Low cost digital detector technology for emerging economies

Karim S Karim

WATERLOO ENGINEERING

engineering.uwaterloo.ca

Acknowledgments

STAR Group (especially Sina Ghanbarzadeh, Shiva Abbaszadeh, Michael Adachi and Ryan Mann)

- Individuals
  - Dr. Caridad Borras, Chair, Health Technology Task Group (HTTG), IUPESM
  - Prof. Andrew Karellas, Dept of Radiology, U. Mass.
  - Dr. Gijs Walraven, Director of Aga Khan Health Services, France
  - Dr. William Falk, Managing Partner - Health at PwC Canada
- Organizations
  - Grand Challenges Canada
  - Natural Sciences and Engineering Research Council of Canada
  - Ontario Research Fund
  - Canada Foundation for Innovation
  - Giga-2-Nano Facility, University of Waterloo

WATERLOO ENGINEERING

Outline

- X-ray imaging for underserved populations
- Why is digital X-ray ideal?
- Disruptive low cost digital X-ray
- Sensor technology
- Pixel circuit technology
- Summary

X-ray Screening and Diagnostics

- Gold standard for many diseases
  - Used in underserved areas to diagnose catastrophic ailments, especially in children
- Lung diseases
  - Tuberculosis (i.e. for screening)
  - Pneumonia
  - COPD
  - Pneumo-thorax
- Bones
  - Fractures
  - Osteo-myelitis
- Disease burden of cardiac failure is not high in low -income countries
  - Also, cardiac failure can be satisfactorily established by clinical examination
- Source: Director, Aga Khan Health Services, France

Issues with X-Ray Imaging

- Quality
  - Poor quality image can lead to incorrect diagnosis
  - Untrained personnel may not diagnose image accurately
- Access
  - Qualified personnel to both maintain imaging systems and to interpret film are in short supply
  - Patients have difficulty reaching diagnostic centers
- Cost
  - Health providers cannot afford imaging system price
  - Patients cannot afford test price

Options for X-Ray

Film Screen (circa 1896)	• $15,000 - $25,000 USD initial price • Consumables: Developer, chemical, films, storage • Poor compatibility with tele-radiology • Regular equipment maintenance required • Good image quality
Computed Radiography (circa 1975)	• $50,000 - $70,000 USD price • Consumables: Imaging plates • Compatible with tele-radiology • Some equipment maintenance required • Satisfactory image quality
Digital X-ray (circa 2000)	• $100,000 - $150,000 USD initial price • No consumables and minimal equipment maintenance • Instant image to facilitate rapid diagnosis • Fully compatible with tele-radiology • High image quality

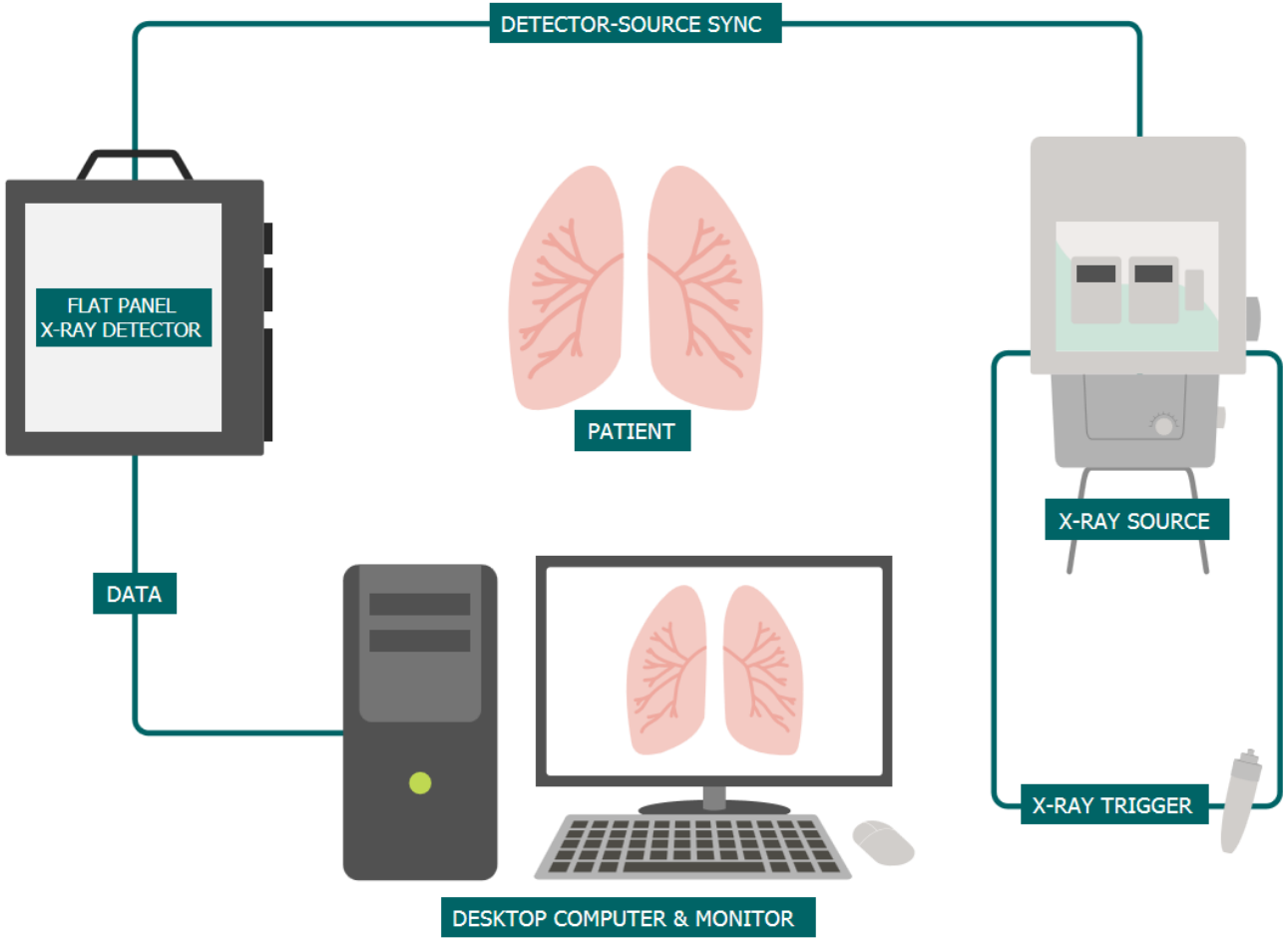
Challenge

- Cheaper film-screen and CR systems are being increasingly sold to developing nations and to hospitals in underserved populations
- Both technologies do not provide the many benefits of digital and can be leapfrogged
- However, digital is expensive making the cost-benefit argument relevant only to hospitals with high volumes (e.g 400-500 patients daily) or rich donors
- Low cost digital X-ray represents an opportunity for disruptive innovation to provide essential diagnostic capability to underserved or rural areas that have low patient volumes

