Photon Meadow conference

Camarda Massimo, SenSiC GmbH

"Silicon Carbide ultra-thin membranes for X-ray beam position and intensity monitoring"

Outline

- Consideration on solid-state sensors for inline photon diagnostic
- Comparisions on solid state sensors materials
- Opportunities offered by Silicon Carbide membranes
- Achievments (for synchrotron beams)
- Results on “First light” at the Swiss Free Electron Laser
- Conclusions

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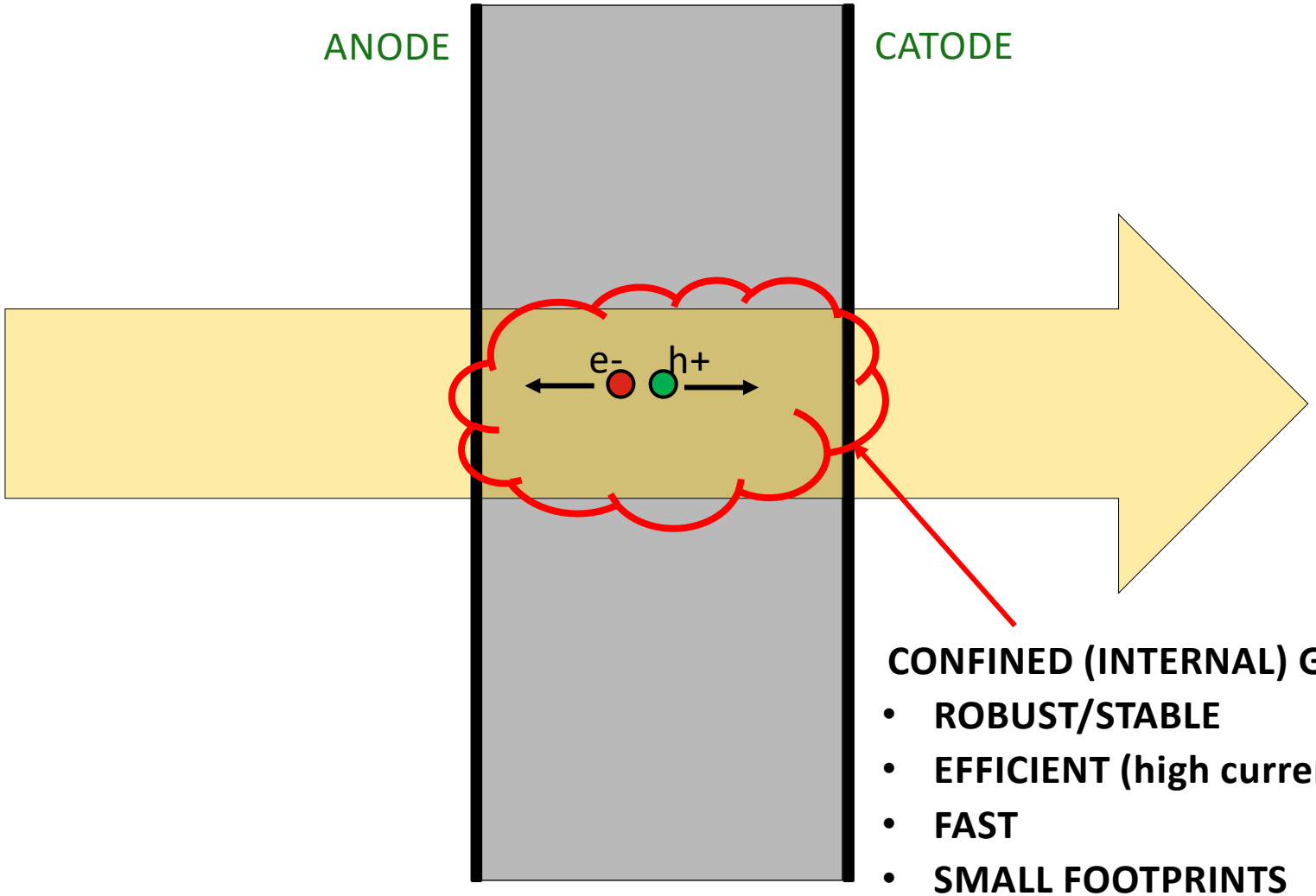
Considerations on solid-state sensors for inline photon diagnostics



CONFINED (INTERNAL) GENERATION

- **ROBUST/STABLE**
- **EFFICIENT (high currents)**
- **FAST**
- **SMALL FOOTPRINTS**

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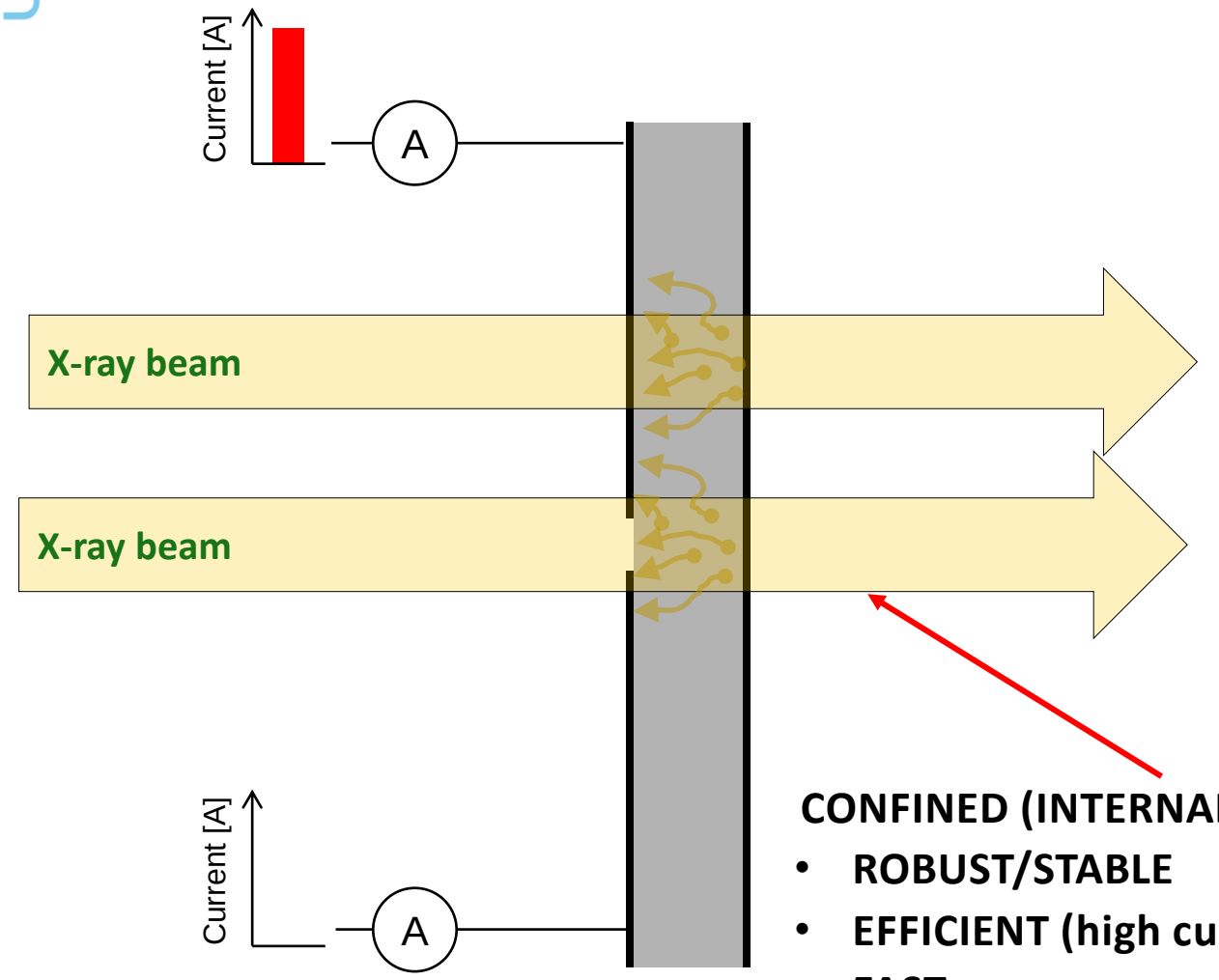
Considerations on solid-state sensors for inline photon diagnostics



CONFINED (INTERNAL) GENERATION

- **ROBUST/STABLE**
- **EFFICIENT (high currents)**
- **FAST**
- **SMALL FOOTPRINTS**
- ***HIGH LATERAL RESOLUTIONS***

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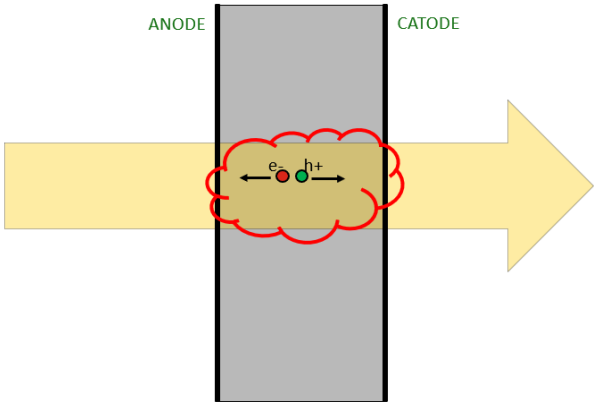
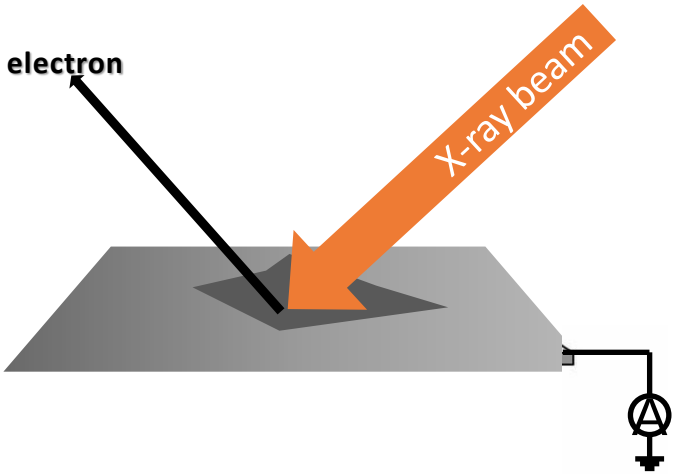
Comparison of X-ray sensors

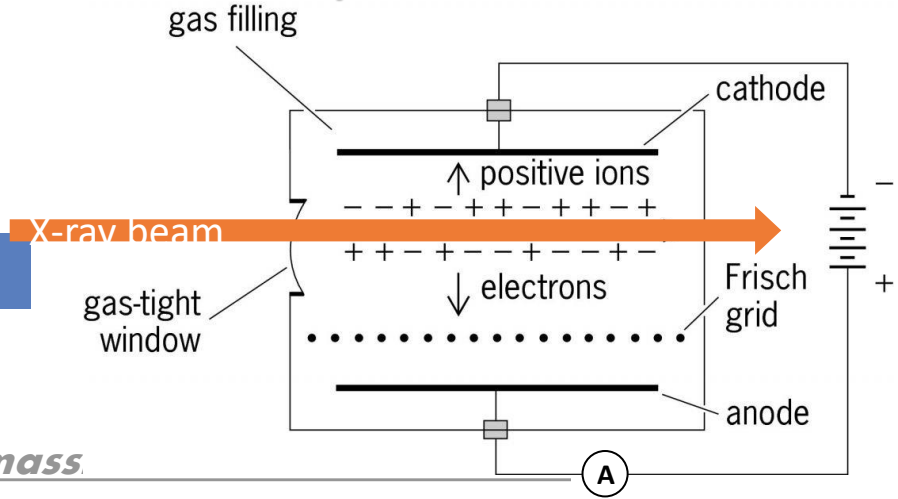
solid-state based
***internal* photoemission**



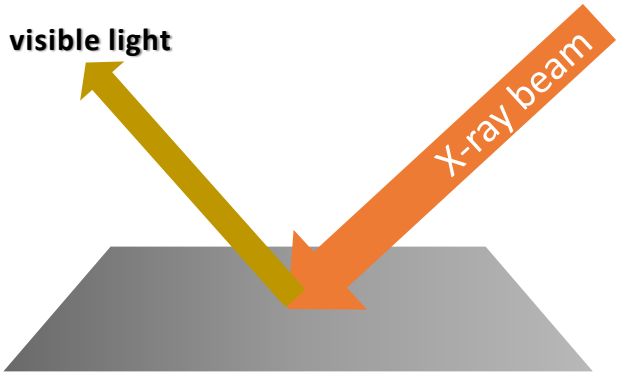
metal based
***external* photoemission**



