# Large-Area Radiation-Hard Synchrotron X-ray Detectors

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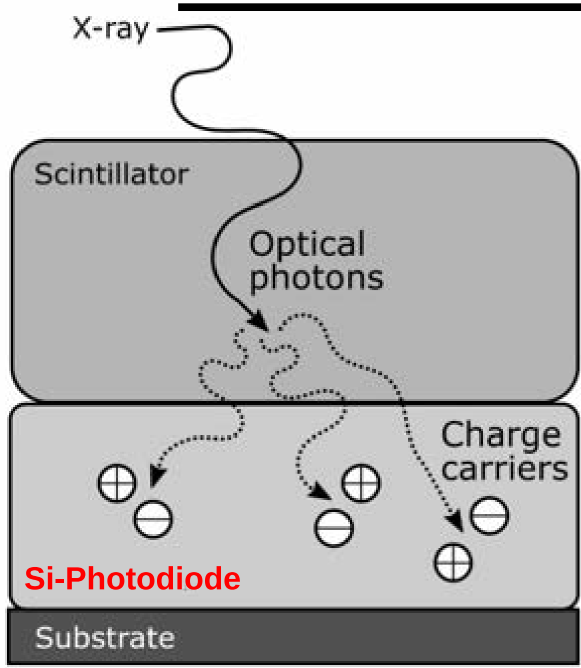
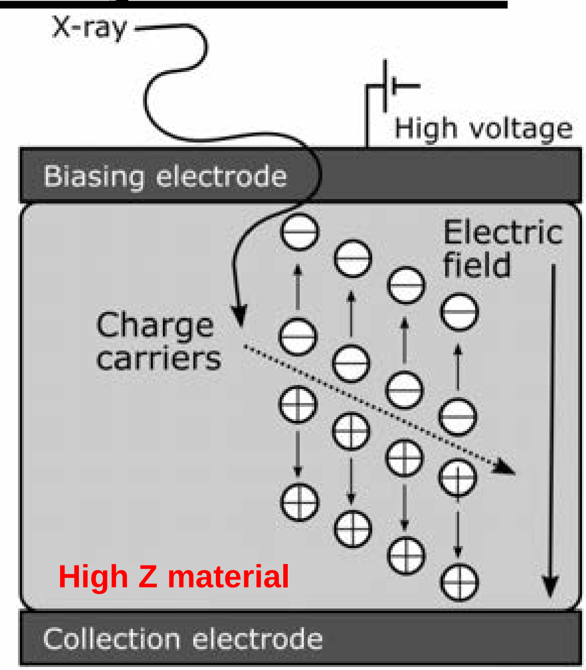
# Solid-State hard X-ray Detection




Indirect conversion




Direct conversion

- Limited Spatial Resolution by thick scintillator
- Low efficiency with thin scintillator
- Light sensible camera

- Spatial Resolution limited by charge diffusion (use thin material layer)
- High Absorption for Hard X-Rays
- Low Noise with small pixel pitch

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# Project Overview

| SPECS | VALUES |
|---|---|
| Detector thickness | ~200 µm |
| Detector bias voltage | ~100 V |
| Detector leakage current | ~10 nA/cm$^2$ |
| X-ray energy range | 30 – 100 keV |
| Active Area | demonstator = 1x1 cm$^2$ |
| Pixel size | 10x10 µm$^2$ |
| Integration time | 1 ms to 100 ms |
| Fabrication process | TSMC 65 nm |

**CapeSym Inc.** , in collaboration with **Instrumentation Division** at BNL, aims to develop a novel X-ray imaging detector based on Perovskite (MAPbI3) as sensitive element.

Functionalization
& deposition

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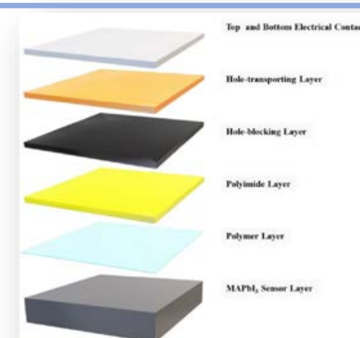


