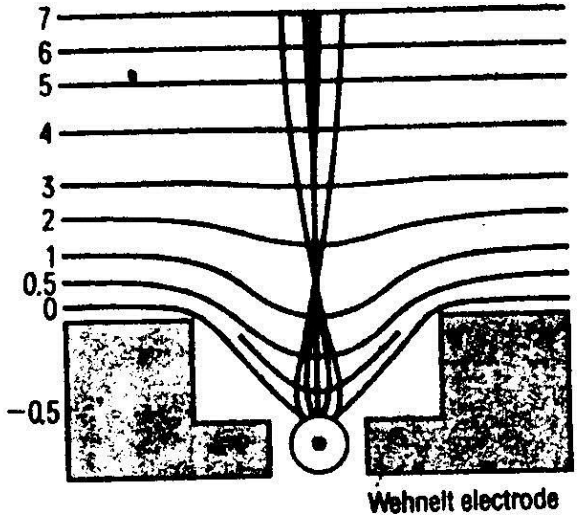


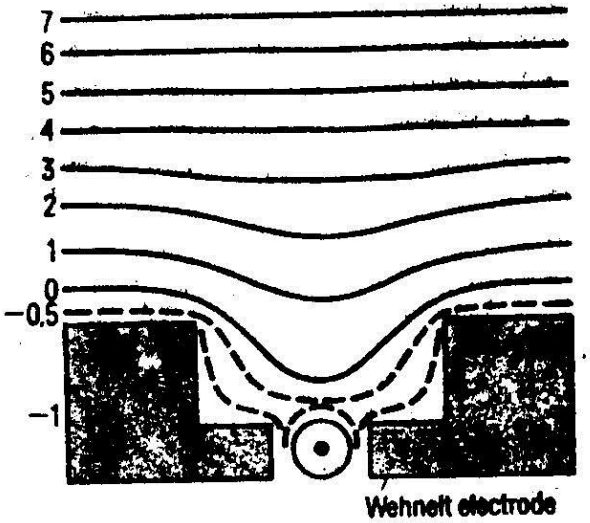


a) Cylindrical filament opposite plane anode

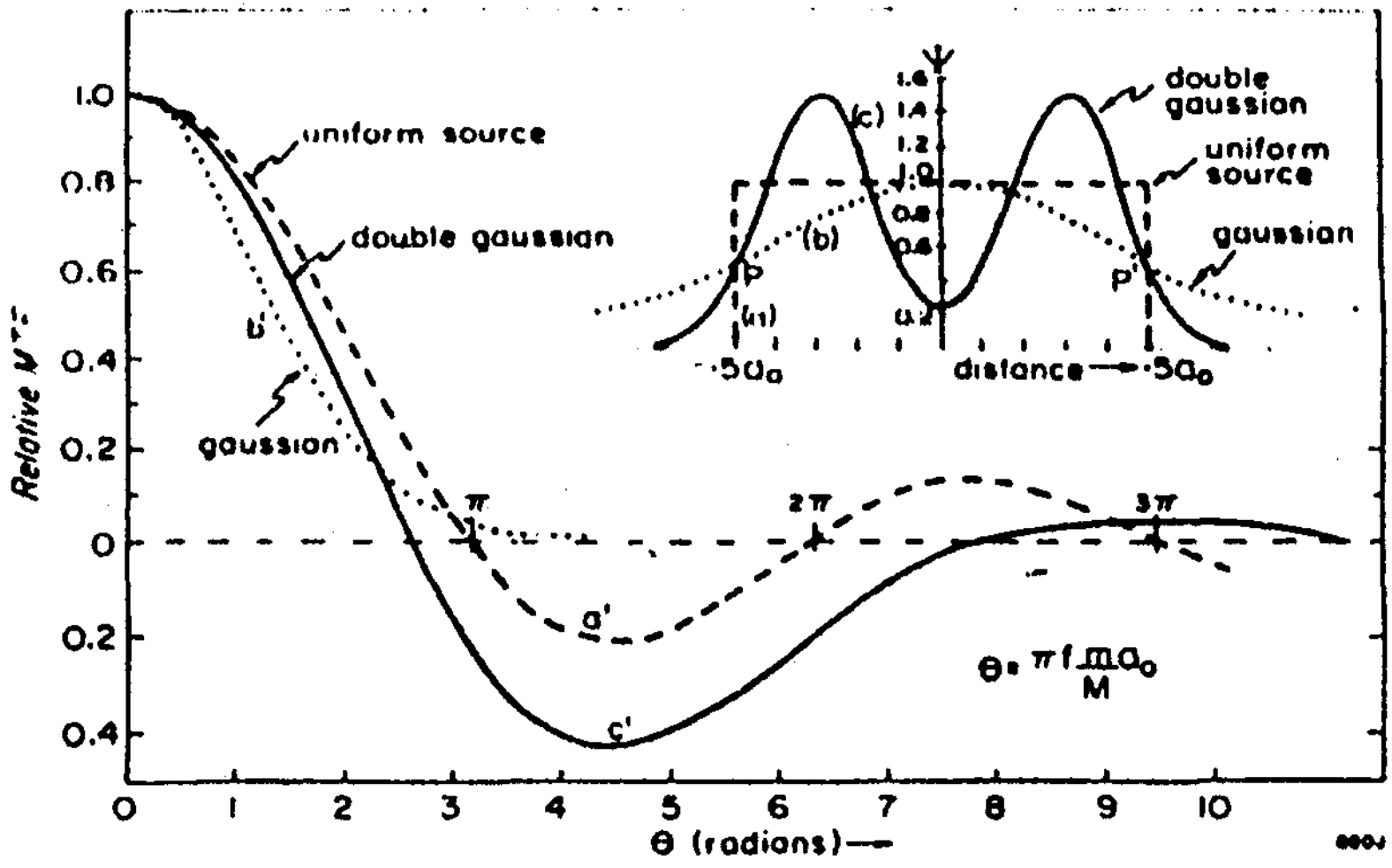


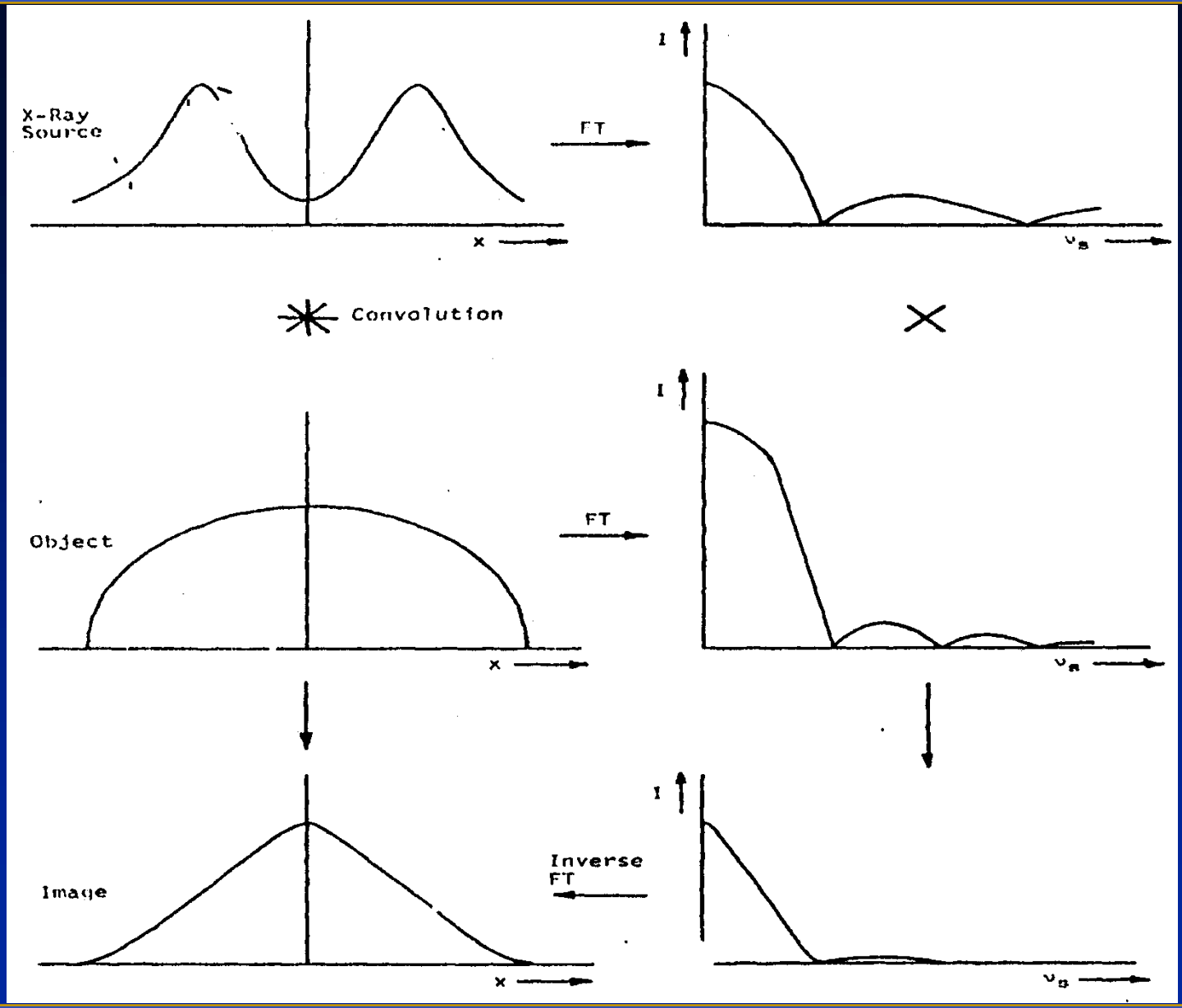