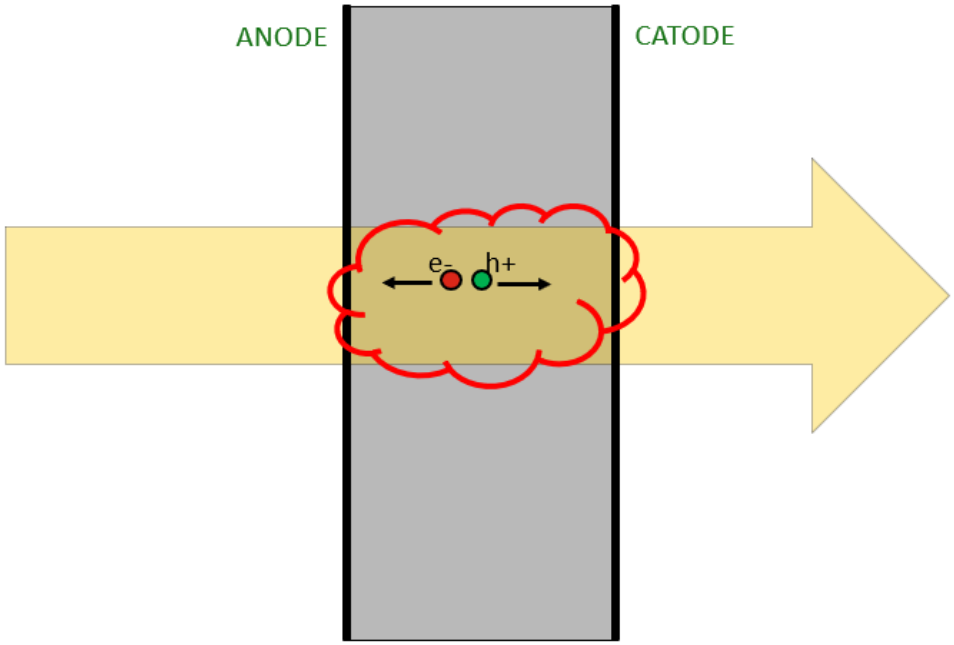
gas based
photoionization



fluorescence screen



Considerations on solid-state sensors for photon diagnostics



CRITICAL ASPECTS

- ***transparency (>98%)***
- **stability over time (device degradation)**

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Best possible material for solid-state sensors

DIAMOND (CARBON)

Property	Diamond
melting point	4500°C
Thermal conductivity	>1500W/m/K
Xray transparency	high

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Best possible material for solid-state sensors

DIAMOND (CARBON)

Property	Diamond
material costs	very high
Available crystal size	0.25cm^2 (5mmx5mm)
Quality of crystals	“optical” grade
Electron/Hole generation energy	13eV
Doping control	**minimal (>1E20cm-3)**

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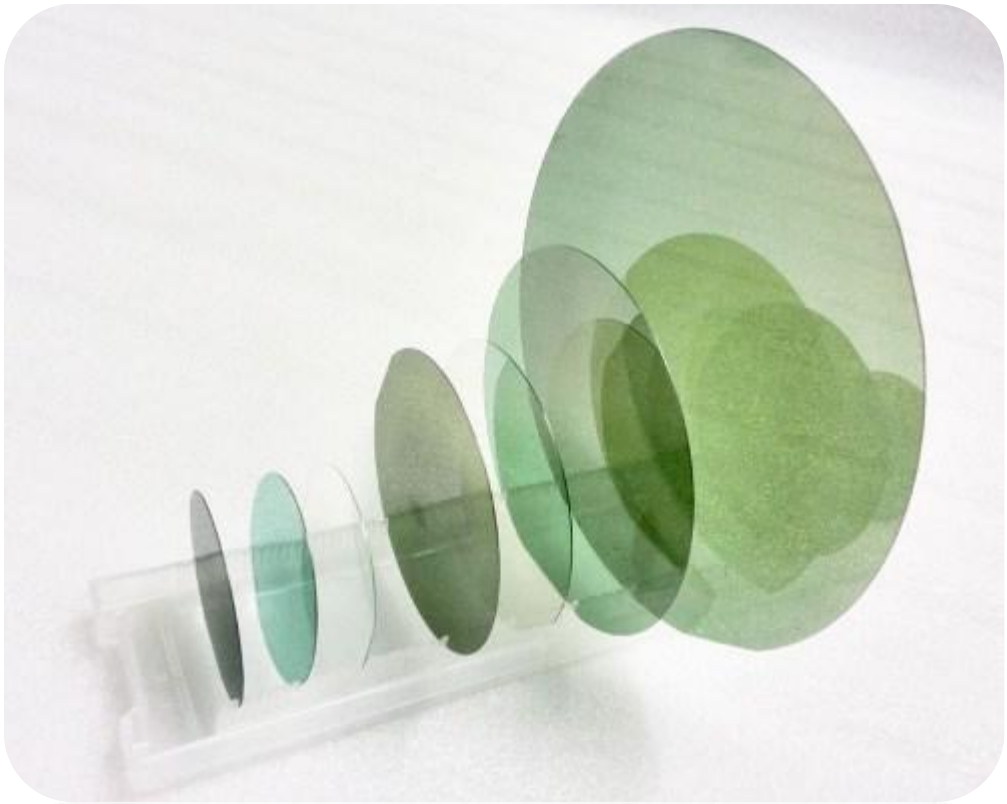
Best possible material for solid-state sensors

SILICON CARBIDE



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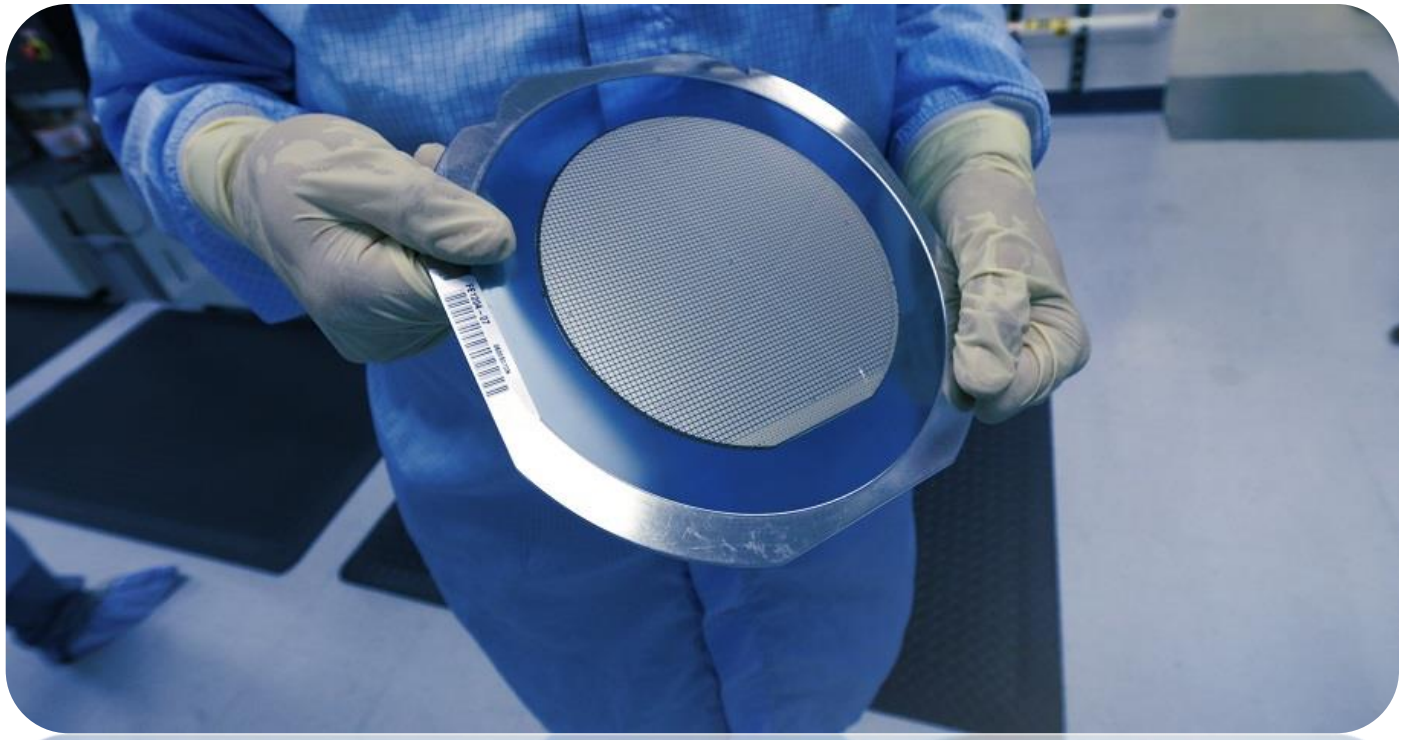

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Best possible material for solid-state sensors

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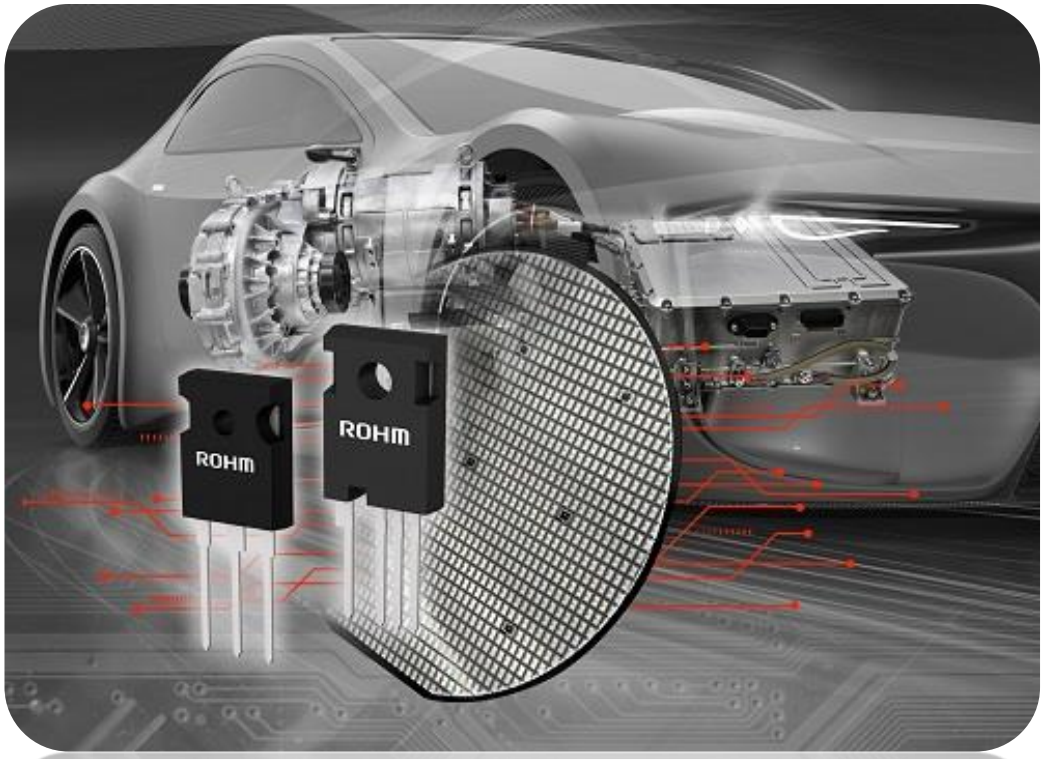

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Best possible material for solid-state sensors

Property	Diamond	Silicon Carbide	
melting point	4500°C	2700°C	
Thermal conductivity	>1500W/m/K	400W/m/K	
material costs	very high	medium/low	
Available crystal size	0.25cm^2 (5mmx5mm)	315cm^2 (8inch)	**x1260!**
Quality of crystals	"optical/electrical" grade	fully industrial	
Electron/Hole generation energy	13eV	7.8eV	**Higher signal**
Doping control	minimal (>1E20cm-3)	high (>5E13cm-3)	**Better sensitivity**
Stability of metallisations	low	high	**Better reliability**

