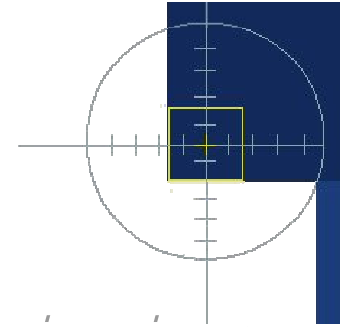


# Amorphous Silicon Pixel Detectors for Radiography

**Gerhard Roos**

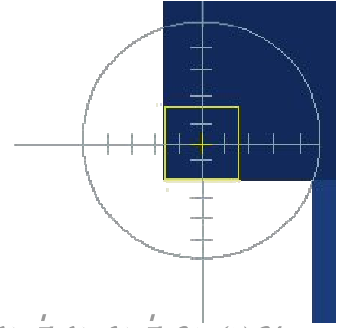
*Varian Imaging Products*



# *Amorphous Silicon Flat Panel Image Detectors*

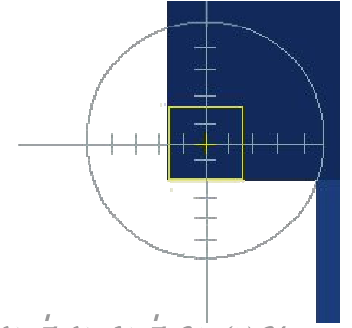
## Presentation Outline

- **Background**
- **Operation**
- **Typical Specifications**
- **Current Applications and Trends**



*Amorphous Silicon Flat Panel Image Detectors*

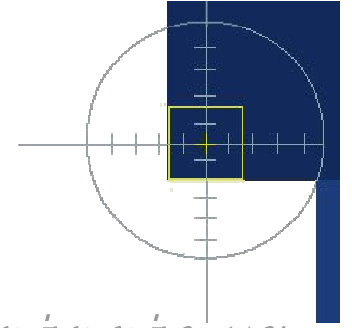
# Background



## *Amorphous Silicon Flat Panel Image Detectors*

### Definition

- **Large area integrating image detectors**
- **Deposition of amorphous silicon structures on glass**
- **Inverse flat panel display**
- **Mostly used for medical radiographic imaging**



## *Amorphous Silicon Flat Panel Image Detectors*

### Flat Panel History

#### **1985 to 90 – Theoretical studies and early research**

-Xerox PARC, Varian, GE, Thomson, Philips, U. Mich. etc.

#### **1991 – First small area functional prototypes**

#### **1993 – First full size (40 x 64 cm) prototypes**

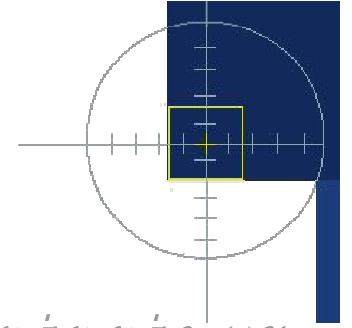
#### **1997 – First commercial products announced**

#### **1998 – First production shipments**

#### **1998 – Cone Beam CT application published**

#### **2003 – First commercial CBCT products**

#### **2006 – Annual volume >8000 imagers**



## *Amorphous Silicon Flat Panel Image Detectors*

**a-Si as image detector**

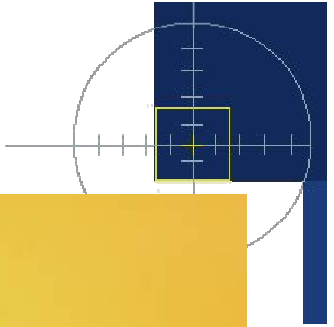
### **Advantages:**

- **Low cost per area, large area per device**
- **Radiation hard**
- **Good quantum efficiency**

### **Disadvantages:**

- **Time response**
- **Uniformity**
- **Simple, relatively large pixel structures only**
- **Complex system implementation**

# PaxScan 4030 Imager



## Receptor:

14" x 16" x 1.5"- 2.5"  
Fiber-optic data cable  
24V dc power cable  
Passive cooling

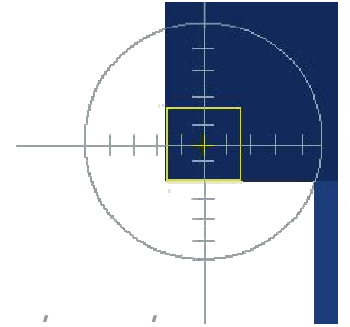
## Command Processor:

10" x 11" x 2.5"  
Real-time normalization  
Recursive filter  
Frame accumulation  
X-ray generator control signals  
16 bit digital video output



## Power Supply:

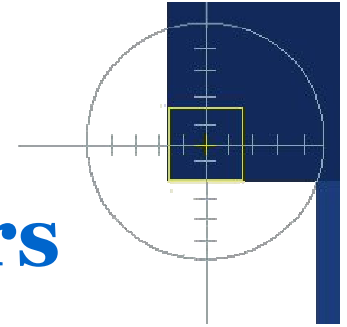
10" x 11" x 2.75"  
5V/10A, 24V/3A



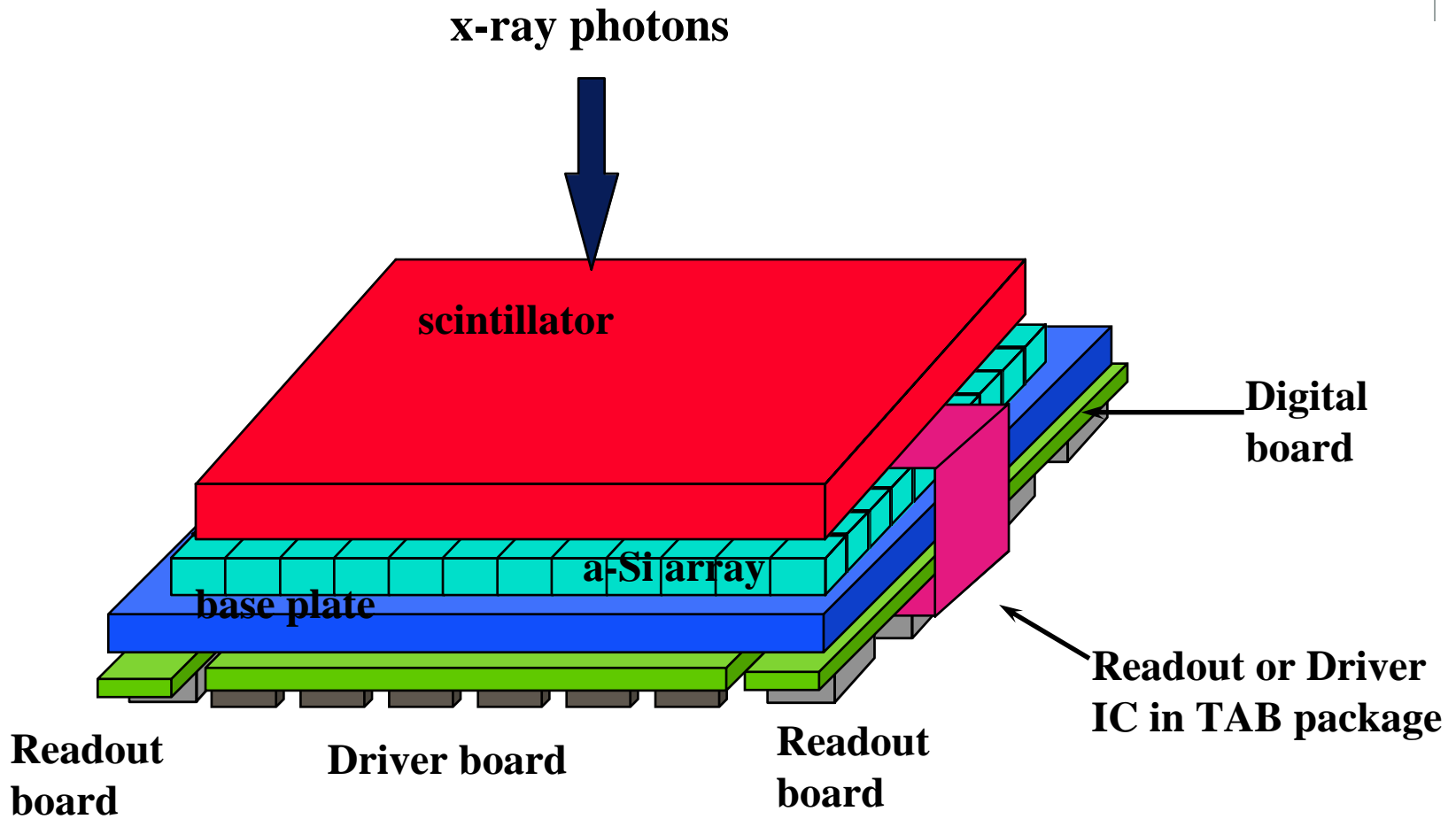
*Amorphous Silicon Flat Panel Image Detectors*

