PSI Center for Photon Science

JUNGFRAU Prototypes with iLGAD Sensors for Soft X-ray RIXS

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Resonant Inelastic X-ray Scattering (RIXS)

Powerful spectroscopic technique at synchrotrons and X-ray Free-Electron Lasers (XFEL) that has **demanding detector requirements**

High energy resolving power
- High spatial resolution in vertical direction (~1 μm)

"Photon-hungry"
- Large detector area
- Large duty cycle

Time-resolved measurements and multidimensional scans
- High image frame rate

→ **Difficult with CCD and CMOS**
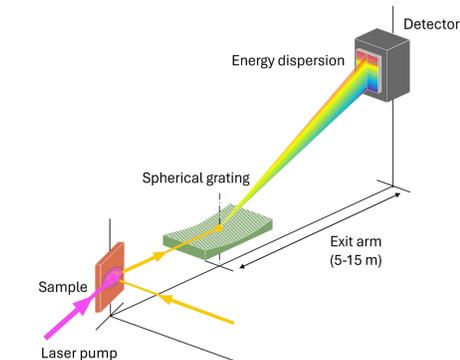
Hybrid Pixel Detectors

Challenge

Operate at soft X-ray energies (200 eV - keV)
- High quantum efficiency (QE)
- High signal-to-noise ratio

Figure 1: Schematics of time-resolved RIXS

Inverse Low Gain Avalance Diode (iLGAD) Sensors with Thin Entrance Window

Solution

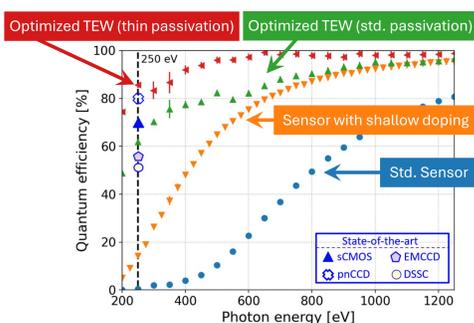### Thin Entrance Window

Figure 2: Evolution of the TEW technology by PSI and FBK and comparison to state-of-the-art detectors for soft X-rays

iLGAD Technology

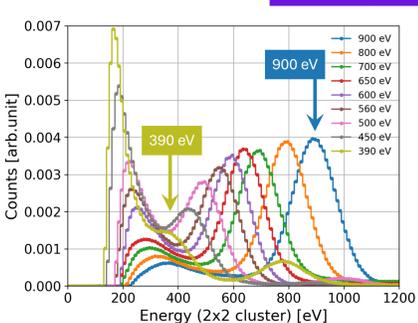Ref. S. Li's presentation (Session 5, July 8th)

Figure 3: Spectral response of the iLGAD to soft X-rays, displaying double-peak feature due to absorption depth dependent gain

High spatial resolution with interpolation
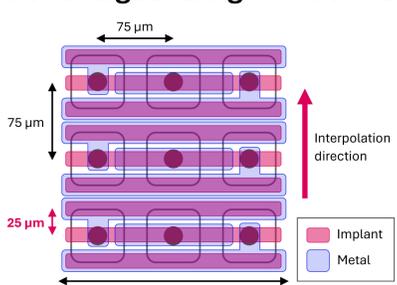
Use **charge sharing** between neighboring pixels

$$\eta_y = \frac{Q_{top}}{Q_{bottom} + Q_{top}}$$

Figure 4: Schematic layout of iLGAD sensor with rectangular pixels ("strixels") to enable interpolation in vertical direction

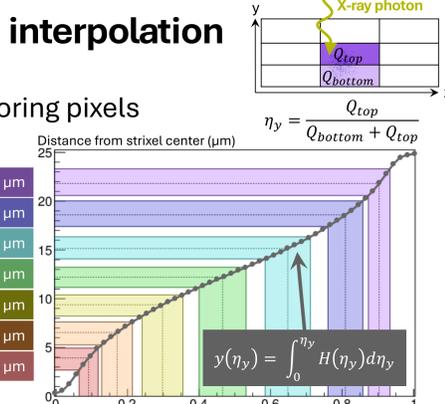$$y(\eta_y) = \int_0^{\eta_y} H(\eta_y) d\eta_y$$

