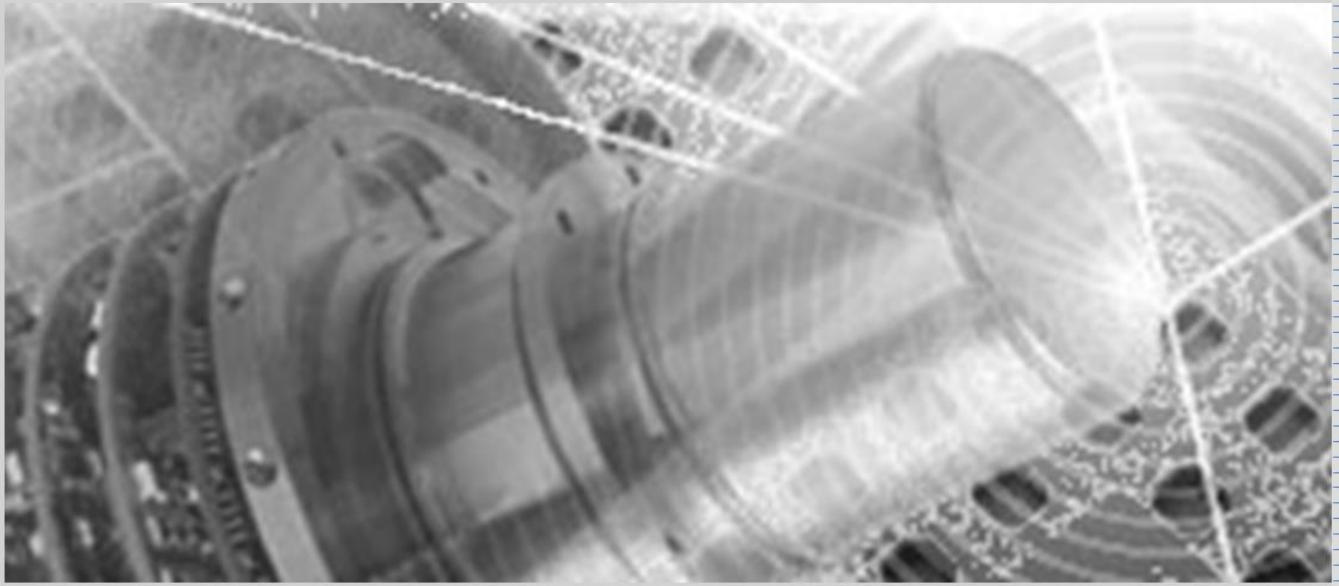
AIM Infrarot-Module GmbH



Improved Low Dark Current MWIR/LWIR MCT Detectors: First results of ROIC and MCT measurements

Holger Höhnemann, Toulouse, July 4, 2018

Overview

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- Introduction Low Dark Current (LDC) Program
- ROIC Highlights
- FPA and Test Devices
- Test Stand Design
- Selected Measurement Results
- Summary

Objectives of the LDC program

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- The requirements for optical astronomy are highly demanding detectors for nearly photon counting in the mid- and long wave IR range.
  - Therefore the detector chip shall have a negligible dark current.
  - The read out circuit shall have a low saturation value for the collected photons.
  - The detector shall have negligible noise.

- The former ESA low dark current project was adressing the MCT detector chip mainly, but the available ROICs and test environments gave some limitations to the achievable results.
- Within this ESA project „Development OF Low Dark Current MWIR/LWIR Detectors“ an improved MCT material as well as a suitable read out circuit and an appropriate test set up should be prepared and characterised.