Our Goal: Offer Digital X-ray at the cost of ownership of Film-screen X-ray

WATERLOO ENGINEERING

Digital x-ray system



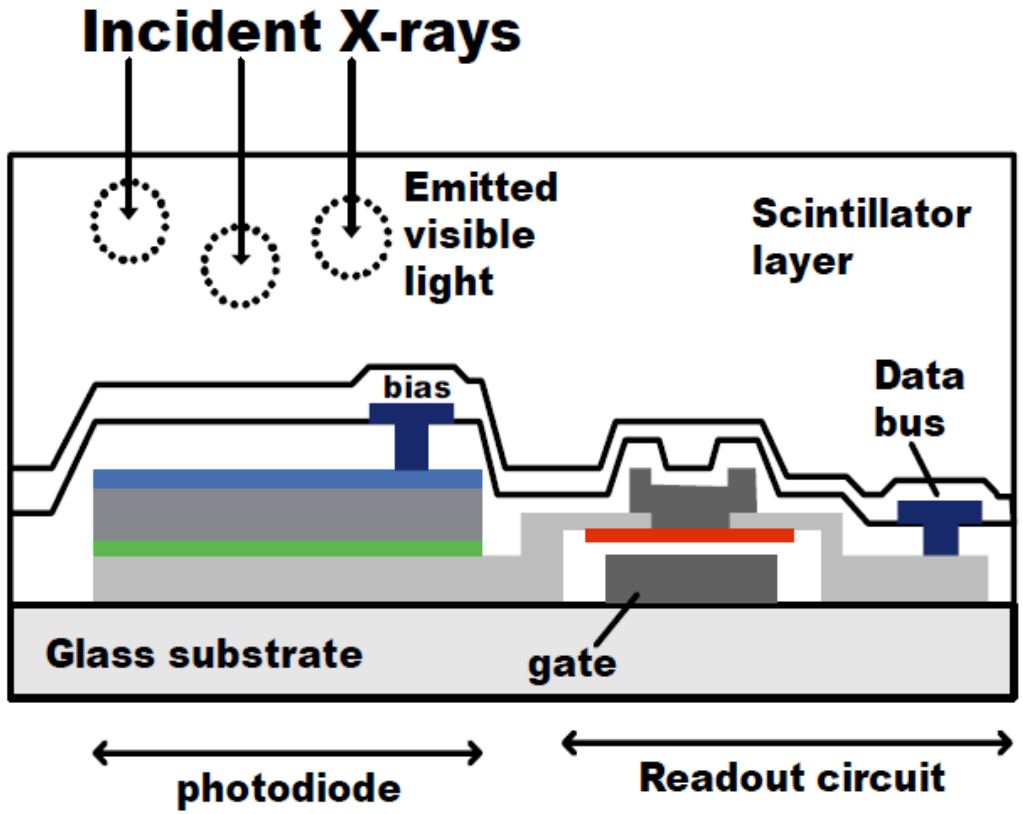
WATERLOO
ENGINEERING

Major System Components

- Digital flat panel X-ray detector (>50% of system price)
- X-ray source generator
- Source-panel synchronization hardware
- Computer software and hardware for image display

Current Detector Technology (Indirect Detection)

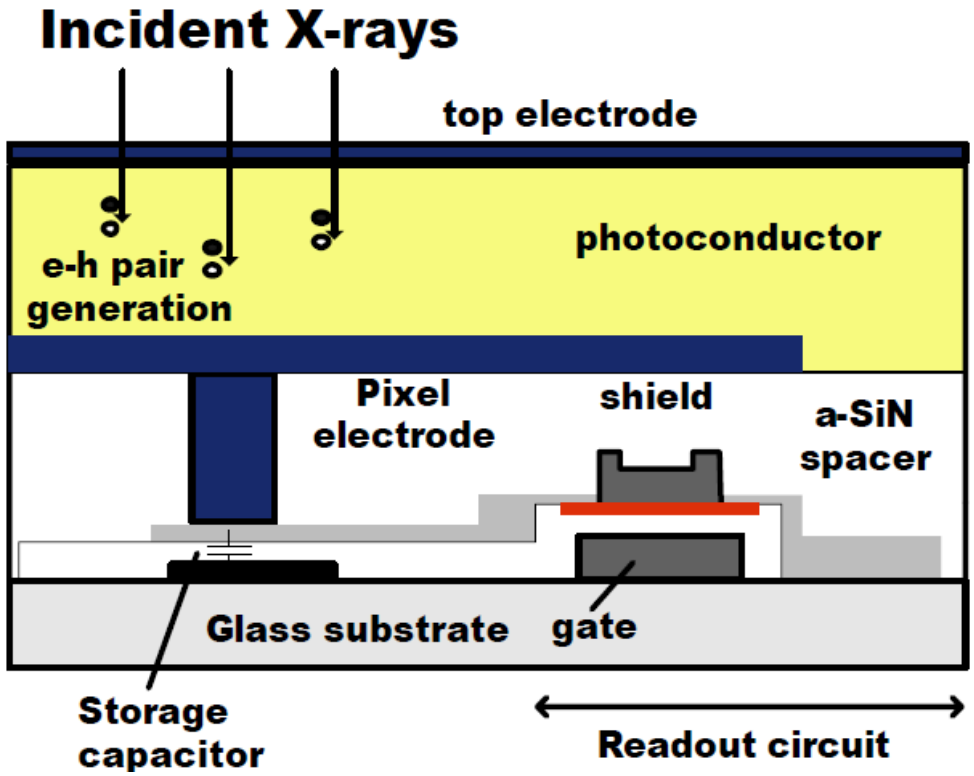
- Specialized process requires a p-doped contact layer for sensor
  - Typical display TFT facility cannot supply this
- Selling price becomes high because
  - large capital investment into dedicated fabrication facility
  - Manufacturers want to recover the sunk capital costs
  - Thus, volumes are low
  - Chicken-egg situation