Readout ASIC
& testing system

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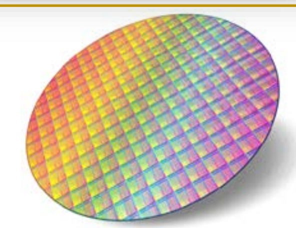
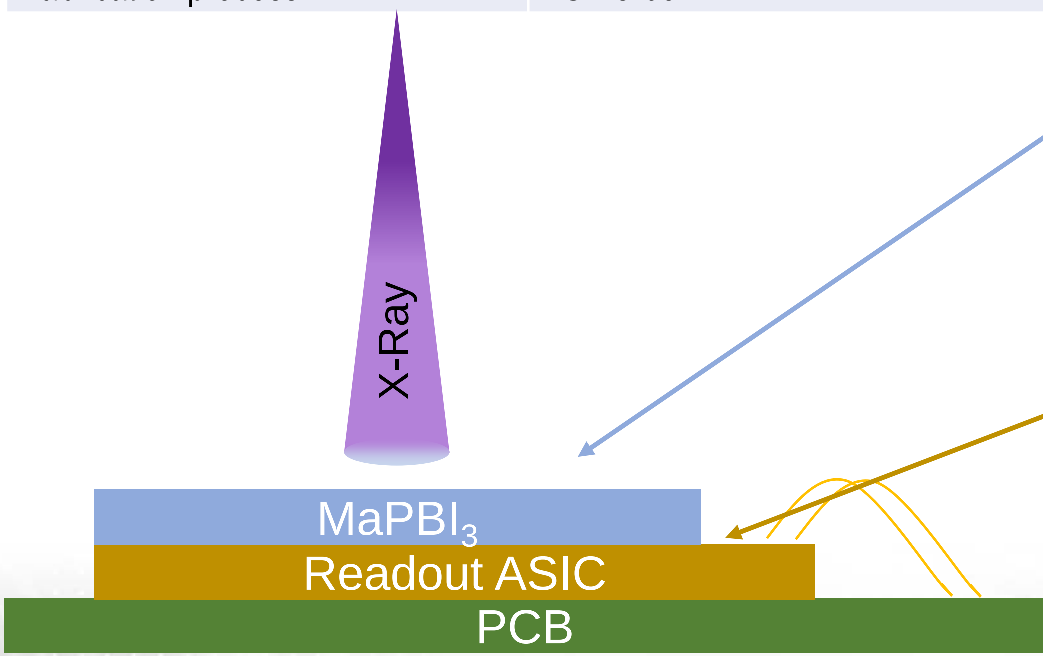
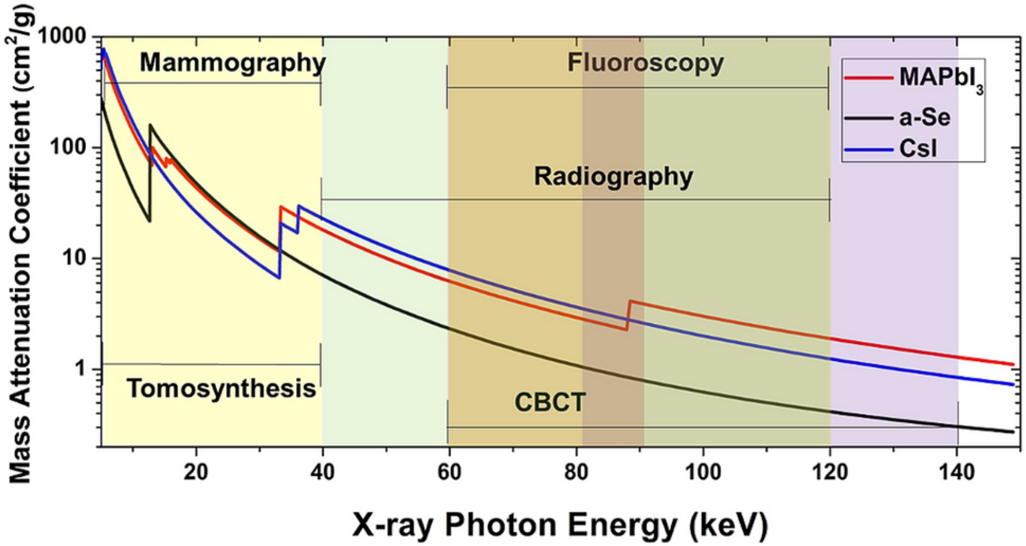
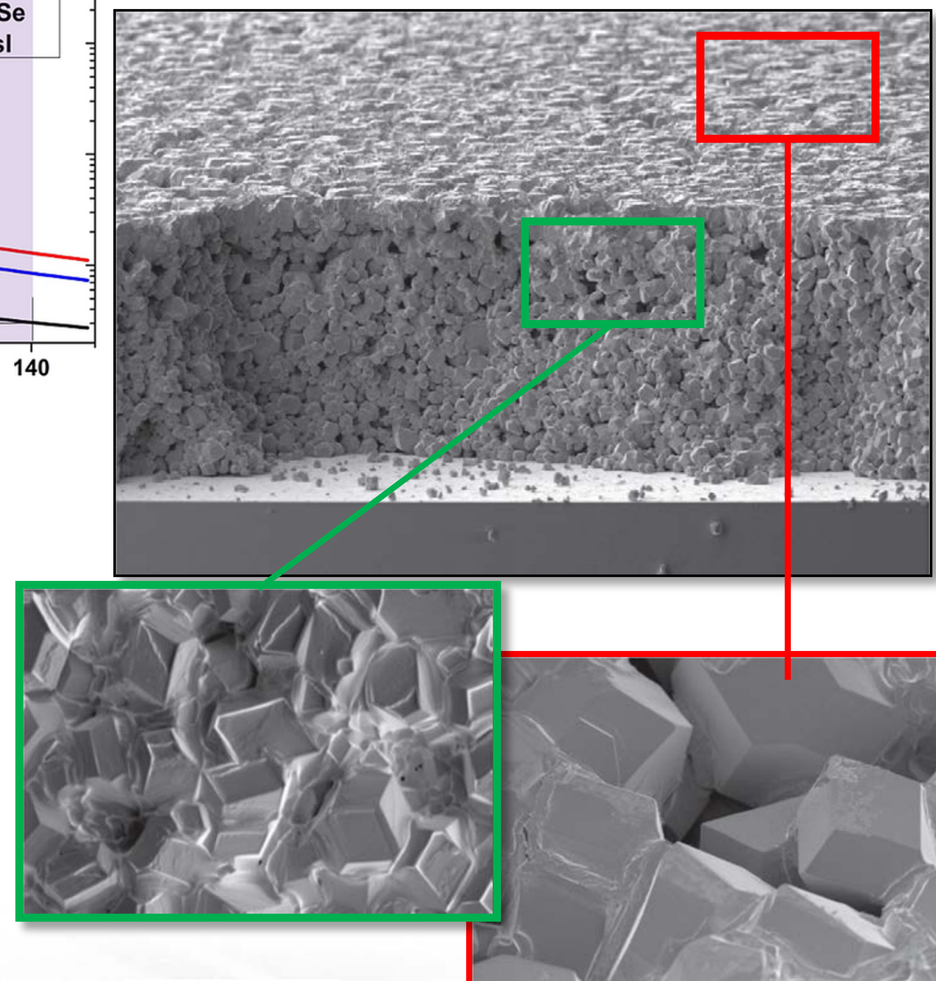





