PAUL SCHERRER INSTITUT

PSI

Towards full Silicon Carbide based beam monitoring

Mar Carulla

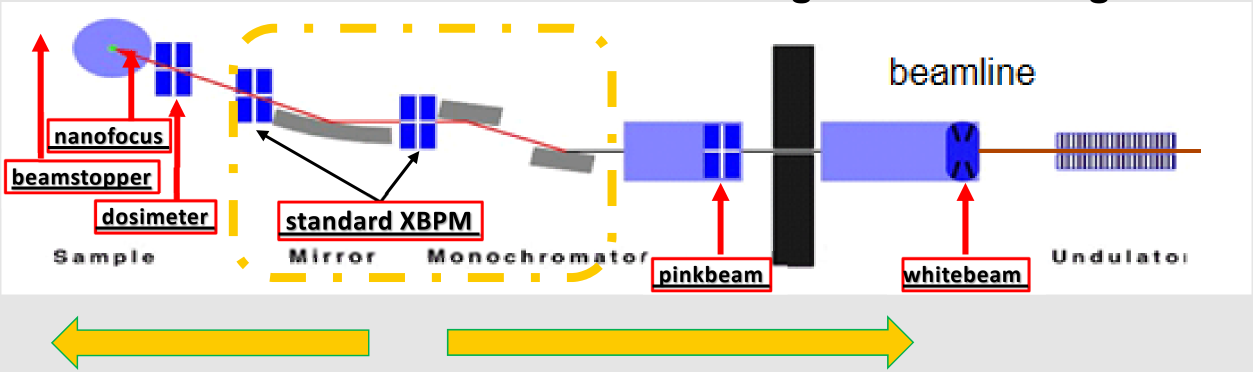
IBIC 2019
International Beam Instrumentation Conference
MAX IV ESS EUROPEAN SPALLATION SOURCE
Malmö, Sweden
8-12 September 2019

Outline

- Overview of beam monitors at SLS
  - Advantages and drawbacks
- State-of-art on solid state monitors for hard Xray
  - SiC vs. Diamond
- Wafer scale processing of SiC XBPM
  - SiC XBPMs produced on 4 inch. wafers
- Current Installations
  - microSAX: After mono, beam stopper and I_0
  - PXI: Pinkbeam
- Future installations
  - nano-imaging
- Extension towards soft-, pink- and white-beams
- Conclusions and outlook

Overview XBPM

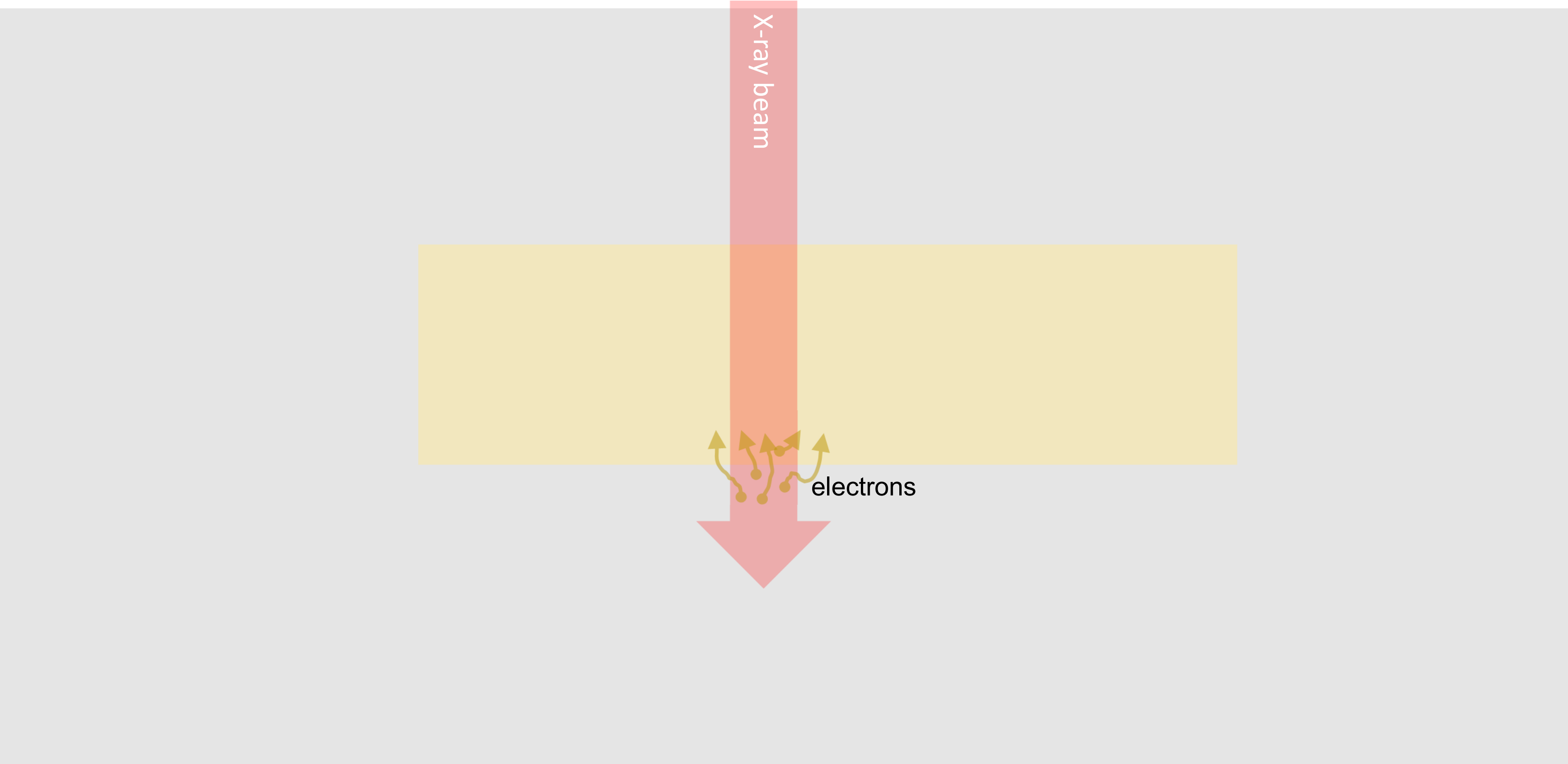
---- Several locations for beam alignment/focusing ----



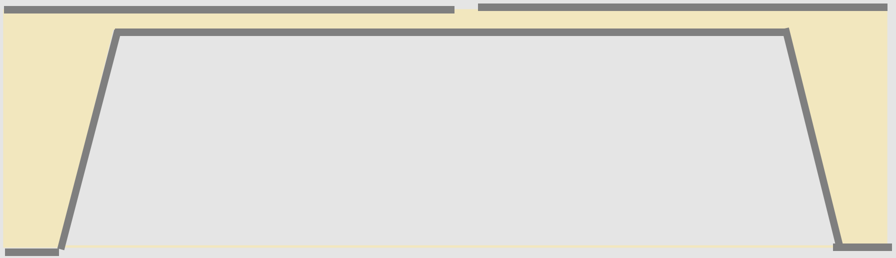
Requirements for in-line X-ray beam monitors

1. Transparency (<2%)
2. Stability over time, i.e. radiation hardness
3. Uniformity (transmittance and photocurrent)
4. Fast response (μs)
5. Easy of fabrication/ Easy of usage / low footprint / vacuum compatibility