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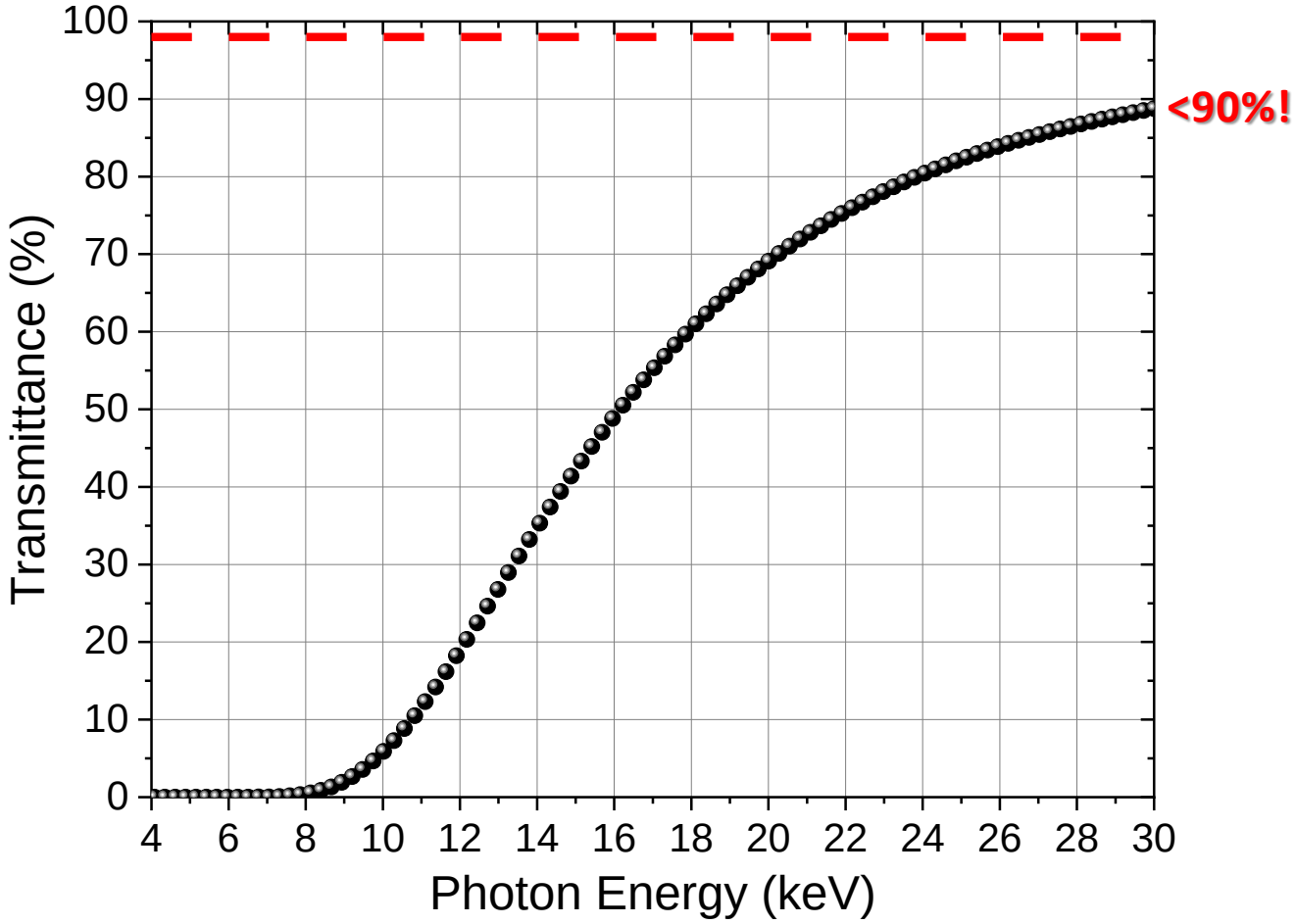
Best possible material for solid-state sensors



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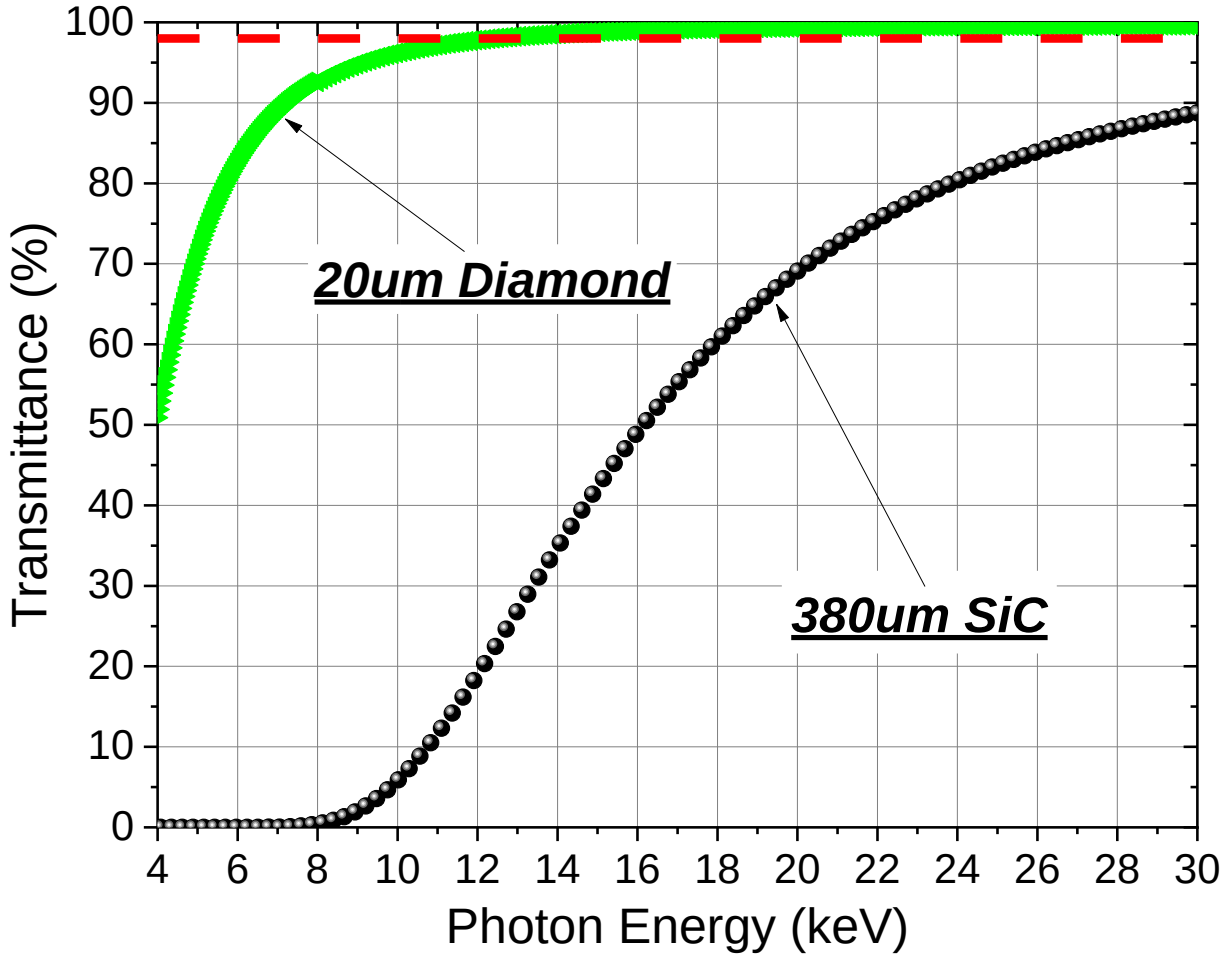
Best possible material for solid-state sensors



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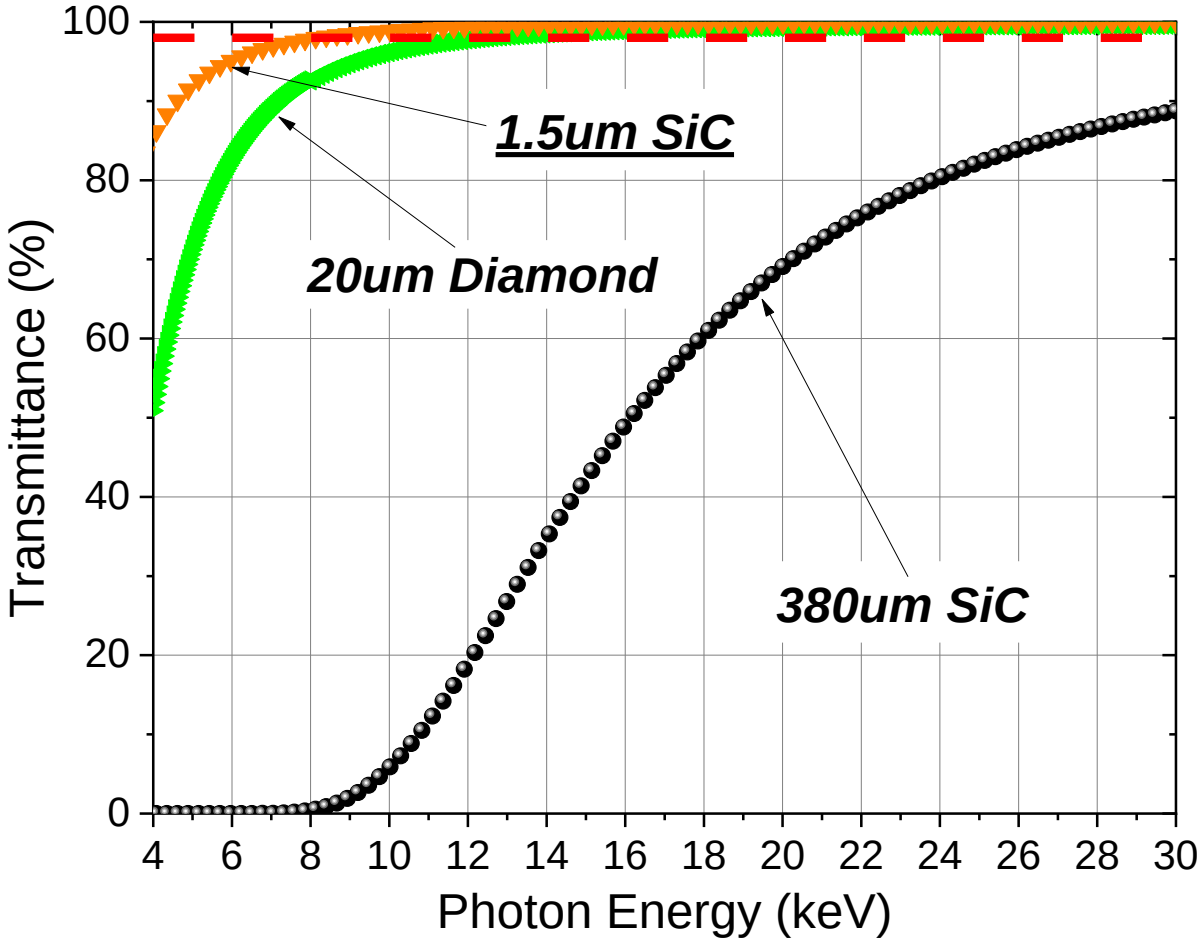
Best possible material for solid-state sensors



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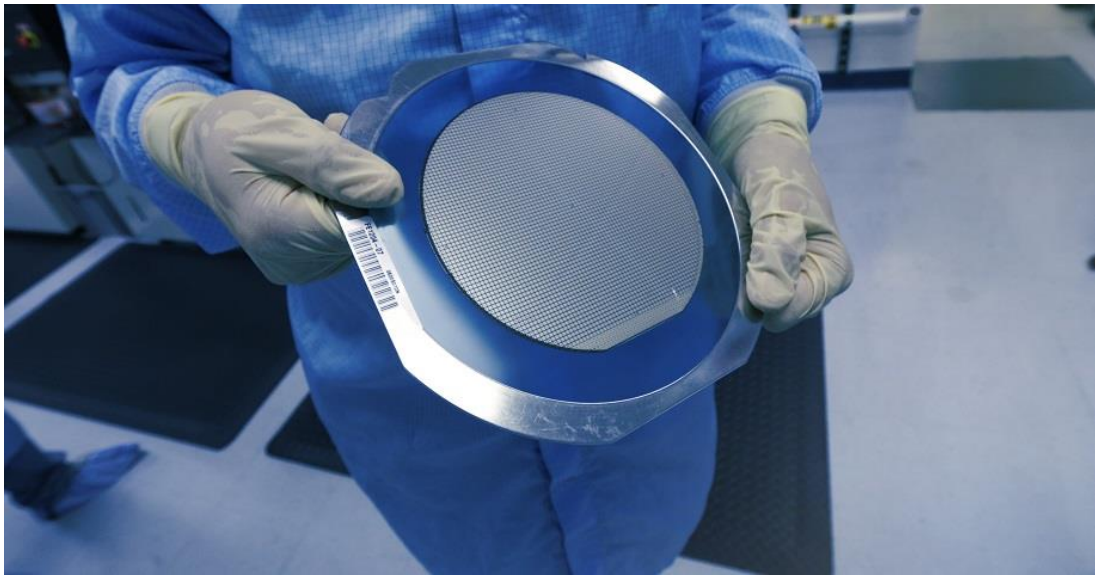
Best possible material for solid-state sensors

SILICON CARBIDE



<0.025% etching error needed! (on several mm²)

IMPOSSIBLE TO HANDLE!!