b) Focussing effect of the Wehnelt electrode





MTF of various shape of Focal Spot




X-Ray
Source
x
FT
I
ν_x
Convolution
Object
x
FT
I
ν_x
Image
x
Inverse
FT
I
ν_x

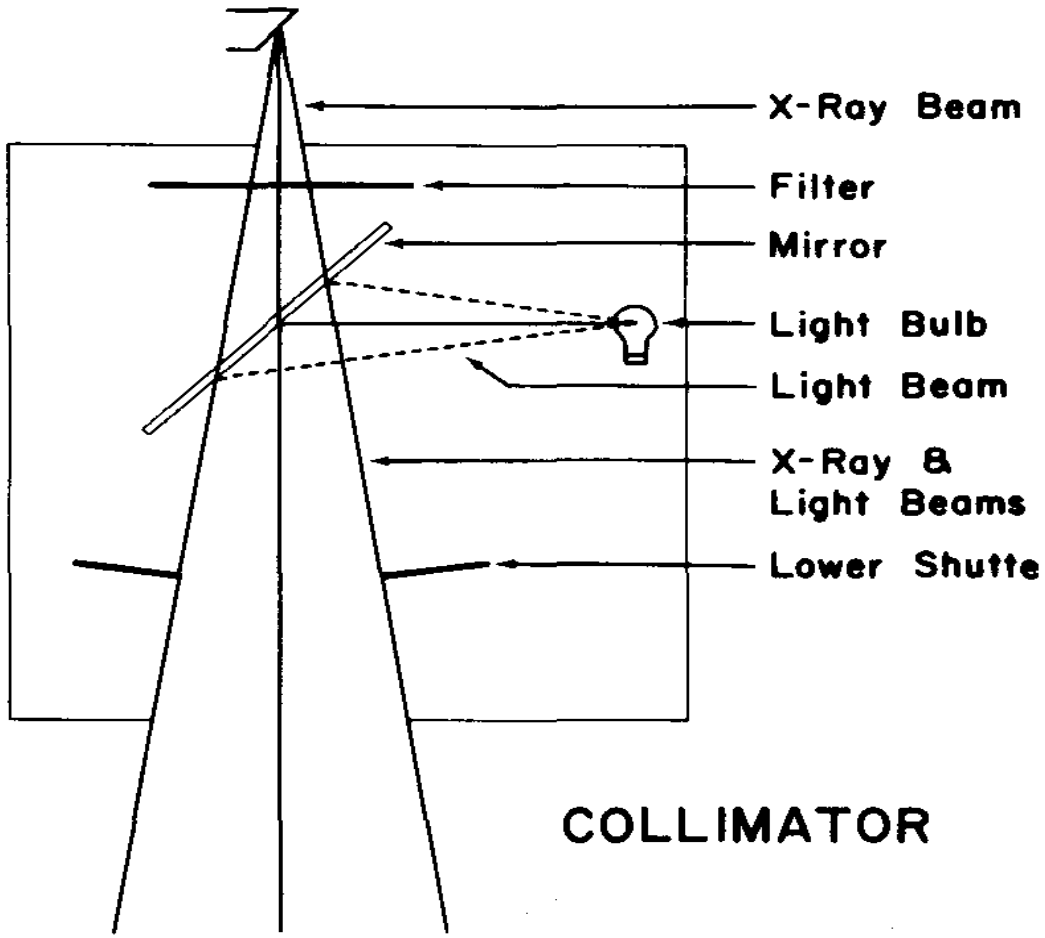
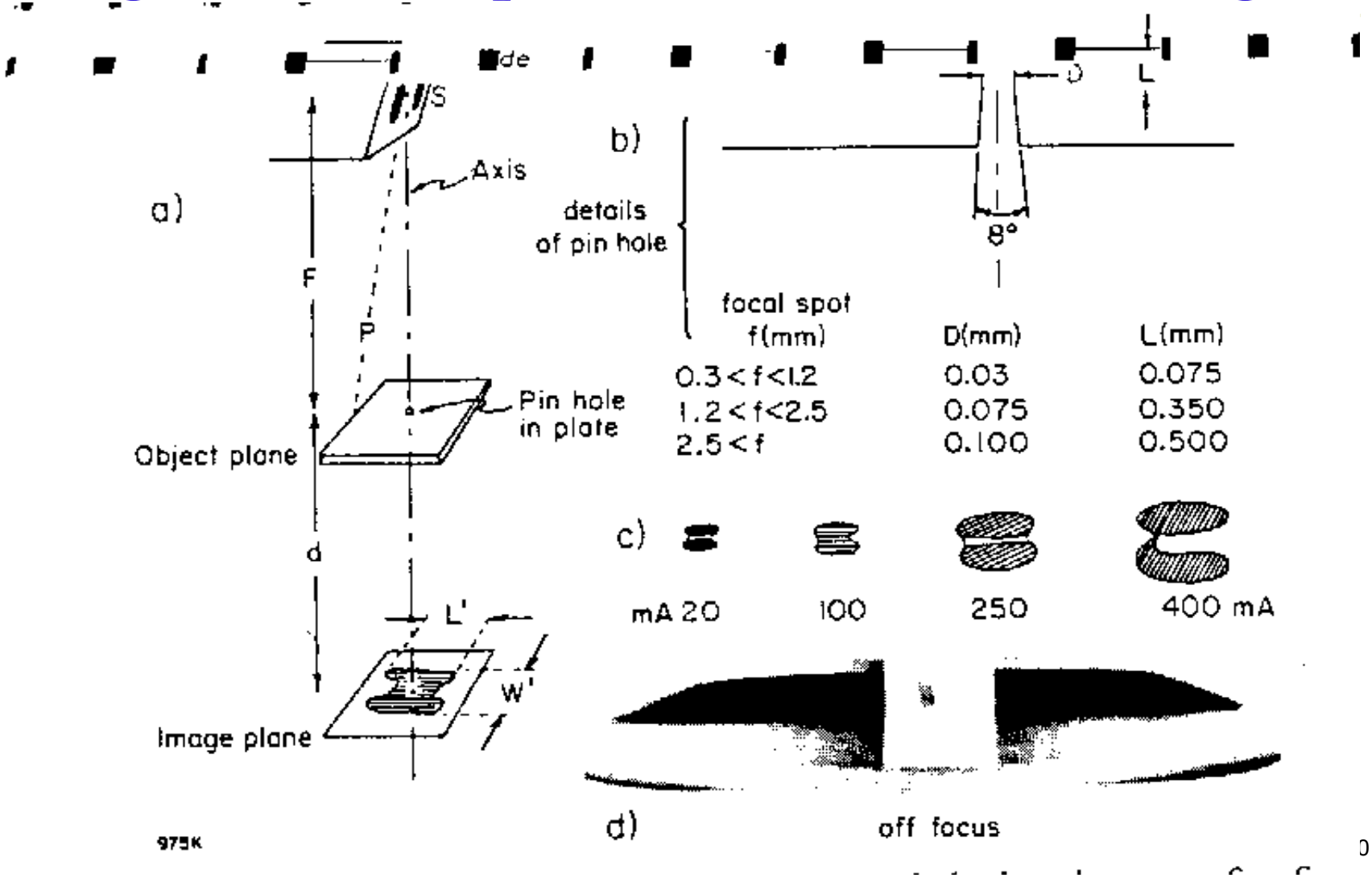