Solid state XBPMs



Solid state XBPMs



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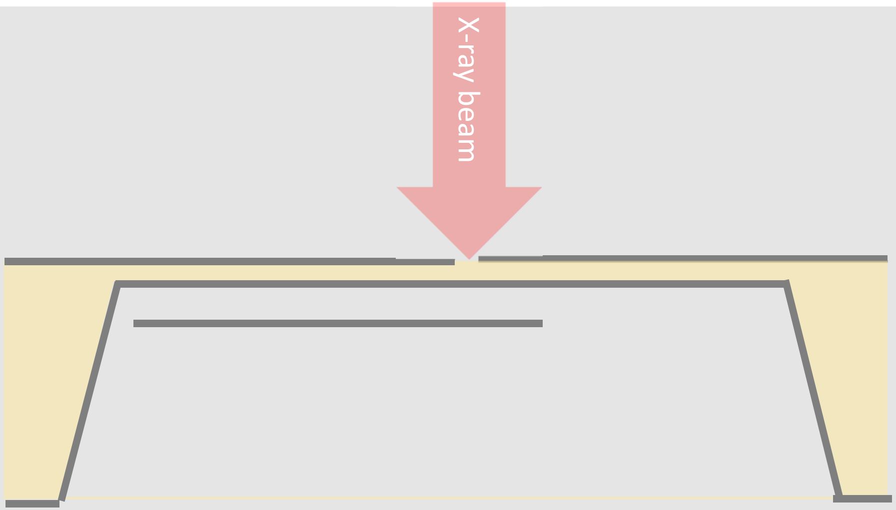
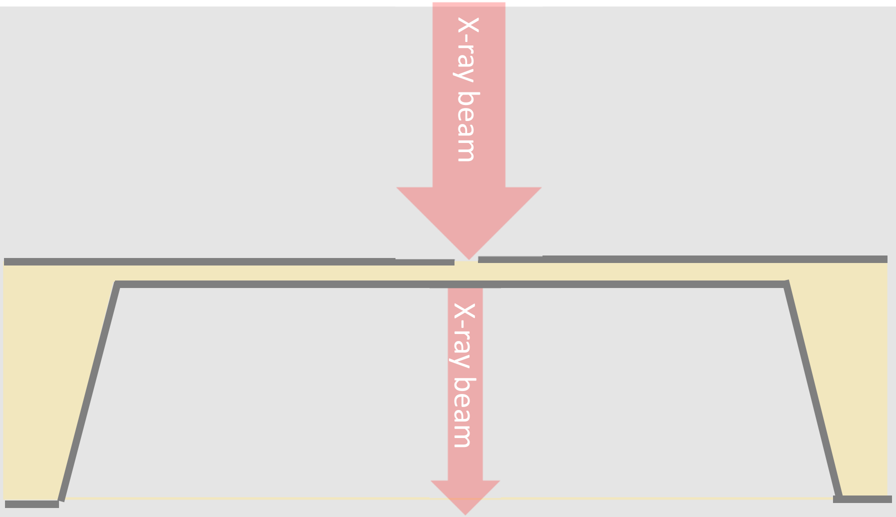
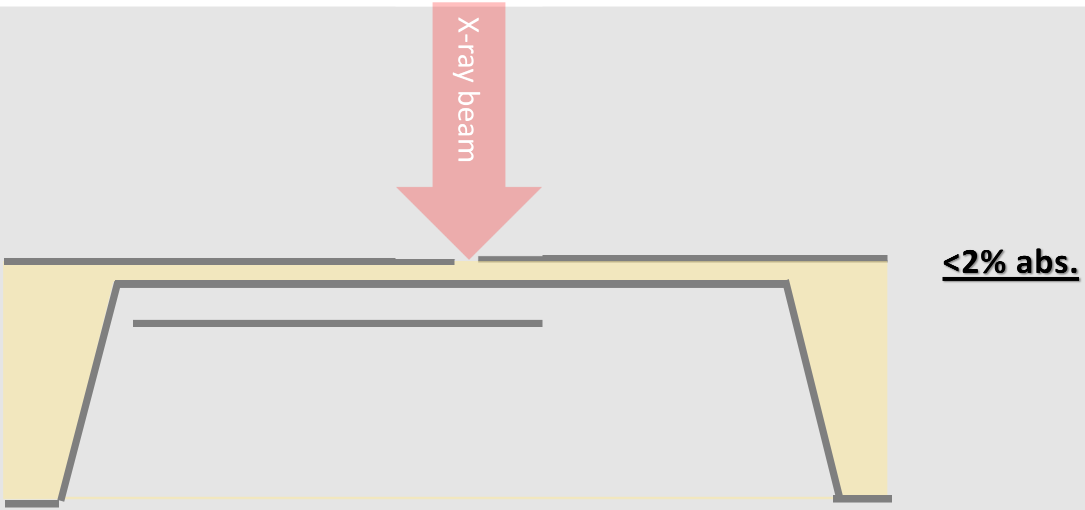


Solid state XBPMs



<2% abs.

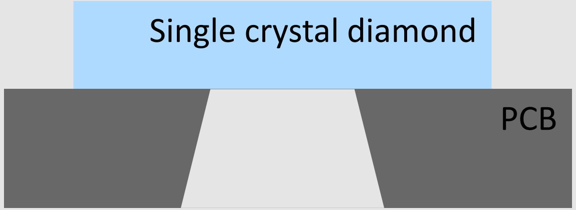
Solid state XBPMs



Solid state XBPMs

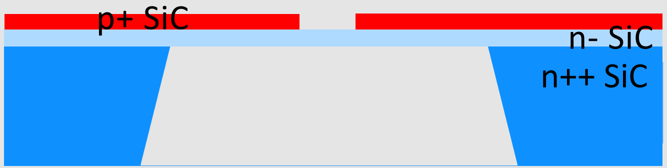
DECTRIS, RIGI
SYDOR

Limited in quality
Poor time response



CIVIDEC
SYDOR

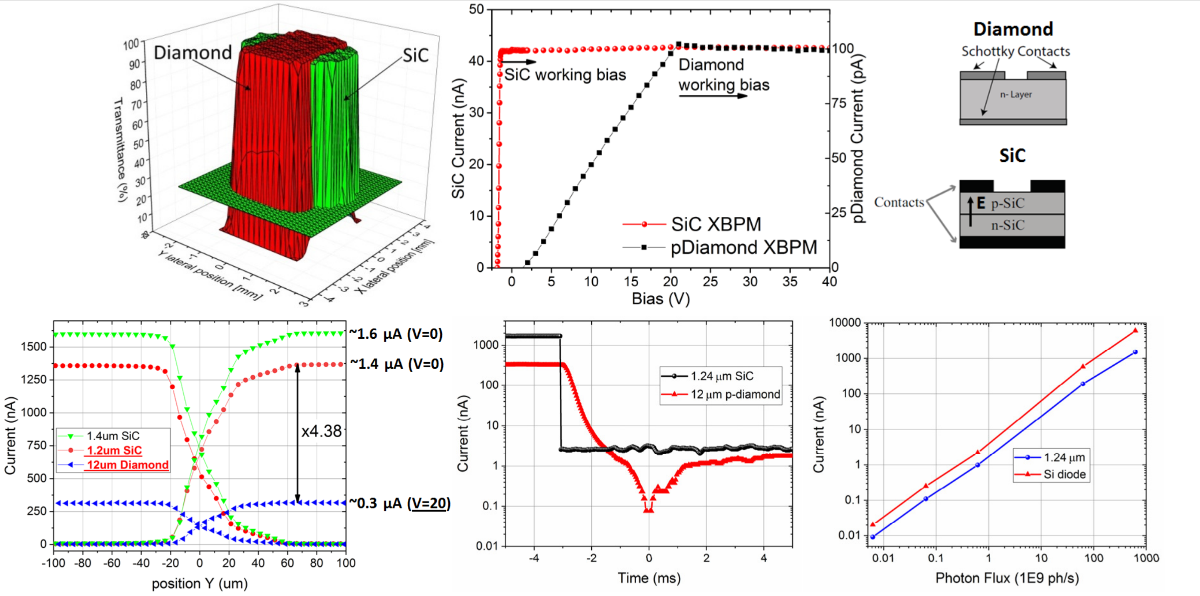
Limited in thickness
Limited in size



PSI, <u>only!</u>

<u>up to 4-8 inch</u>
<u>down to 1um (0.1)</u>
<u>multiple level mems.</u>

Solid state XBPMs
Comparison with polycrystalline diamond



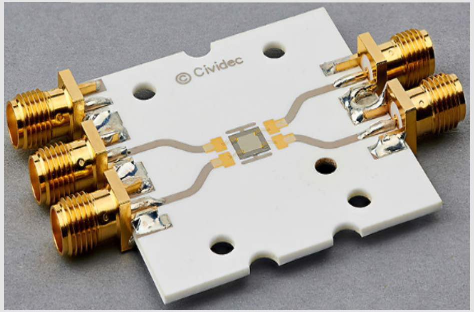
- **SiC XBPM clearly superior to "RIGI" polycrystalline XBPM.**
- **RIGI now out of the market (No other polycrystalline XBPM vendors)**

***Nida S. et al “Silicon carbide X-ray beam position monitors for synchrotron applications”: J. Synchrotron Rad. 2019. 26, 28-35**
https://doi.org/10.1107/S1600577518014248

