Ph.D. in Information Technology
Thesis Defense

July 2nd, 2026
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Sala Schiavoni - Building 20A

Maurizio GHISETTI – XXXVII Cycle

QUALIFICATION OF THE DEPFET SENSOR WITH SIGNAL COMPRESSION: A 1 MEGAPIXEL ULTRAFAST IMAGER FOR SOFT X-RAYS FOR THE EUROPEAN XFEL

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Abstract:

Novel X-ray Free-Electron Laser (XFEL) sources are capable of generating high-brilliance ultra-short pulses of spatially coherent X-rays. Their properties allow for new experiments in the fields of solid state physics, materials science, chemistry, biology and medicine that can probe the structure and dynamics of matter in extreme conditions or nanoscale objects such as single proteins. The unprecedented capabilities of these new X-ray sources and the requirements coming from the experiments call for the development of a new paradigm of 2D imaging detectors that pushes for advancements in terms of speed, noise and dynamic range, as well as in the definition of the calibration procedures.

The DSSC (DEPFET Sensor with Signal Compression) consortium is developing a novel soft X-ray imager for the European X-ray Free Electron Laser (EuXFEL) located in Hamburg, Germany. The goal is to install at the EuXFEL a 1 Megapixel camera suitable for photon energies in the range between 0.25 and 6 keV, capable of acquiring 4.5 million frames per second and providing a dynamic range of up to several thousand of photons per pixel per pulse (i.e. some MeV of deposited energy), while maintaining single-photon detection capability down to 0.5 keV. The sensor, one of the key factors to achieve the required performances, is a silicon hybrid pixel detector with two main design variants. In the first preliminary version, the pixel is of passive type, i.e. charge is collected by a passive anode and readout by the ASIC. The second design, more ambitious, shares the same pixel layout except for the integration of an innovative transistor, an adapted version of the Depleted P-channel Field Effect Transistor (DEPFET), specially designed to achieve signal compression at high intensity levels. The latter pixel design combines very low capacitance of the sense node with a nonlinear response and is therefore meant to provide simultaneously low noise readout and high dynamic range.

This PhD thesis deals with the characterization, calibration and optimization of the DSSC detector, challenging tasks due to the peculiar properties of the system (such as the nonlinear analog compression and the limited resolution of the ADC) and to the demanding target performances. This work presents the analysis and results of the first characterization of the DSSC system. Experimental procedures and data analysis techniques have been proposed and validated on a prototype DEPFET module of 128 × 512 pixels with focus on the main properties (e.g. gain, noise and nonlinear pixel response). More specific characterizations have been carried out to study the response to soft X-rays (<1 keV) and the charge collection efficiency within the pixel. The achieved results led to the optimization of the detector operation in real life experiments, while also provided a deep understanding of several key aspects that may be considered in future detector developments. Finally, the main performance figures and the first complete calibration of the first assembled DEPFET camera are presented.

PhD Committee

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