ESA Project „Low Dark Current MWIR/LWIR“

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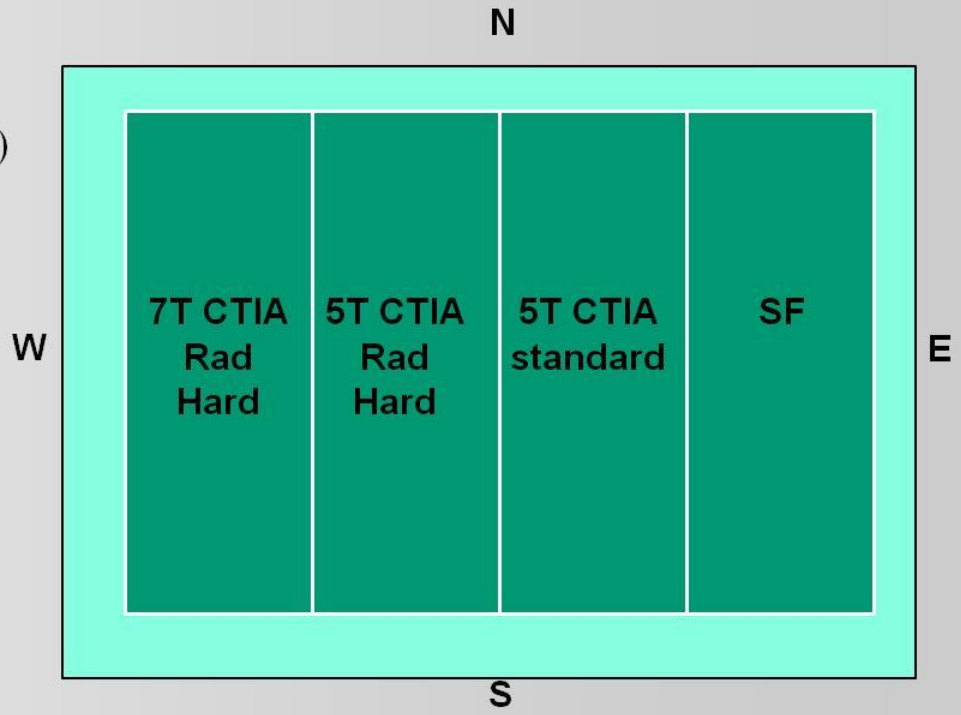
- A consortium of three partners was set up to achieve the required goals:
  - AIM Infrarot Module: as project leader and for MCT improvement
  - CAELESTE B.V: for the ROIC design
  - University of Cardiff, School of Physics & Astronomy: for the cryogenic tests

- Within this project a ROIC was designed, which has four different input stages for direct comparison of the capabilities of the different topologies.
- AIM applied some process modifications to improve the dark current behaviour for N-on-P and also for P-on-N MCT detector devices.
- University of Cardiff has prepared a highly light tight cryogenic test dewar to allow really dark measurements.

ROIC Overview

- Array size : 4x320 (H) x 1080 (V)
  - MCT arrays with 320x320 pixels were assembled on this ROIC
- Pixel pitch: 20 µm
- Different Arrays are dedicated to different input stage topology:
  - 7T rad hard CTIA
  - 5T rad hard CTIA
  - 5T CTIA (using standard cell design)
  - Source follower