Solid state XBPMs

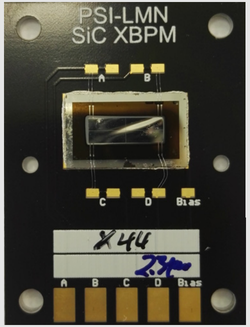
Comparison with *single crystalline* diamond

single crystal Diamond



8 order linearity
~ns response
20 µm min. thickness
7 mm² Active Area

SiC XBPM

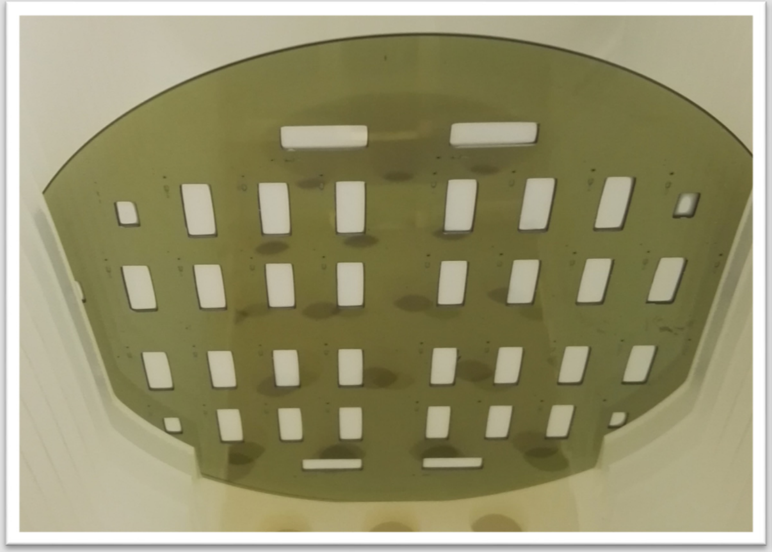


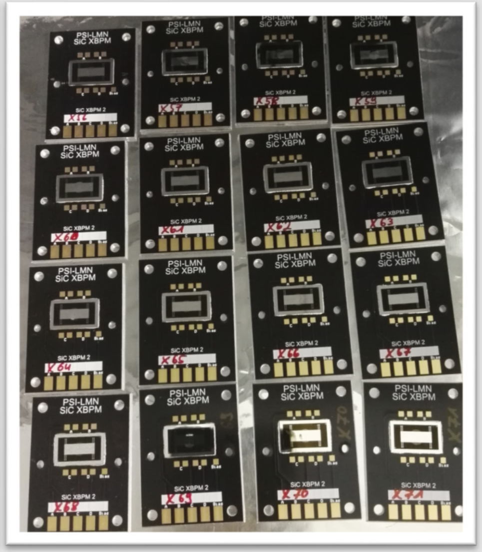
4 order magnitude linearity*
~µs response*
2 µm min. thickness
36 mm² (72 mm²) Active Area (x5)

* limited by measurement setup

** considering different att. length

Wafer scale processing

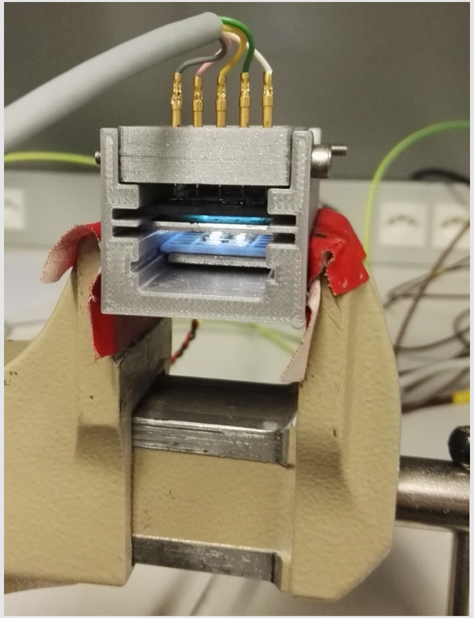


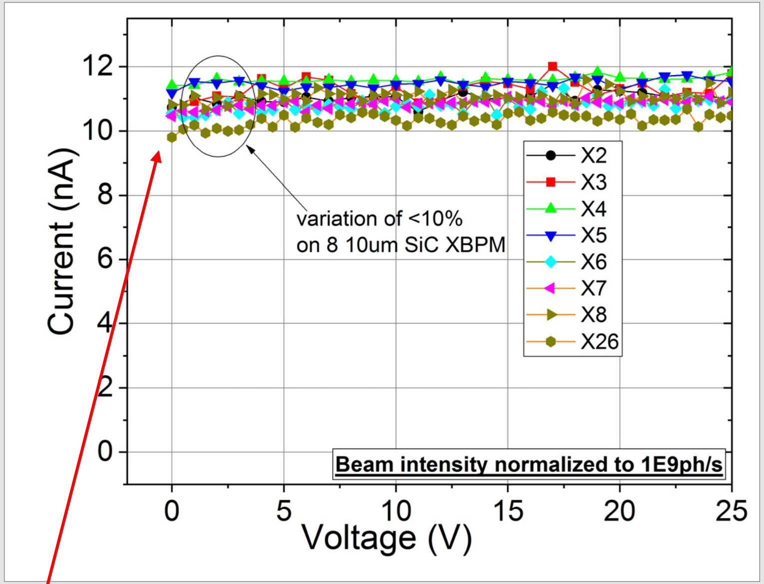


- **50 devices per wafer**
- **Wafer processing lasts 2 weeks**

Wafer scale processing of SiC
Stability

- Fully automated UV (325nm) LED based screening system





Operation at 0V

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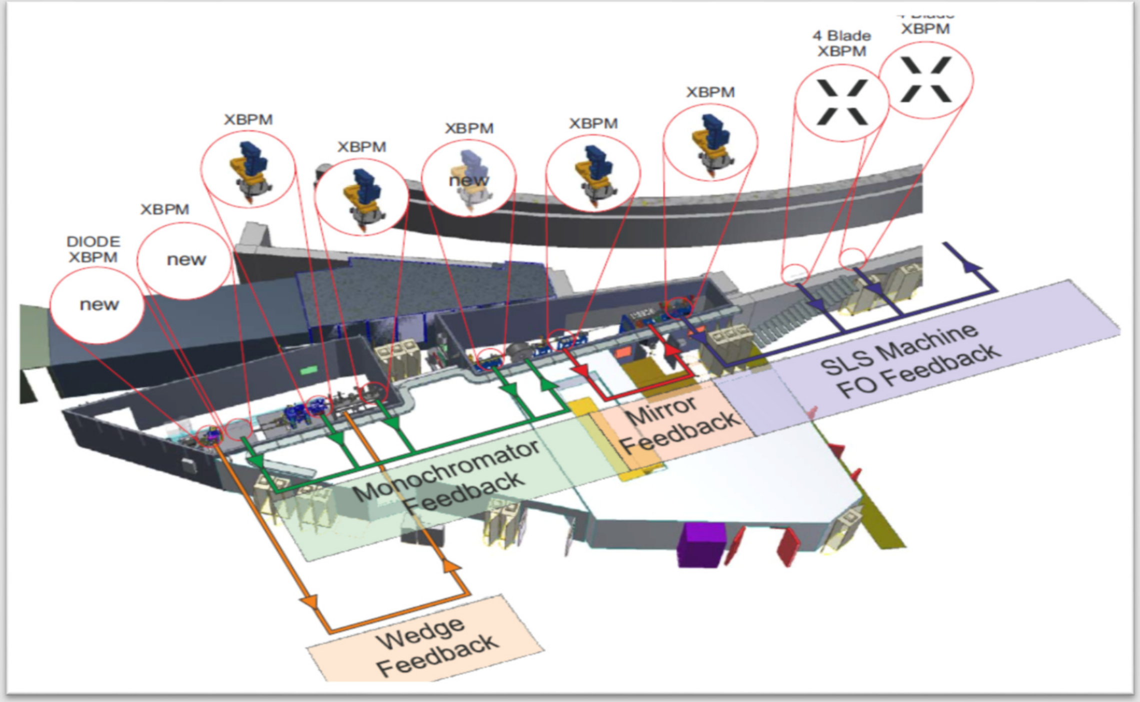
Current installations at microXAS



- **Currently installed @ microXAS:** 3 XBPMs (after mono, I0, and beam-stopper)

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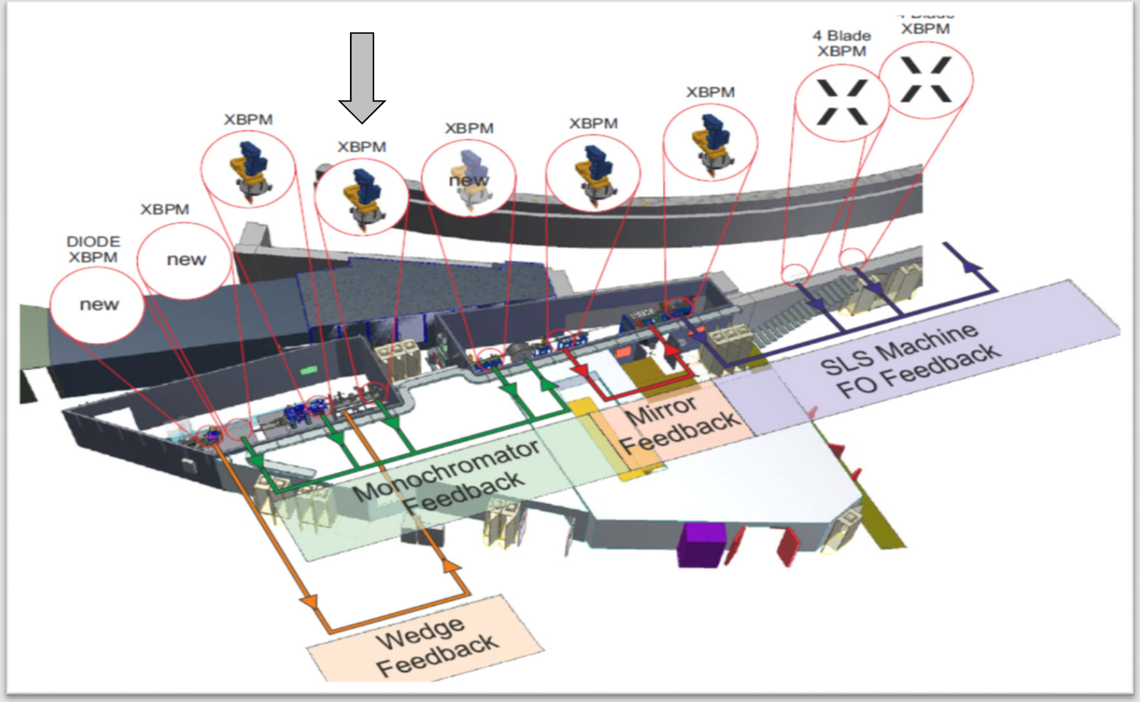