Figure 7–4 Alignment of light and x-ray beams

Change of focal spot size with tube loading



A schematic of the high-voltage cathode-anode circuit.

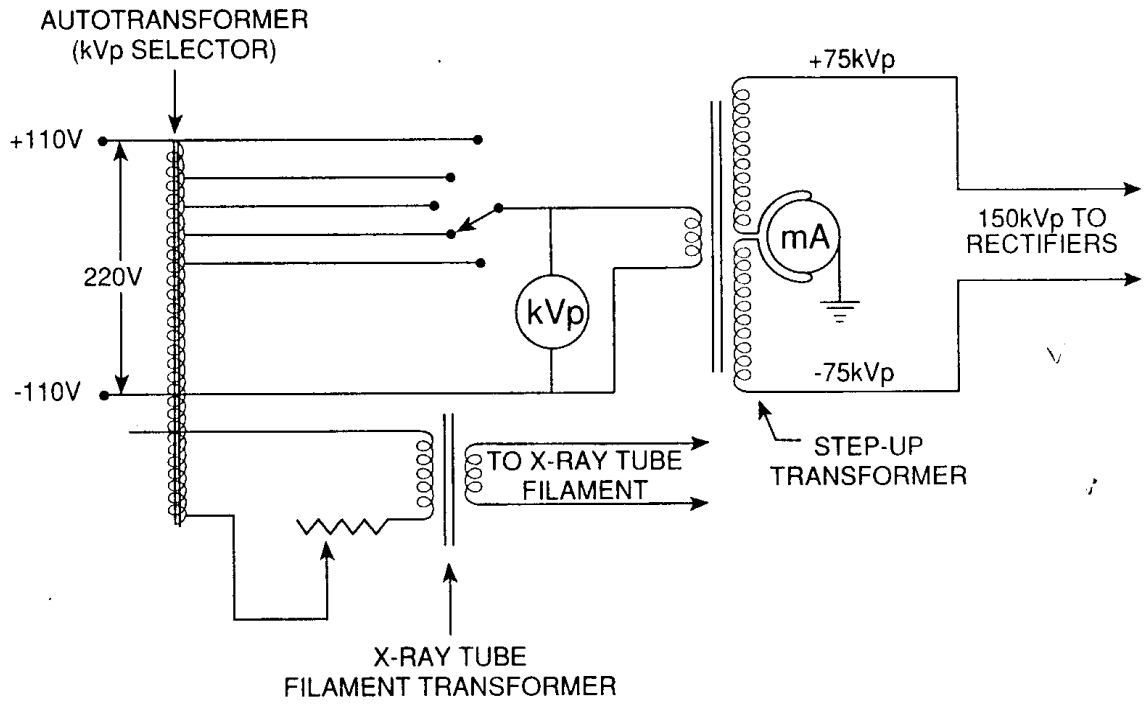


Figure 3–5 High-voltage (cathode-anode) circuit and x-ray tube filament circuit

Ripple factor: The variation in the voltage across the x-ray tube expressed as a percentage of the maximum value.

