Room temperature 96x96 InGaAs/InP SPAD array for SWIR imaging

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We present a 96x96 InGaAs/InP single photon avalanche diode array optimized for detection at 1550 nm wavelength. The array has a pixel pitch of 25 µm and a fill factor of 28.3%. At room temperature the dark count rate of a pixel is typically 87 kcps at a photon detection efficiency of 15%. The breakdown voltage of a subset of 6x96 pixels has a median value of 62.2 V with a standard deviation of 72 mV.

Device structure

- InGaAs/InP epitaxial layers grown and processed on a **3-inch InP substrate** via MOVPE, PECVD and dry plasma etching
- Pixels defined by zinc diffusion regions of 15 µm diameter, arranged in a **96x96 array** with **25 µm pitch**, resulting in a **fill factor of 28.3%**
- Contacts metallized via electron-beam physical vapor deposition for **isolated anodes and common cathode**
- Backside illuminated **SWIR imaging sensor** for flip-chip hybridization with a **CMOS readout integrated circuit (ROIC)**

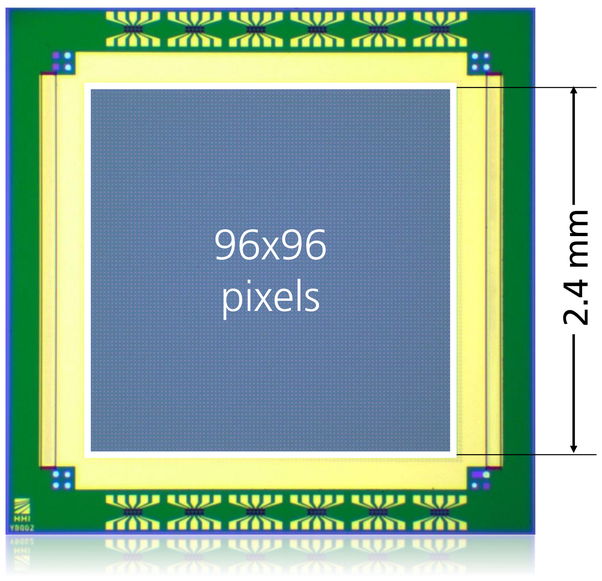

Fig. 1. Processed 96x96 InGaAs/InP SPAD array chip with 25 µm pitch

Experimental results

Measurement setup and method

We obtained our measurement results by single-pixel probing and pre-biasing below the breakdown voltage via the DC path of a bias tee and gating with a square pulse generator via the AC path for Geiger mode operation. A picosecond pulse laser is attenuated down to an average photon rate of 0.5 photons per pulse and gate.

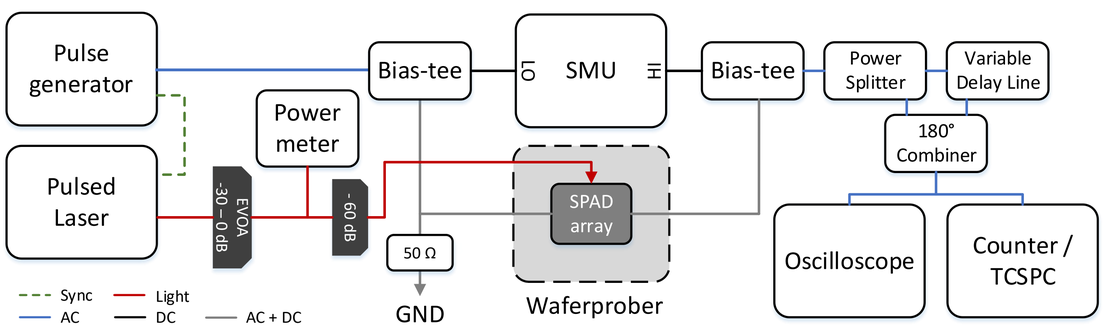

Fig. 2. Measurement setup for gated operation of SPADs

Measurement results

Figures 3 to 5 show our measurement results of the DCR statistics, DCR vs. PDE for a representative SPAD, and the breakdown voltage statistics.