Block diagram of the System

# PEROVSKITE (MAPbI3)



| Parameter | Value |
|---|---|
| Thickness | 100um to 1mm |
| Bias Voltage | ~100V |
| Energy/Charge Conversion | 12 – 15 |
| Collected Charge | Holes |
| Charge mobility | ~140 $cm^2/V{\cdot}s$ |


- A. Datta et al, “A new generation of direct X-ray detectors for medical and synchrotron imaging applications”, https://doi.org/10.1038/s41598-020-76647-5
- Kim et al, “ Printable organometallic perovskite enables large-area ,low-dose X-ray imaging”, https://doi.org/10.1038/nature24032.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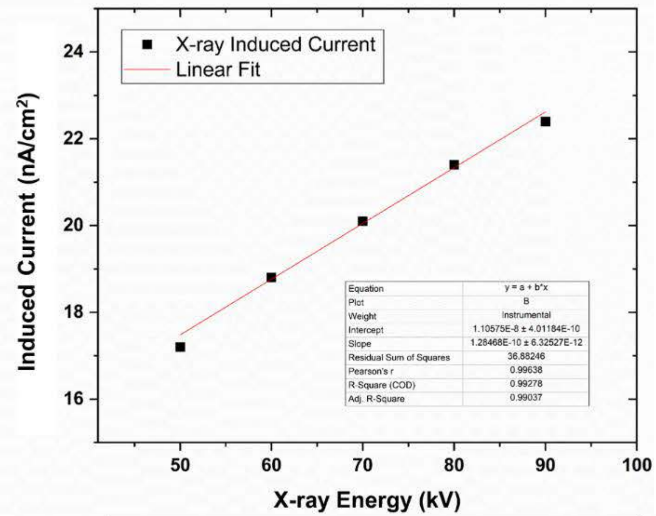
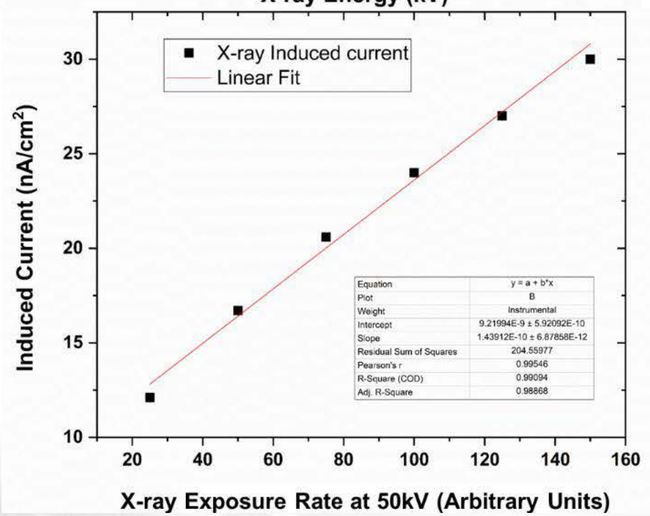
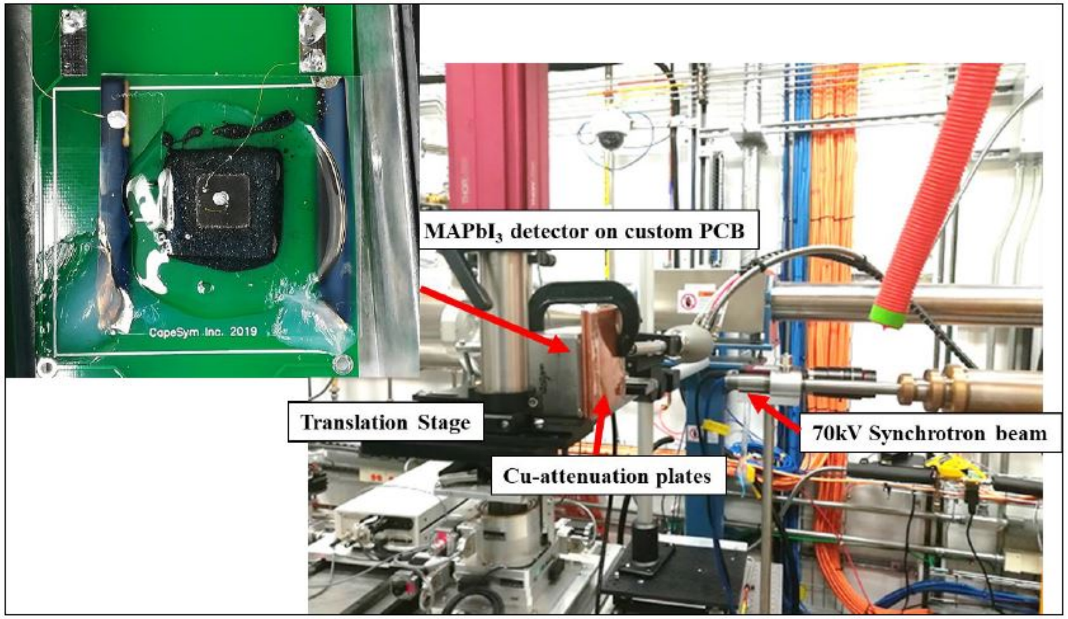
# MAPbI3 characterization with hard X-Ray @ XPD(NSLS-II)




Experimental set-up for synchrotron response testing of MAPbI3 detectors at the XPD beamline at the NSLS-II (2019).

Plots show the linearity with respect to the incoming X-ray energy and X-ray exposure rate of the 200μm-thick detectors, respectively. As can be seen, the X-ray response of the detectors is linear and hence shows the feasibility of linear X-ray response of MAPbI3-based detectors.