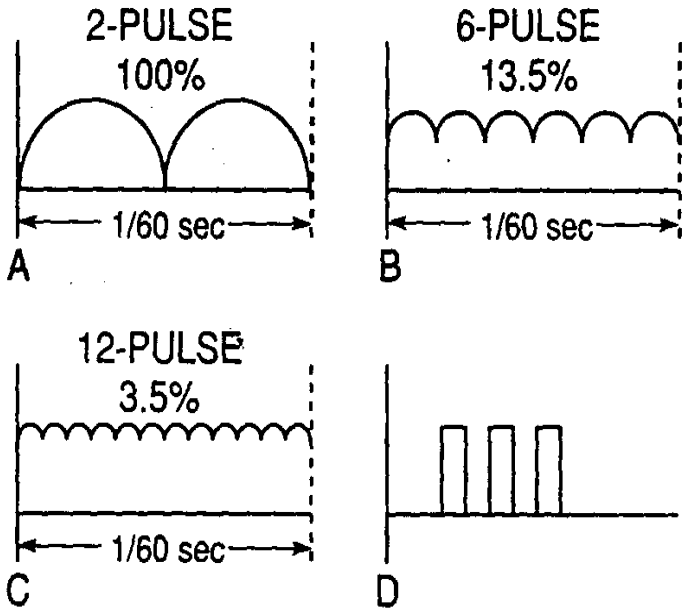


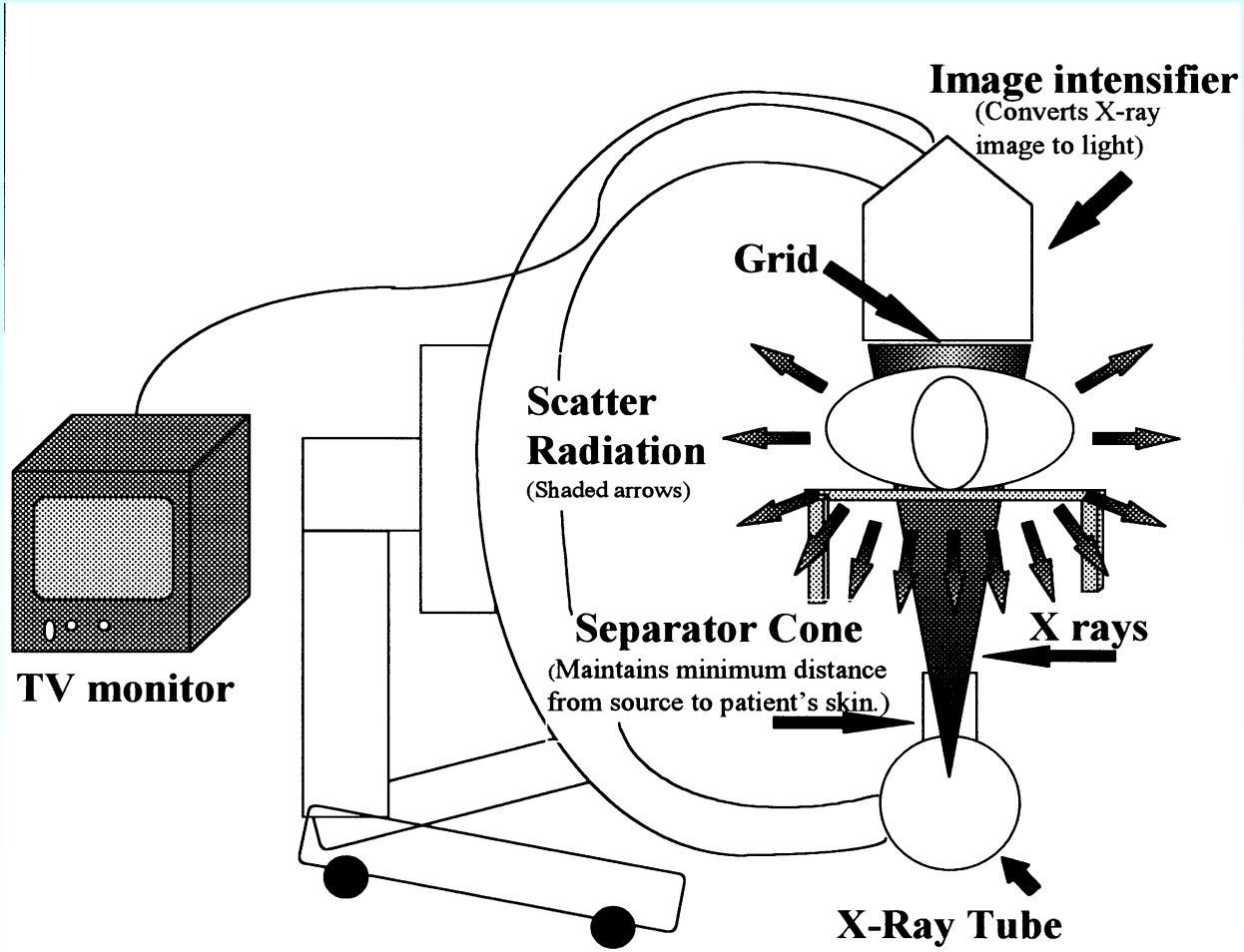
Figure 3–22 The ripple factor in single-phase two-pulse (*A*), three-phase six-pulse (*B*), and three-phase twelve-pulse (*C*) circuits. (*D*) Chopped DC

Full-wave rectification better

Three-phase full wave (6 phase) rectification- better still.

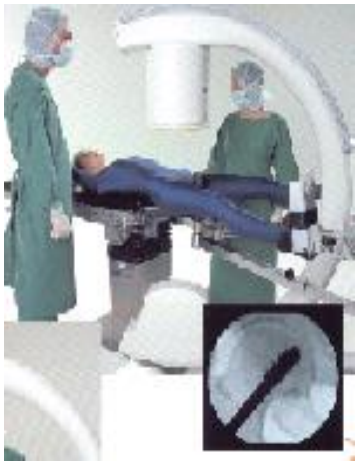
Three-phase full wave (12 phase) rectification- Closer to DC field.

Fluoroscopy system



Different fluoroscopy systems

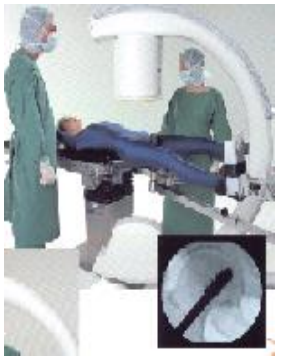
- **Remote control systems**
  - Not requiring the presence of medical specialists inside the X-ray room
- **Mobile C-arms**
  - Mostly used in surgical theatres.



Different fluoroscopy systems

- **Interventional radiology systems**
  - Requiring specific safety considerations.

    Interventionalists can be near the patient during the procedure.



- **Multipurpose fluoroscopy systems**
  - They can be used as a remote control system or as a system to perform simple interventional procedures

Two types of Fluoroscopy are:

- ***under-couch tube design***
- ***over-couch tube design***
- ***Over-couch tube design offers a greater distance between tube and both patient and intensifier.***
  - ***This improves image quality by reducing geometric unsharpness and reduces radiation skin dose to the patient.***
- ***Under-couch tube design provides direct fluoroscopy screen and therefor allows operator to be close to the patient.***

Image Intensifier component and parameters

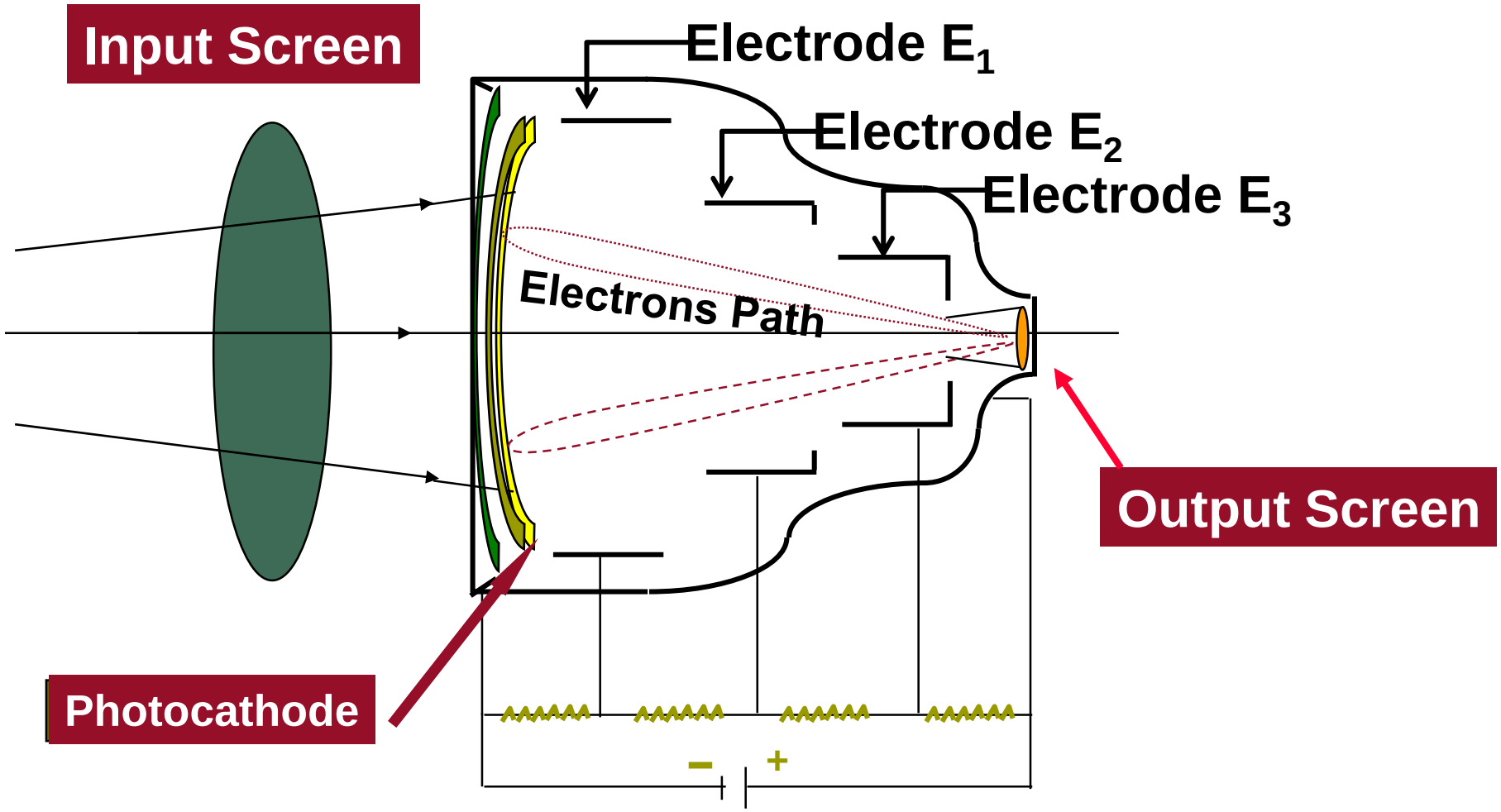

Input Screen
Electrode E_1
Electrode E_2
Electrode E_3
Electrons Path
Output Screen
Photocathode
–
+