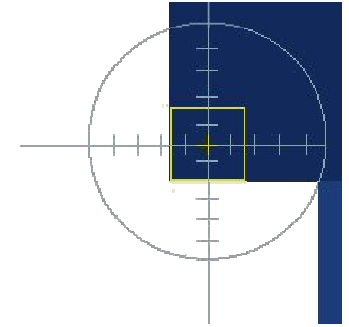
# Operation



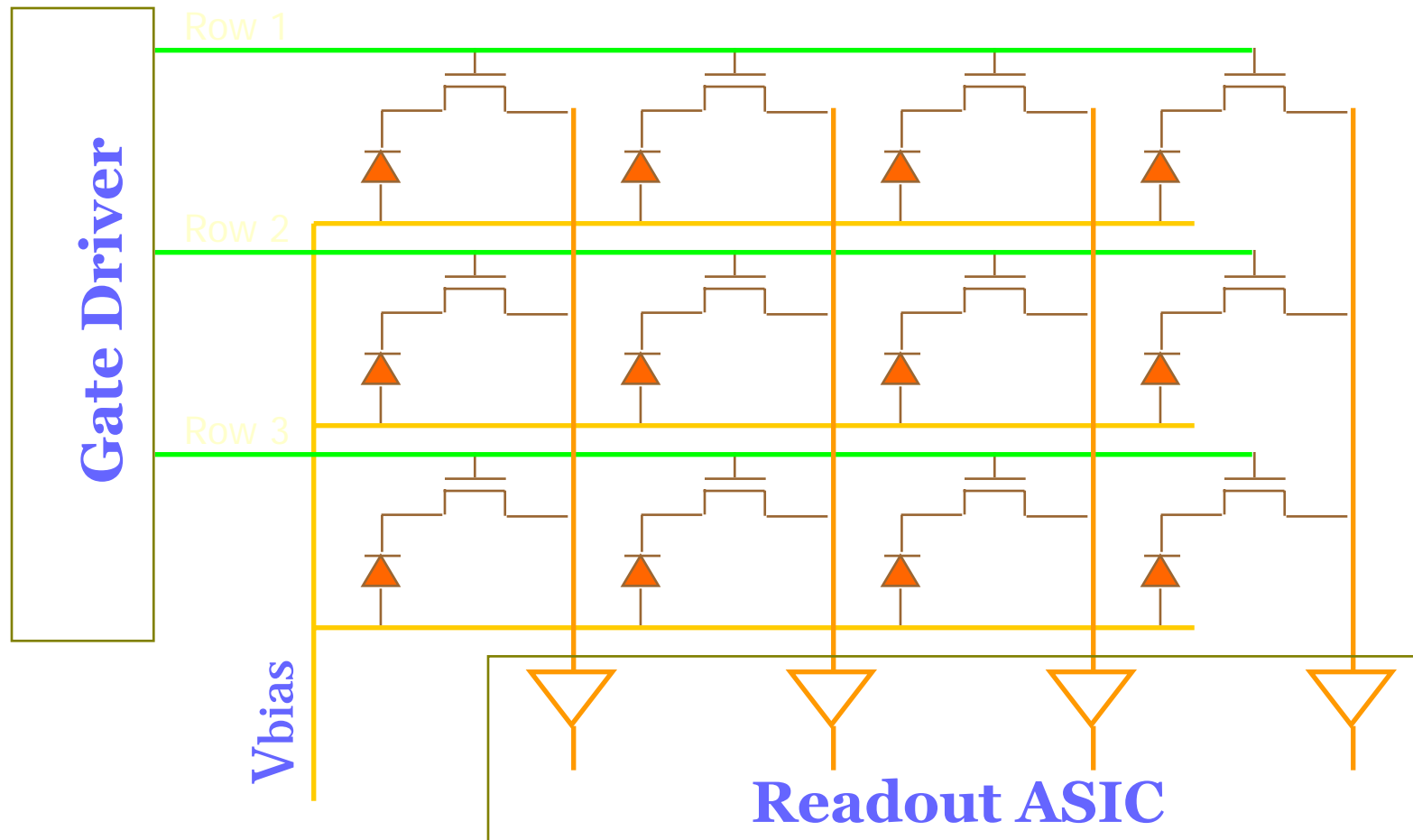


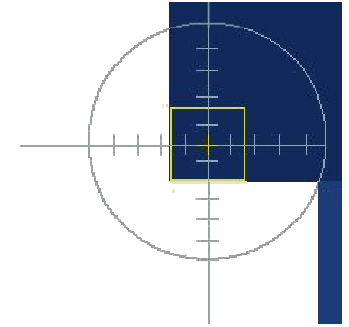
# Indirect Conversion Imagers



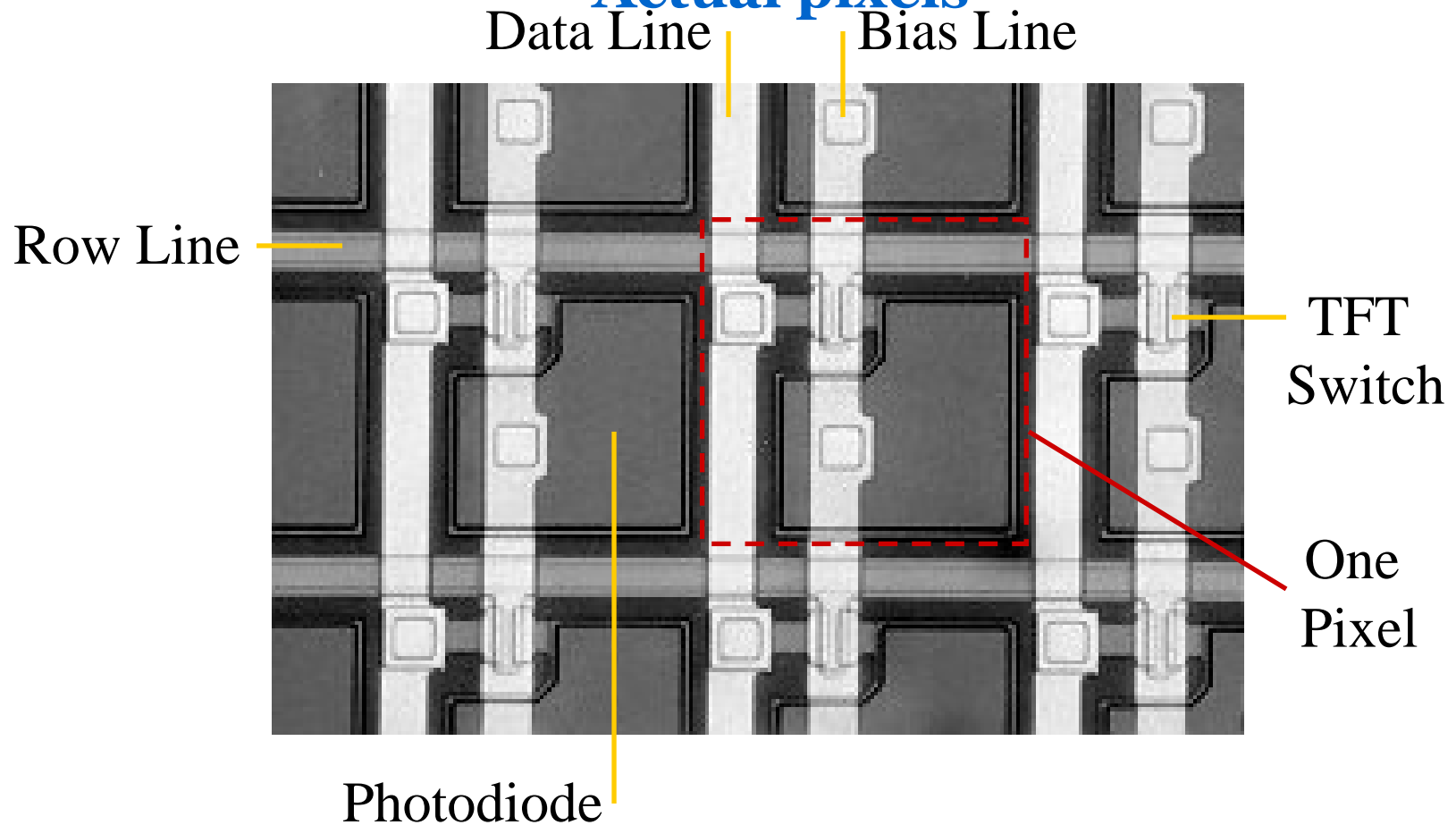


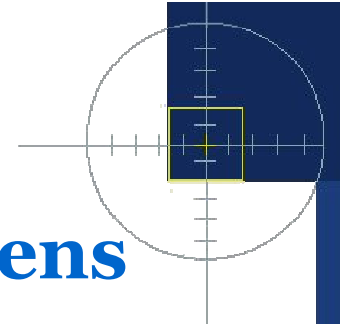
## Indirect Conversion Imagers - Sensor Schematic