***Images taken from phase I final report DE-SC0019658**

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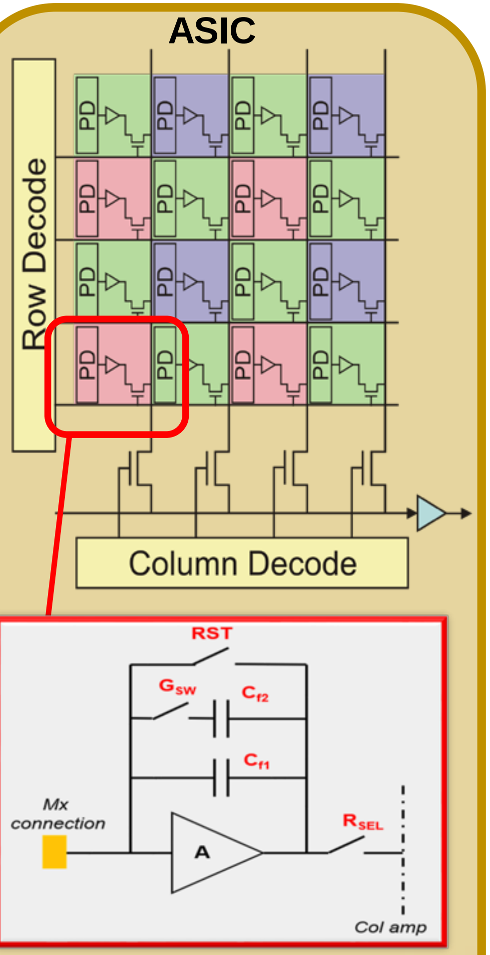
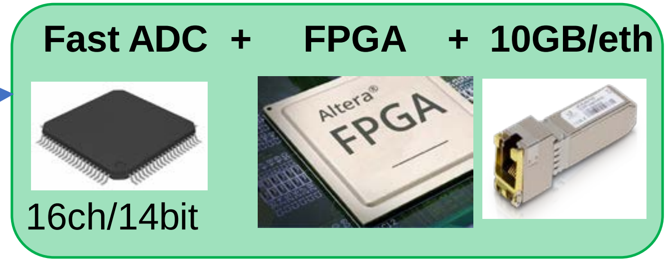
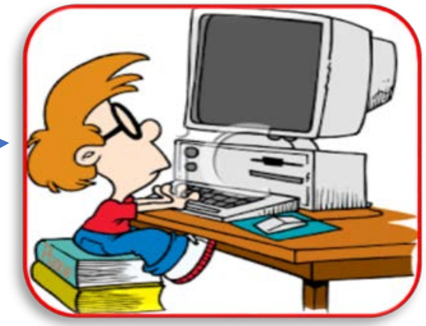
# Readout ASIC and system




MAPS architecture but with expose electrode (No PD)