Image intensifier systems

Image intensifier component

- **Input screen**: conversion of incident X-rays into light photons (CsI) ***Sodiun- activated caesium iodide***
  - **1 X-ray photon creates ≈ 3,000 light photons**
- **Photocathode**: conversion of light photons into electrons

  Caesium* or *antimony
  - **only 10 to 20% of light photons are converted into photoelectrons**
- **Electrodes** : focalization of electrons onto the output screen
  - **electrodes provide the electronic magnification**
- **Output screen**: conversion of accelerated electrons into light photons; ***Zinc Cadmium Sulphide***

Image intensifier parameters (I)

- **Conversion coefficient** (**Gx**): the ratio of the output screen brightness to the input screen dose rate [$cd.m^{-2}\mu Gys^{-1}$]
  - Gx depends on the quality of the incident beam (IEC publication 573 recommends HVL of 7 ± 0.2 mm Al)
  - Gx is directly proportional to:
    - **the applied tube potential**
    - **the diameter (ϕ) of the input screen**
      - **input screen of 22 cm ➔ Gx = 200**
      - **input screen of 16 cm ➔ Gx = 200 x $(16/22)^2$ = 105**
      - **input screen of 11 cm ➔ Gx = 200 x $(11/22)^2$ = 50**

Image intensifier parameters (II)

- **Brightness Uniformity**: the input screen brightness may vary from the center of the I.I. to the periphery

Uniformity = $(Brightness_{(c)} - Brightness_{(p)}) \times 100 / Brightness_{(c)}$

- **Geometrical distortion**: all x-ray image intensifiers exhibit some degree of pincushion distortion. This is usually caused by either magnetic contamination of the image tube or the installation of the intensifier in a strong magnetic environment.

Image distortion

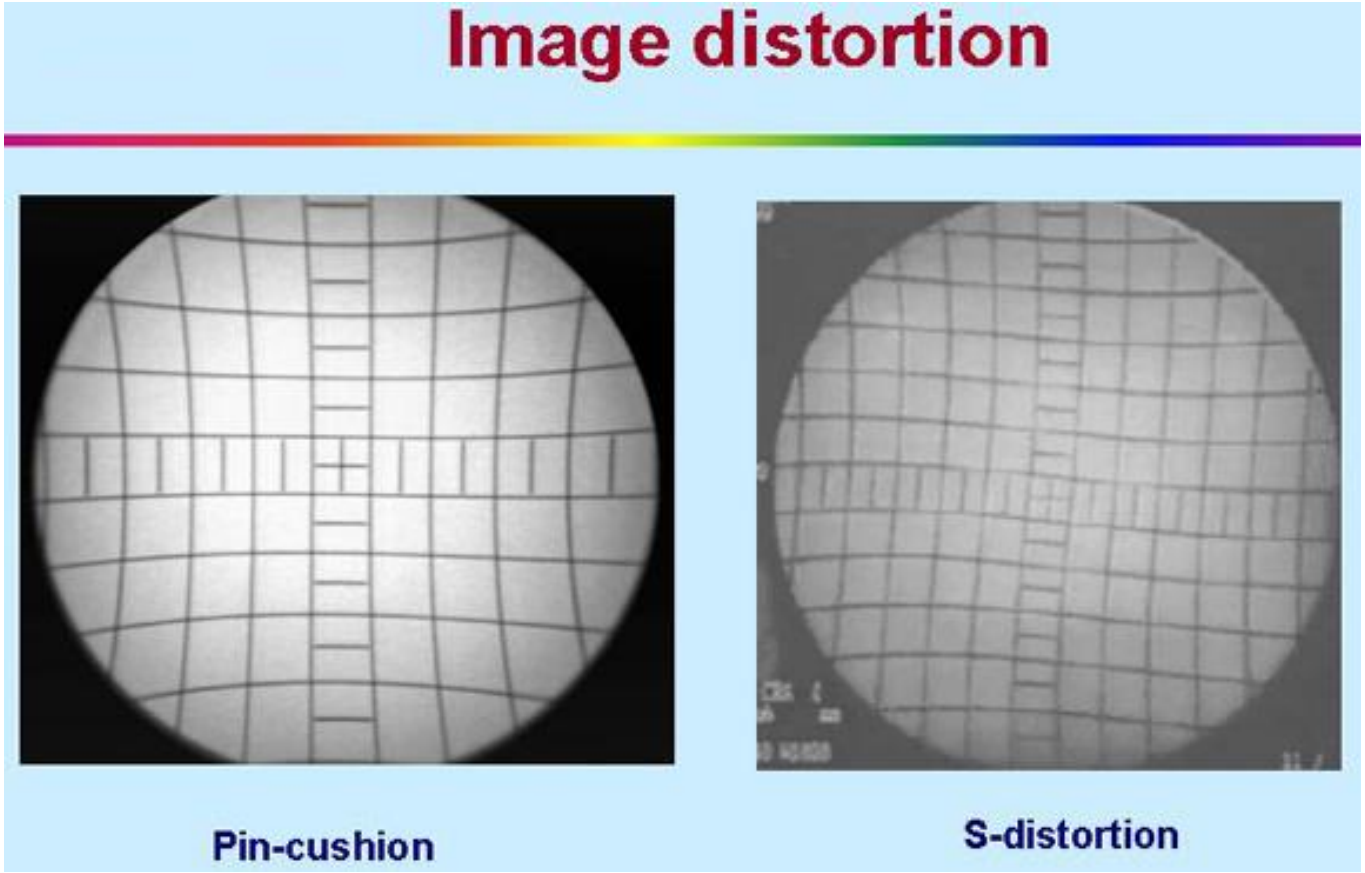


Image intensifier parameters (III)

- **Spatial resolution limit**:
- It provides a sensitive measure of the state of focusing of a system
  - it is quoted by manufacturer
  - it can be measured optically
  - it correlates well with the high frequency limit of the Modulation Transfer Function (MTF)
  - it can be assessed by the Hüttner resolution pattern