# Indirect Conversion Imagers - Actual pixels



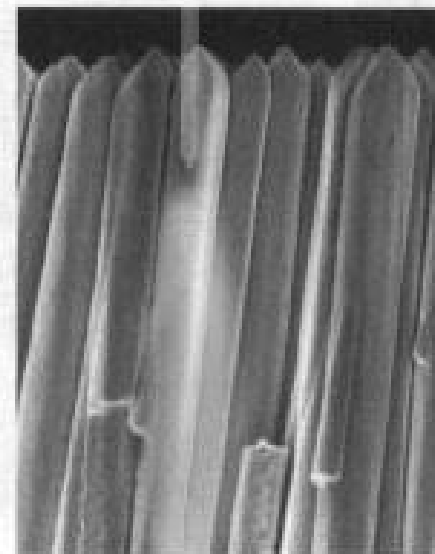


# Commonly Used Scintillator Screens

Phosphor

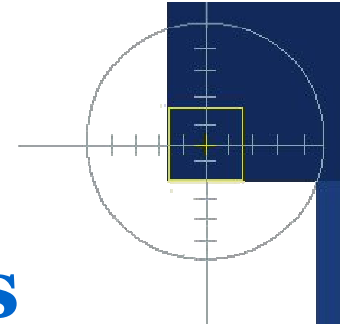
Cesium Iodide

Layer  
Structure



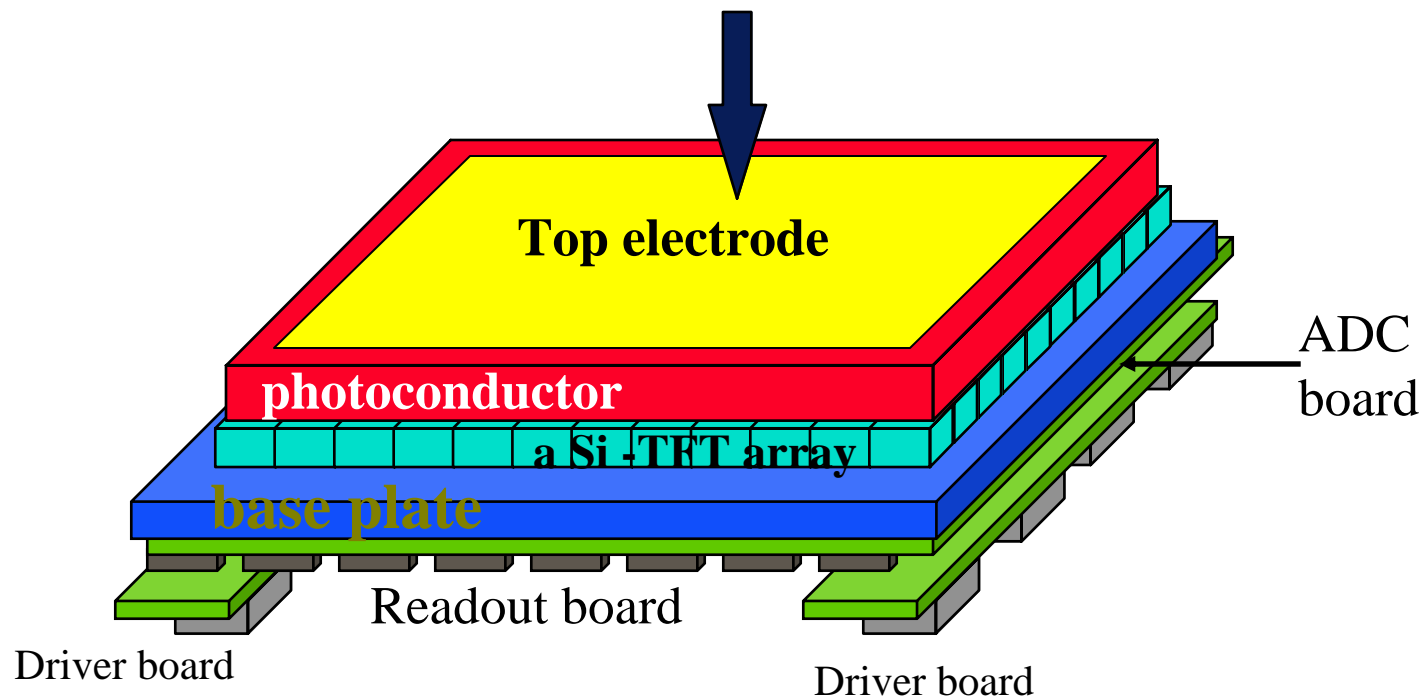
Light  
Spreading

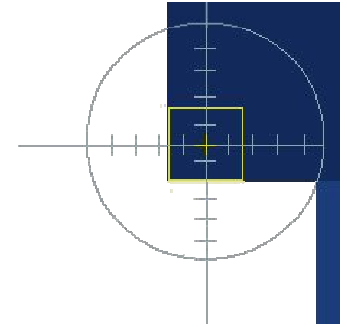




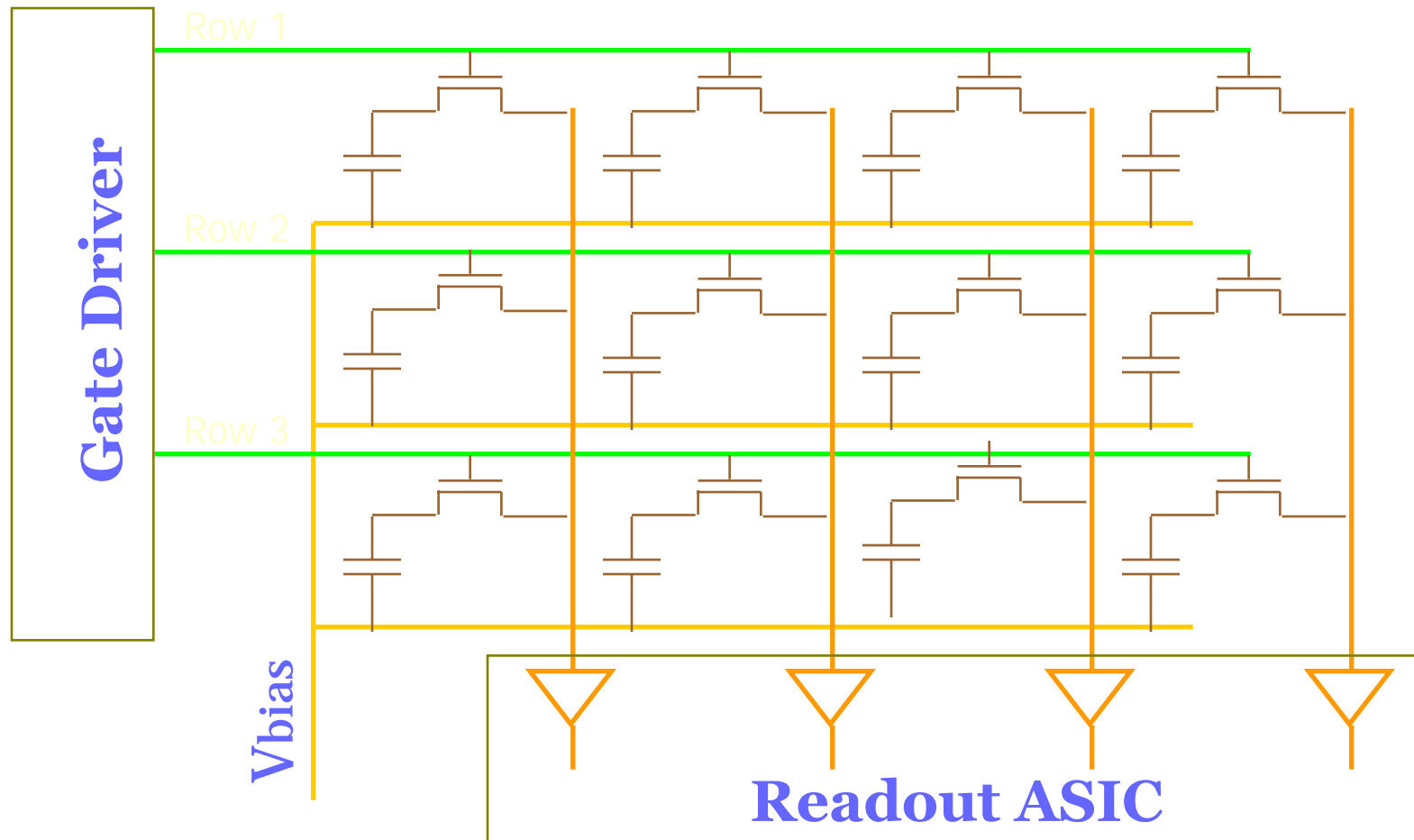
# Direct Conversion Imagers

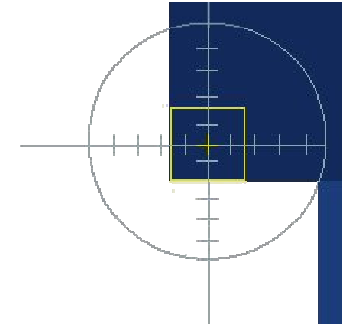
x-ray photons





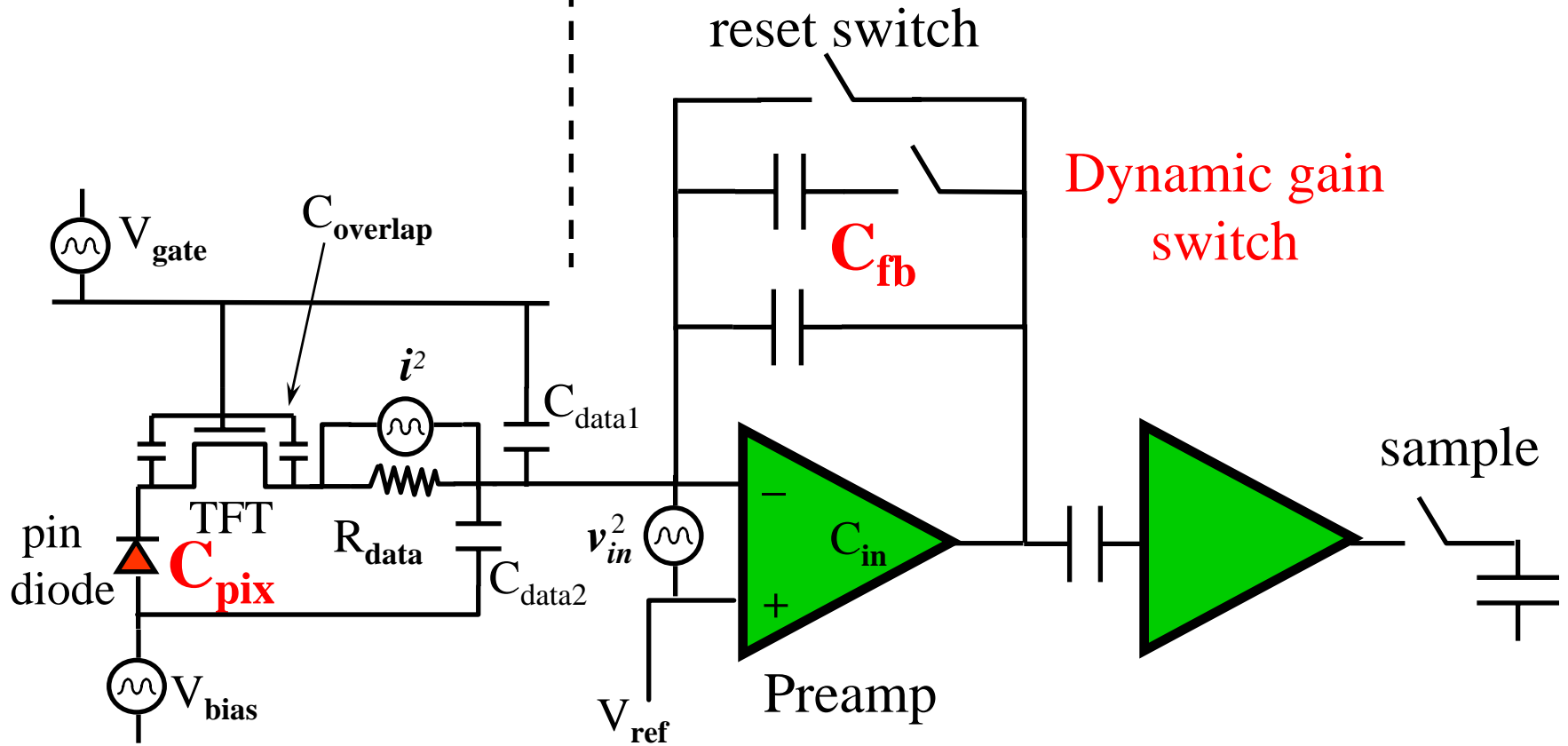
## Direct Conversion Imagers - Sensor Schematic

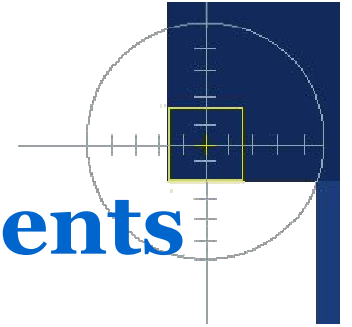




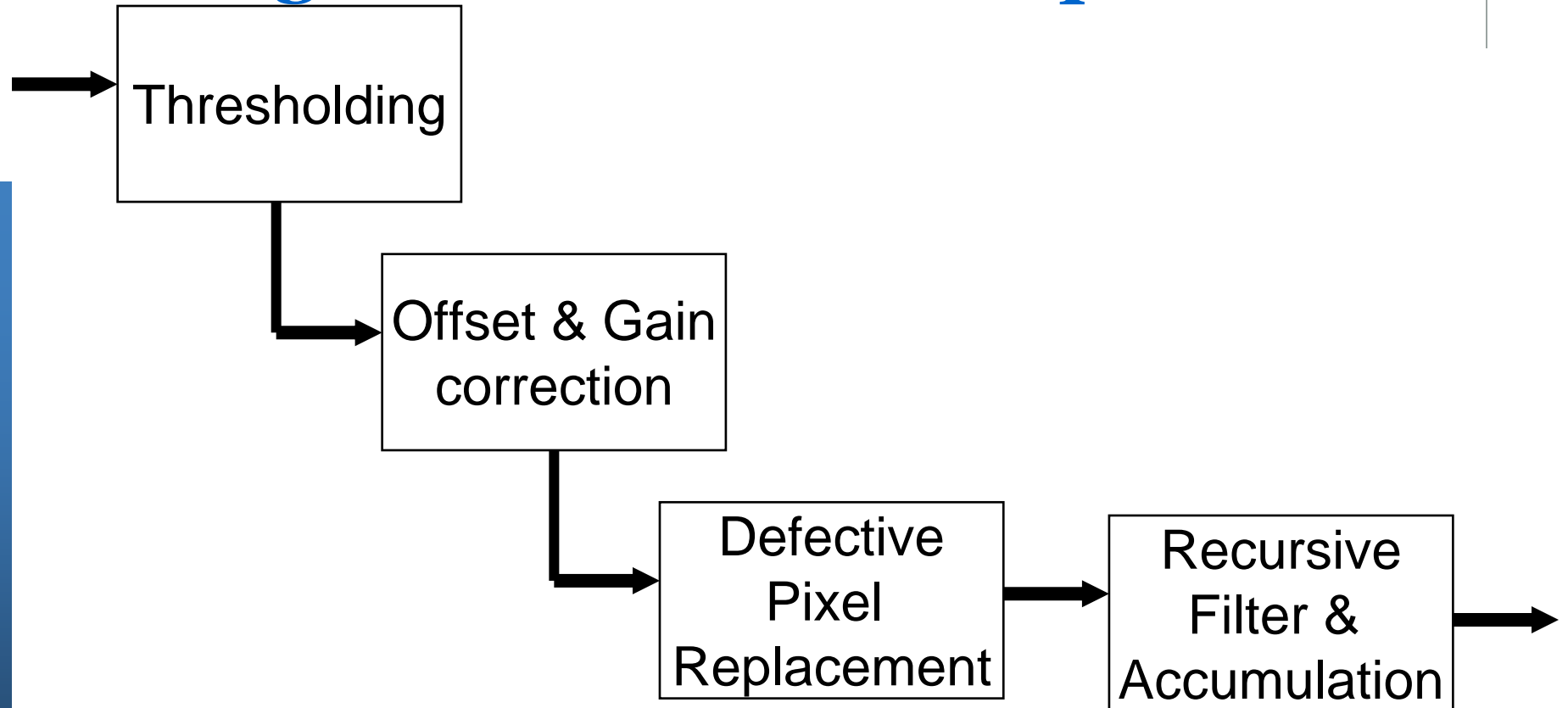
# Typical signal readout

a-Si array ← readout chip

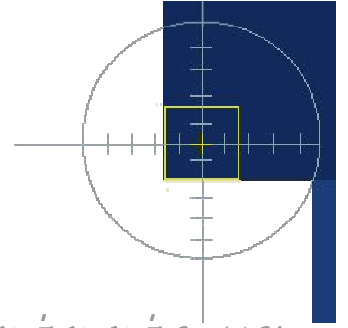




# Image Normalization Requirements

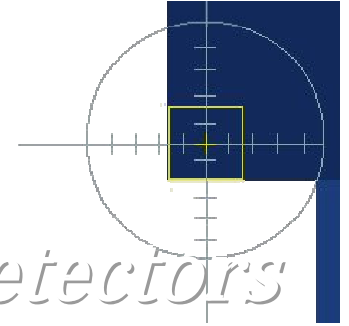






*Amorphous Silicon Flat Panel Image Detectors*

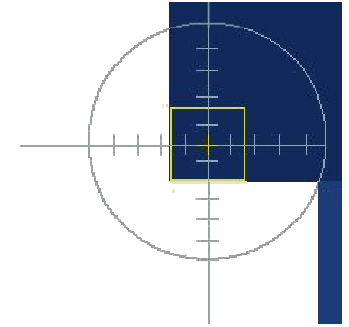
# Specifications



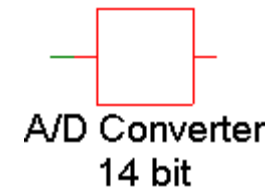
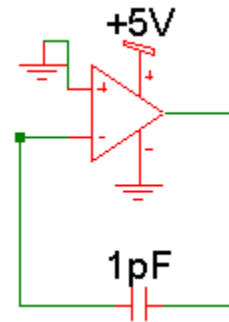
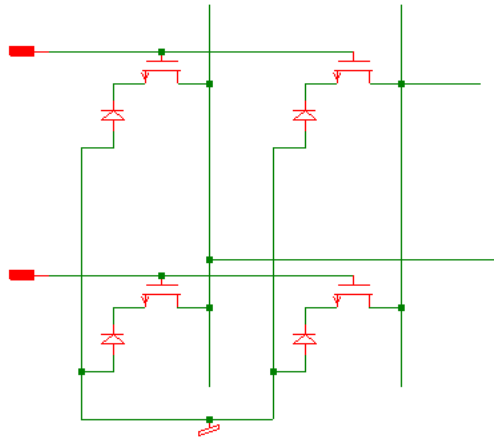
## *Amorphous Silicon Flat Panel Image Detectors*