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Best possible material for solid-state sensors

x.2 Patented thinning technology
more patents (x2) in pipeline

Free-standing sensors

>3mm wide

<1.5um thickness

BEAM

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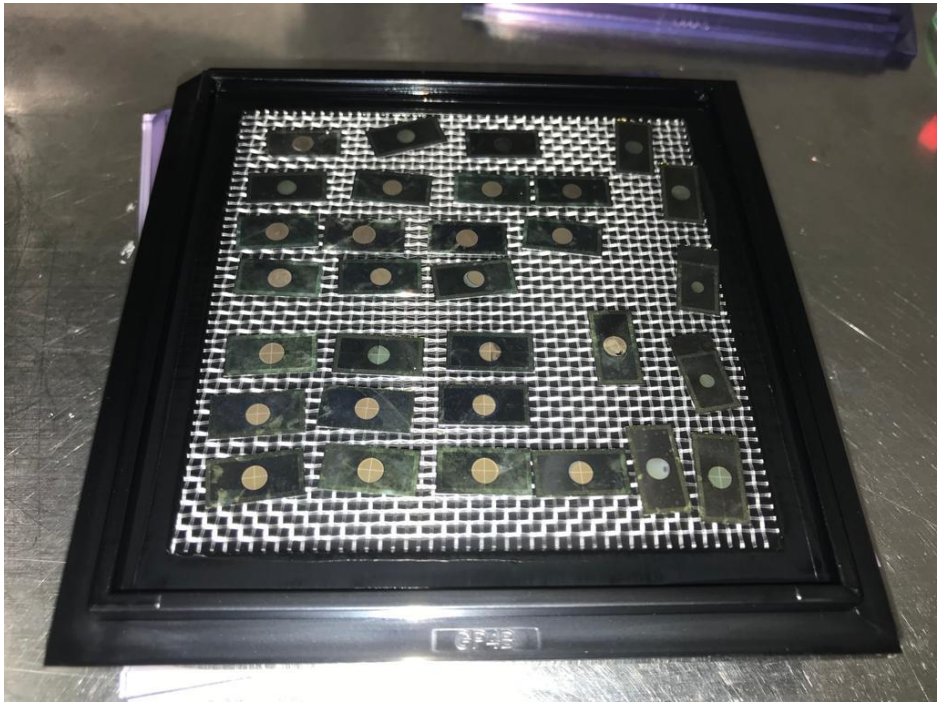
Best possible material for solid-state sensors

SILICON CARBIDE

FREE-STANDING MEMBRANES

INTENSITY AND POSITION MONITORS



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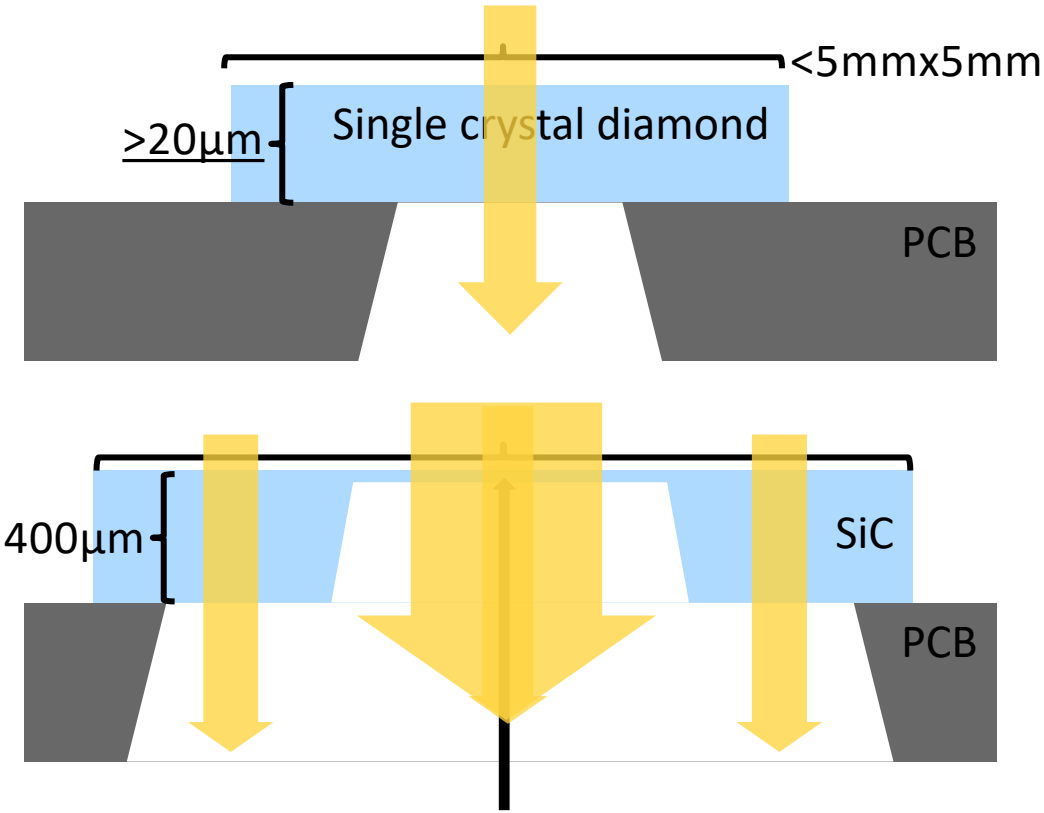
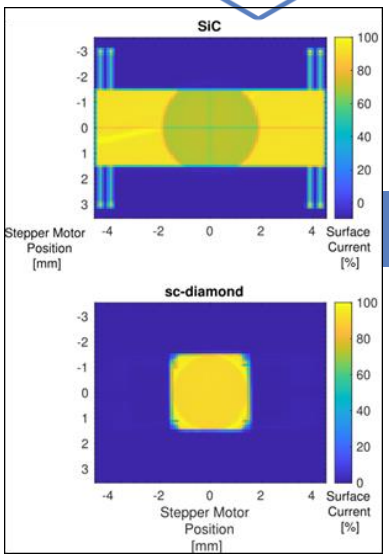
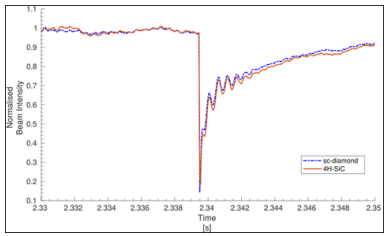
Diamond or Silicon Carbide?

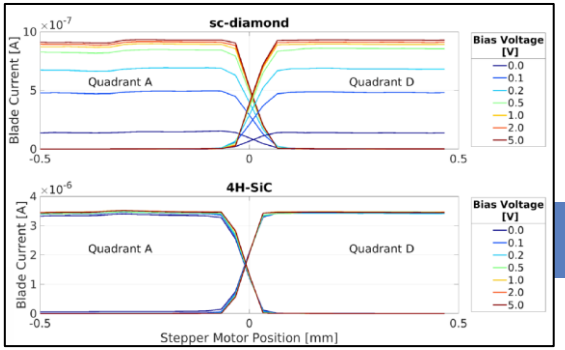
“A direct experimental comparison of single-crystal CVD diamond and silicon carbide X-ray beam position monitors” *C. Houghton, JSR 30, 876 (2023)*







SenSiC



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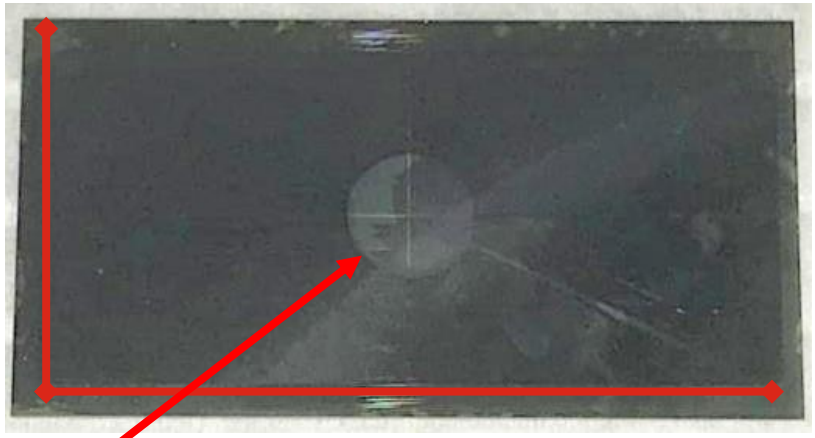
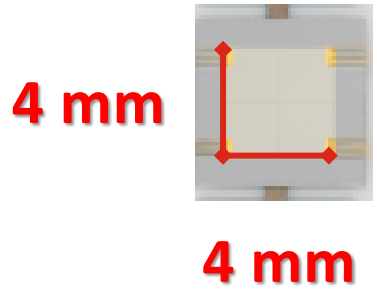
*up to instrumental limits

Best possible material for solid-state sensors

SILICON CARBIDE



CVD DIAMOND



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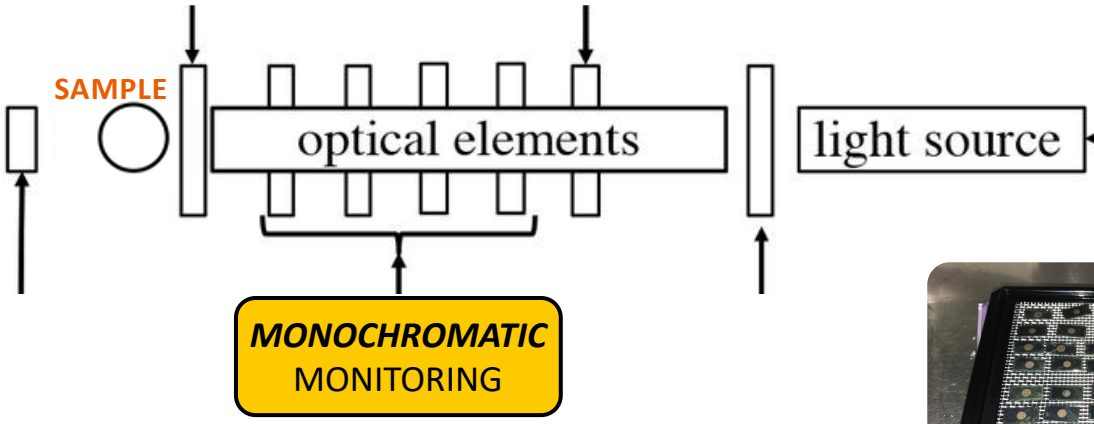
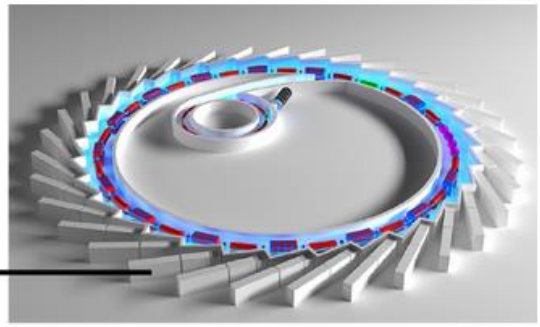
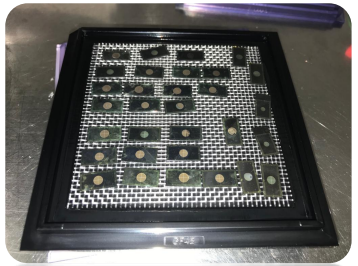
Locations for in-line Synchrotron monitoring