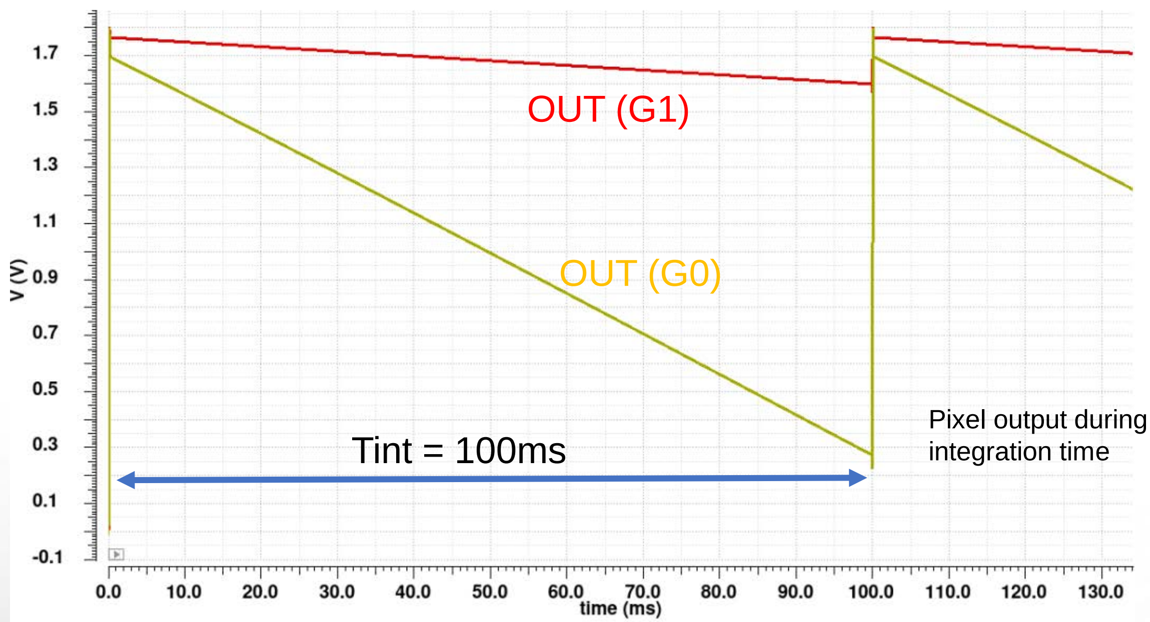
x 16



$Cf_2/Cf_1$~10:

- Single photon sensitive, Dynamic Range ~ 100ph/pixel @ 60KeV, Tint = 100ms

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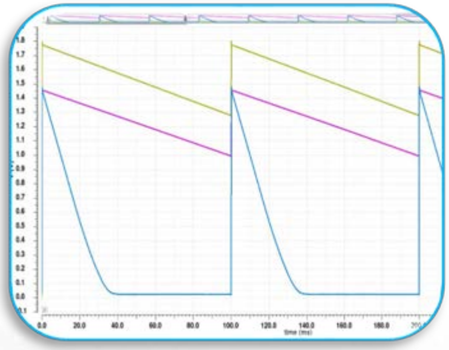
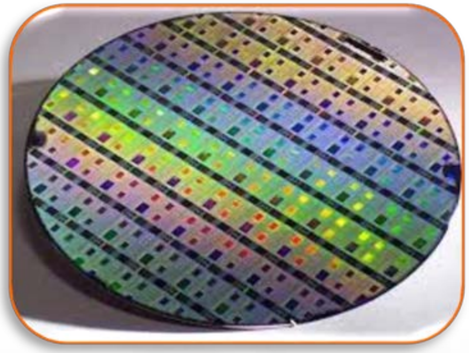
# Project Schedule

| 2019 | Jan 2021 | Nov 2021 | Mar 2022 |
|---|---|---|---|
| **Phase I** | **Phase II Design** | **ASIC Submission** | **MAPBI3 Deposition &Testing** |





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# SUMMARY

- MAPbI3 is a novel material suitable for direct hard X-Ray detection
- Linear response to the incoming flux has been proven at XPD @ NSLS-II (2019)
- Design of 1Mpixel (10um pitch) readout ASIC is on going
- Expected ASIC submission in Nov 2021
- Material deposition and study of ASIC electrode contact electrochemical properties
- Detector Test in 2022

# THANK YOU


[1] R. A. Lujan and R. A. Street, “Flexible X-ray detector array fabricated with oxide thin-film transistors,” *IEEE Electron Device Letters*, vol. 33, no. 5, pp. 688–690, May 2012.

[2] A. Parsafar, C. C. Scott, A. El-Falou, P. M. Levine and K. S. Karim, "Direct-Conversion CMOS X-Ray Imager With 5.6 um x 6.25 um Pixels," in IEEE Electron Device Letters, vol. 36, no. 5, pp. 481-483, May 2015, doi: 10.1109/LED.2015.2410304.

[3] A. Datta, Z. Zhong, S. Motakef, “A new generation of direct X-ray detectors for medical and synchrotron imaging applications,” Scientific Reports 10, 20097 (2020). https://doi.org/10.1038/s41598-020-76647-5.

[4] Kim, Y., Kim, K., Son, DY. *et al.* Printable organometallic perovskite enables large-area, low-dose X-ray imaging. *Nature* **550,** 87–91 (2017), https://doi.org/10.1038/nature24032.

[5] Takayanagi et al., "A low dark current stacked CMOS-APS for charged particle imaging," International Electron Devices Meeting. Technical Digest (Cat. No.01CH37224), Washington, DC, USA, 2001, pp. 24.2.1-24.2.4, doi: 10.1109/IEDM.2001.979566.

[6] CapeSym Inc. website: https://www.capesym.com


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