Line pair gauges

GOOD RESOLUTION POOR RESOLUTION

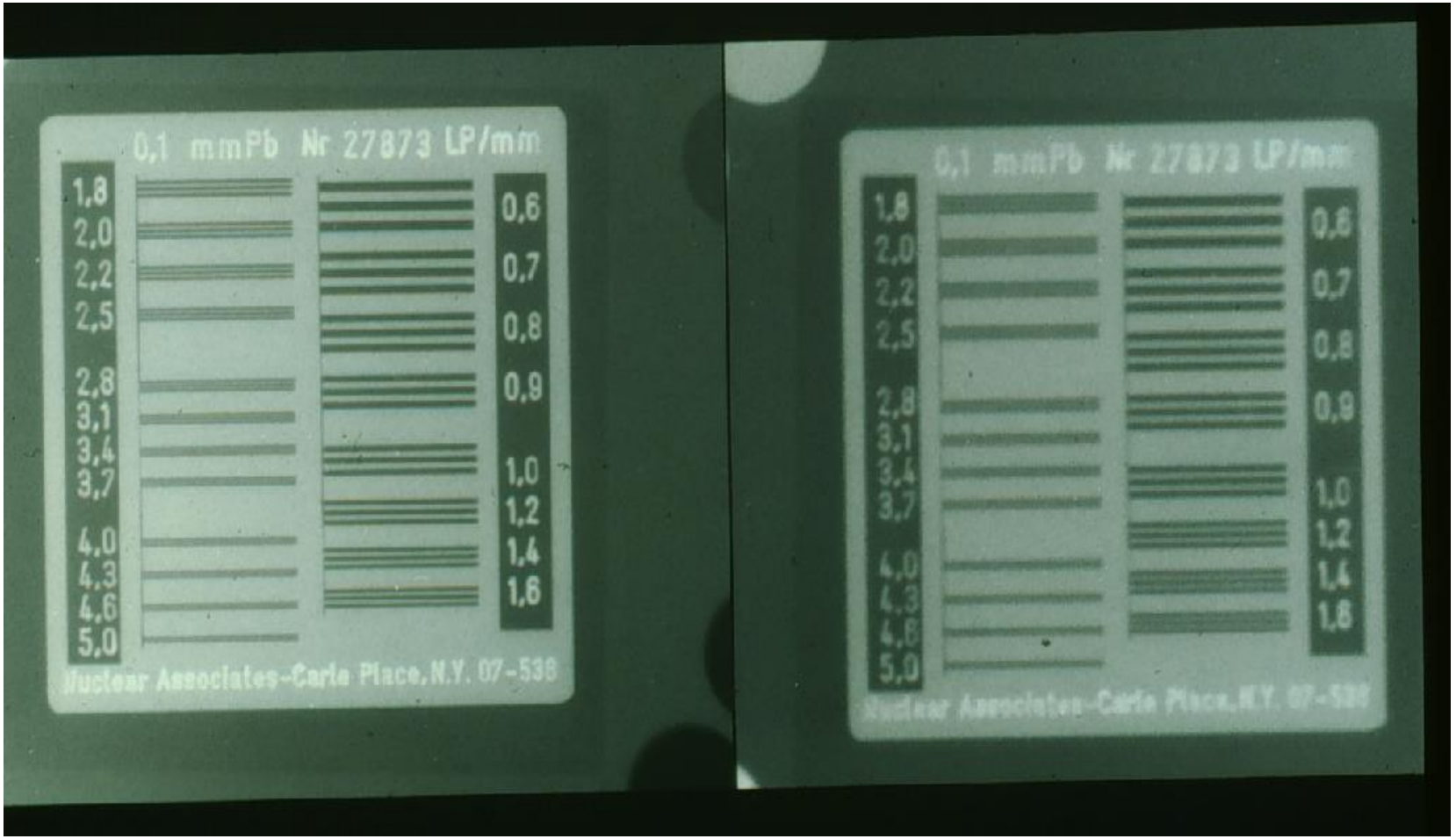


Image intensifier parameters (IV)

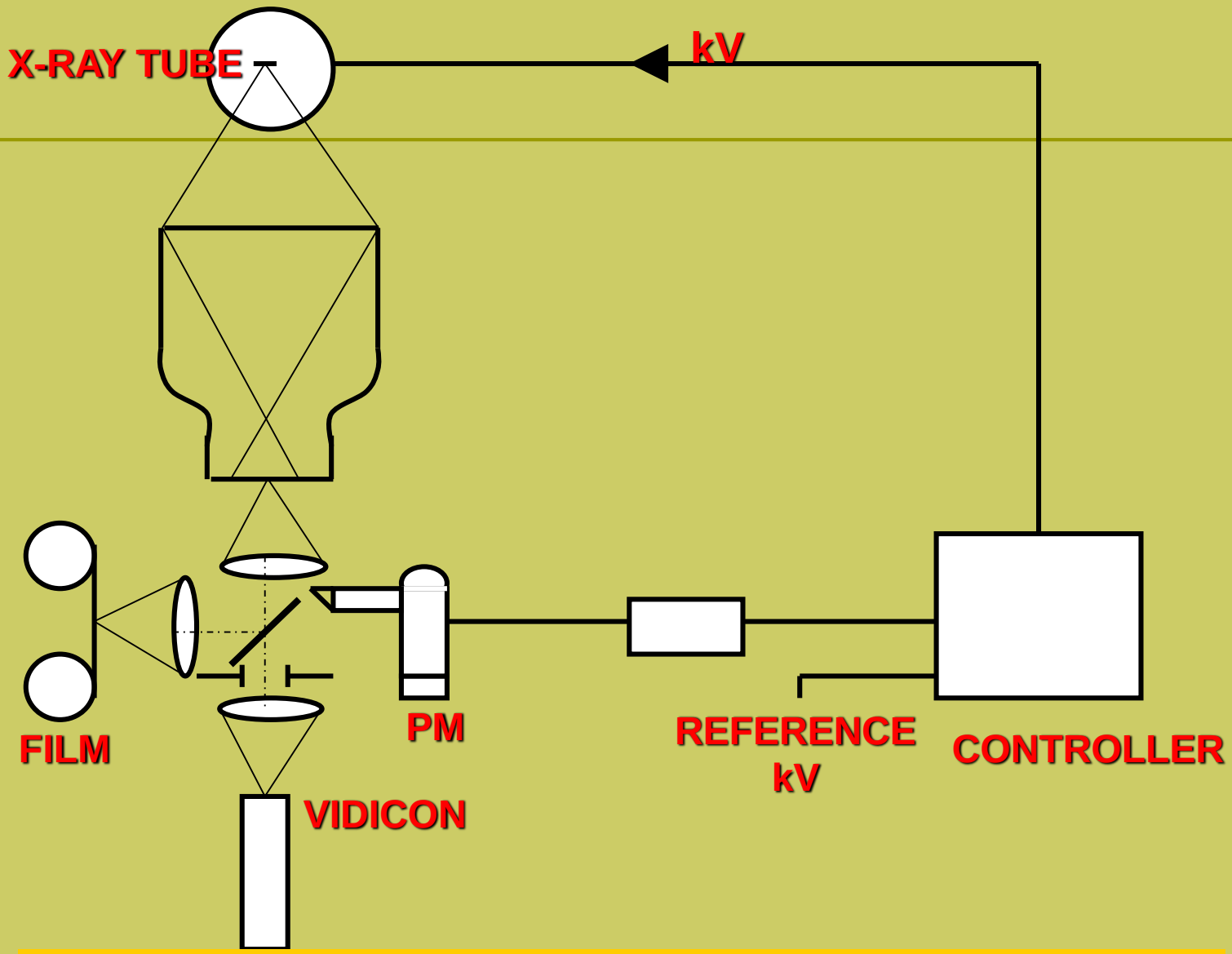
- **Overall image quality:**

  threshold contrast-detail detection

- X-ray, electrons and light scatter process in an I.I. can result in a significant loss of contrast of radiological detail.
- The degree of contrast is effected by the design of the image tube and coupling optics.
  - **Spurious sources of contrast loss are:**
    - accumulation of dust and dirt on the various optical surfaces
    - reduction in the quality of the vacuum
    - aging process (destruction of phosphor screen)
  - **Sources of noise are:**
    - X-ray quantum mottle
    - photo-conversion processes

Image intensifier - TV system

- Output screen image can be transferred to different optical displaying systems:
  - **conventional TV**
    - Generating a full frame of 525 lines (in USA)
    - 625 lines and 25 full frames/s up to 1000 lines (in Europe)
    - interlaced mode is used to prevent flickering
  - **cinema**
    - 35 mm film format: from 25 to 150 images/s
  - **photography**
    - rolled film of 105 mm: max 6 images/s
    - film of 100 mm x 100 mm