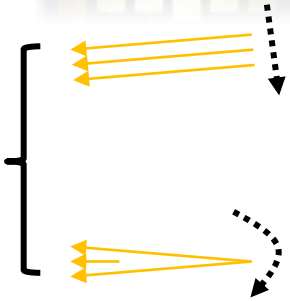






Commercially available XBPM

1) **Monochromatic**
2) ***Hard-Xray***
3) ***Position***
4) Only on ***single-feedback*** schema



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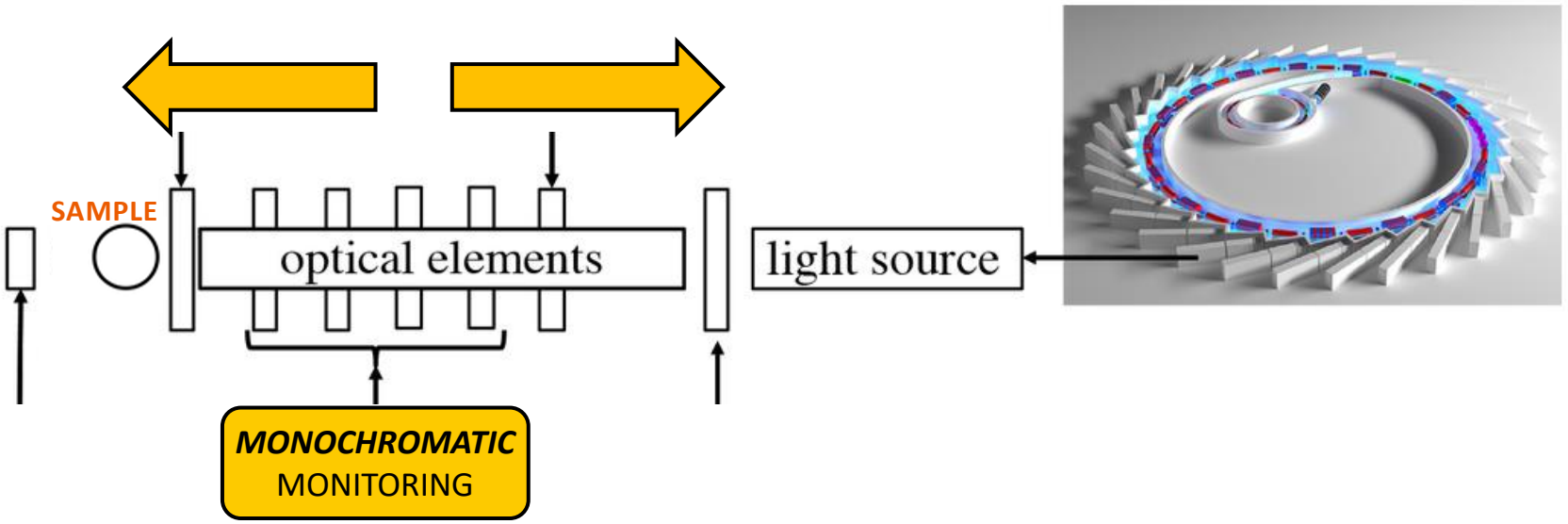
Locations for in-line Synchrotron monitoring



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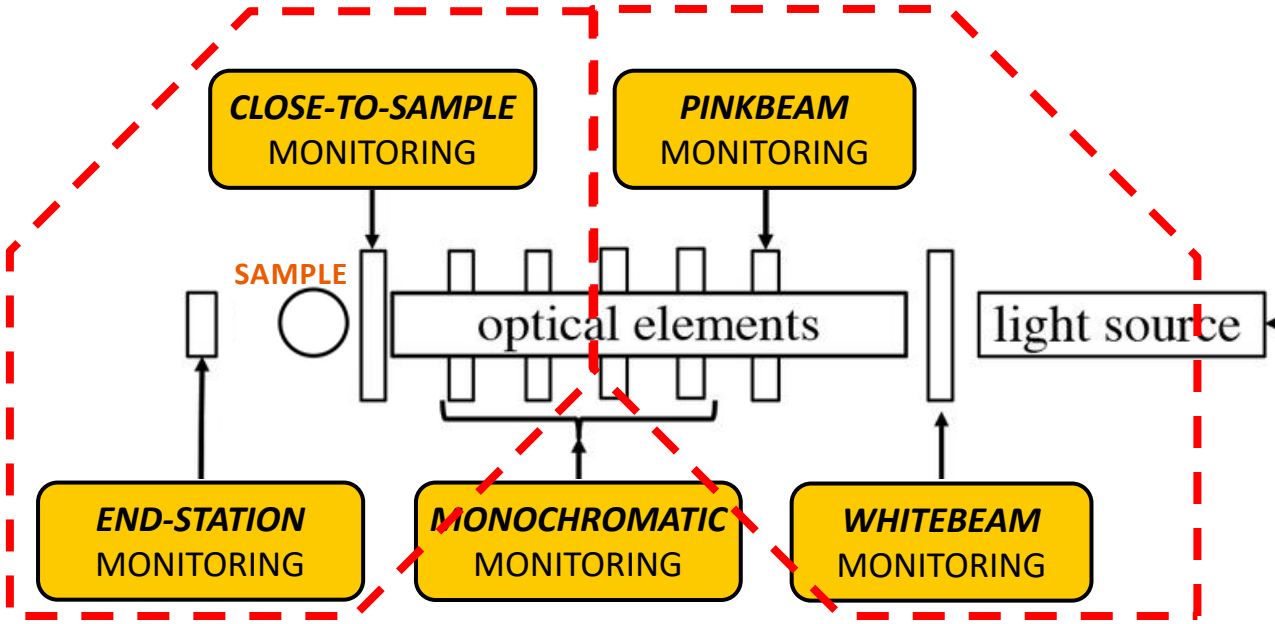

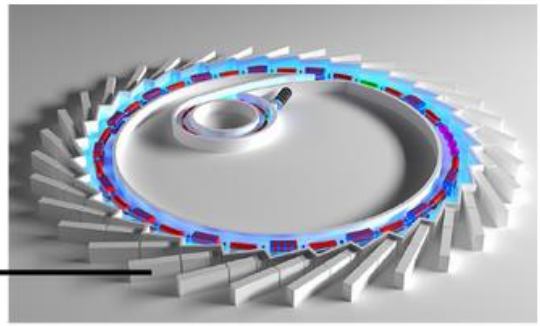

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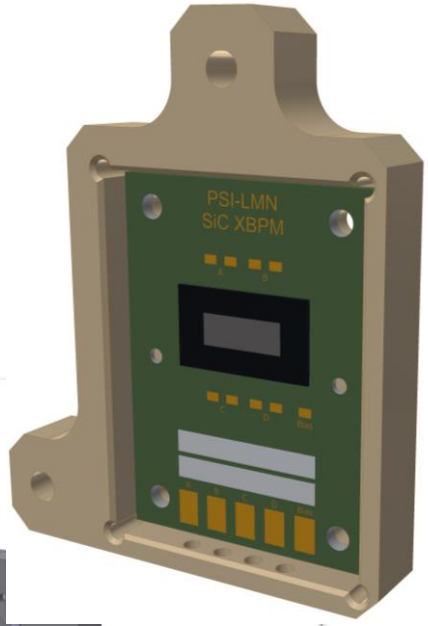
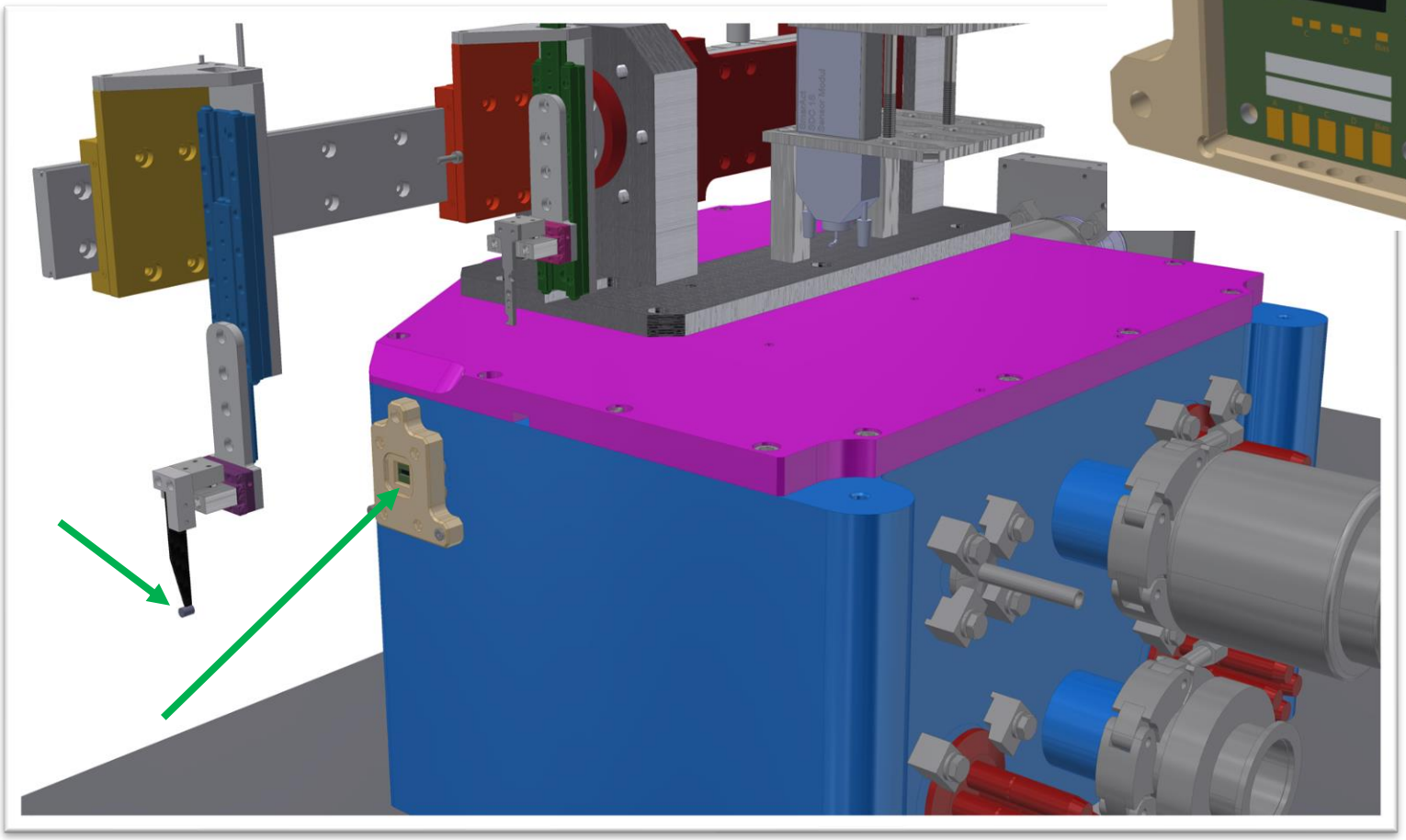
Near sample monitoring

-Fast/compact intensity sensor*





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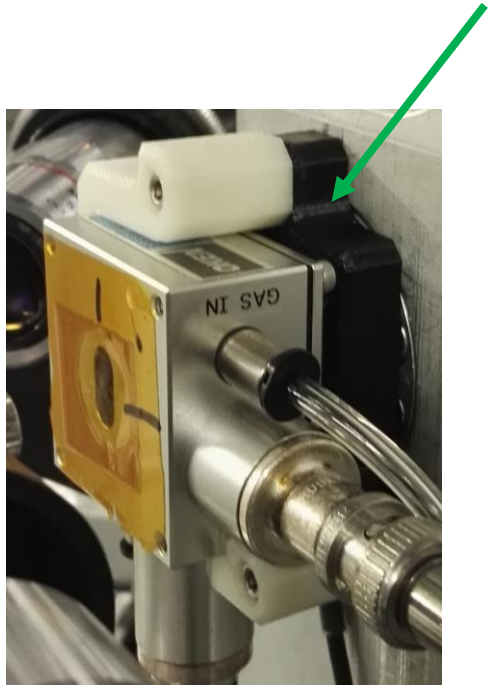
Near sample monitoring