### **Typical Specifications for Medical Flat Panels**

- **Entrance exposure: 5 nGy/frame to 50  $\mu$ Gy/frame**
- **High exposure DQE:**
  - ◆ **Diagnostic ~70% at 80 kV and ~40% at 125 kV**
  - ◆ **Therapy Portal Imaging ~2% at 6MV**
- **Photodiode quantum efficiency: ~80% (500 to 600 nm)**
- **Spatial resolution (10% MTF): 3.5 to 10 lp/min**
- **12 to 17 bit A/D conversion**
- **Pixel time constant ( $C_{\text{pix}} \times R_{\text{TFT}}$ ): 1 to 10  $\mu$ s**
- **Pixel size: 65  $\mu$ m to 500  $\mu$ m**
- **Pixel capacity: 0.5 to 50 pC**
- **Readout rate: >32  $\mu$ s/line; 0.1 to 100 frames per second**
- **Dark current: <1 pA/mm<sup>2</sup>**
- **Active area: 200 x 200 mm to 430 x 430 mm**



## Flat panel dynamic range



### ➤ Flat panel

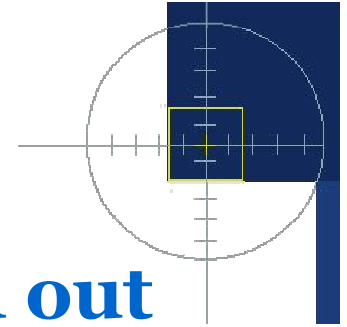
- ◆ noise  $\sim 1000 \bar{e}$
- ◆ Saturation  $\sim 60M \bar{e}$
- ◆ 60k range at 1x1
- ◆ 120k range at 2x2

### ➤ Charge amplifier

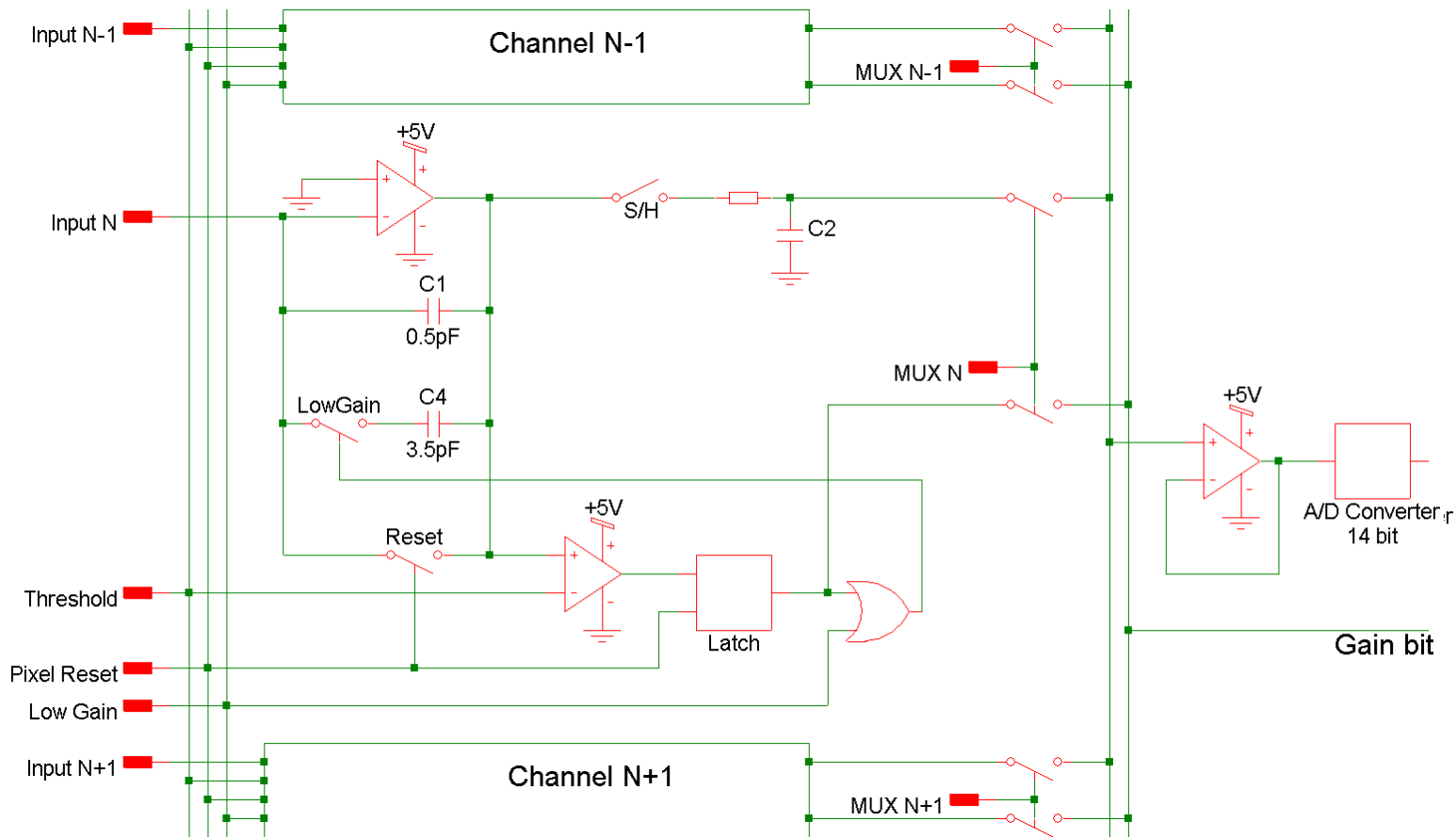
- ◆ noise  $\sim 1700 \bar{e}$
- ◆ Saturation  $\sim 12M \bar{e}$
- ◆ 7k range at 1x1
- ◆ 10k range at 2x2

