X- and β-ray sensitive CMOS Sensors for Science and Society

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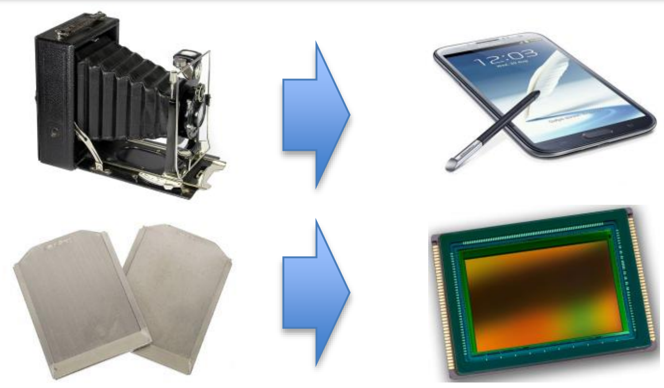
CMOS Monolithic Active Pixel Sensors (MAPS) in optical imaging:



Silicon pixel sensors (e.g. MAPS) caused **a revolution in optical imaging**. They provide:

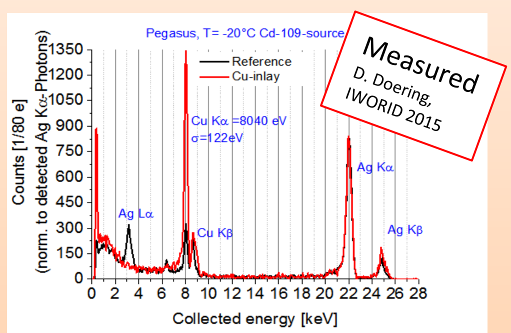
- Higher sensitivity to light
- Real time digital signal processing and data storage
- Reuseability

The knowledge to build radiation sensitive MAPS is available in the high energy physics. However, nuclear imaging (X-ray, β-ray) does still widely rely on photographic films and phosphor imager plates.

The dream: Repeat this revolution in X- and β-ray imaging

Ultra fast X-ray fluorescence spectrometer

Each pixel serves as an X-ray spectrometer. A megapixel sensor may provide highly competitive detection performances:



***Sensitivity**: > 600 keV*
***Resolution**: dE ~120 eV (@ 8keV, so far ~180 eV)*
***Counting rate**: few 10 MHz (so far ~0.1 MHz)*

The device might serve to identify unwanted atoms in materials in real time (e.g. toxines in water).

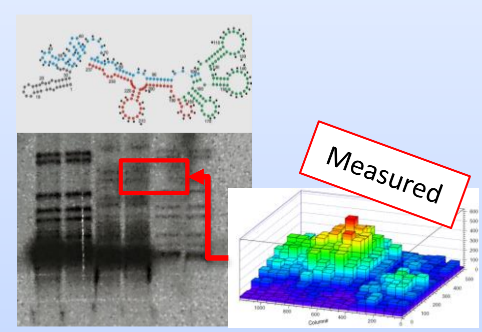
Challenge: Back-thinning, full depletion

Synergy: Radiation hard vertex detectors and pixel trackers for FAIR and LHC.

Intended users: Standard applications, real time analysis (e.g. water monitoring, quality assurance).

Ultra sensitive β - autoradiograph

β-autoradiography detects radioactively labeled biomolecules. This allows e.g. to measure the structure of mRNA (see example).



MAPS may increase the spatial resolution of the measurement. Their excellent sensitivity to β-rays will allow for reducing the related nuclear waste as well as radioactive exposure of personnel and give access to more labels e.g. ^{3}H.

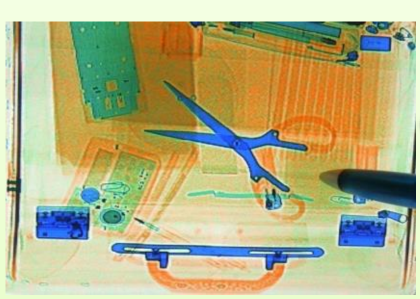
Challenge: Back-thinning, big surface (stitching), very low intensity measurement (~ 1Bq/cm² for 24 h).

Synergy: Ultra thin vertex detectors.

Intended users: Biomedical research centers (example shown: cell regulation & cancer research)

True color X-ray cameras

The sensitivity of MAPS for X-ray energies may be used to build true color X-ray cameras (1 full spectrum per group of pixels).



This will provide colored X-ray pictures. Combined with X-ray absorption spectroscopy, it will allow for identifying material signatures in pictures (e.g. copper, iron).

Challenge: Big surface (stitching), high counting rate, integration.

Synergy: Sensors for synchrotron radiation sources.

Intended users: Industrial quality assurance, homeland security, medical diagnosis.

Technologies and deliverables

MAPS are routinely used in high energy physics (e.g. STAR HFT). Their sensitivity to soft X- and β-rays is established. **We propose to adapt them to the use cases:**

X-ray spectrometer: Fully depleted, backthinned sensor with few MPixel, 1kfps analog frame readout.

β-autoradiograph: Stitched, backthinned ~100cm² sensor. Digital readout, data sparsification.

X-ray camera: Stitched, backthinned ~100cm² sensor. Fast analog readout with data sparsification.

And integrate them electrically and mechanically to working prototypes.

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