-Fast/compact intensity sensor*



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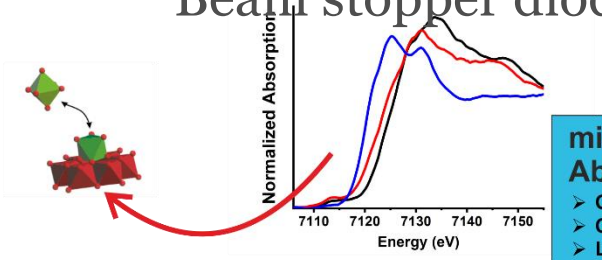
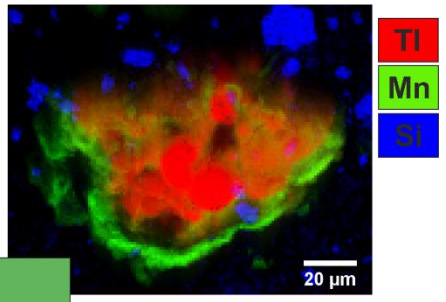
Near sample monitoring

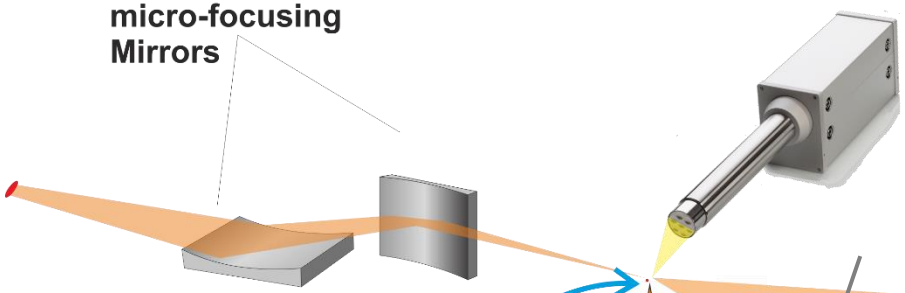
-Beam stopper diode (no transmittance mode)



microscopic X-ray Absorption-Spectrocopies
- Oxidation state
- Chemical speciation
- Local atomic coordination



micro-focusing Mirrors

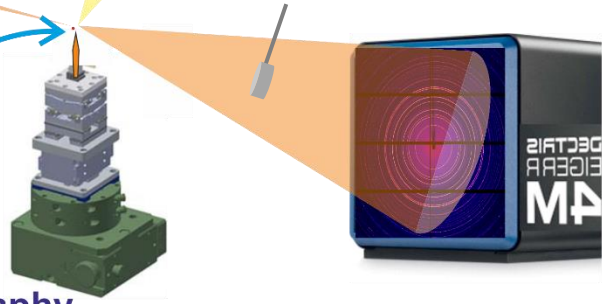


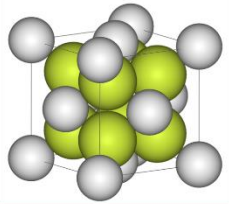
XRF detector
- Local element stoichiometry/composition

Spot-size

$\gtrsim 1 \times 1\ \mu m^2$

2D raster scan and
3D scanning tomography





XRD detector
- Crystalline phase identification
- Chemical speciation
- Stress

Courtesy: Dario Sanchez

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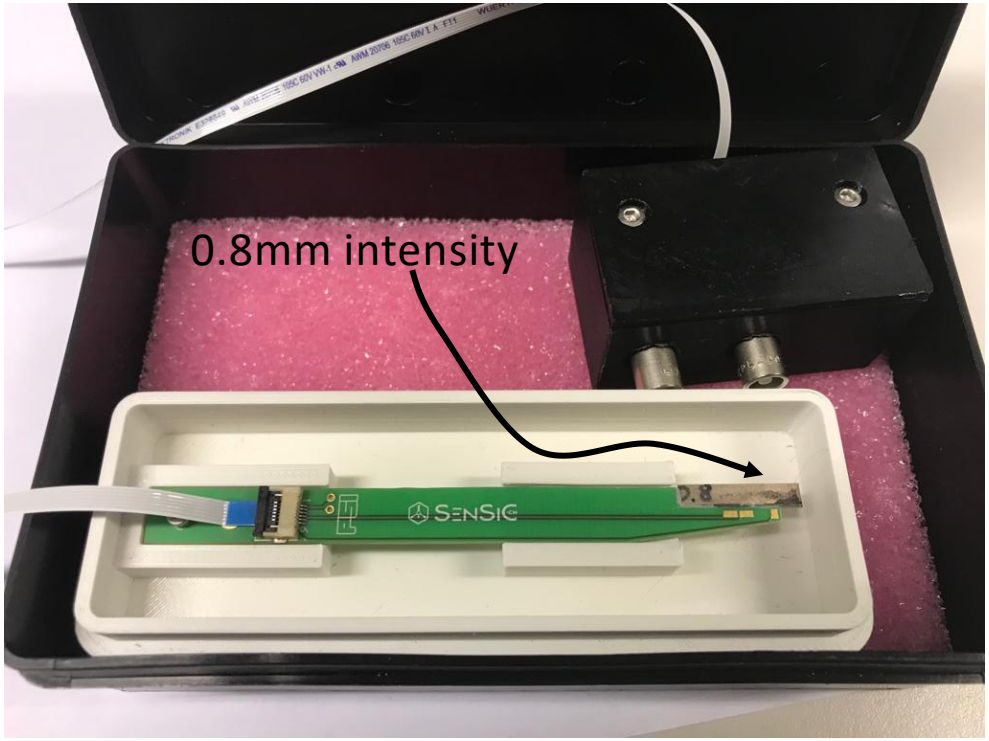
Near sample monitoring

-Beam stopper diode (no transmittance mode)



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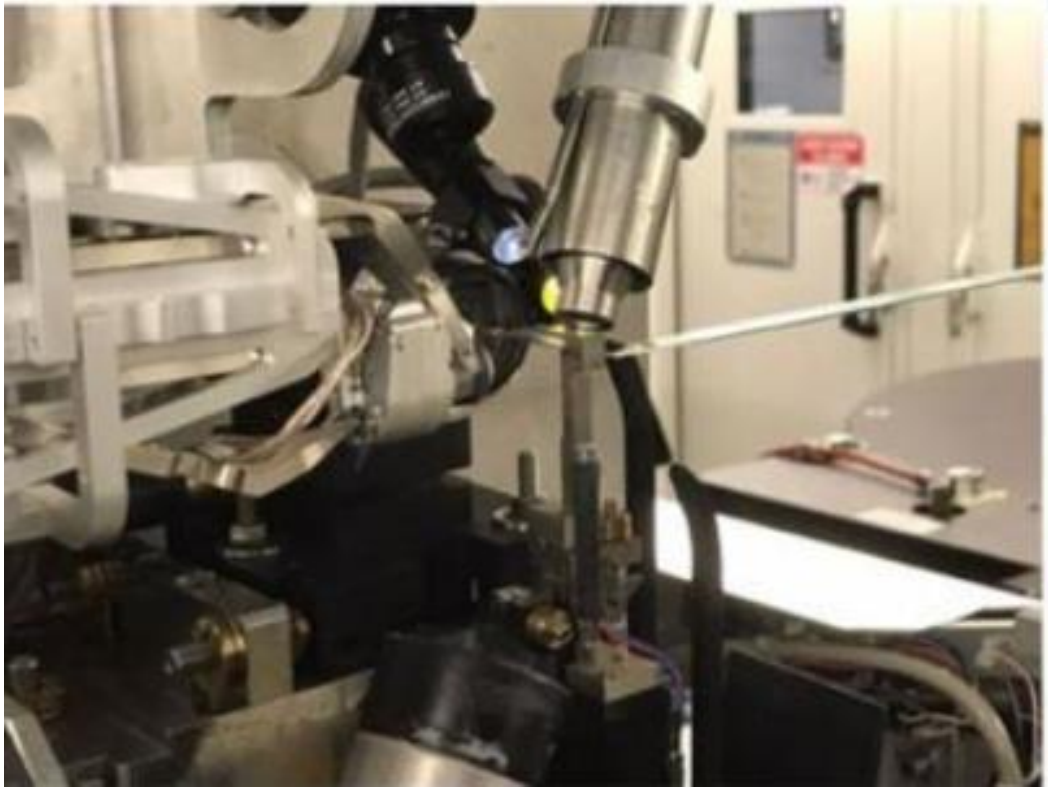
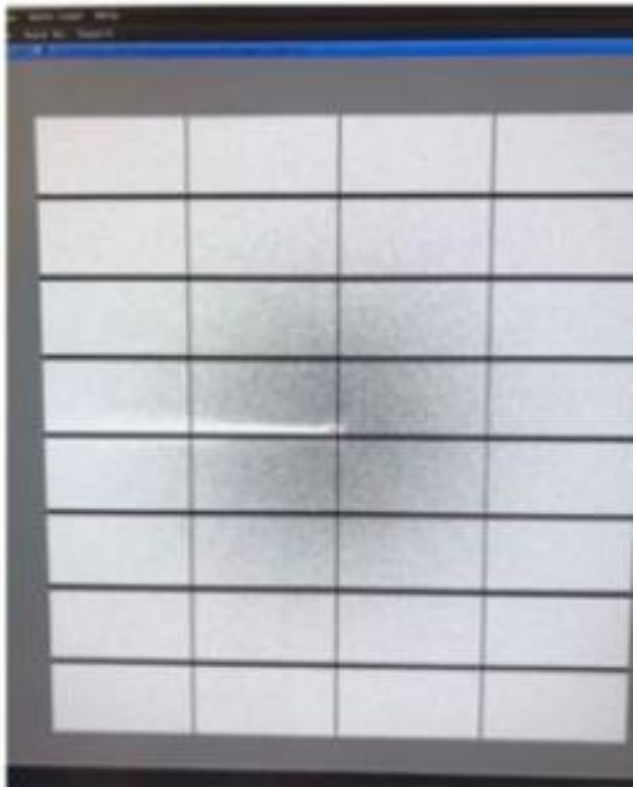
Near sample monitoring

-Beam stopper diode (no transmittance mode)





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Near sample monitoring

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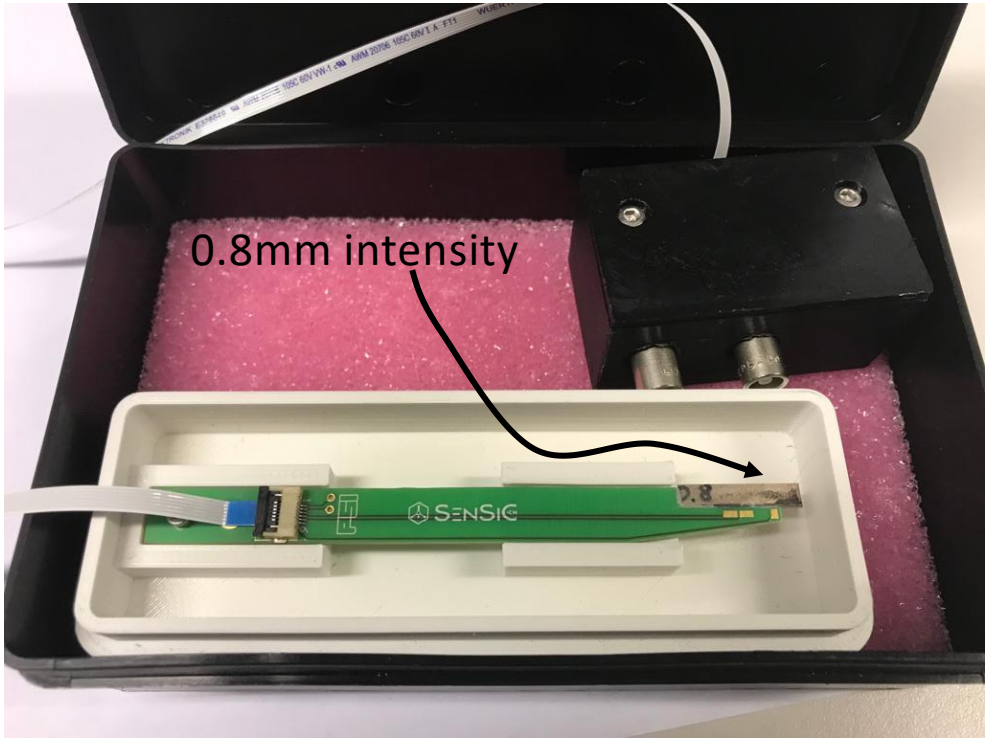