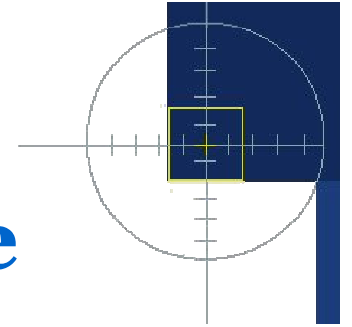
### ➤ A/D converter

- ◆  $< 16k$  range

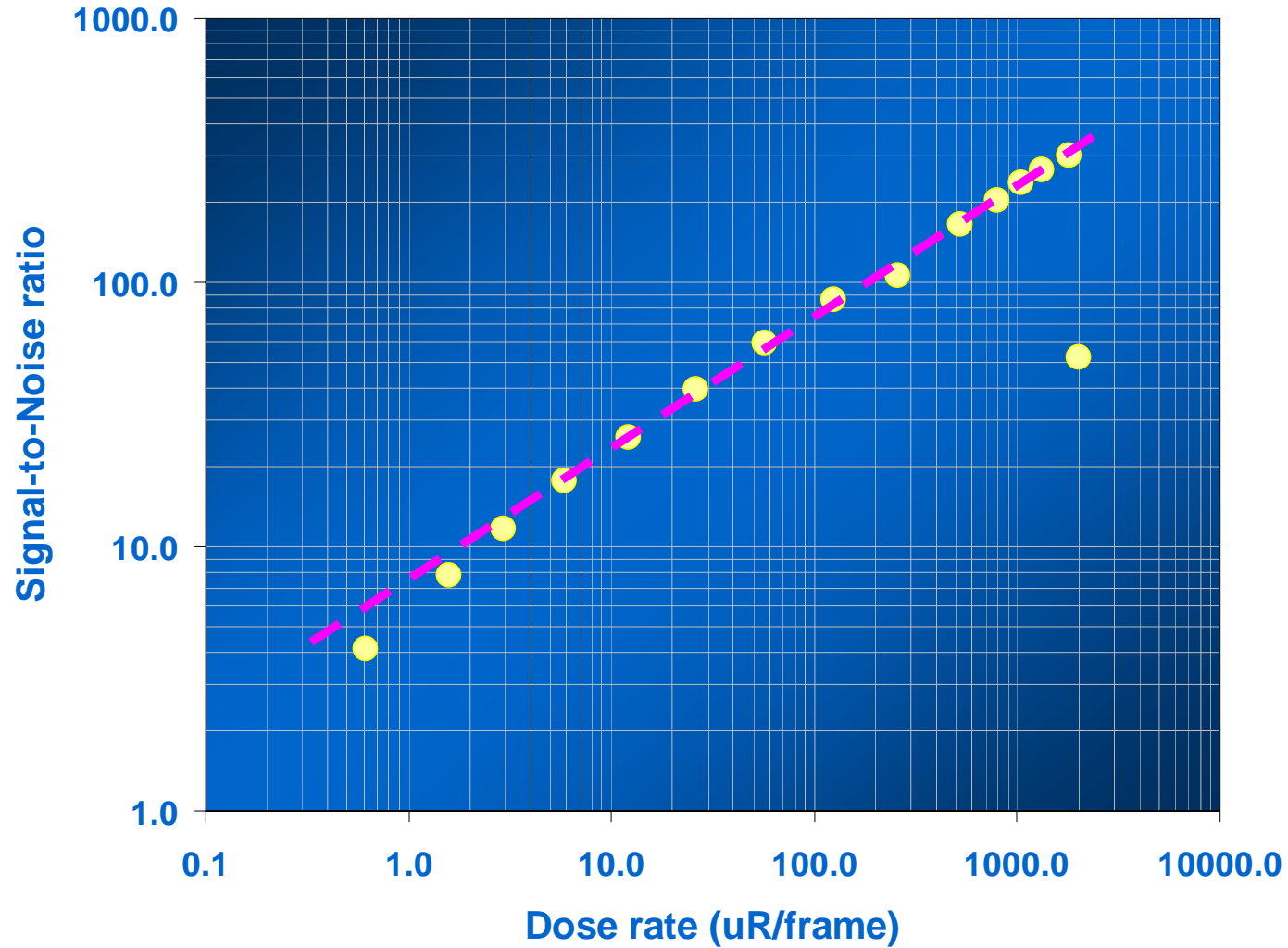


# Multiple gain ranging flat panel read out

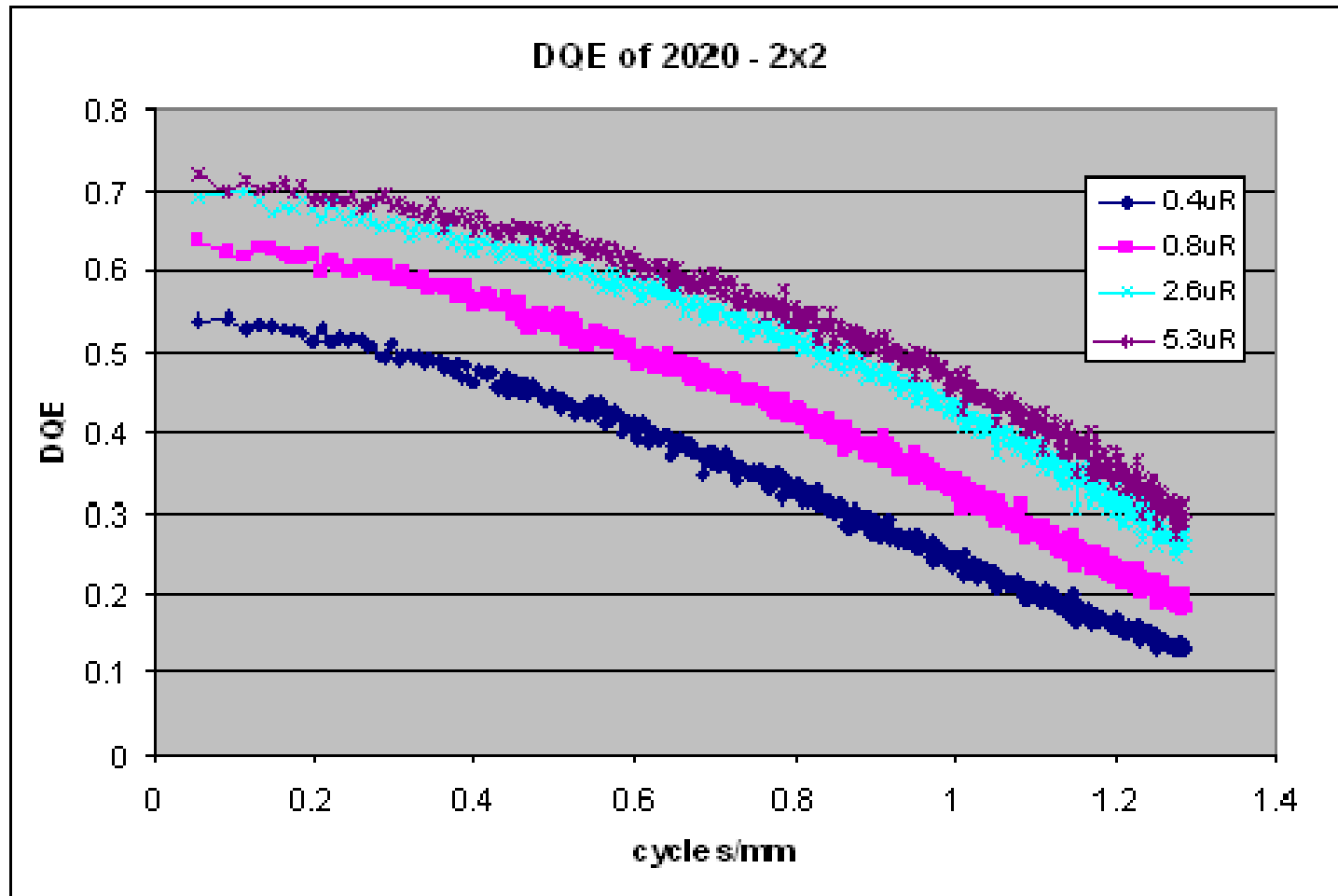
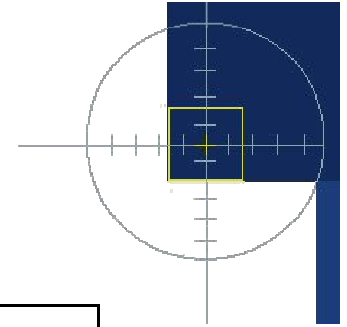


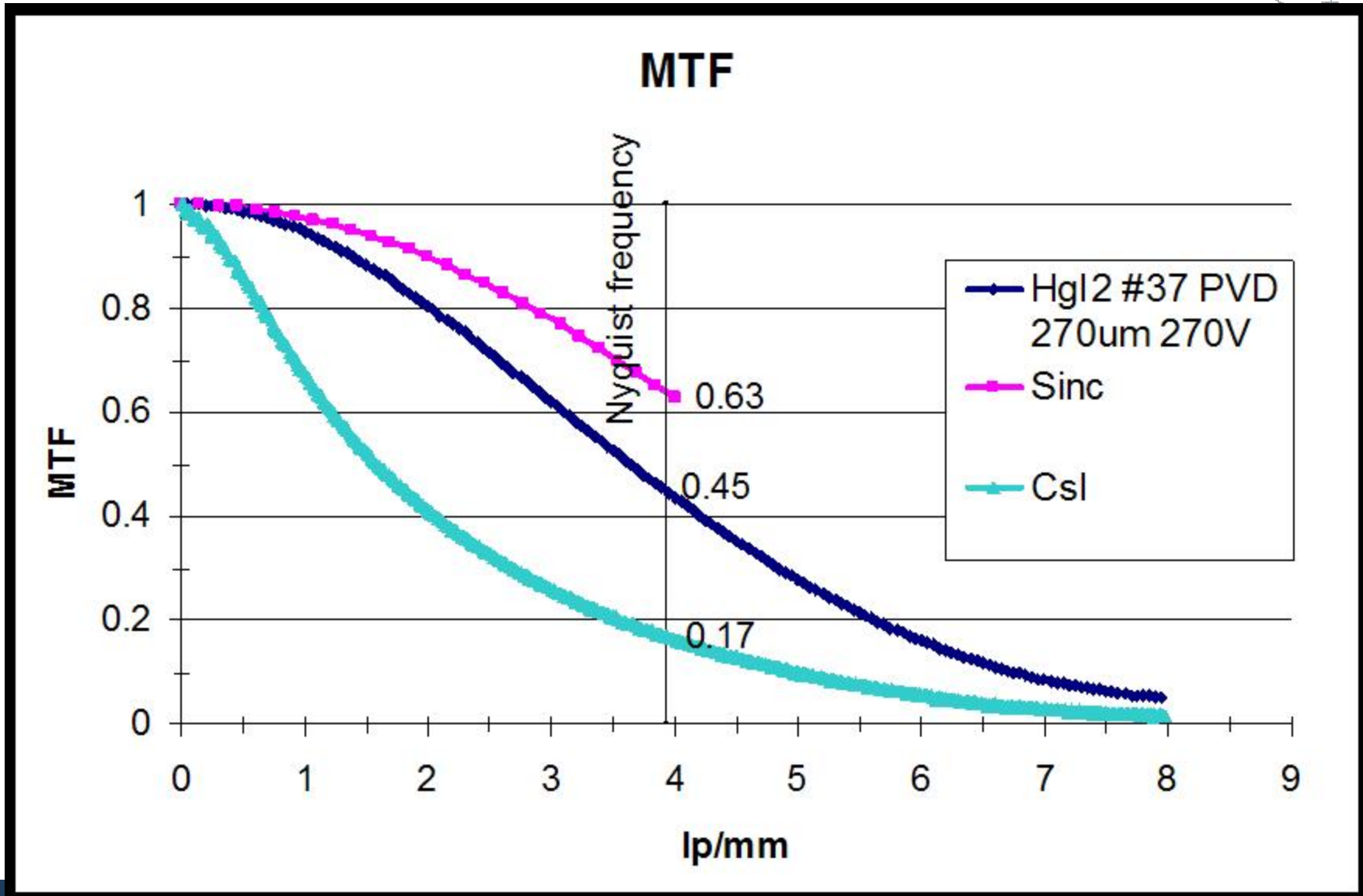
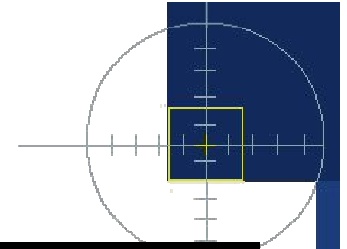