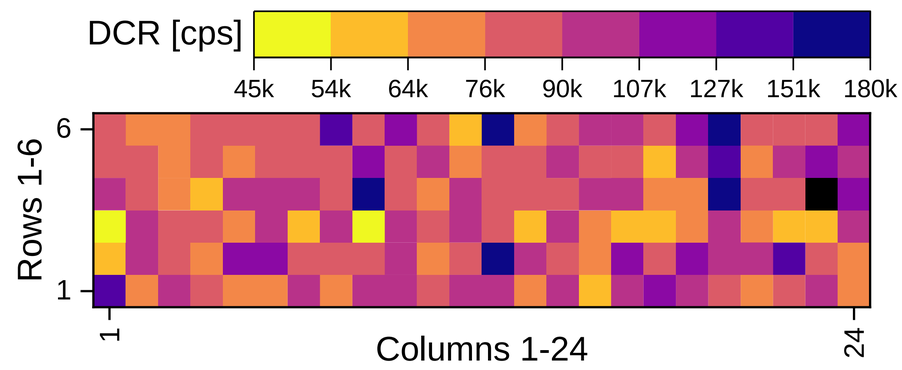

Fig. 3. DCR statistics of a subset of 6x24 pixels at room temperature

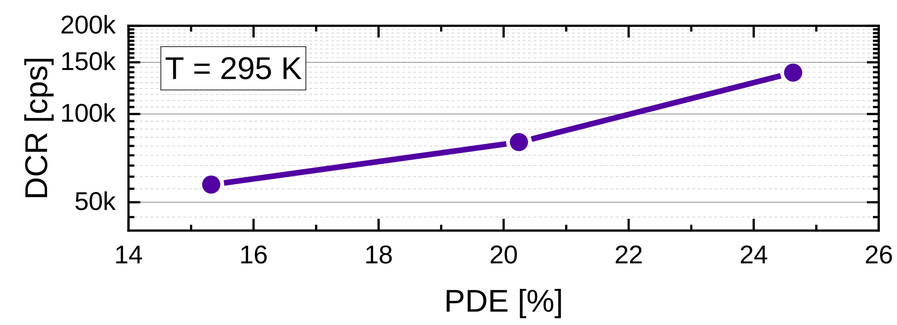

Fig. 4. DCR vs. PDE at 1539 nm of an equivalent front illuminated SPAD

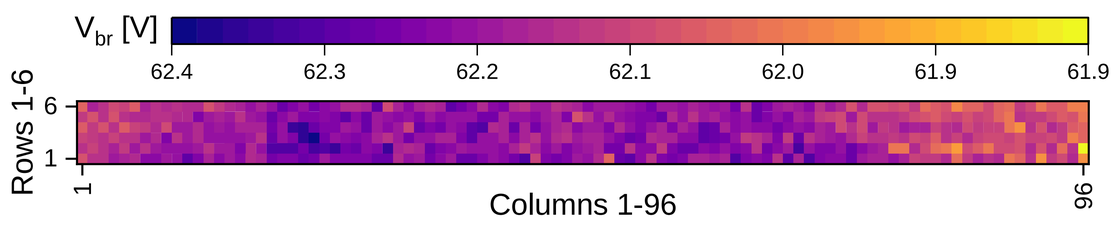

Fig. 5. Breakdown voltage statistics of a 6x96 subset

- **DCR** in the range of 45-175 kcps with a median value of **only 87 kcps** (492 cps/µm²) for a 6x24 subset
- 15% PDE at corresponding excess bias
- 62.2 V breakdown voltage with standard deviation of **only 72 mV** for a 6x96 subset

Conclusion

We have successfully developed and fabricated a 96x96 InGaAs/InP SPAD array and partially characterized it in terms of DCR, PDE and breakdown voltage. The results prove that this is an excellent candidate for a SWIR imaging sensor in low-light applications like LiDAR. The dark count rate is less than half compared to the latest published results[1] of InGaAs SPAD pixels at room temperature and same PDE.

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1 S. Wang et al., "Design, Fabrication, and Characteristic Analysis of 64 × 64 InGaAs/InP Single-Photon Avalanche Diode Array," J. Electron. Mater., vol. 51, no. 5, pp. 2692–2697, May 2022, doi: 10.1007/s11664-022-09531-9.