Figure 5: Estimation of the spatial resolution for 25 μm vertical pitch using η_y-interpolation of data from a focused X-ray beam scan

Combining iLGAD sensors with JUNGFRAU

Figure 6: Single-chip JUNGFRAU-iLGAD prototypes (2 × 2 cm²) with 75 × 75 μm² pixels
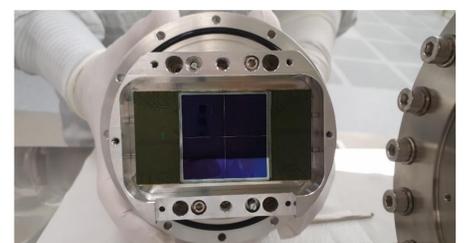

Figure 7: 4 × 4 cm² JUNGFRAU-iLGAD module with 25 μm pitch strixel geometry for RIXS
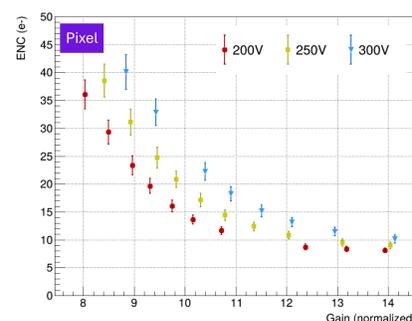
Characterization Results

Noise

Figure 8: Equivalent noise charge (ENC) as a function of iLGAD multiplication gain for different bias voltages, for the square pixel geometry. At high gain, shot noise dominates
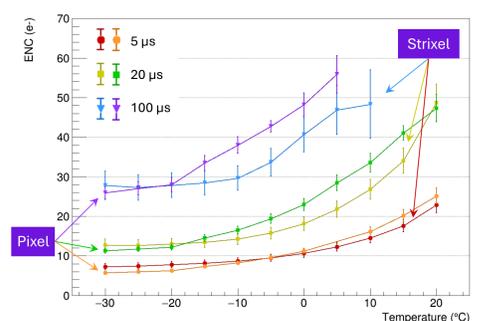

Figure 9: ENC as a function of temperature compared for different integration times and between pixel and strixel geometries
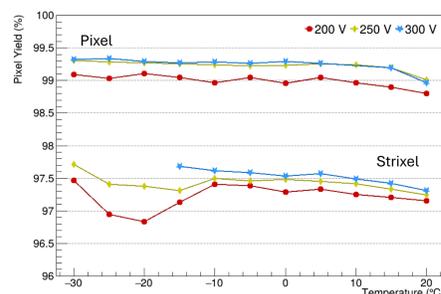
Working Pixel Yield

Figure 10: iLGAD pixel yield as a function of temperature compared for 75 × 75 μm² pixel and 25 μm pitch strixel geometries
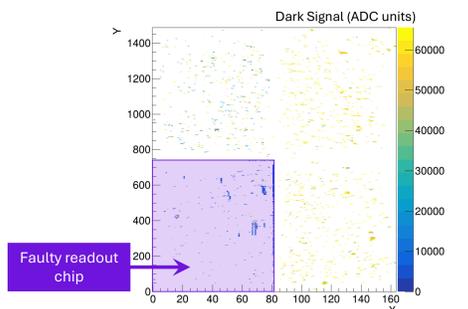

Figure 11: Map of flagged pixels for the strixel iLGAD module (0°C, 300 V bias, 10 μs integration time). The dark signal is plotted in color scale for each flagged pixel

Outlook

- **Pilot experiments at RIXS beamlines** at SwissFEL and European XFEL
- **New iLGAD R&D batch** with higher gain and thinner oxide in 2026

References

- J. Zhang et al. 2022 JINST 17, C11011
- M. Carulla et al. 2024 Sensors 24, 942
- V. Hinger et al. 2024 Front. Phys. 12

Acknowledgements

European XFEL