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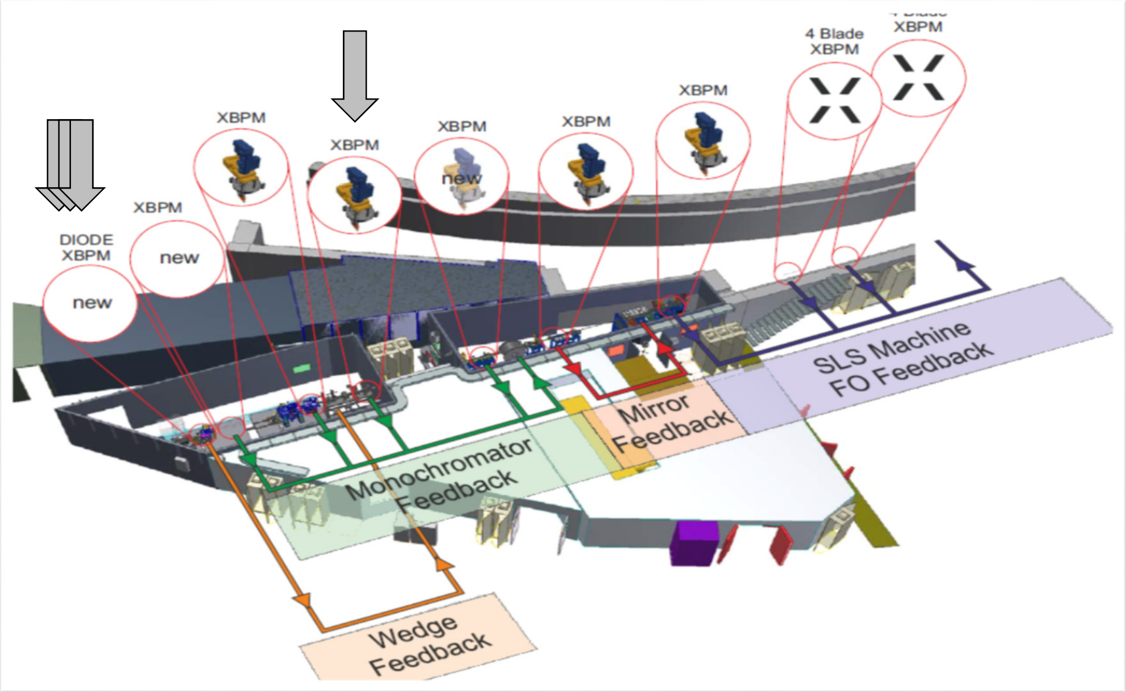

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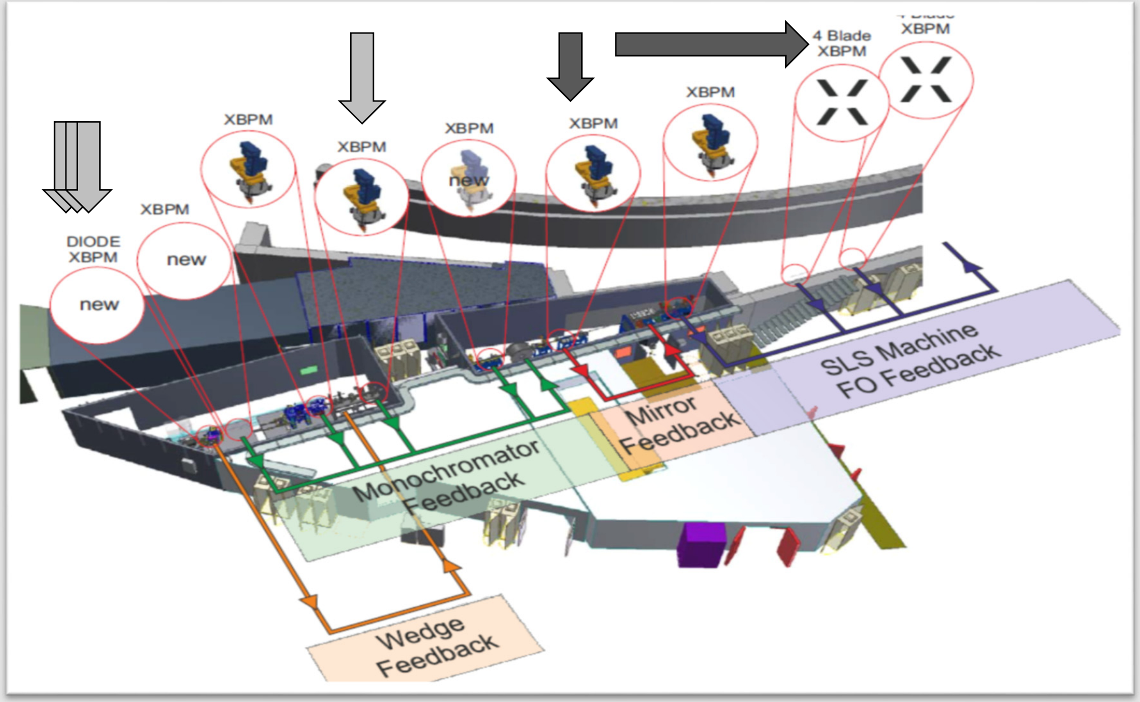

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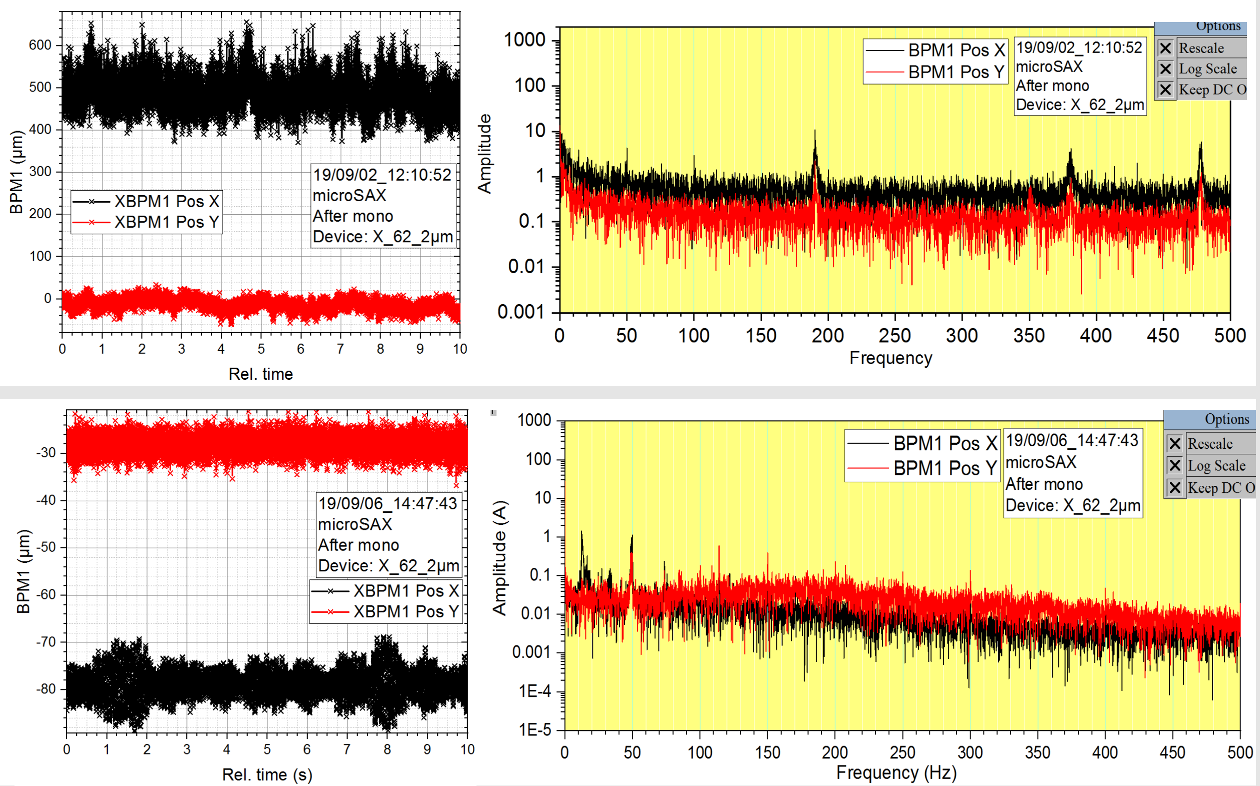
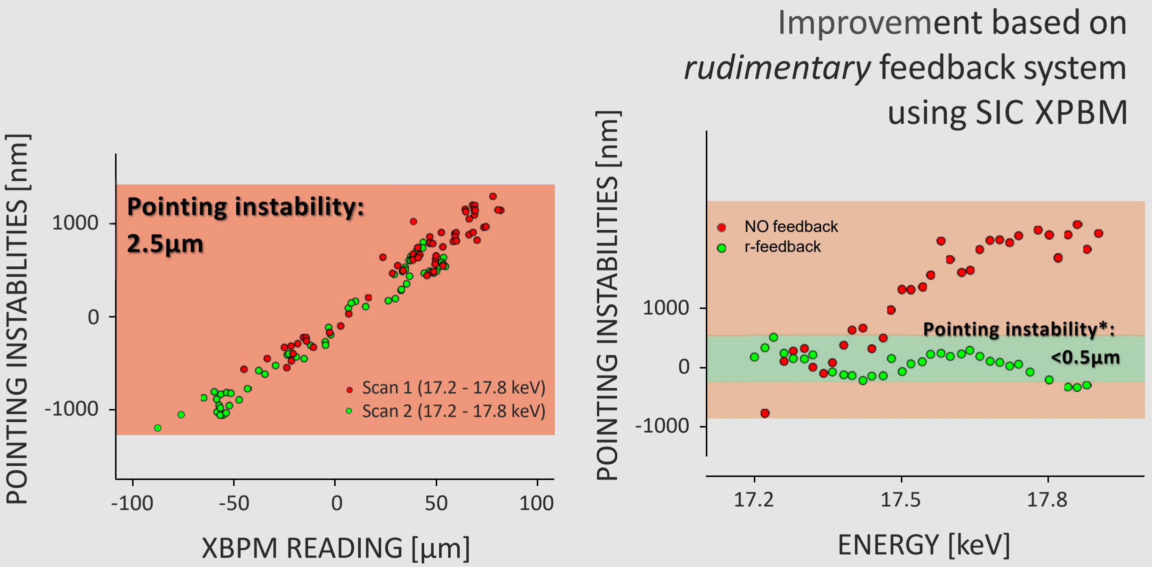
Current installations at microXAS