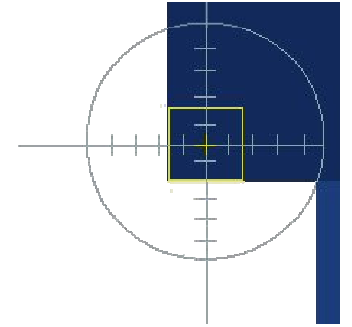
# Signal-to-noise performance



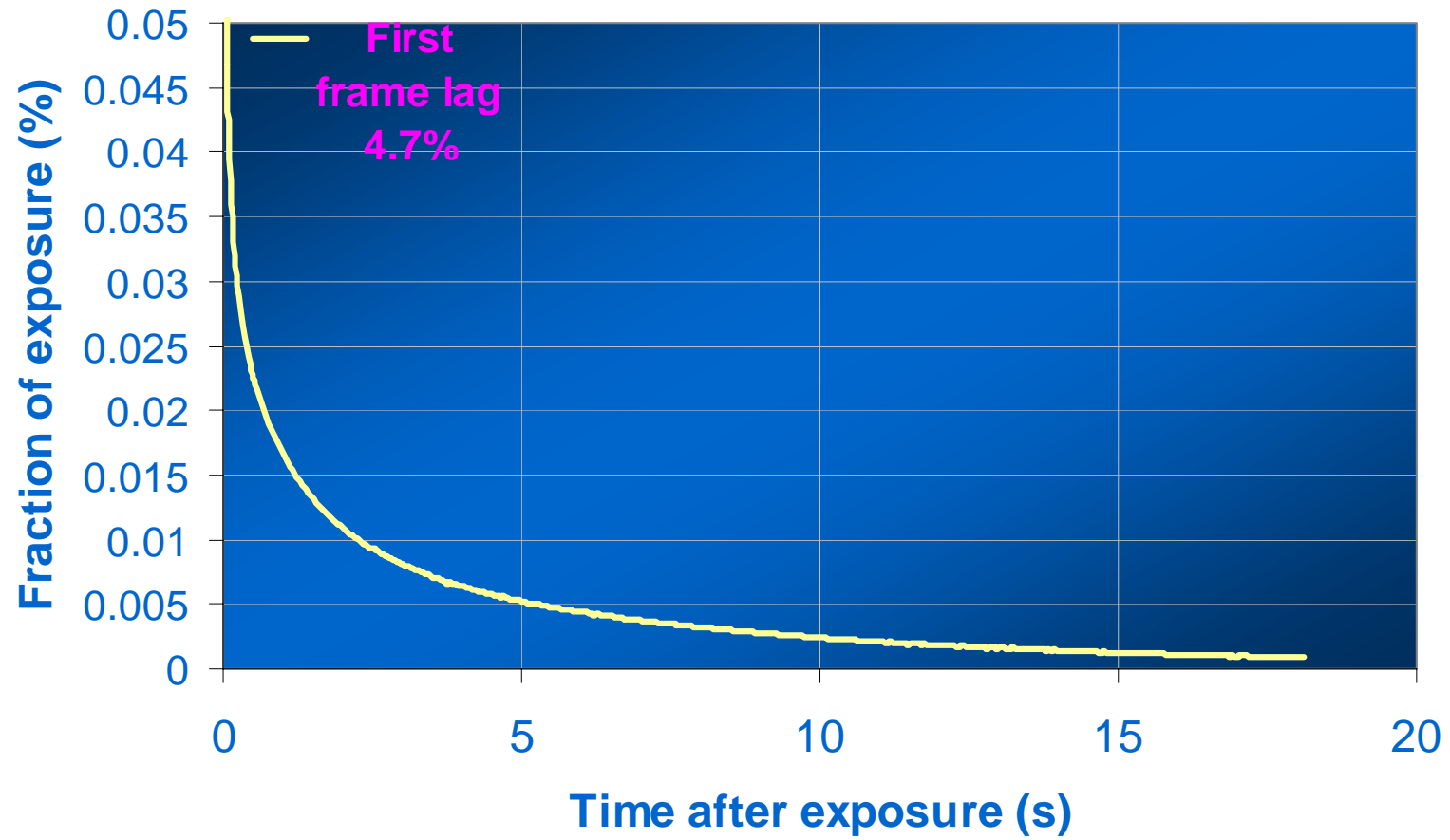
# DQE in Low Dose Fluoroscopy



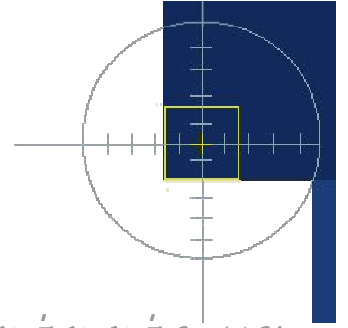




# Image lag

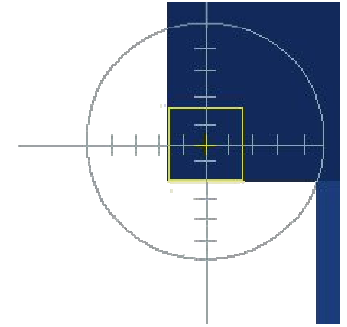






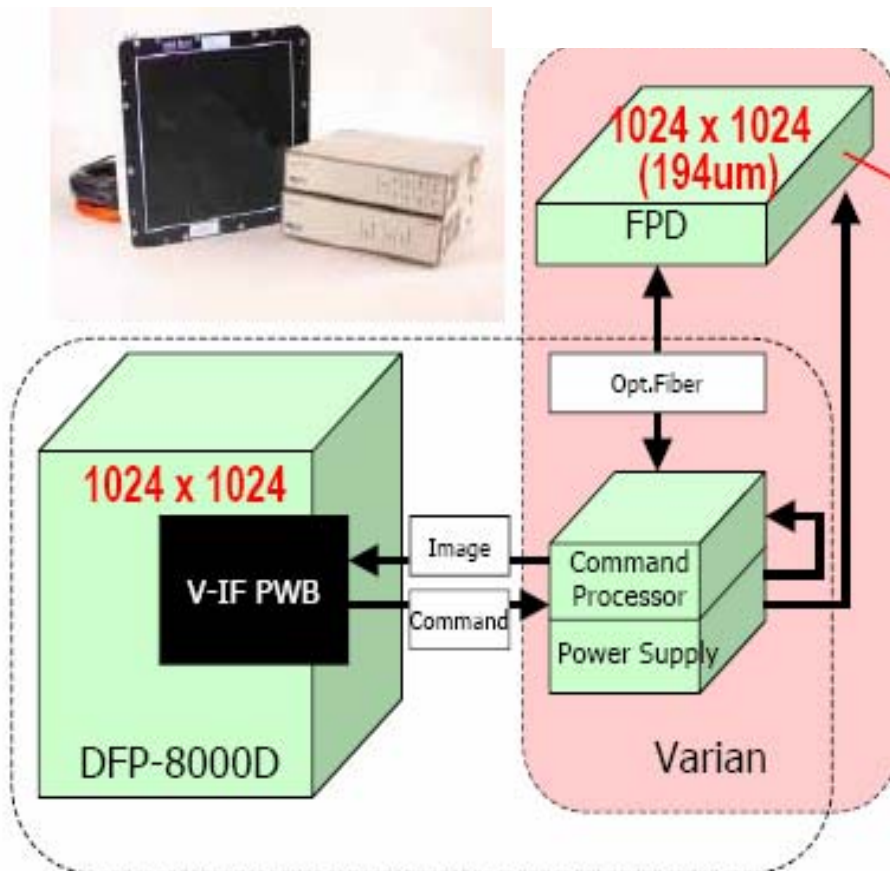
*Amorphous Silicon Flat Panel Image Detectors*

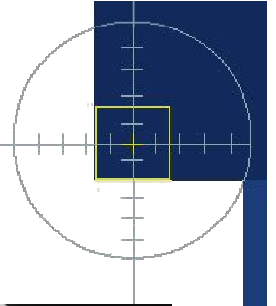
# Applications



# Cardiac Imaging

## - Radiography and fluoroscopy





## Flat panel imager



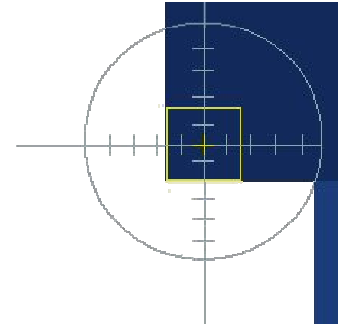
85kVp, 200mA, 80msec

## Image intensifier



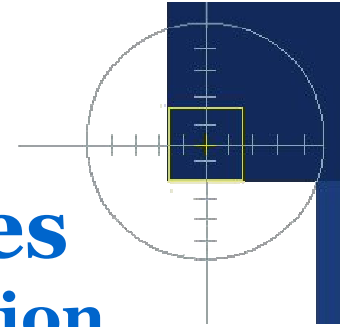
85kVp, 200mA, 100msec

- *Better contrast for imaging small blood vessels, at 20% less dose*
- *Image quality is uniform out to the edges*



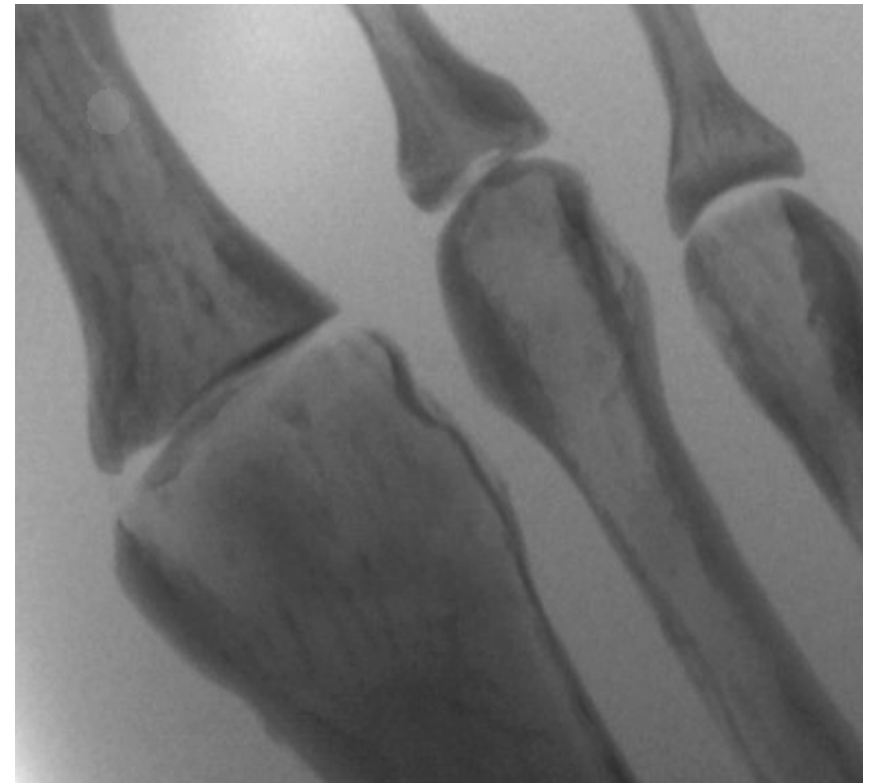
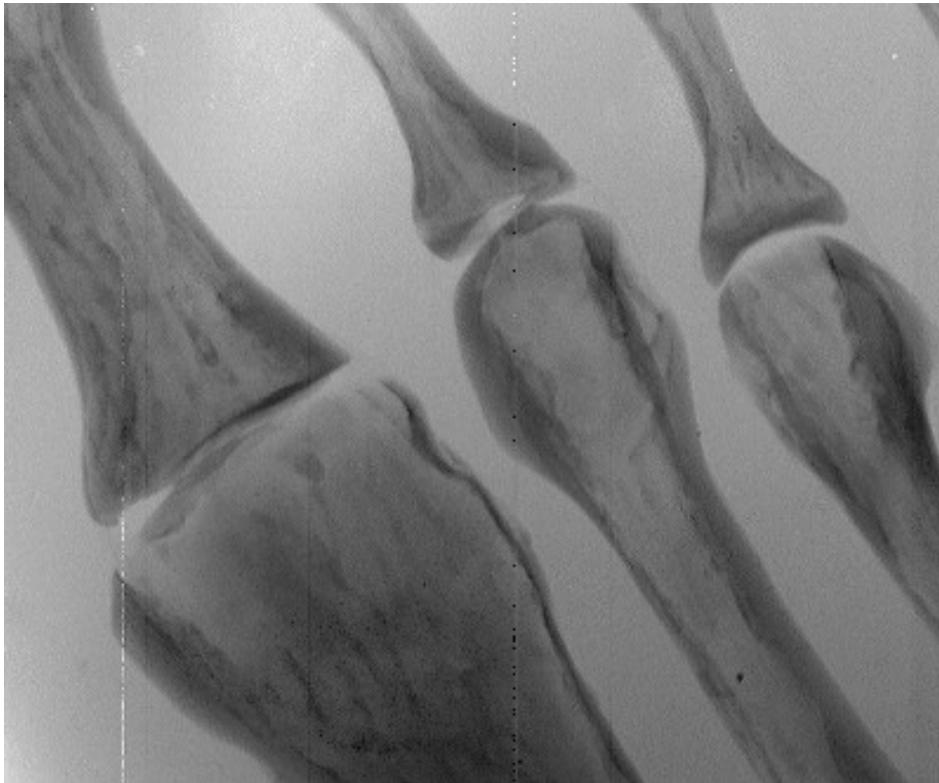
# Radiographic images

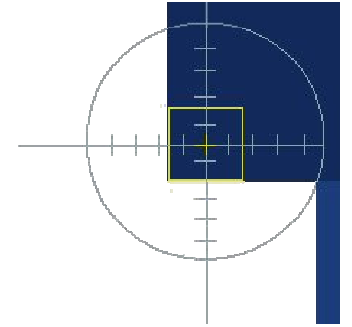




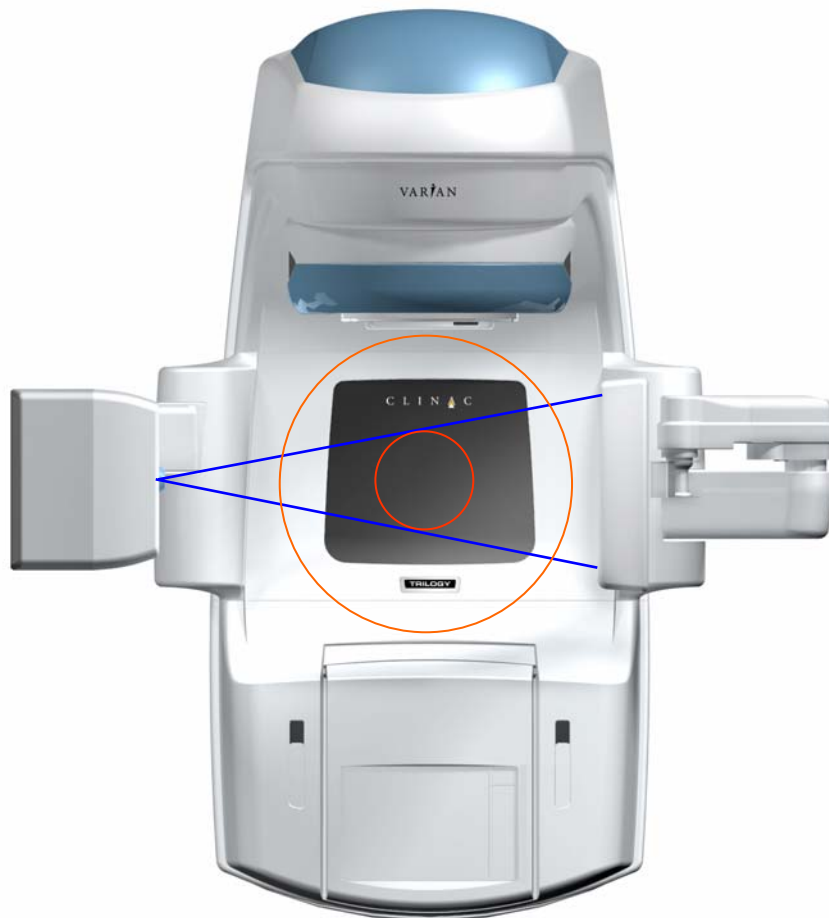
# Radiographic images

- direct vs. indirect conversion



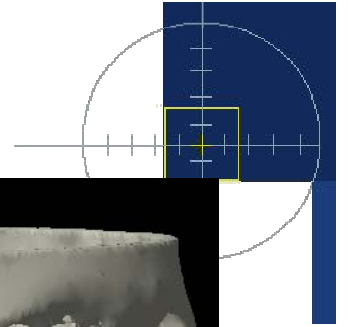
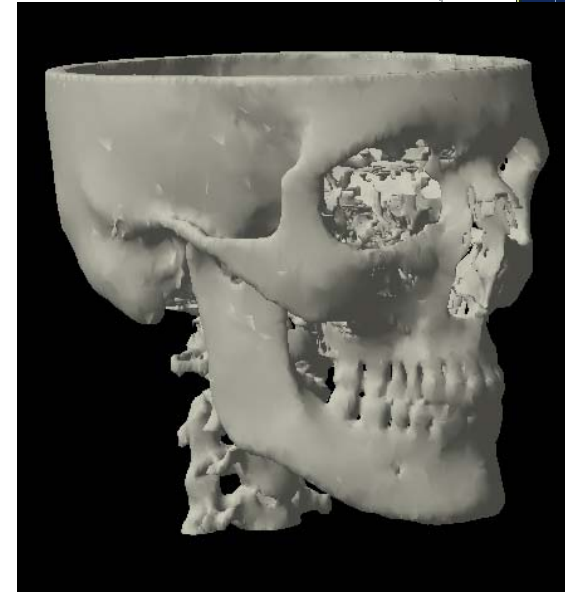


