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Calibration Strategy and Experimental Qualification of the Non-Linear Response of the First DEPFET Pixel Sensors of the DSSC Camera

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A novel design of the Depleted P-Channel Field Effect Transistor (DEPFET) with non-linear response is at the heart of the 1 Mpixel DSSC camera (DEPFET Sensor with Signal Compression) currently being developed for ultra-fast imaging of soft X-rays at the European XFEL. The simultaneous requirement of single-photon detection down to 0.5 keV and dynamic range up to 104 photons/pixel/pulse is here solved by introducing a non-linear compression of the DEPFET transistor response while the readout electronics is kept linear. The first full-size sensors produced by PNSensor GmbH have been mounted to give birth to the first ladder (128x512 pixel), one of the 16 independent units forming the DSSC camera.

Now the calibration of a 1 Mpixel DEPFET sensor with signal compression is the key to reach the desired performances but also the major challenge, due to the need to accurately qualify the response of each pixel in different conditions. The aim of this work is to discuss the general calibration strategy, to present the experimental results of the first calibration campaigns on the DSSC ladder and to discuss the open issues.

X-ray spectra were acquired to assess gain and noise performances in the linear region of the DEPFET response by means of a pulsed X-ray source (PulXar) that can provide trains of X-ray pulses with duration as short as 25 ns at high burst rate (up to 4.5 MHz) which effectively mimics the time structure of the beam at XFEL. The reduced number of ADC bit makes gain calibration from spectra fitting particularly dependent on the fitting model which has been carefully optimized to tailor the specific detector properties.
To qualify the full non-linear response of each pixel, from the linear region to the high intensity end, we conducted a dedicated test at the SQS beam line where we can produce intense shots of monochromatic photons (soft X-rays) with a smooth spatial distribution to allow irradiation of a whole quadrant of the camera. The XFEL beam hits an Aluminum target and the DEPFET ladder is at 90-degree to collect fluorescence photons (Al K 1.48 keV).

The presentation will focus on the evaluation of the first DEPFET ladder performance with low energy photons and on the measurement techniques, modelling and parametrization of the DEPFET response. The achieved results validate the calibration strategy of the full DSSC camera and show achievement of noise levels below 20 electrons rms and an input range of deposited energy up to several MeV per pixel per pulse.

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