WATERLOO ENGINEERING

Current Detector Technology (Direct Detection)

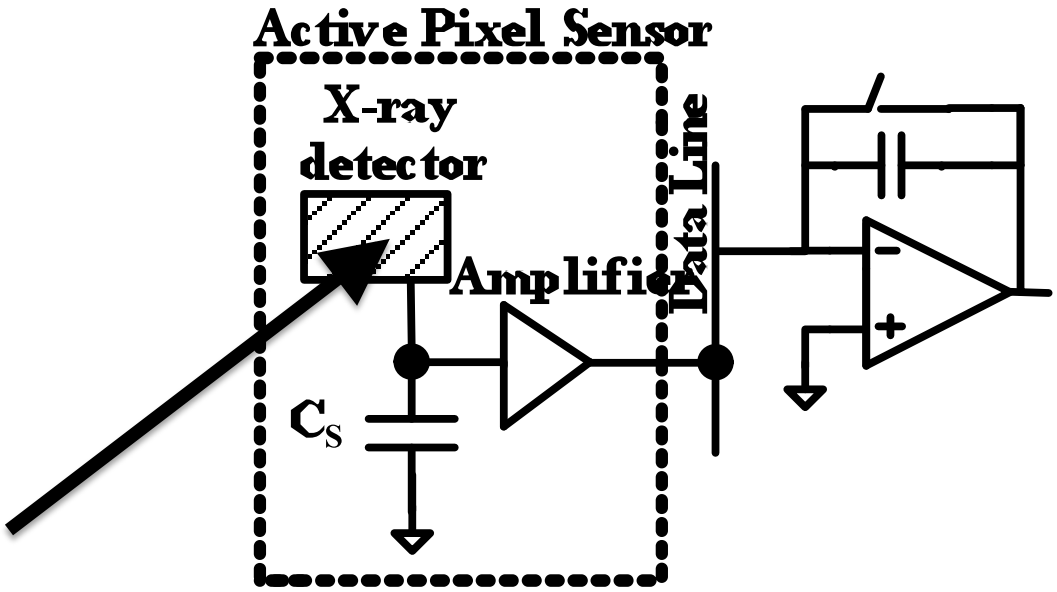
- Manufacturing cost potentially lower since TFT display manufacturing facility can be leveraged
- However, dedicated back -end selenium sensor fabrication process needed
- Yields/reliability not as high as indirect detection so volumes low, prices high
- Currently, prices even higher due to duopoly situation in mammography

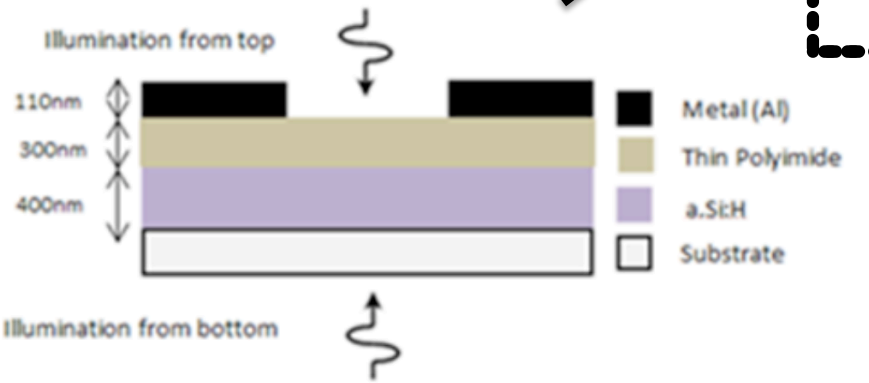


WATERLOO ENGINEERING

Our Disruptive Detector

- Amorphous silicon MSM sensor integrated with an amplified pixel
- Manufacturing cost lowest since TFT display facility can build both sensor and pixel circuit





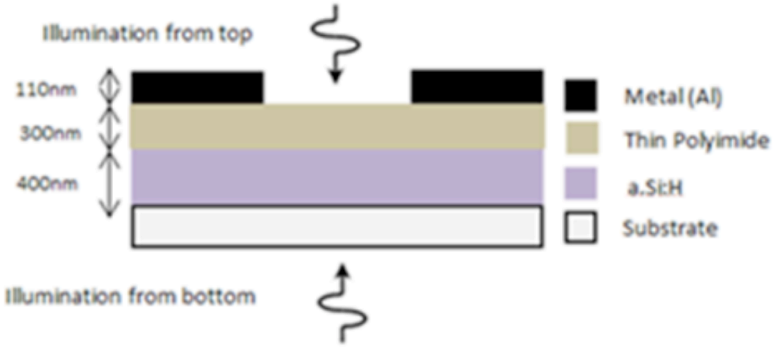
WATERLOO ENGINEERING

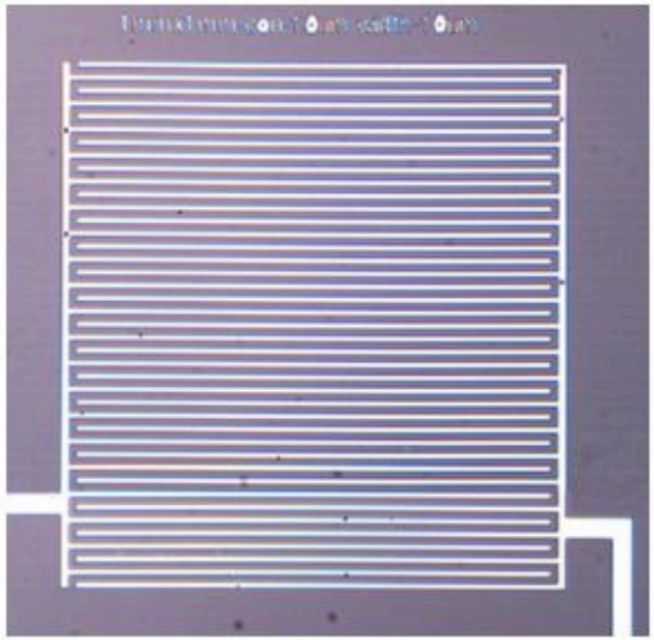
Disruptive Detector Technology - Advantages

- In contrast to existing PIN photosensors, the MSM has a simpler fabrication process, no absorption loss through a top electrode, gives higher dynamic range and comparable QE
- Amplified pixels have higher SNR for lower X-ray dose and reduce off -panel circuit complexity (by MUXing) when compared to PPS pixels
- When both innovations are put together, the question arises:
- Are higher quality and lower cost possible right now?
- “Yes!”