- 0.8mm intensity monitor
- 2mm intensity monitor
- 2mm position monitor
- 3mm position monitor

*

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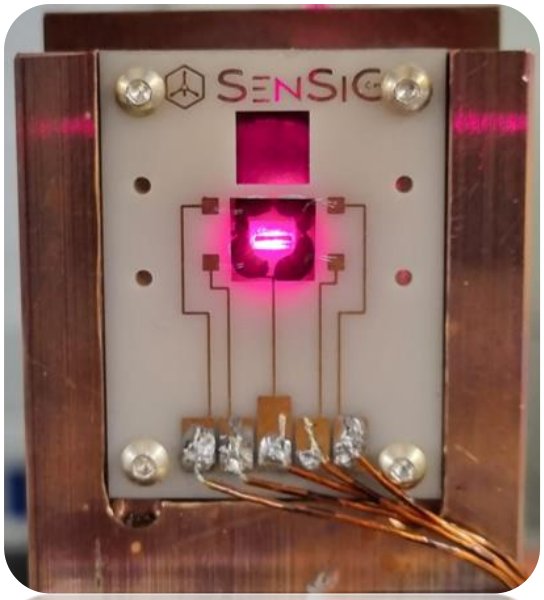
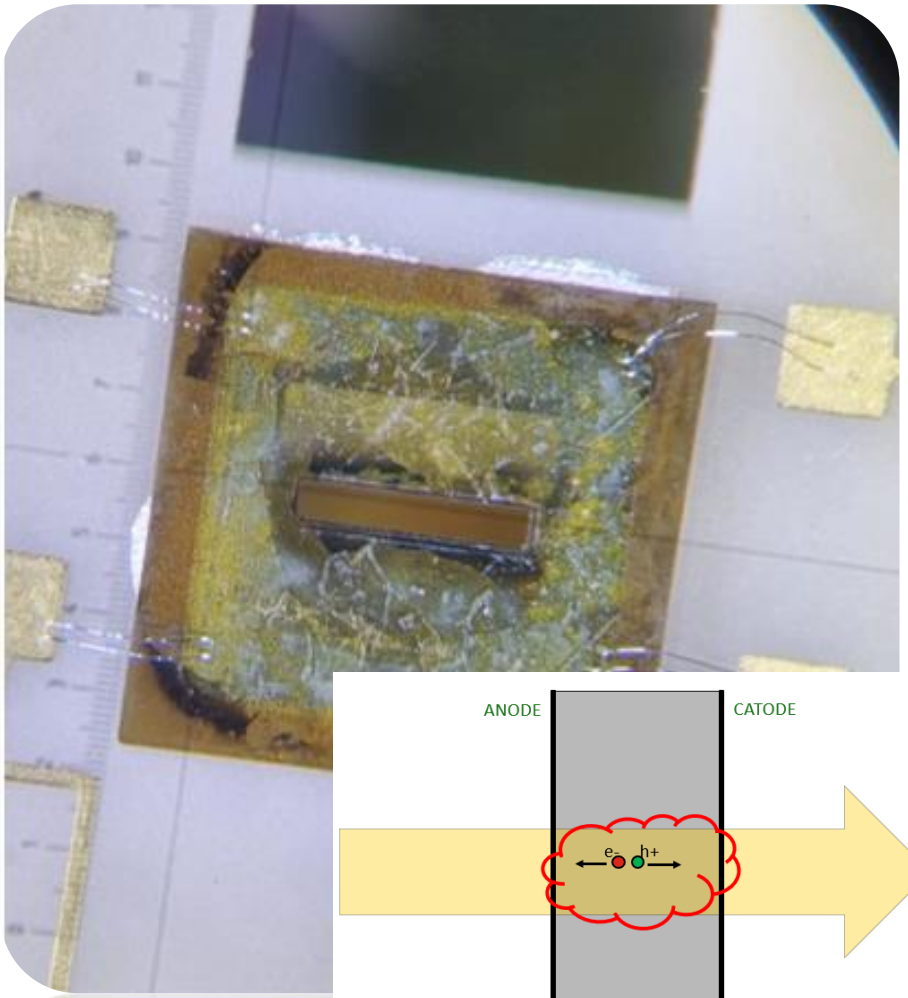
POLYCHROMATIC MONITORING





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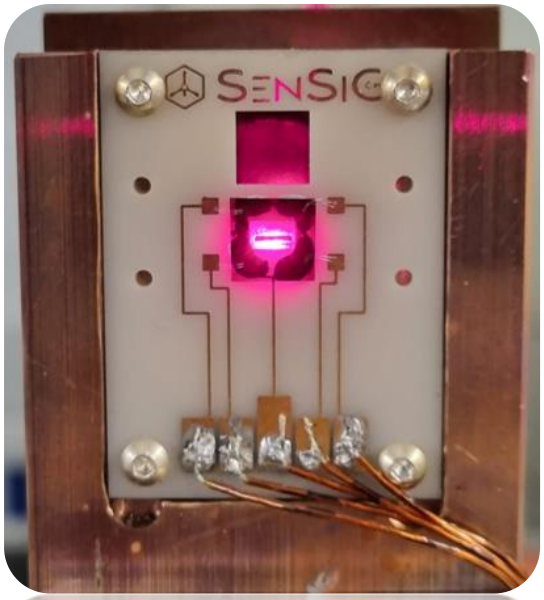
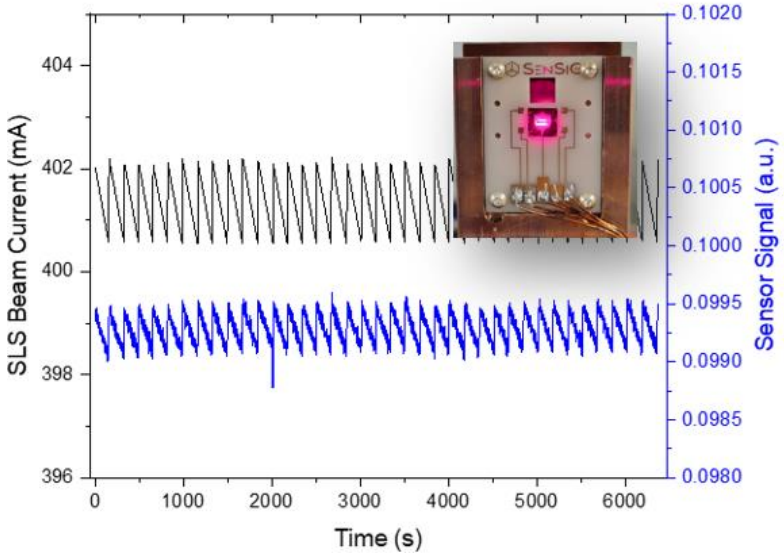
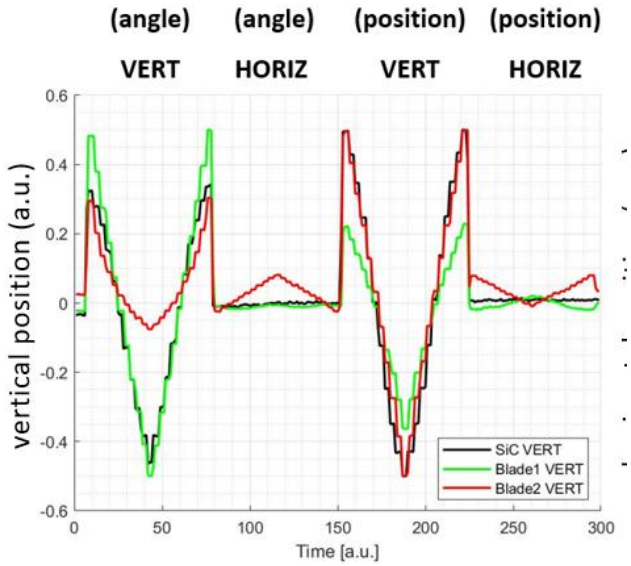
POLYCHROMATIC MONITORING







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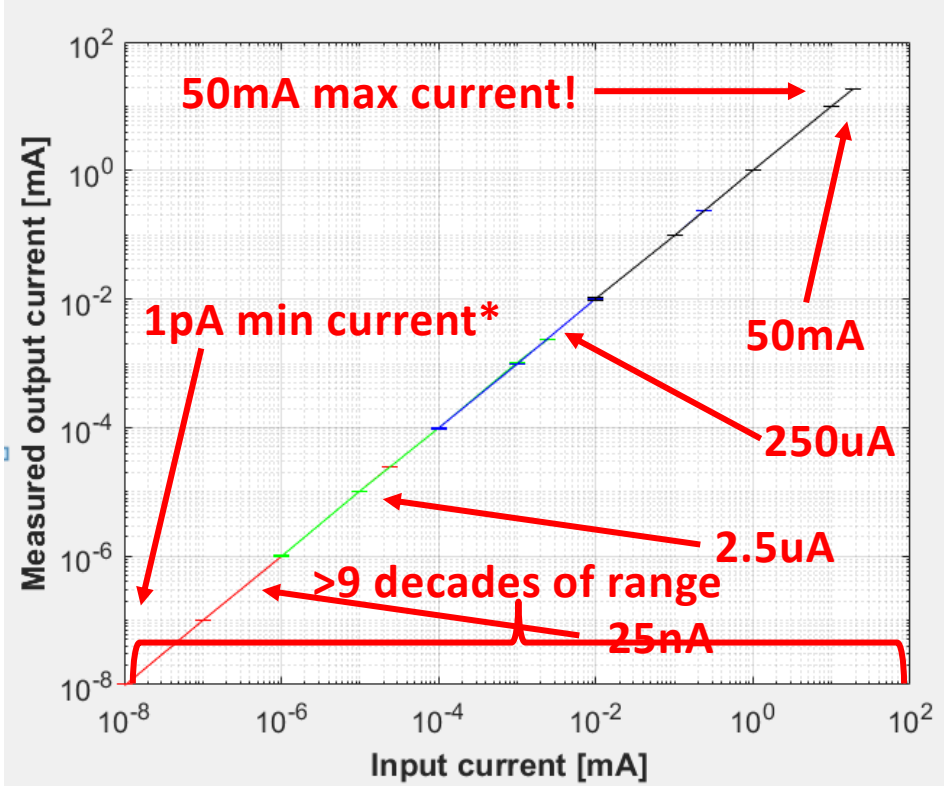
NEW READOUT SYSTEM