-first implemented SiC XBPM

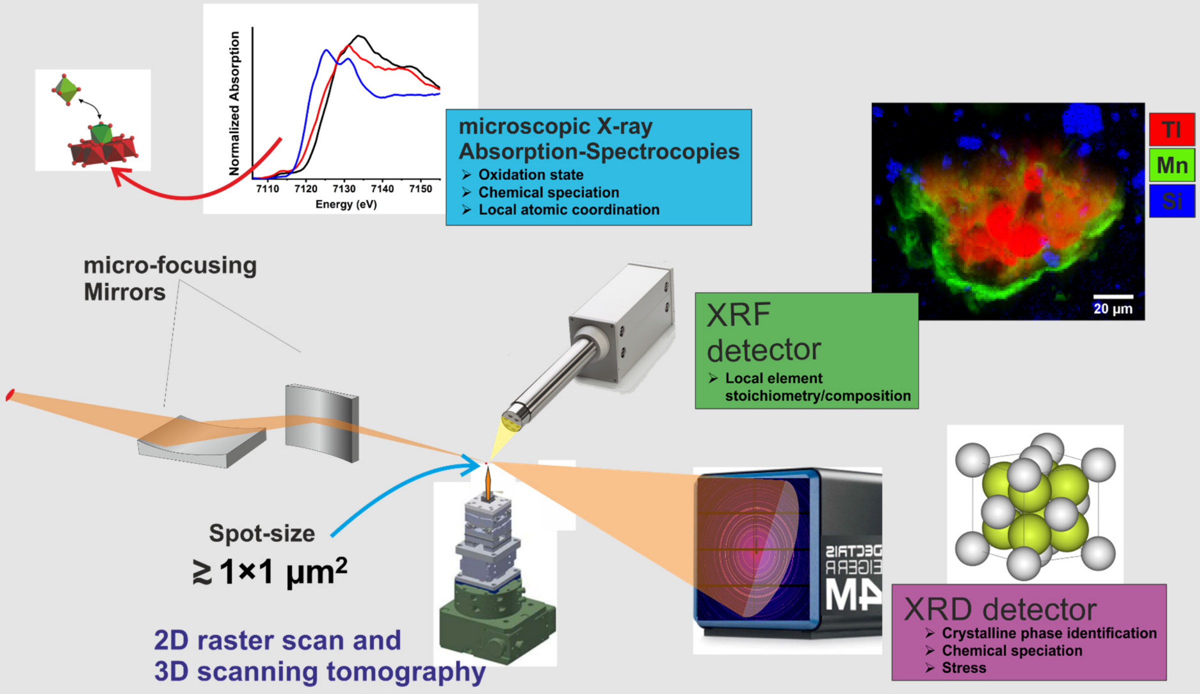


Current installations at microXAS
-first implemented SiC XBPM



*sigma: <400nm

Current installations at microXAS
-Beam stopper diode (no transmittance mode)



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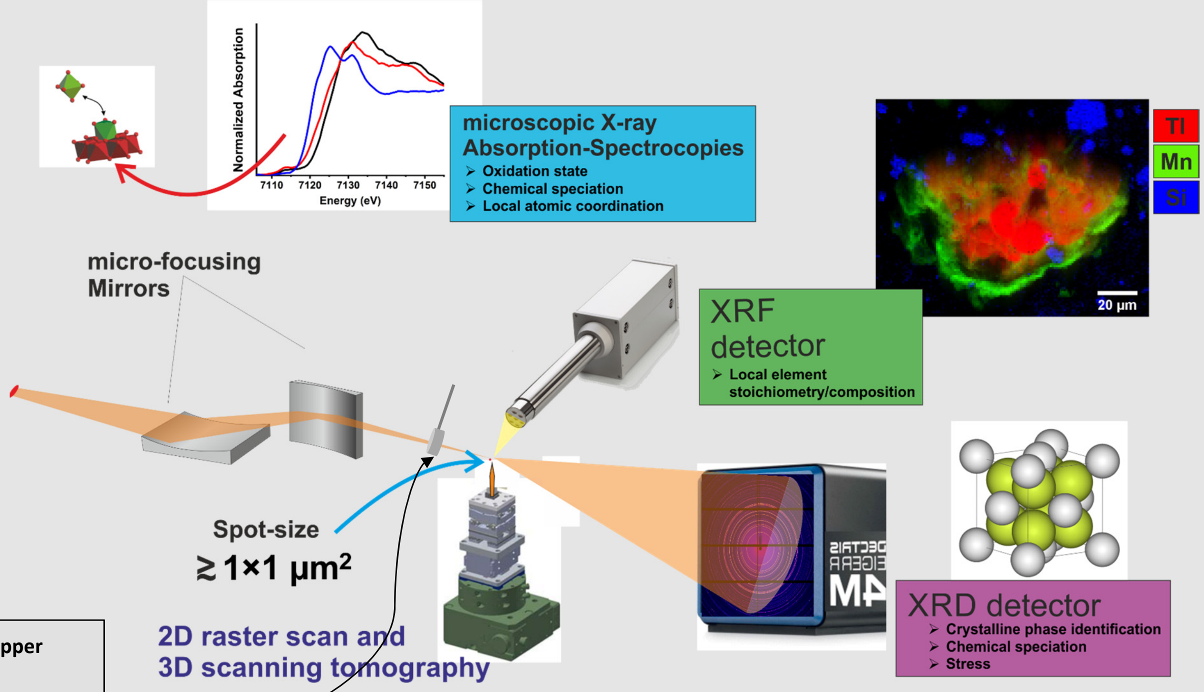
Current installations at microXAS
-Beam stopper diode (no transmittance mode)



Absorption → SiC Diode on the beamstopper

- **Absorption Contrast Imaging**
- **X-Ray Absorption Spectroscopy**

Collaboration of microXAS team with Massimo Camarda, Laboratory for Micro- and Nanotechnology, PSI