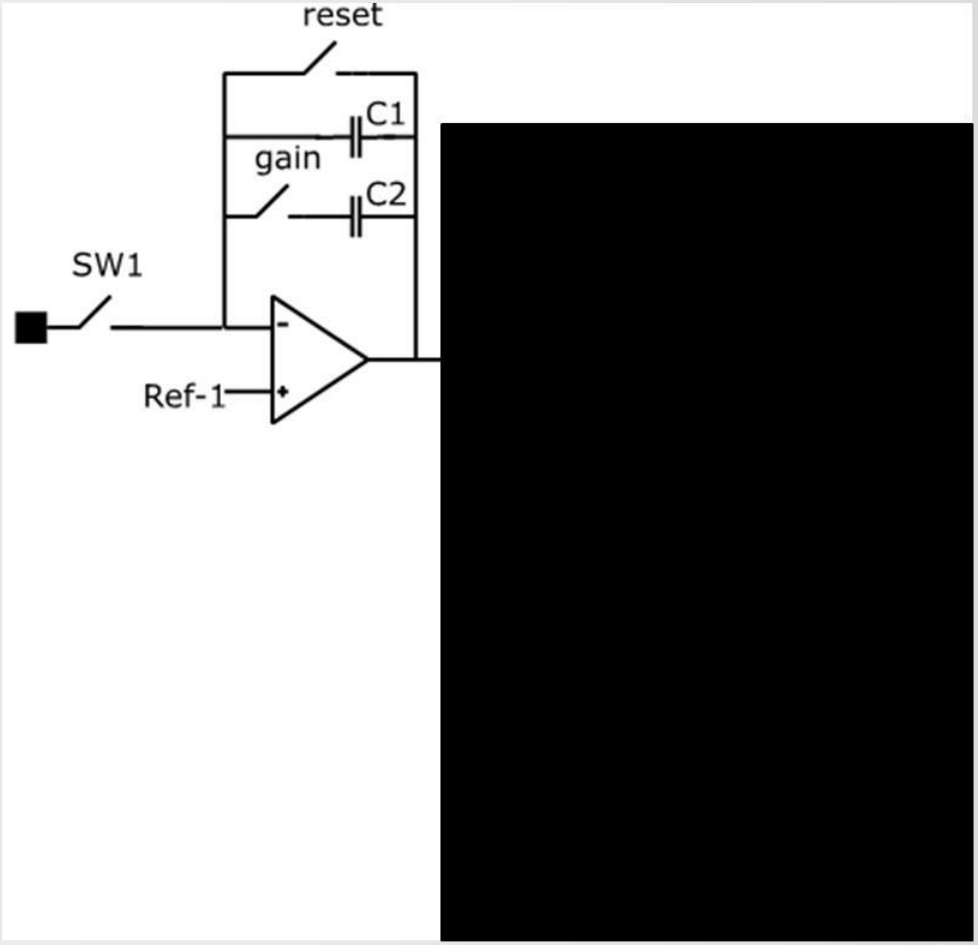


- Each Segment assigned to single Video output.
- Each segment can be operated „stand alone“.

ROIC Capabilities

- Shutter modes:
  - Integrate While Read (IWR)
  - Integrate Then Read (ITR)
  - Rolling shutter (RS)
  - Non-Destructive Readout (NDR) or Fowler sampling
- Radiation hardness
  - TID, SEU, SEL
- Indium bump to MCT, 'P on N' and 'N on P' type
- Programmable Integration capacitance: 8fF, 40fF
- Pixel readout rate: 20 MHz
- Operating temperature: 40K – 80K – 300K
- CMOS Technology : 0.18 µm XFAB

ROIC Input Stage



- Fully programmable pixel
- CTIA based
- Bi-directional
  (N on P, P on N)
- CDS
- Programmable integration capacitor

- All shutter modes:
  - IWR global shutter
  - ITR snapshot shutter
  - Rolling shutter
  - NDR Fowler sampling