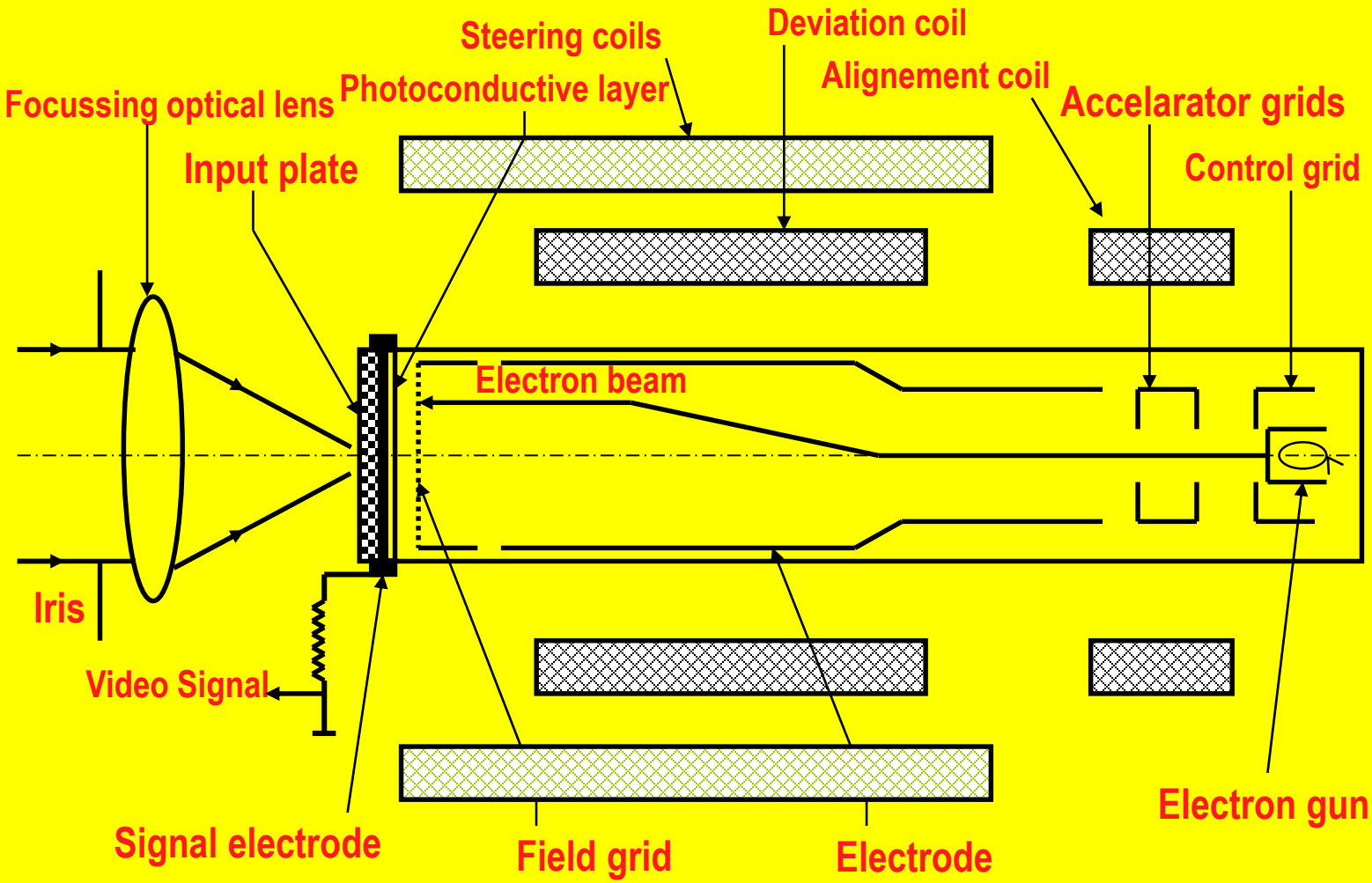


GENERAL SCHEME OF FLUOROSCOPY

Type of TV camera

- **VIDICON TV** camera
  - (antimony trisulphide)
  - improvement of contrast
  - improvement of signal to noise ratio
  - high image lag
- **PLUMBICON TV** camera (suitable for cardiology)
  - lead oxide
  - lower image lag (follow up of organ motions)
  - higher quantum noise level
- **CCD TV** camera (digital fluoroscopy)
  - digital fluoroscopy spot films are limited in resolution, since they depend on the TV camera (no better than about 2 lp/mm) for a 1000 line TV system

Photoconductive camera tube



TV camera and video signal

- یک نوع دوربین مورد استفاده در سیستم فلورسکوپی ***Vidicon*** نامیده می شود که از شیشه خلأ بـه قـطـــر ۲ تا ۳ سانتی متر و طول ۱۰ تا ۲۰ سانتی متر تشکیل شده است.
- **صفحه ورودی دوربین از سه لایه تشکیل شده است:**
- ۱- لایه خارجی از شیشه که محافظت را بعهده دارد.
- ۲- داخل شیشه از لایه ای از ***Zinc oxide*** پوشانده شده، هادی الکتریکی شفاف ***(Transparent)*** می باشد لذا اجازه می دهد نور به لایه سوم منتقل شود. این لایه ***Signal electrod*** نام دارد.
- ۳- لایه داخل موزائیکی به صورت میلیون ها سلول فتوالکتریک کوچک (***Antimony TriSulphide***) که هدایت الکترون را نسبت به افزایش نور افزایش می دهد (***Photoconductor***).

TV camera and video signal

- طرف دیگر دوربین تفنگ الکترونی است که از فیلامان، گرید و الکترود شتابدهنده تشکیل شده است.
- فیلامان براساس حرارت تولید الکترون می کند.
- گرید کنترل میزان جریان الکترون را فراهم می کند.
- الکترود شتابدهنده دارای سوراخی در مرکز است که الکترون ها از وسط آن عبور کرده و شتاب میگیرند (با ۲۰ تا ۶۰ ولت).
- الکترون های حاصل از تفنگ تحت اثر فیلد های الکتریکی نزدیک تیوب دوربین باعث حرکات افقی و عمودی منظم (***Scanning***) شده تا میدان مستطیلی صفحهٔ حساس ***Photoconductor*** را بپوشاند (نام میدان ***Raster*** است).

TV camera and video signal (IV)

- In a typical television system, on the first pass the set of **odd** numbered lines are scanned followed by the **even** numbers (**interlaced**).

- The purpose of interlacing is **to prevent flickering** of the television image on the monitor, by increasing the apparent frequency of frames (50 half frames/second).

- **In Europe, 25 frames are updated every second**.