MSM Sensor – Innovative Step

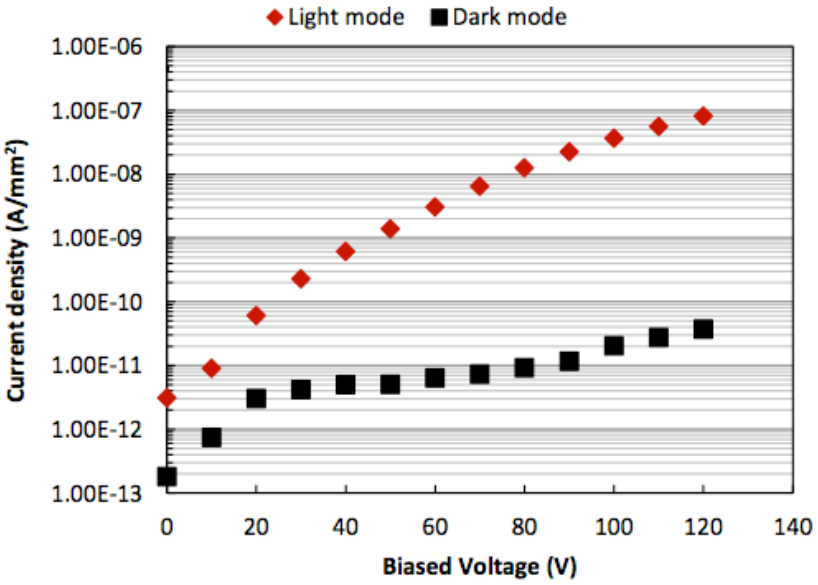
- In the past, low photocurrents and high dark currents were a key problem in the MSM structure
- We introduced an organic interface layer to allow application of high E field to increase photocurrent while keeping dark current low
- Although this organic layer is normally insulating, we operate it at high fields in soft breakdown
- High dynamic range of MSM can enable R/F type imaging