# Radiation Therapy

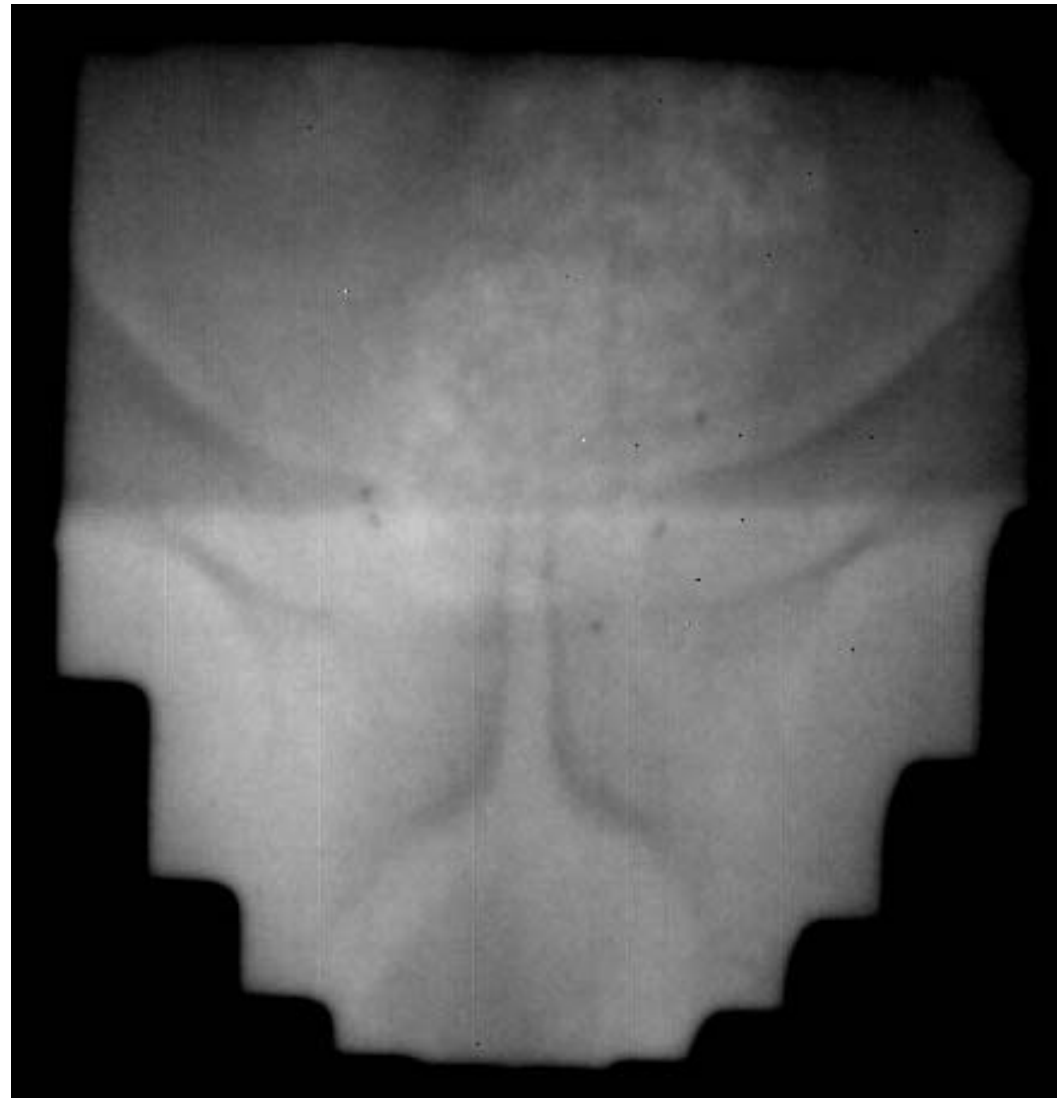
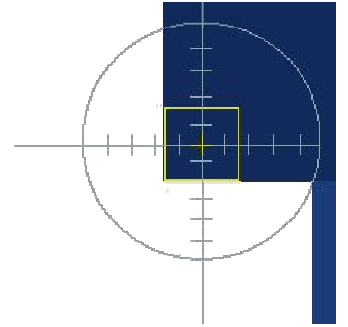


- **Therapy Portal Imaging**
- **Orthogonal Radiography and fluoroscopy**
- **Cone beam CT**

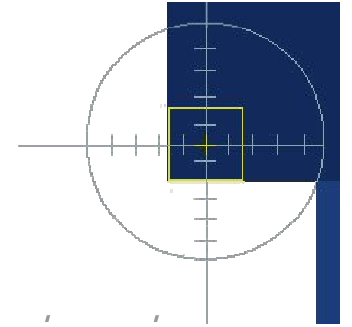
# CBCT scan of a human head



# MV Portal Images



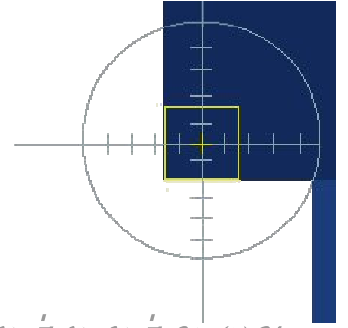




## *Amorphous Silicon Flat Panel Image Detectors*

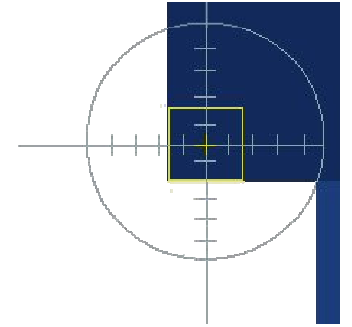
### **Also:**

- **Mamography and CT Mamography**
- **Wireless radiography**
- **Dental radiography and CT**
- **Security applications**
- **Industrial non-destructive testing**
- **Scientific research**



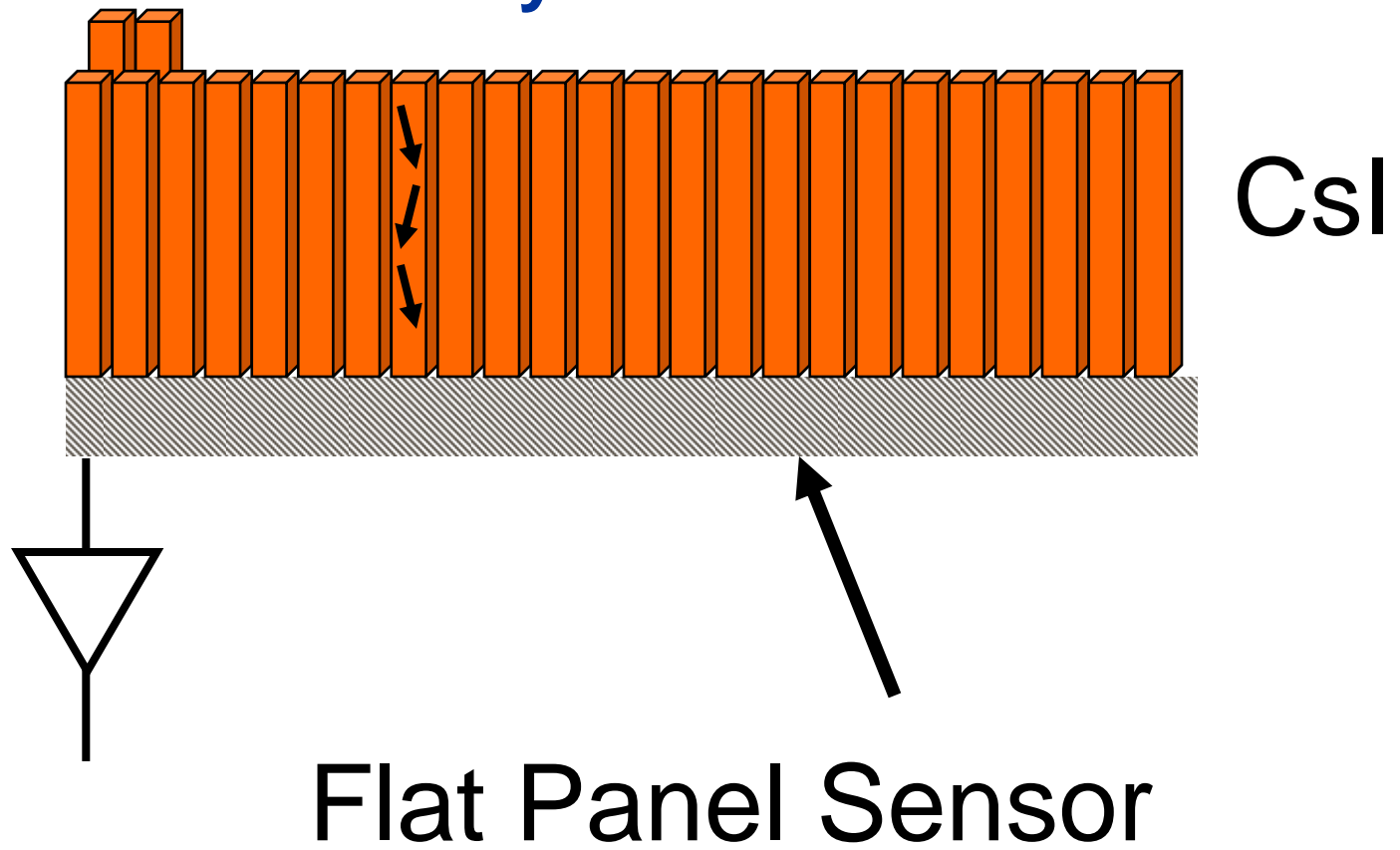
*Amorphous Silicon Flat Panel Image Detectors*