- 3D Mechatronic Integrated Device

Courtesy: Dario Sanchez

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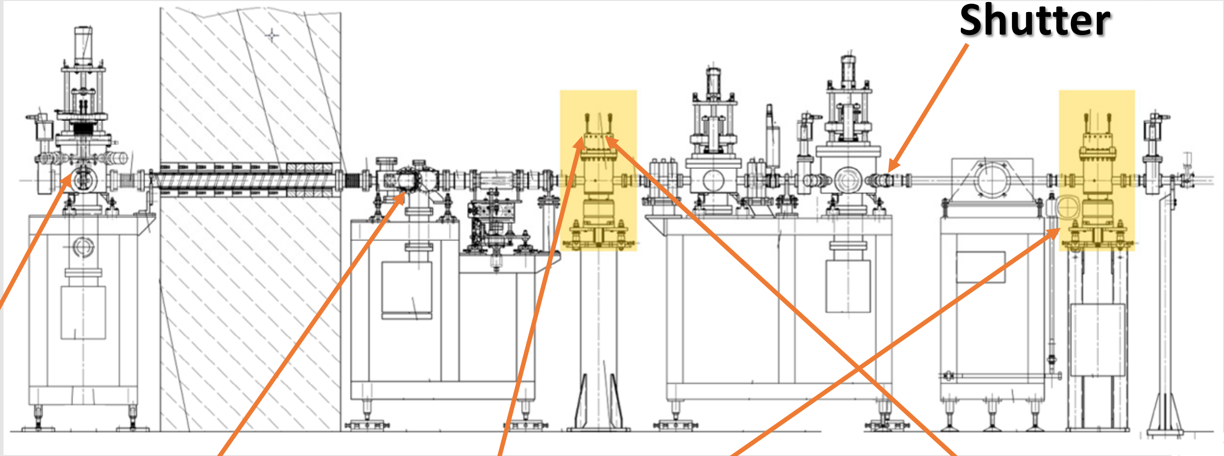
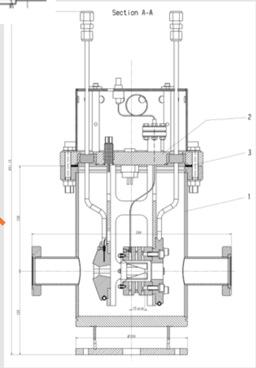
Current installations at PXI (pinkbeam)

Shutter





Pinkbeam 80µm C window

800W (36W)

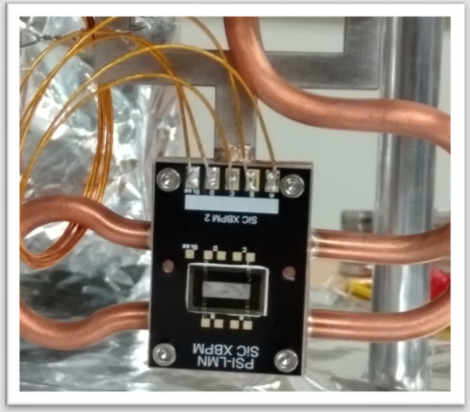
<1% at 12.4keV

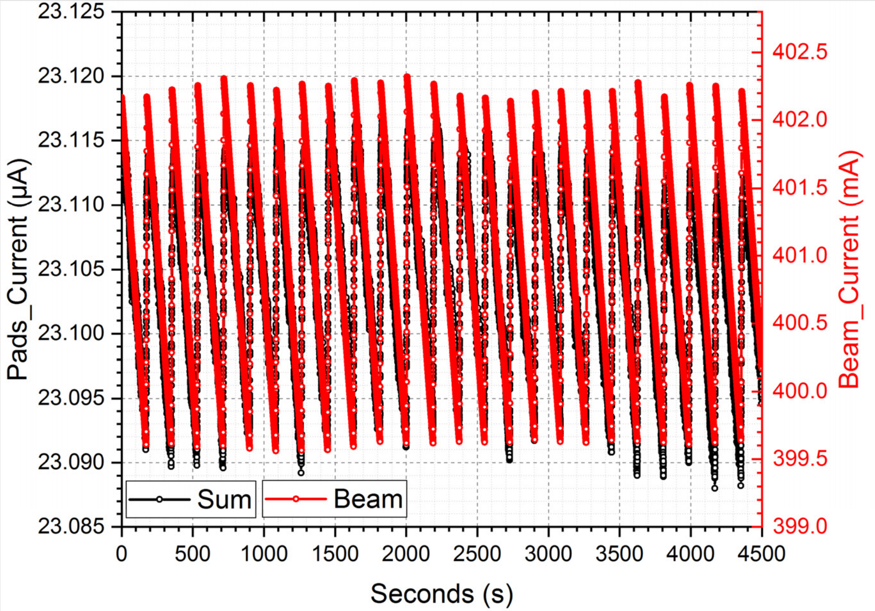
currently on 2µm device installed at PXI

Whitebeams

2kW (5.2mm gap)

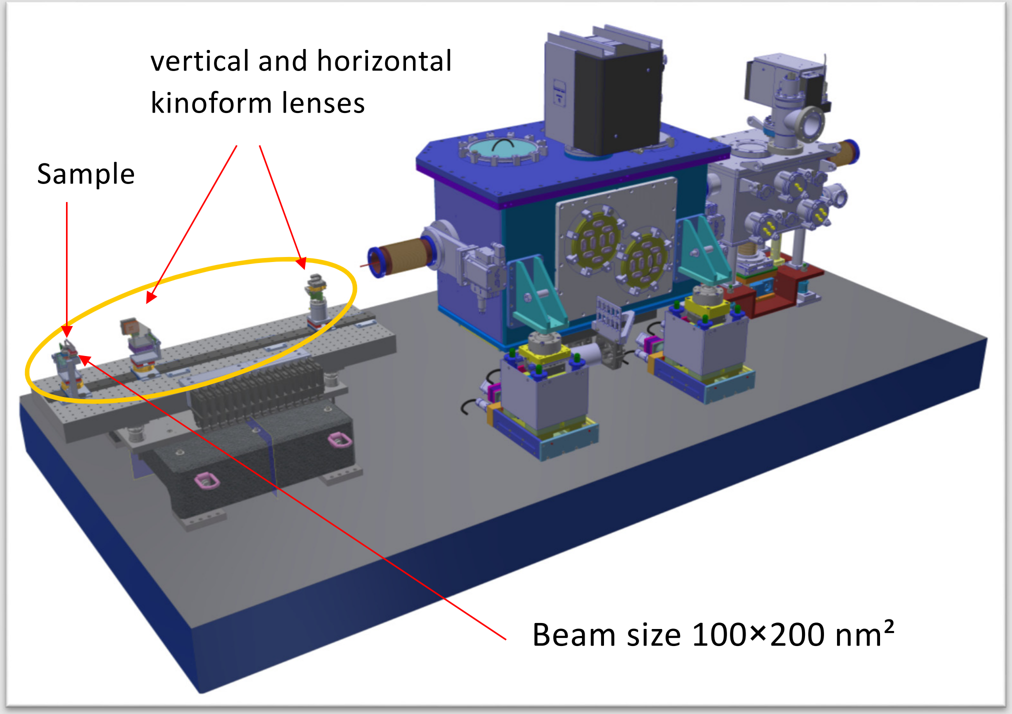
Current installations at PXI (pinkbeam)





- 2 µm XBPM was installed 1 month ago at PXI pinkbeam (after diamond window).
- The measured current is several order of magnitude lower than the expected one.

Future installations: Near sample monitoring -3 compact XBPM for nano-imaging



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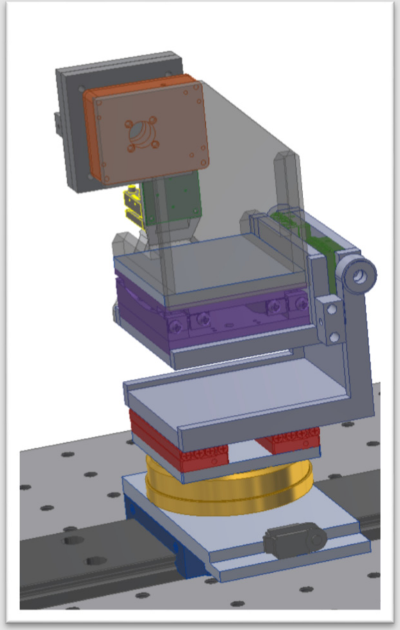
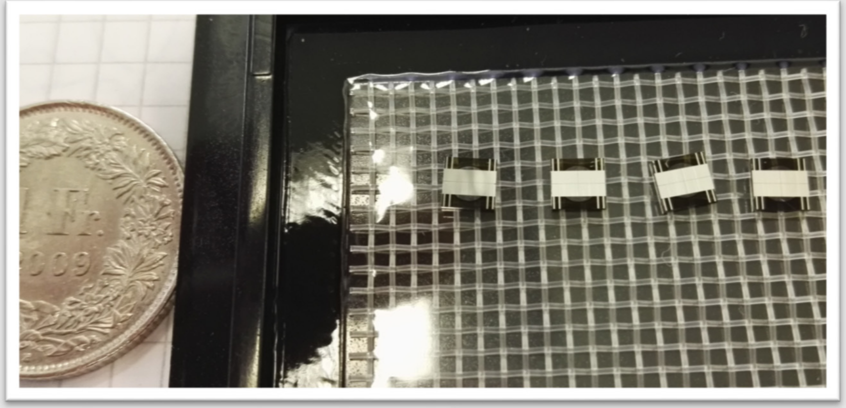
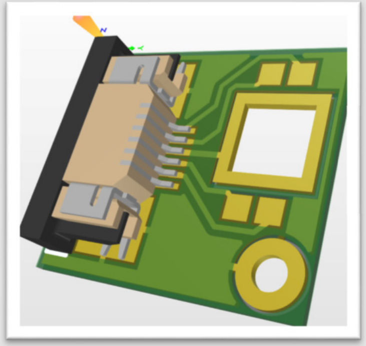
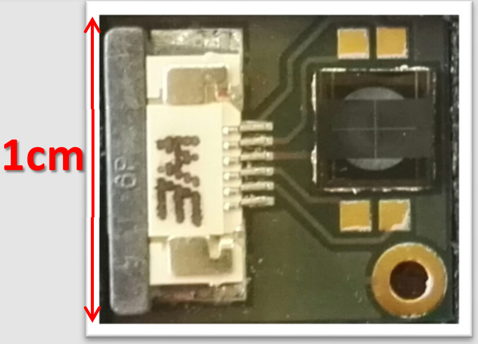