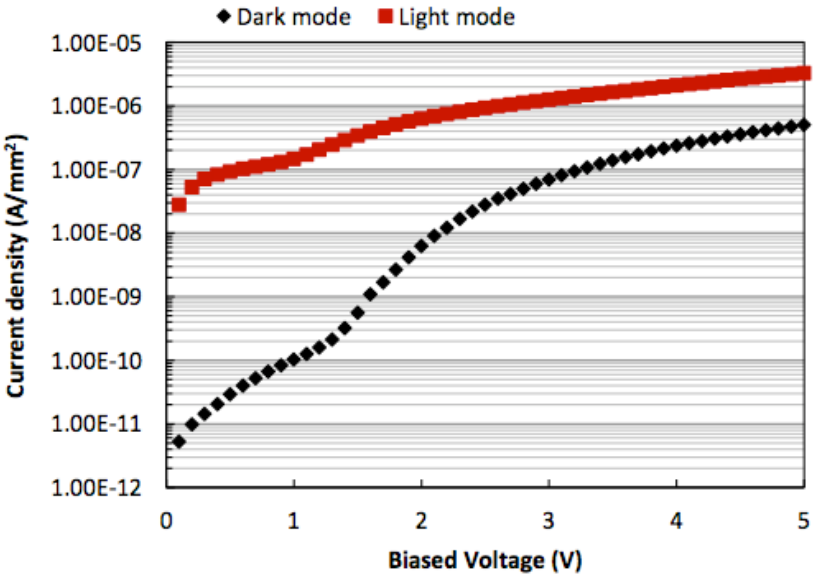


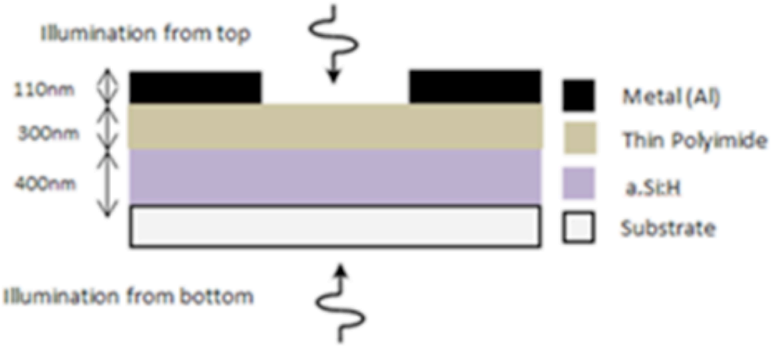


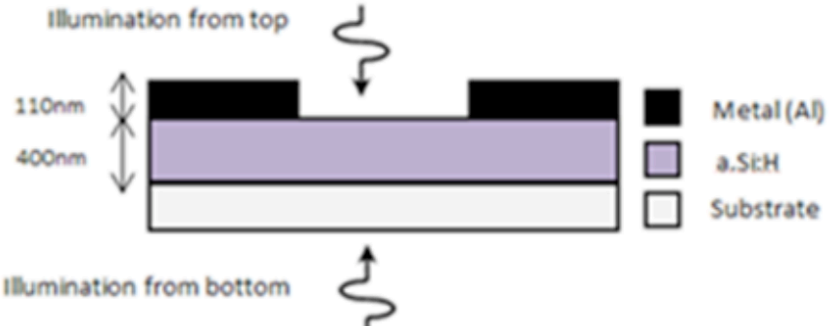
WATERLOO ENGINEERING

MSM Sensor - Performance





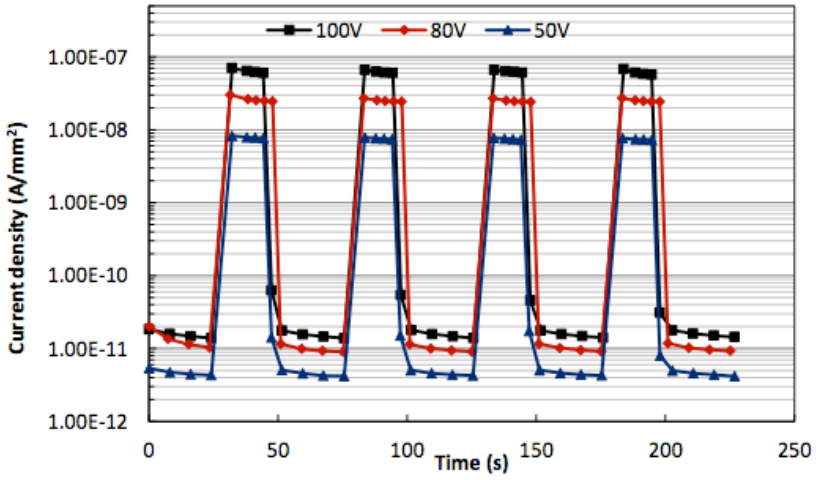


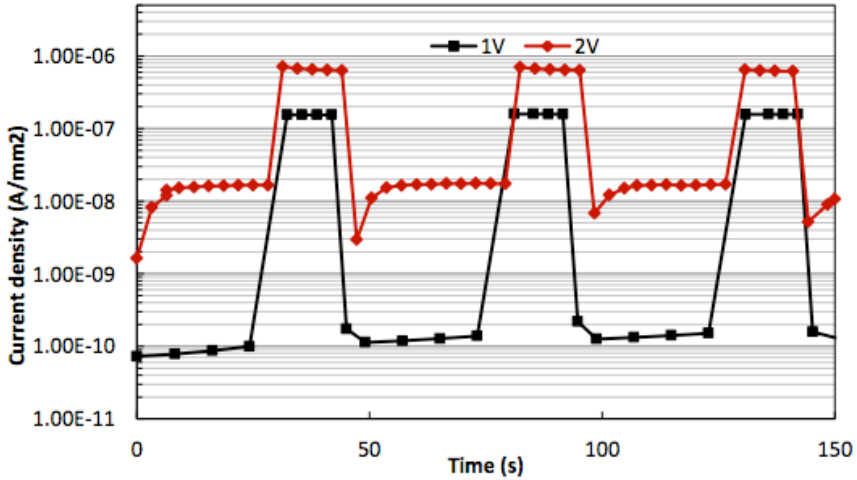


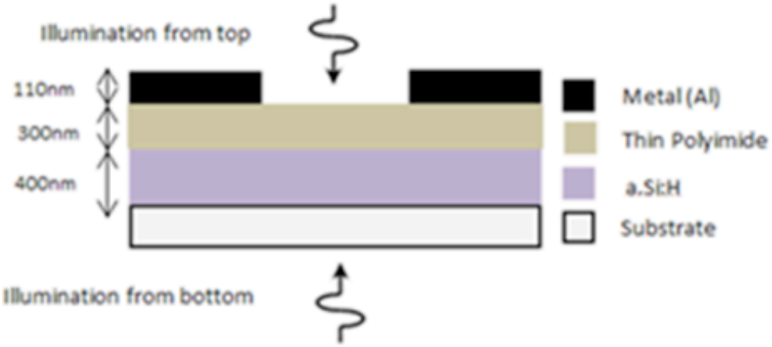
*S. Ghanbarzadeh etal, SPIE Medical Imaging, Feb 2013

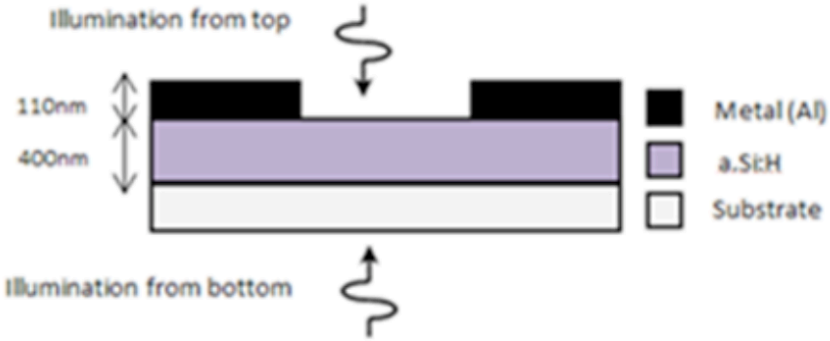
WATERLOO ENGINEERING

MSM Sensor - Transients









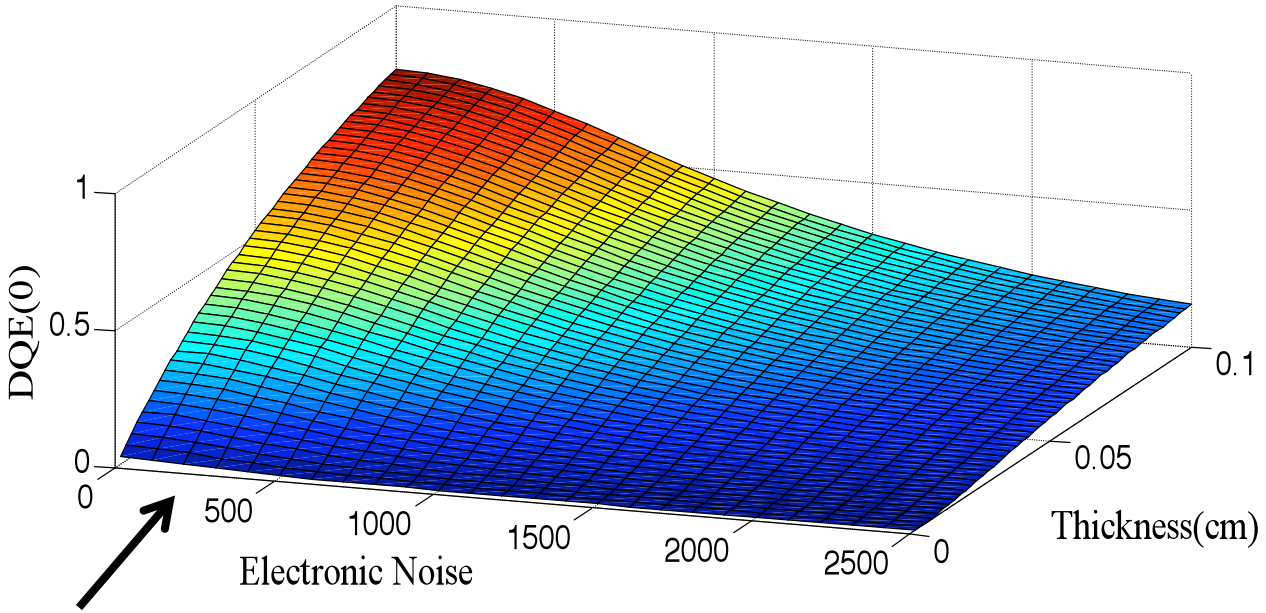
*S. Ghanbarzadeh etal, SPIE Medical Imaging, Feb 2013

