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Characterisation of a Novel Wafer-Scale CMOS Detector Optimised for 100keV CryoEM

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Advancements in electron detection have significantly improved the quality of biological structures resolved by cryogenic electron microscopy (cryoEM). Using direct electron detectors (DEDs) with high detective quantum efficiency (DQE), researchers can solve structures quicker and easier than in the past. The majority of structures deposited in the Electron Microscopy Data Bank were resolved from datasets captured by microscope systems with a resolution below 3Å using 300keV electrons[1,2]. However, Transmission Electron Microscopes (TEMs) operating at 300keV are expensive to purchase and maintain, presenting a financial obstacle for many institutes and a barrier to discovery[3]. There is a deficit of suitable DEDs optimised for 100keV operation, although it is recognised that 100keV TEMs could improve the affordability of such structure determination as well as increase the ratio of information gained to sample radiation damage caused[3,4].

The C100 DED is a novel CMOS detector optimised for 100keV electrons developed to fill this gap. C100 is a wafer-scale stitched sensor with 54µm pitch pixels forming a large active area of 2048x2048 pixels. The continuous rolling shutter sensor operates with 12-bit effective pixel resolution at a rate of 2000 fps. The frame rate is achieved by sampling and converting multiple rows at a time from two sides, before being serialised at 4.3 Gb/s via the Xilinx Aurora 64b/66b protocol. The sensor's 34 Aurora transceivers transmit over 110 Gbit/s of data, off-chip via Common Mode Logic (CML) lines and via Samtec FireFly optical links to remote camera system hardware outside the vacuum housing.

Here, we present the architectural breakdown of C100 alongside initial results from our characterisation of the sensor's in-pixel source follower, PGA, ADC, PLL and Aurora transceivers. We will finally supplement our characterisation of C100 by presenting the Landau distribution, MTF and DQE for 100keV electrons incident on our small-scale test structure.

[1] M. A. Herzik, M. Wu, and G. C. Lander, 'Achieving better-than-3-Å resolution by single-particle cryo-EM at 200 keV', Nat. Methods, vol. 14, no. 11, Art. no. 11, Nov. 2017, doi: 10.1038/nmeth.4461.
[2] EMDB, 'Electron Microscopy Data Bank', Electron Microscopy Data Bank. https://www.ebi.ac.uk/emdb/ (accessed Feb. 16, 2022).
[3] K. R. Vinothkumar and R. Henderson, 'Single particle electron cryomicroscopy: trends, issues and future perspective', Q. Rev. Biophys., vol. 49, ed 2016, doi: 10.1017/S0033583516000068.
[4] K. Naydenova et al., 'CryoEM at 100 keV: a demonstration and prospects', IUCrJ, vol. 6, no. 6, Art. no. 6, Nov. 2019, doi: 10.1107/S2052252519012612.

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