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Input Cell Design

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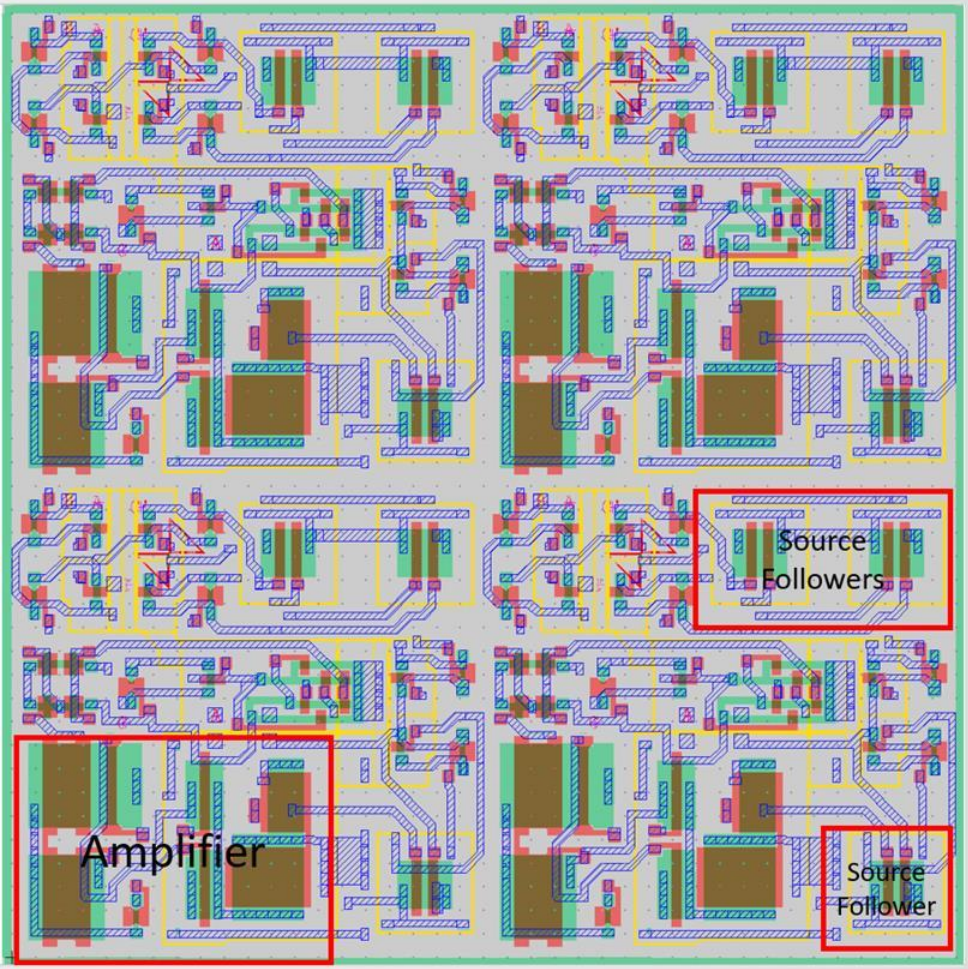
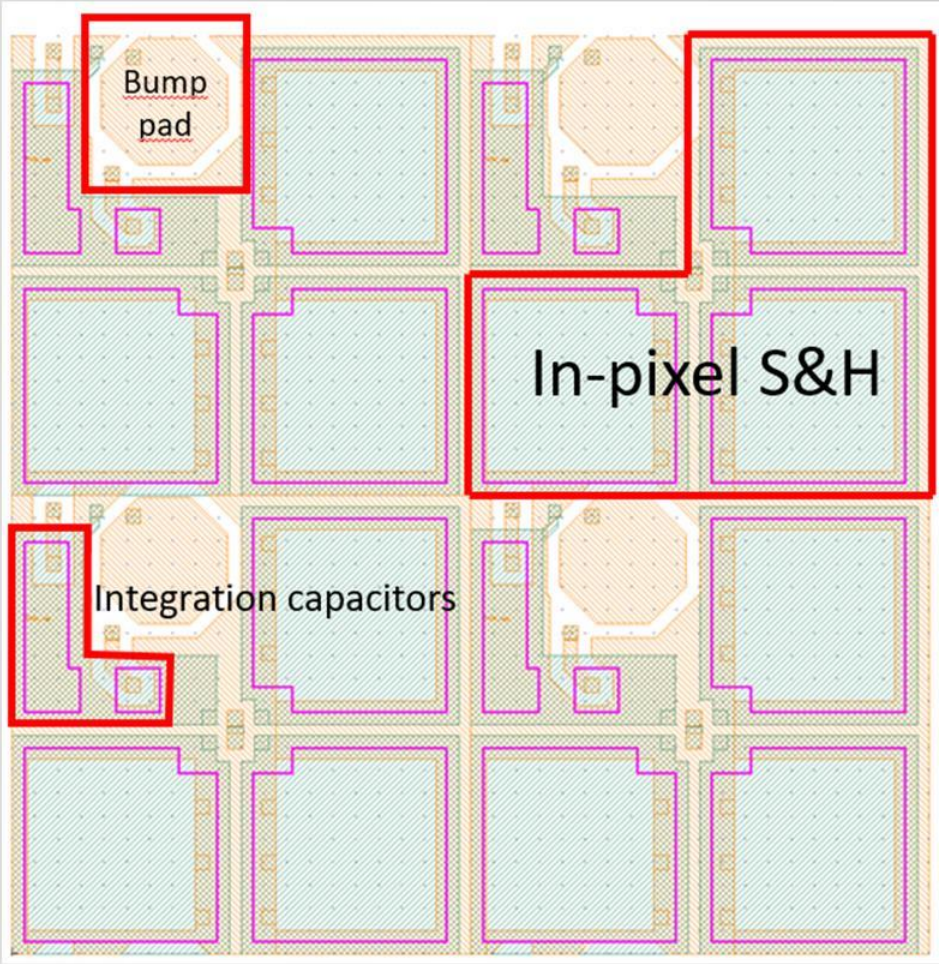
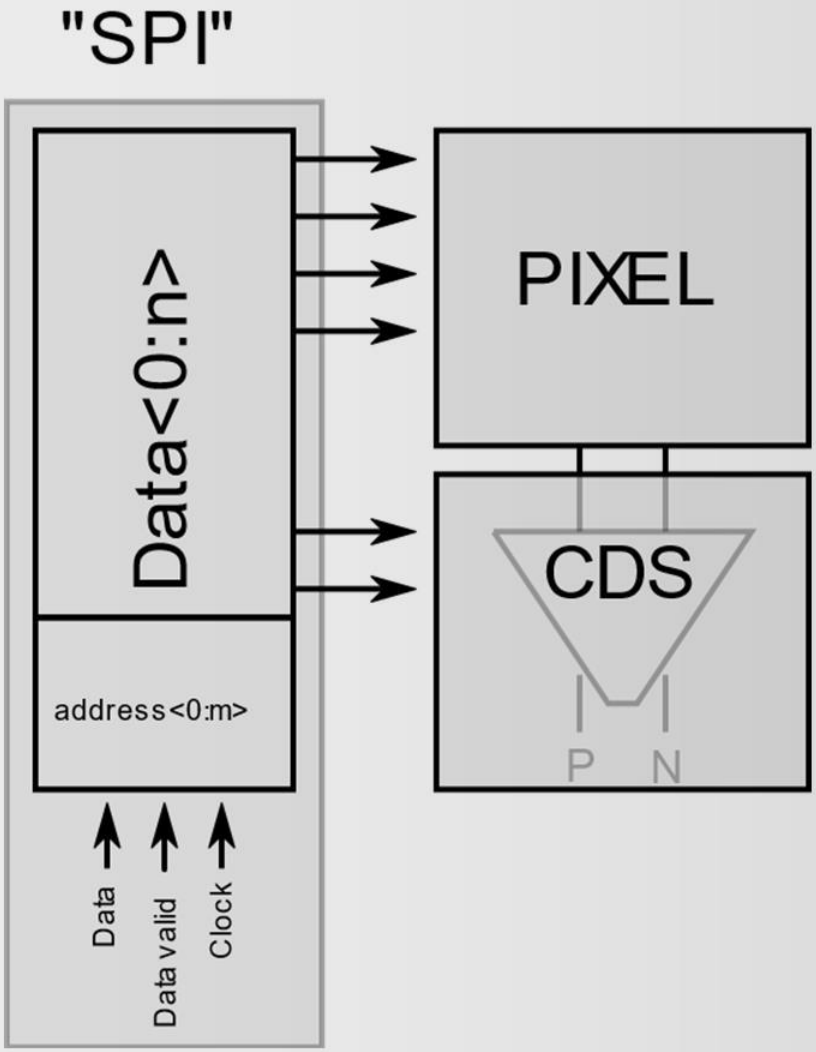
- High density pixel design