WATERLOO ENGINEERING

Amplified Pixel – Innovative Step

- In the past, amorphous silicon instability, size and slow speed were a key problem to TFT amplified pixel sensor design
- We introduced a current mode amplified TFT pixel design to overcome above challenges (amorphous or polysilicon TFT)
- Amplified pixel gives higher SNR → good for low dose electronic noise limited modalities
- Amplified pixel enables output multiplexing → good for lowering price since off-panel charge amplifier component, reliability and assembly costs are substantial (typically 1/3 of the panel manufacturing cost)

Amplified Pixel - Performance



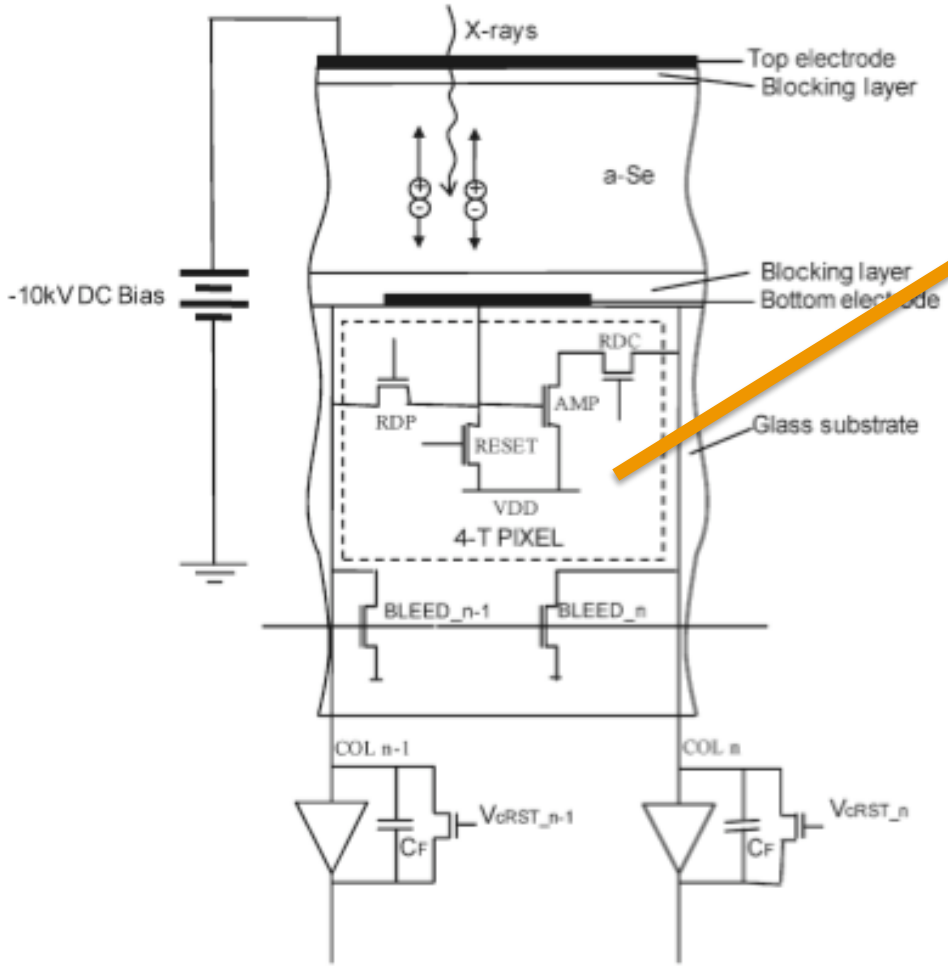
80 kVp beam using overlying selenium sensor

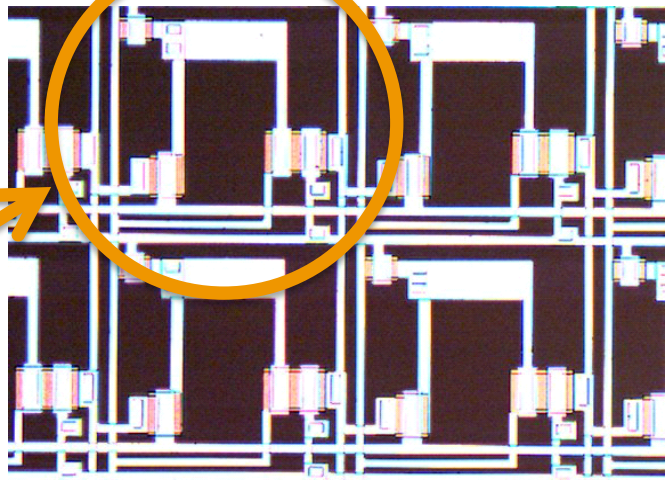
Compare low APS input referred noise to typical PPS noise levels of 1600 electrons for small panels (more for larger)
i.e. 4X-6X improvement in SNR

Technology	Input referred Noise Electrons
Amorphous Silicon APS	380
Polysilicon APS	260

