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Characterization of inverse LGAD Sensors in the Soft X-ray Energy Range

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At the Paul Scherrer Institute (PSI), we are developing inverse Low-Gain Avalanche Diode (iLGAD) sensors with a thin entrance window (TEW) in collaboration with Fondazione Bruno Kessler (FBK). The TEW design is used to enhance the charge-collection efficiency near the sensor surface. In our latest batch, the quantum efficiency (QE) exceeds 85% at 250 eV, which is comparable to state-of-the-art detectors for soft X-rays. Furthermore, compared with conventional sensors, LGADs incorporate an internal gain layer that provides moderate amplification, thereby significantly improving the detector's signal-to-noise ratio (SNR) by a factor of at least five in the soft X-ray energy range.

In this presentation, we will report recent beam-test results obtained at the MAX IV synchrotron using soft X-rays from 390 eV to 2500 eV. The iLGAD sensors were bump-bonded to the MÖNCH and JUNGFRAU charge-integrating readout chips, featuring pixel sizes of 25 μm and 75 μm, respectively. The results demonstrate that single-photon detection can be achieved at 400 eV with an SNR exceeding five. The dependence of the SNR on photon energy and temperature will also be presented.

We further studied the iLGAD spectral response, which exhibits a characteristic double-peak structure, corresponding to hole-initiated and electron-initiated multiplication peaks arising from photon absorption before and after the gain layer. To better understand this behavior, we applied an empirical model to fit the spectra, allowing us to extract the fractions of photons absorbed before and after the gain layer. These fractions are used to estimate the thicknesses of the n^+ and gain layers, and the extracted values show good agreement with process-simulation results.

Finally, we will present the improvements and testing program for the next batch of iLGAD sensors, which are expected to become available in early 2026.

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