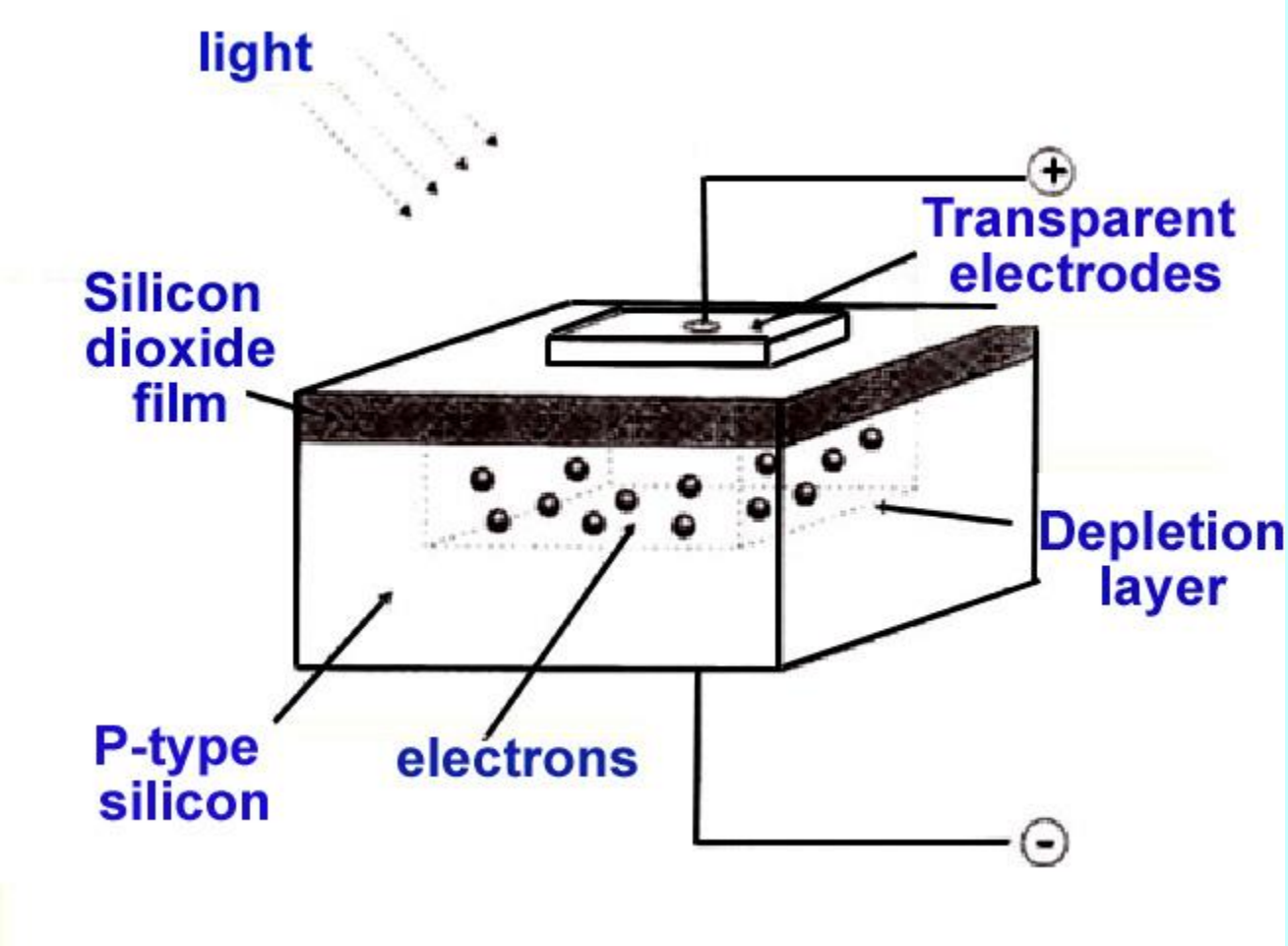
TV camera and Monitor (V)

- The video signal comprises a set of **repetitive synchronizing pulses**. In between there is a signal that is produced by the light falling on the camera surface.
- The synchronizing voltage is used to trigger the TV system to begin sweeping across a raster line.
- Another voltage pulse is used to trigger the system to start rescanning the television field.
- A series of electronic circuits move the scanning beams of the TV camera and monitor in synchronism.
- The current, which flows down the scanning beam in the TV monitor, is related to that in the TV camera.
- Consequently, the brightness of the image on the TV monitor is proportional to the amount of light falling on the corresponding position on the TV camera.

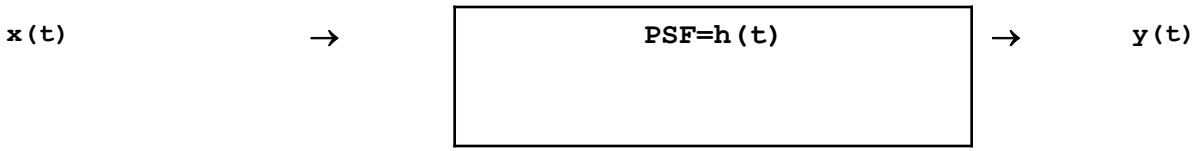
TV camera and video signal (CCD)

- Many modern fluoroscopy systems used CCD (charge coupled devices) TV cameras.
- The front surface is **a mosaic of detectors** from which a signal is derived.

Schematic structure of a charged couple device (CCD)



Linear system



$$y(t) = \int_{-\infty}^{+\infty} h(t-\tau)\, x(\tau)\, d\tau$$

Exmaple of System Components in a Medical Imaging system

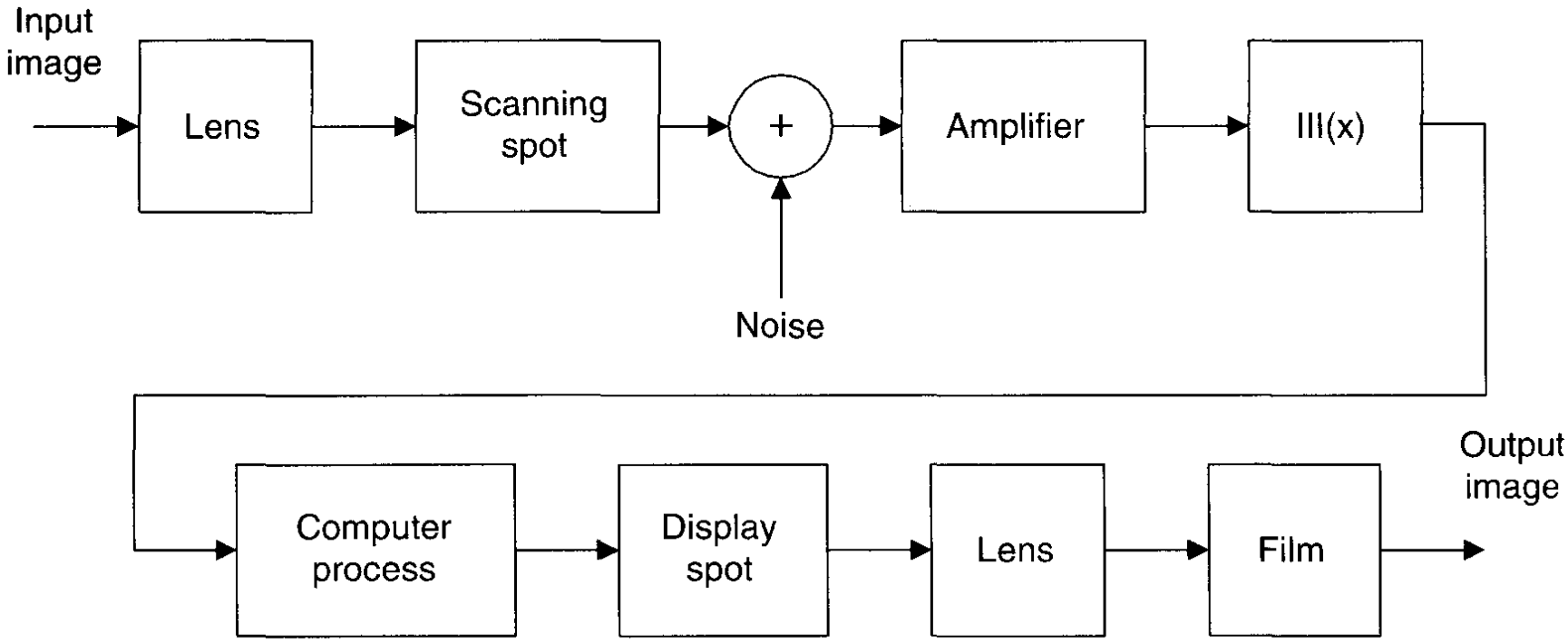


Figure 15–12 The elements of an image processing system

Where to Get More Information

- Physics of diagnostic radiology, Curry et al, Lea & Febiger, 1990
- Imaging systems in medical diagnostics, Krestel ed., Siemens, 1990
- The physics of diagnostic imaging, Dowsett et al, Chapman&Hall, 1998