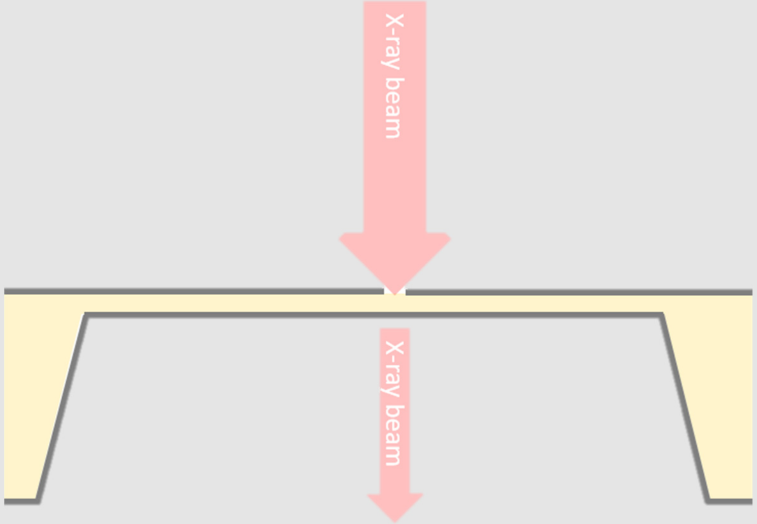
Installation expected
Dec. – Nov. this year





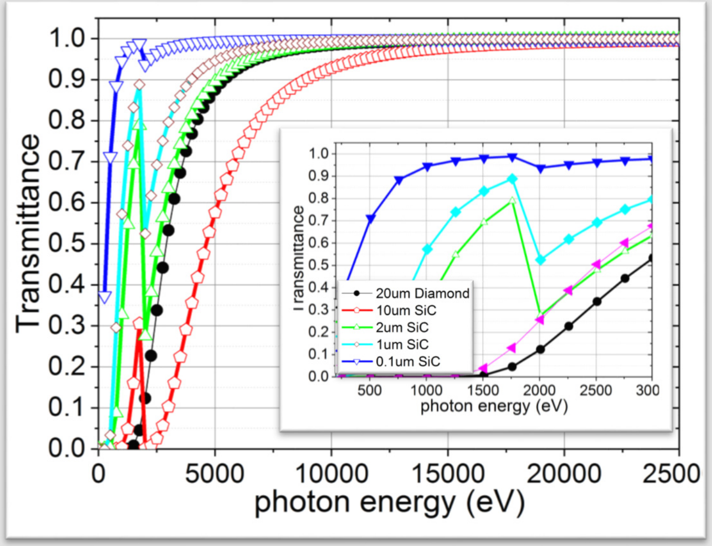


Future extensions: soft/pink/white x-ray beams

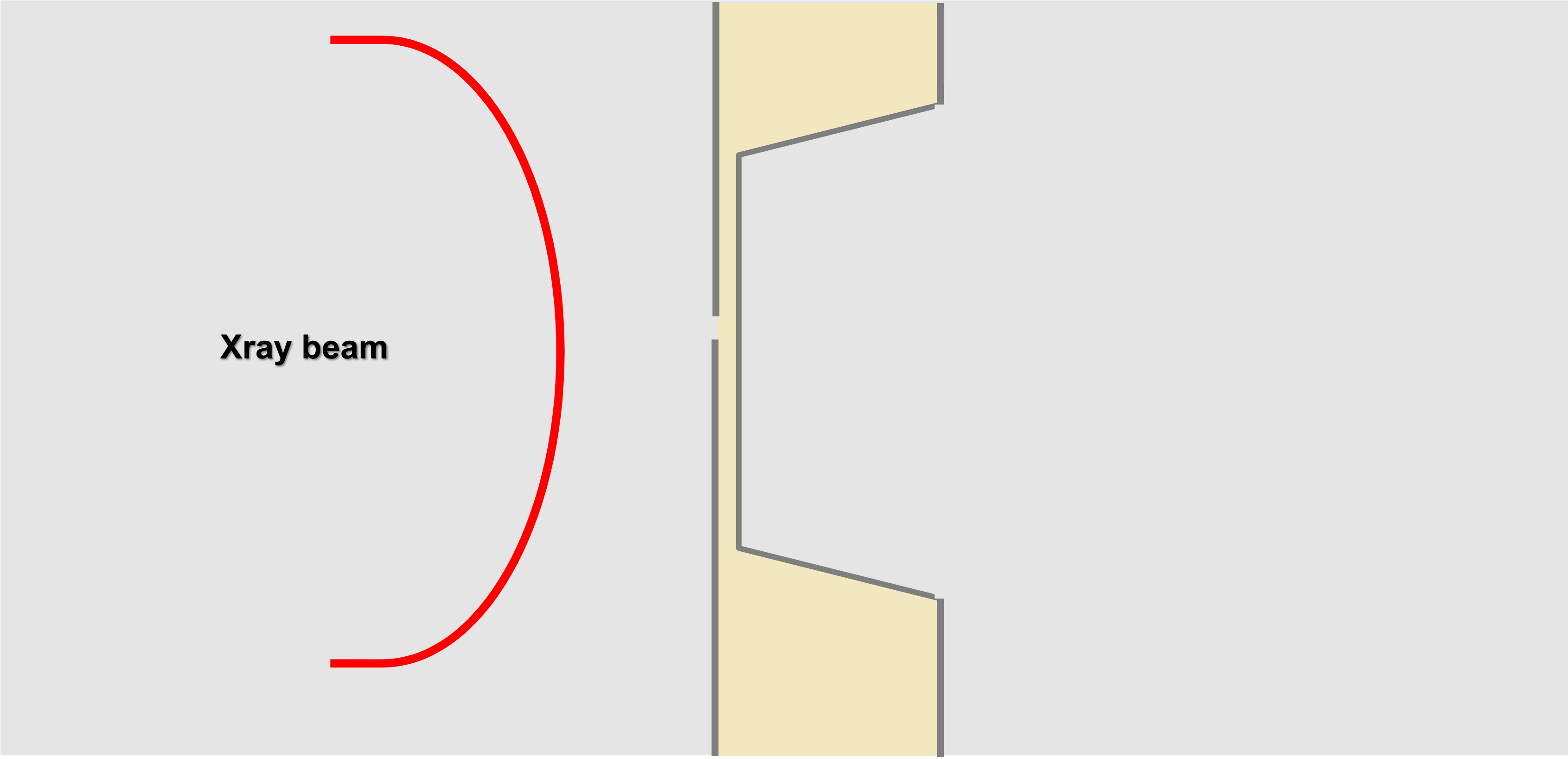


Limitation of thin membranes as XBPM:

1) **high abs. for soft x-ray**
2) **thermal issues for white beams**



Future extensions:
white x-ray beams



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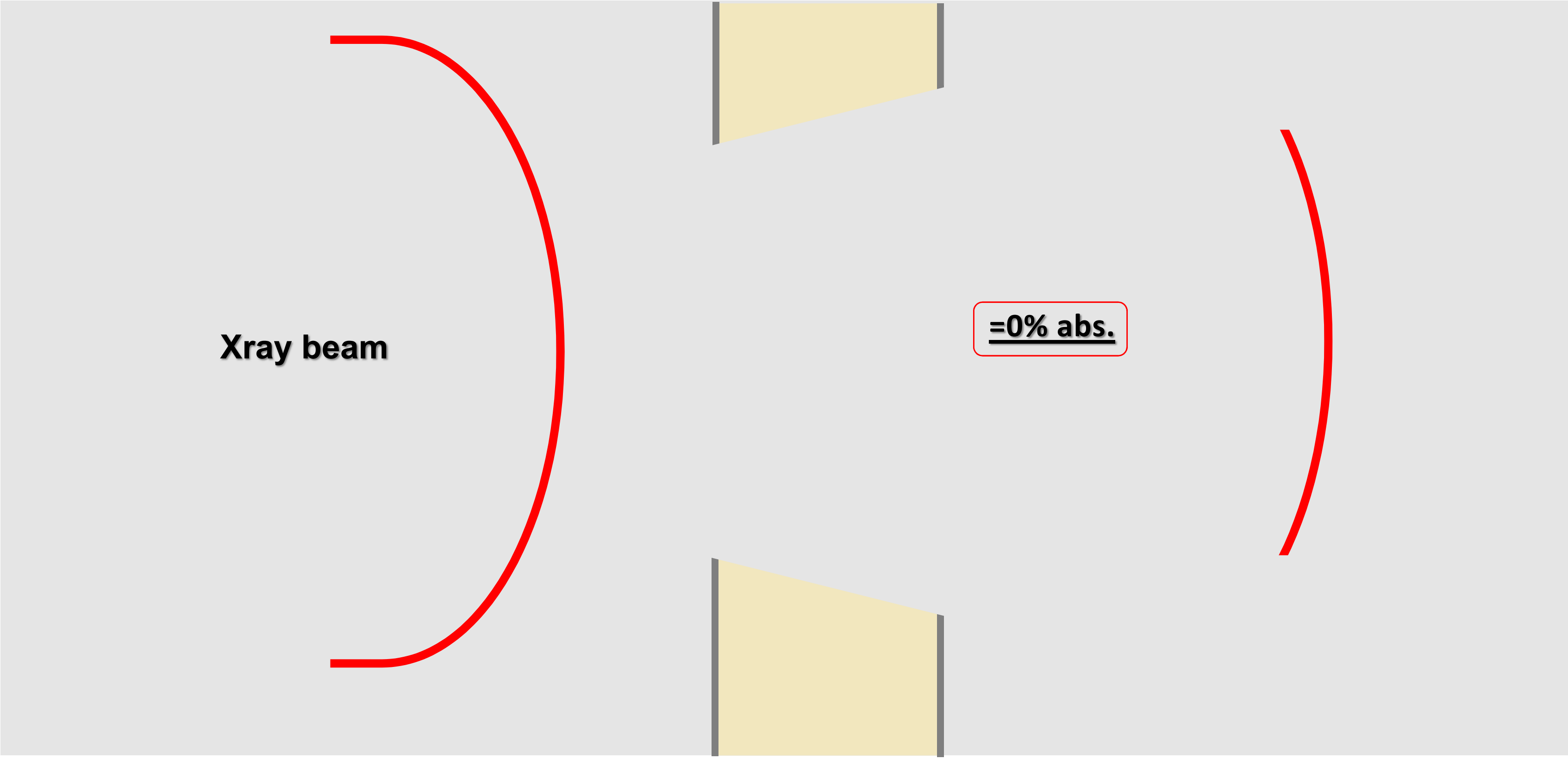

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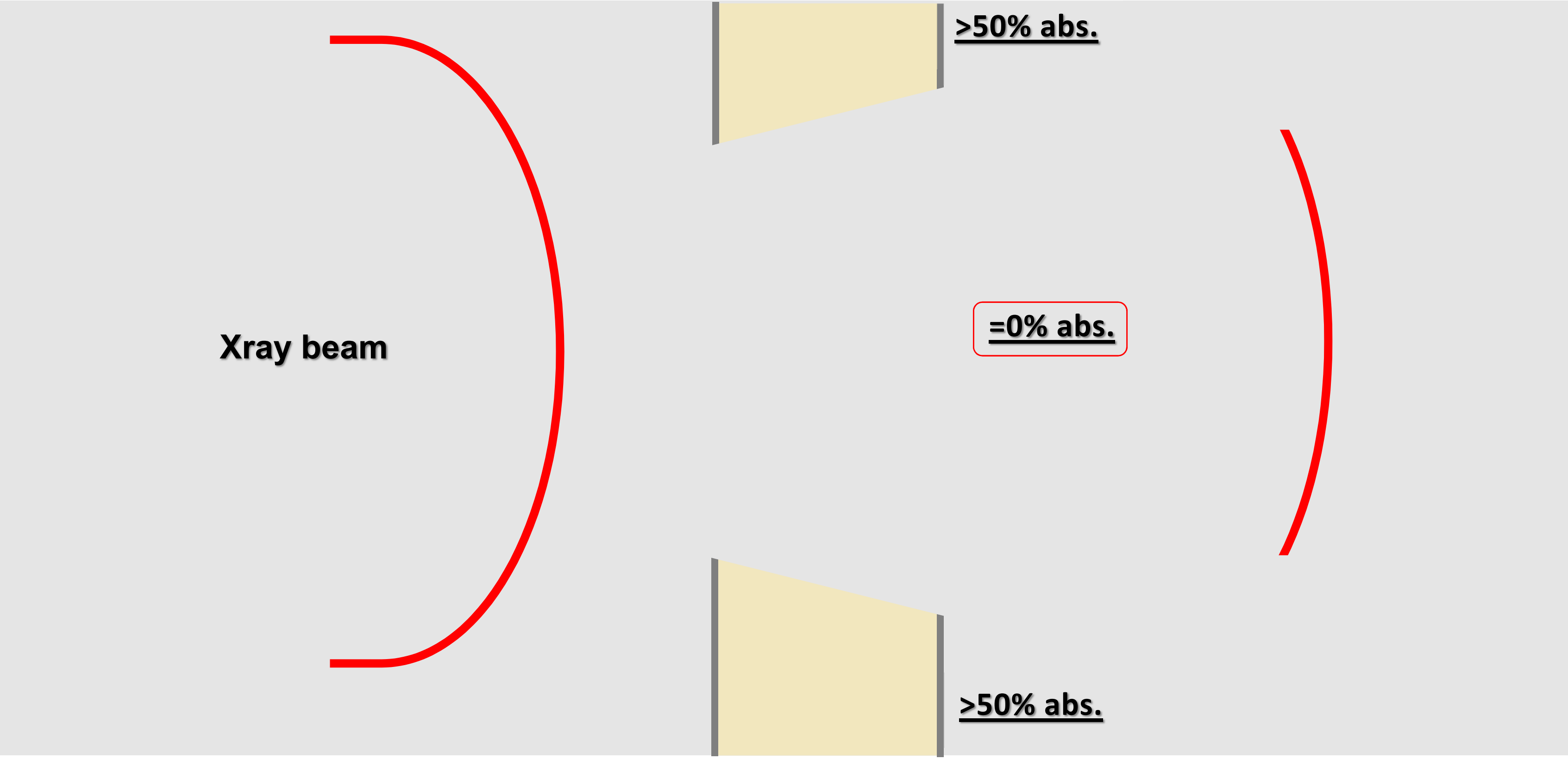
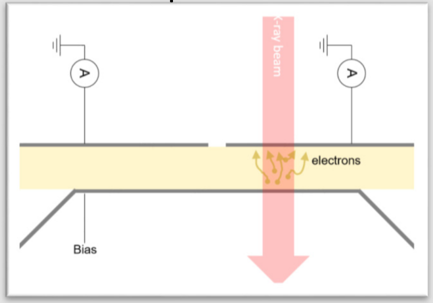


Future extensions:

Why better than blades
Why valuable "functionalized" pin-holes

semiconductor based
internal photoemission



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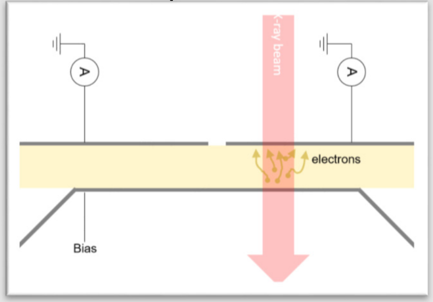

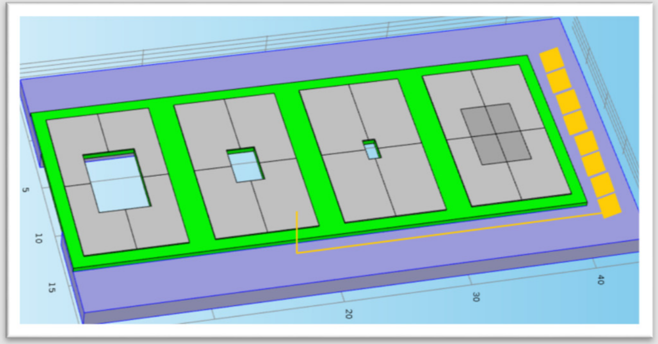

array of 4 devices

1. -- **full membrane,** -- "high res."
2. --"**small pin-hole**": 2.0x1.0mm^2
3. --"**blade opening**": 3.4x2.2mm^2
4. --"**large pin-hole**": 6.0x4.0mm^2

Conclusions and outlook

Conclusions:

- 4H-SiC XBPM: transparency, linearity, signal strength.
- They can be operated at 0V.
- 2 µm 4H-SiC XBPM devices were installed at microSAX (after monochromator) and PXI (pinkbeam) beamlines at PSI.
- PXI (pinkbeam): current several orders of magnitude lower than expected.
- microsSAX (after monochromotar): 20× improvement on beam stability over energy scans

Future work:

- Installation of Compact XBPMs for nano-imaging
- Blade monitors (whitebeam)
- 0.1 µm thin XBPM for soft X-rays

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Acknowledgments

- Hans Sigg
- Oliver Bunk

- Claude Pradervand

- Daniel Grolimund
- Dario Sanchez
- Mario Birri
- Beat Meyer

- *ALL* LMN

- pBPM working group