*M. Izadi etal, IEEE ITED, Jan 2012

Amplified Pixel - Architecture

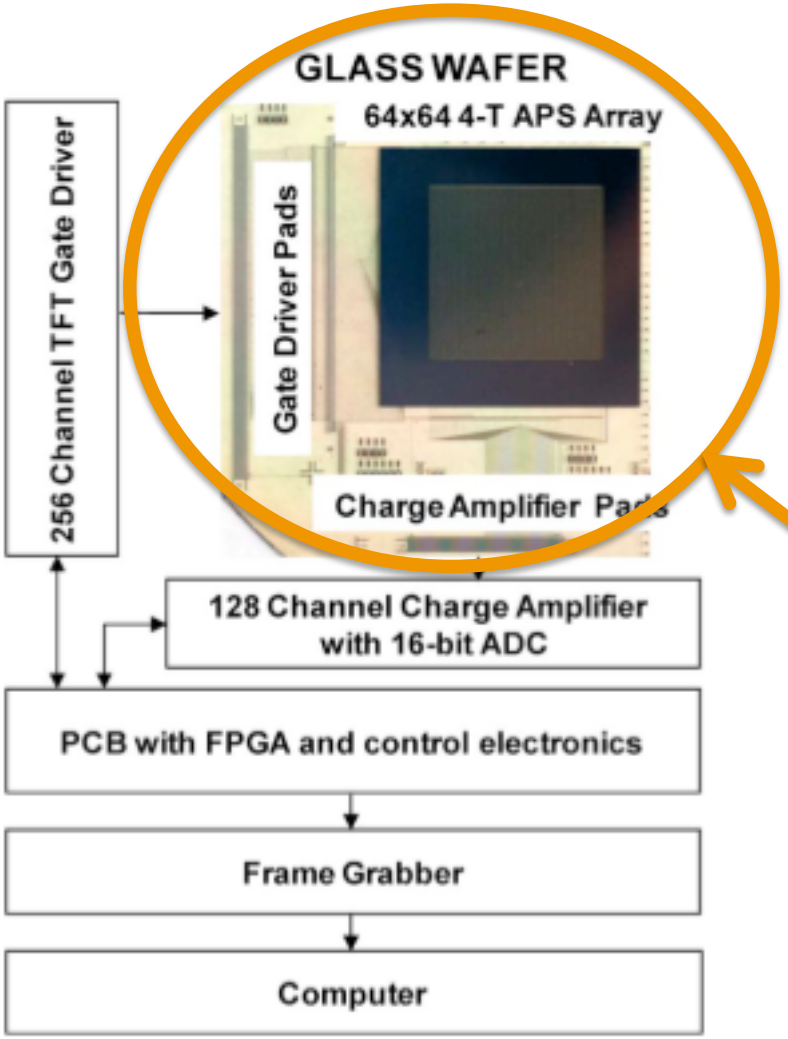


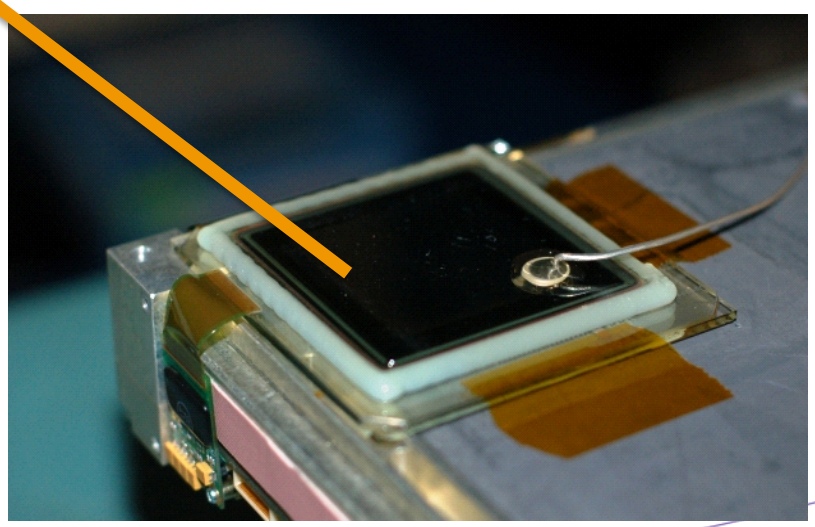


WATERLOO ENGINEERING

*M. Izadi etal, IEEE ITED, Jan 2012

Amplified Pixel - Architecture



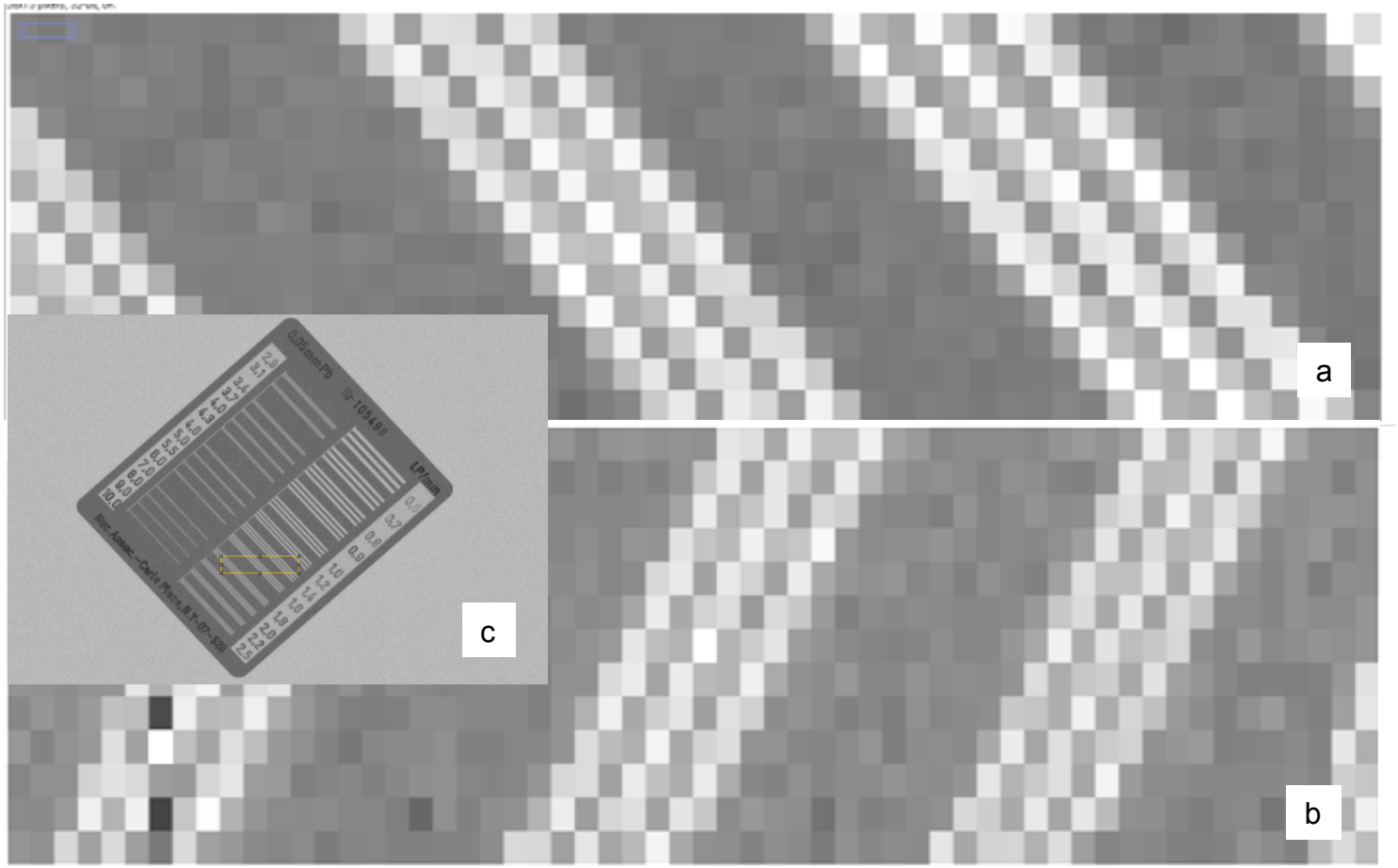


WATERLOO ENGINEERING

*M. Izadi etal, IEEE ITED, Jan 2012

Amplified Pixel Detector - Image

Commercial Analogic FPD14 sold by Toshiba

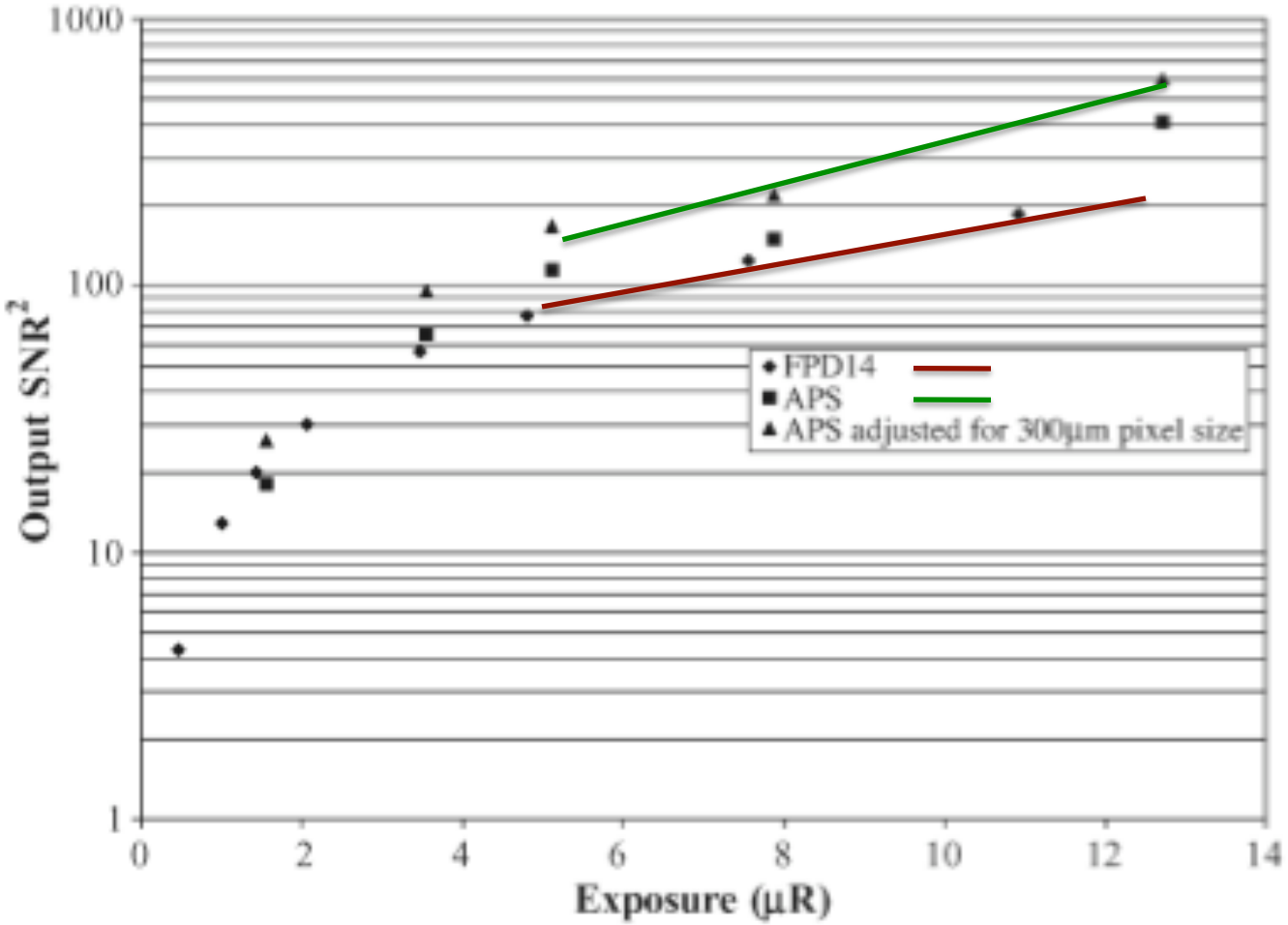


Amplified Pixel Detector

WATERLOO ENGINEERING

*M. Izadi etal, IEEE ITED, Jan 2012

Amplified Pixel Detector - SNR



*M. Izadi etal, IEEE ITED, Jan 2012

WATERLOO ENGINEERING

Summary

- High quality and low cost digital X-ray detector is achieved by fully leveraging existing display manufacturing facilities
  - i.e. no specialized process or layers
  - i.e. no new backend process
- Designing digital X-ray detectors for applications in price sensitive developing and emerging markets (who are desperate for low cost screening and diagnostic technology) will yield the high volumes required to attract display manufacturers
- All of this is achievable today with no further capital investments
- Lower cost, higher quality, right now? Yes!
- “What can I do right now?”
  - Motivate potential end-users in developing and emerging markets to step up and demand new low cost digital X-ray technology

Thank you

Karim S. Karim PhD PEng MBA

- Associate Director, Centre for Bioengineering and Biotechnology, University of Waterloo, Waterloo, Canada
- Full Tenured Professor, Faculty of Engineering, University of Waterloo, Waterloo, Canada

Email: kkarim@uwaterloo.ca

Twitter: karim_s_karim

WATERLOO
ENGINEERING