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Electron photoavalanche diode arrays: A new technology for noiseless high speed near infrared sensors

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To conduct high angular resolution observations of astronomical objects from ground based observatories, adaptive optics is needed to correct the images distorted by atmospheric turbulence. For the adaptive optics (AO) systems, low noise high speeds near infrared sensors are needed for wave front sensing and fringe tracking. Until now the performance of those sensors was based on CMOS detectors. Due to the high analog bandwidth needed for achieving frame rates of 1 KHz the readout noise severely limited the sensitivity. The only way to overcome the CMOS noise barrier is the amplification of the photoelectron signal directly at the point of absorption inside the infrared pixel by means of the noiseless avalanche gain. A breakthrough has been achieved with the development of the near infrared SAPHIRA 320x256 pixel electron avalanche photodiode arrays (e-APD) which have already been deployed in the wave front sensors and in the fringe tracker of the instrument Gravity at the Very Large Telescope Interferometer (VLTI) located on Cerro Paranal in Chile. Results obtained with this new technology will be presented. The detectors now show flat response with high quantum efficiency in the wavelength range from 0.8 μm to 2.5 μm . Sub electron readout noise at frame rates of 1 KHz has been demonstrated. The dark current is as low as 0.02 e/s/pixel for an APD gain up to 8. With this performance, e-APD arrays also have the potential to outperform conventional large format NIR science focal planes. For AO systems of extremely large telescopes and for co-phasing segmented mirror telescopes larger formats are needed. Therefore, a 512x512 pixel SAPHIRA array optimized for AO applications will be developed, which has 64 outputs operating at 10 Mpixel/s/output. This corresponds to frame rates of 2 K frames/s for full single frame readout. The design of this large format SAPHIRA array will be discussed.

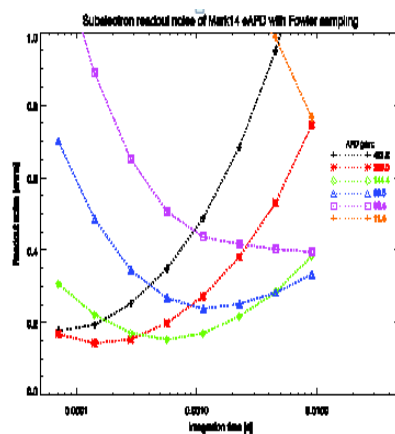


Figure 1: Sub-electron readout noise of Mark14 eAPD at a detector temperature of $T=90\text{K}$ for different APD gains. Number of Fowler pairs is proportional to detector integration time and increase by a factor of 2 for each data point. Number of Fowler pairs from left to right: 2, 4, 8, 16, 32, 64 and 128.

Biography

Gert Finger has developed infrared arrays for astronomy and deployed them in many instruments at European Southern Observatory. He was leading the detector group at ESO. Since his retirement, he holds an emeritus position at ESO and is still actively pushing the development of eAPD technology which has been recently deployed in the Gravity instrument at the VLTI.

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