EPICS (QuadEM) COMPATIBLE, WITH POSSIBILITY OF MUTIPLEXING AMONG SENSORS

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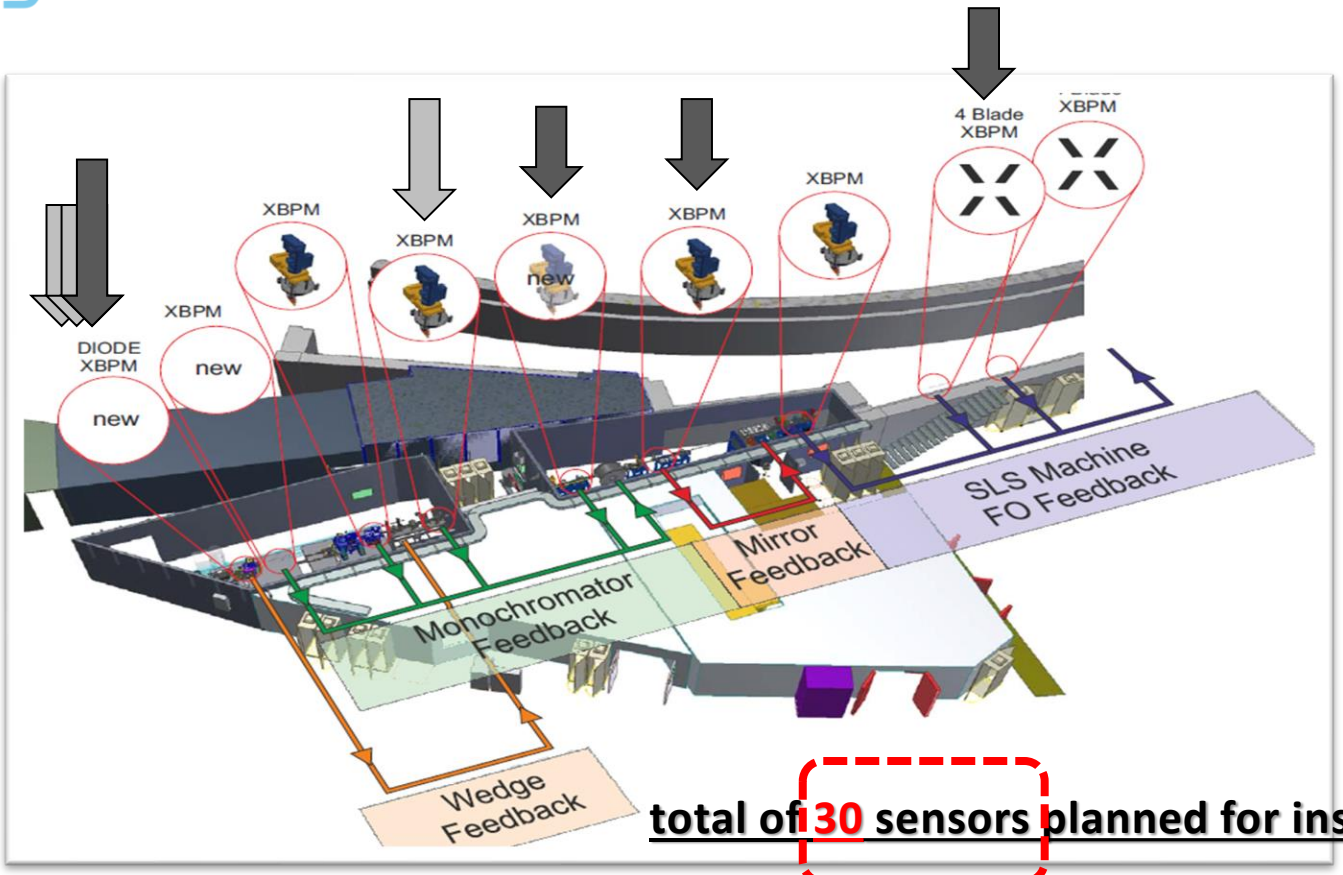
*at 6Hz bandwidths

microXAS@PSI currently represents the most advanced "XBPM-monitored" beamline WW



total of 30 sensors planned for installation

- **Currently installed:**
  n.7 sensors (after mono, I0, nano-focus, pinkbeam and beam-stopper intensity)
- **Planned:** multiple pixelated, before mono, whitebeam, beam-stopper *position*

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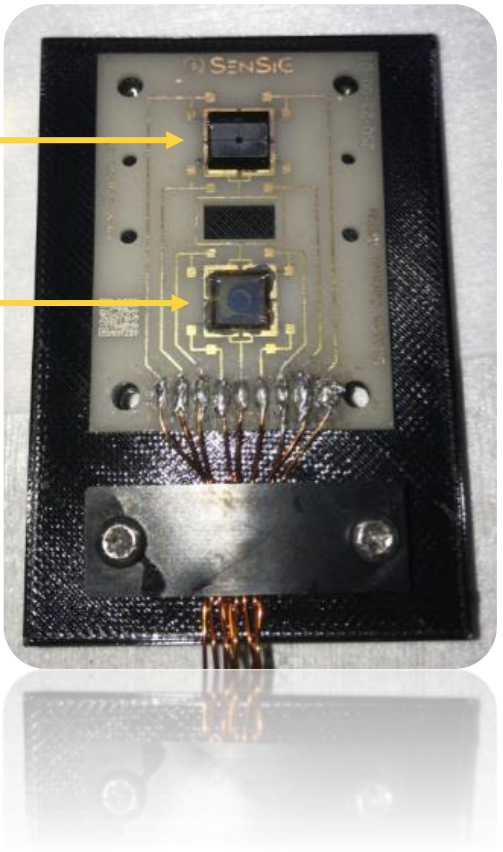
Multi-sensors packaging

SENSOR FOR WHITE BEAM

SENSOR FOR MONOCHROMATIC BEAM



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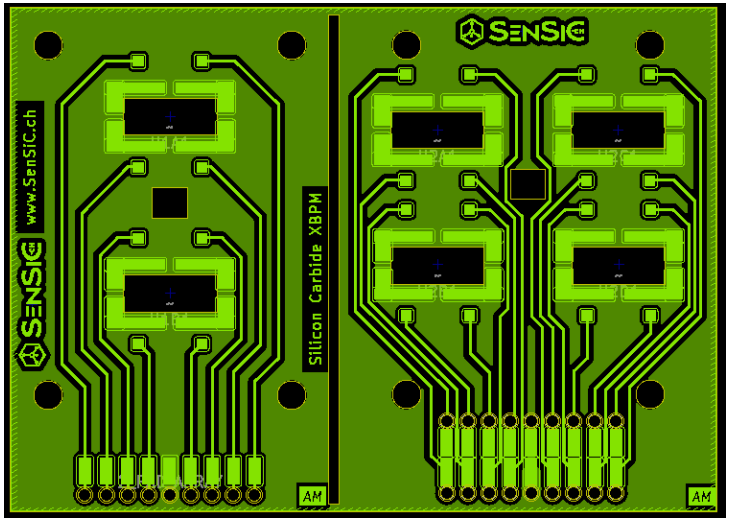
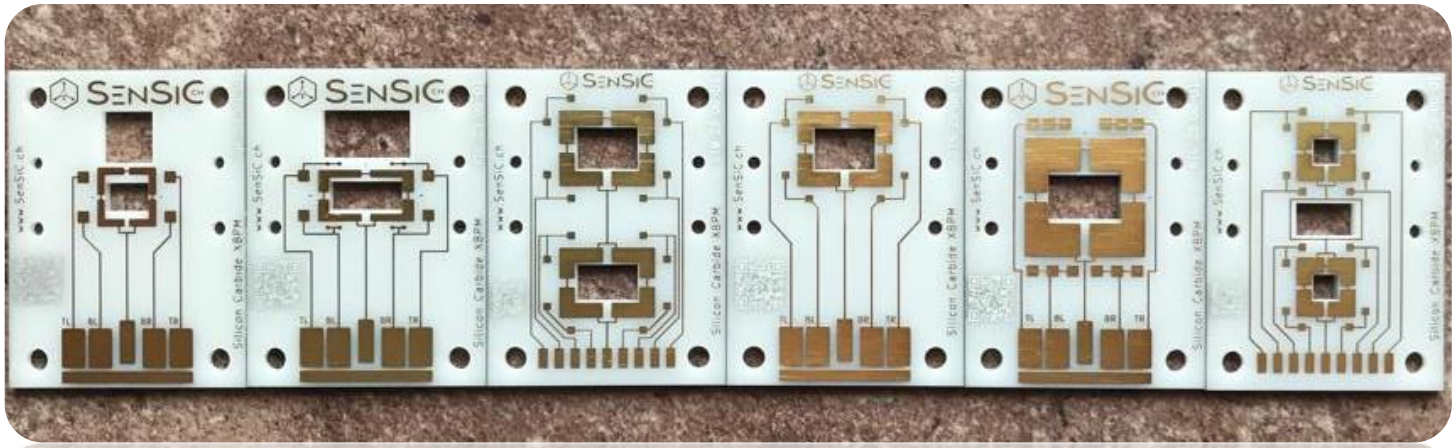
Multi-sensors packaging





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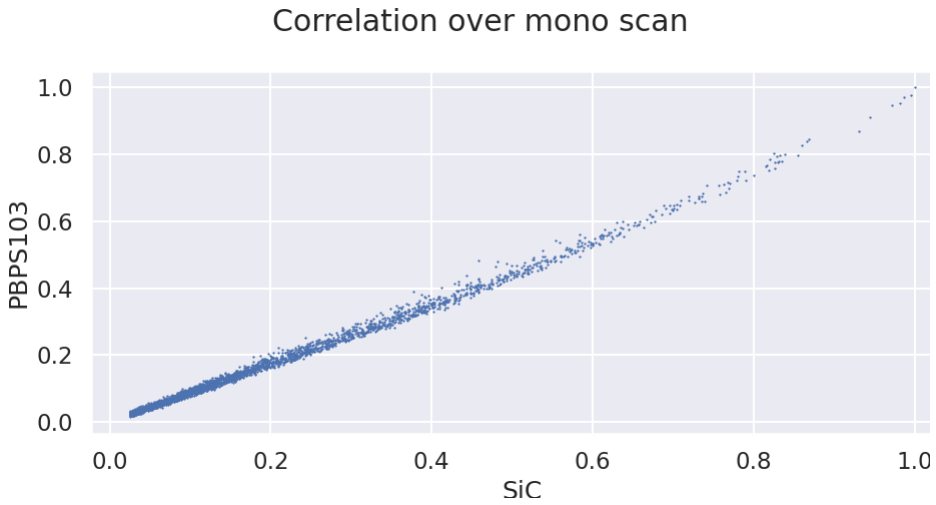
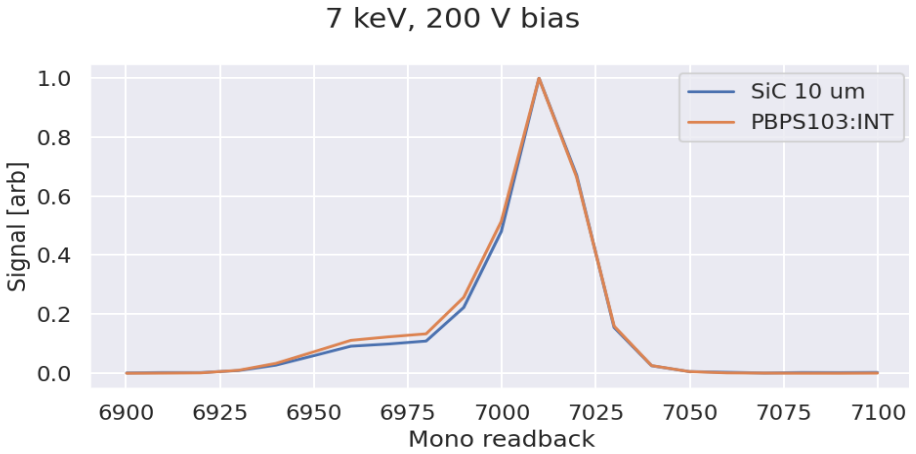
FIRST LIGHT AT SwissFEL

- 7 keV, PINKBEAM, 1 mJ/pulse





Huge signal level

- Needs attenuated mono beam
- 40 dB electrical signal attenuation (x100)
- Biasing increase from 40 - 200 V helps but nonlinearity observed

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CONCLUSIONS

- DEVELOPED INLINE MONITORS WITH GREATER POTENTIALITIES AND POSSIBILITIES THAN DIAMOND BASED ONES
- CONSOLIDATED PRODUCTS : MONOCHROMATIC, INTENSITY/POSITION, MONITORS 1.5um
- NEW PRODUCTS: POLYCHROMATIC, INTENSITY/POSITION, MONITORS
- NEW PRODUCTS: BEAMSTOPPERS, INTENSITY/POSITION, OF DIFFERENT SIZES (<0.8mm)
- NEW PRODUCTS: READOUT SYSTEMS (EPICS COMPATIBLE) WITH VERY LARGE DYNAMIC RANGES (UP TO 50mA)
- DEVELOPING MULTY-CHIP SENSORS (X2). (X3-X4 IN PROGRESS)
- FIRST PROMISING TEST AT XFEL

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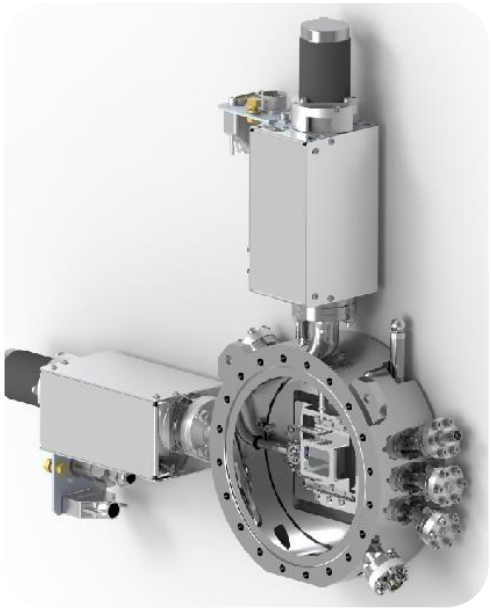
COLLABORATION WITH FMB-OXFORD



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