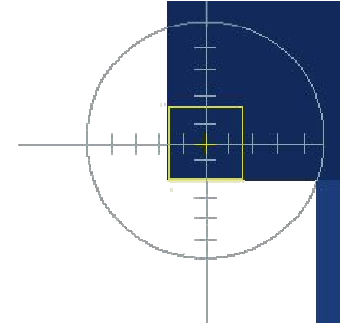
# Alternatives



# Improved MV Sensitivity

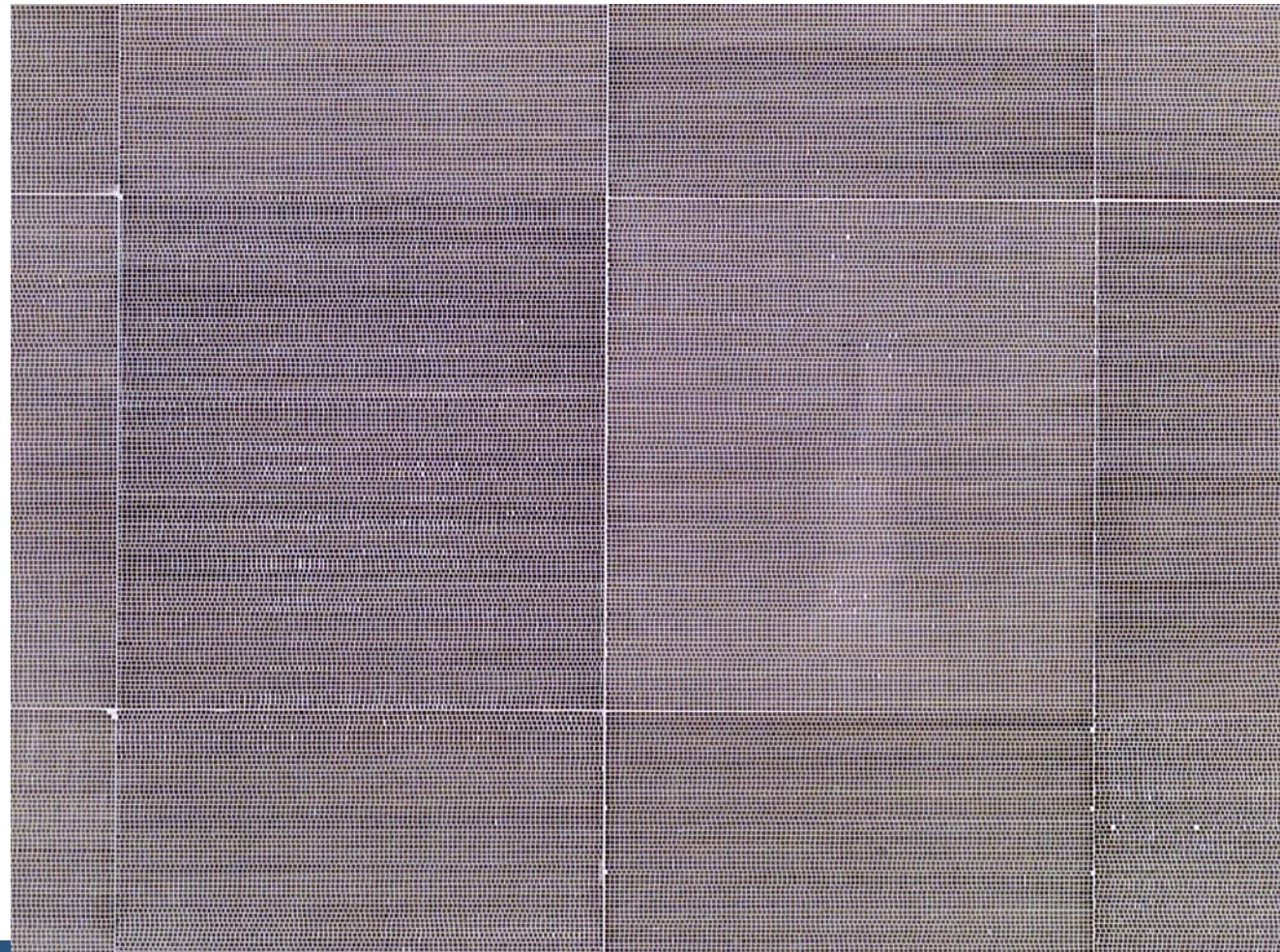
- CsI array scintillator

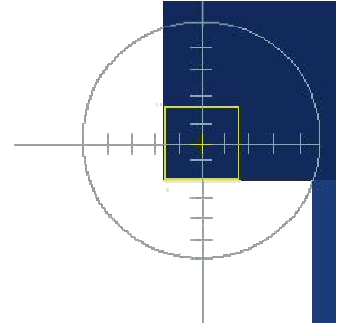




# Csl array Scintillator

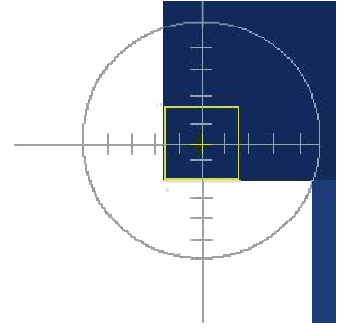
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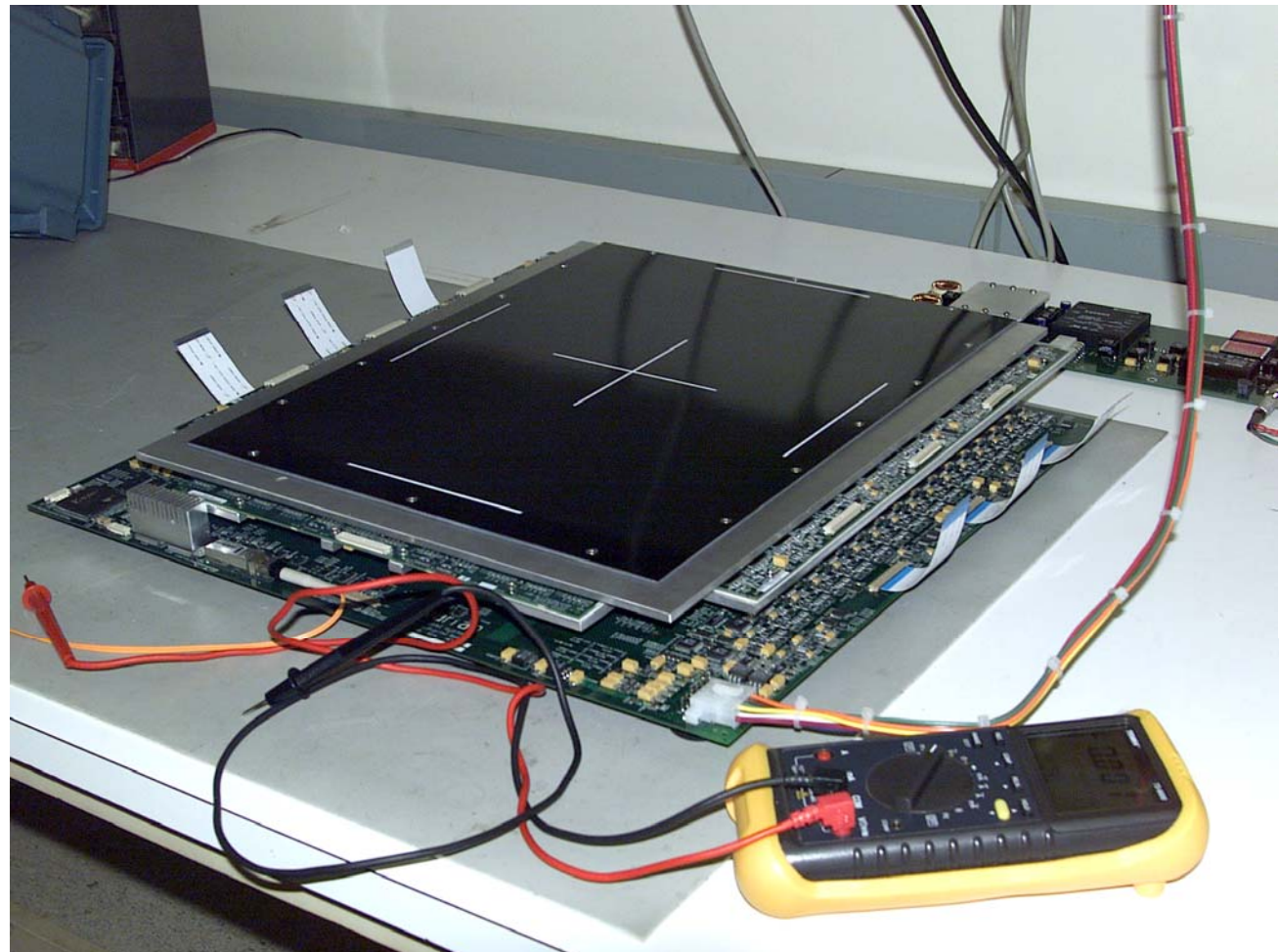


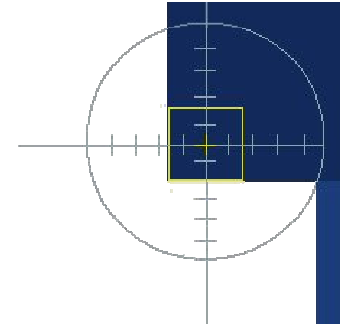
# CsI array Scintillator





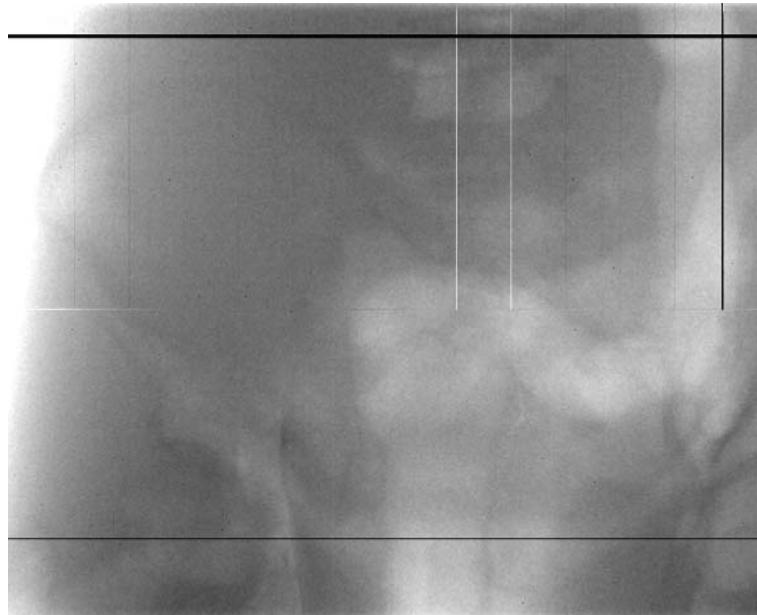
# Prototype MV Imager





## Comparison

Conventional

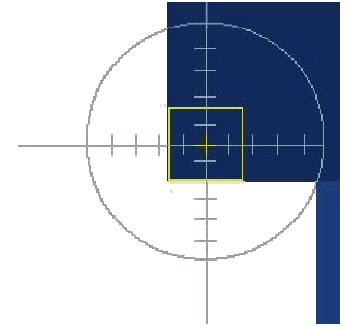


Dose = 0.092 cGy

CsI Array Scintillator



Dose = 0.046 cGy



## Fast readout

### Strip Detectors:

64 x 576

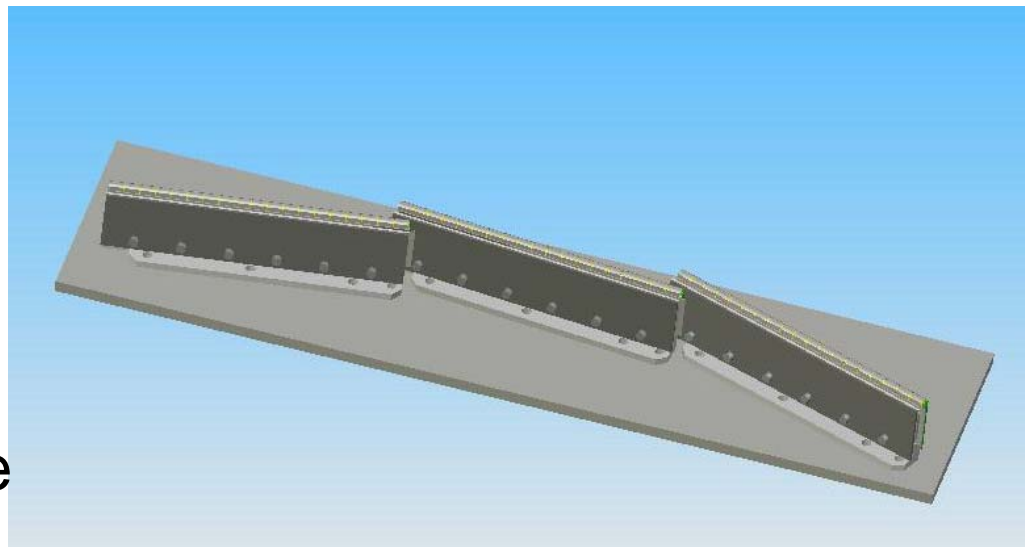
3.3 x 30 cm

520  $\mu\text{m}$  pixel

1700 fps 1x1

3000 fps 2x2

Photon counting mode





# Phase-2 Concept