ROIC Programming



- The pixel array, column readout and other blocks are controlled by serial to peripheral like interface
- Toggling of a switch requires uploading logic ‘1’ and logic ‘0’ for a particular ASPI bit
- Any shutter mode can thus be obtained by simple FPGA programming

FPA assembly 1

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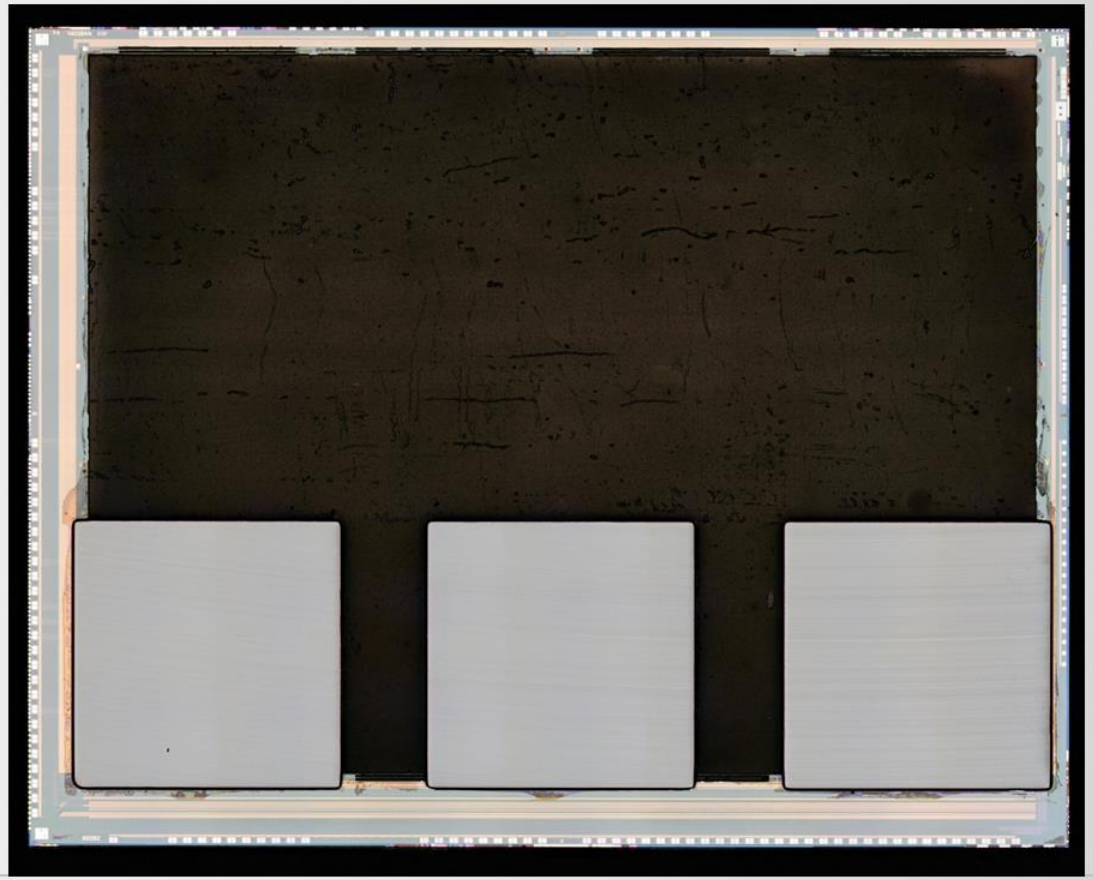
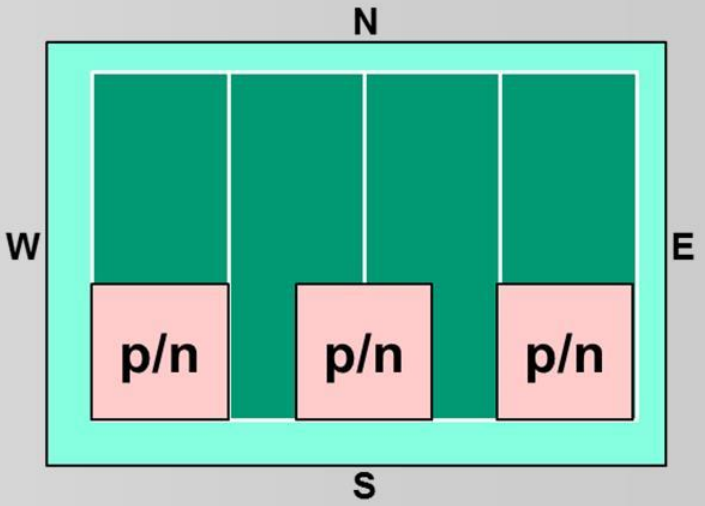
- AIM has assembled two different types of FPAs: Devices for the selection of the input stage and devices for comparison of MCT samples.
- For assembly 1 three MCT detectors of the same type with cut-off values at 12.5µm@40K are hybridized on one ROIC.





Test Device for assembly 1

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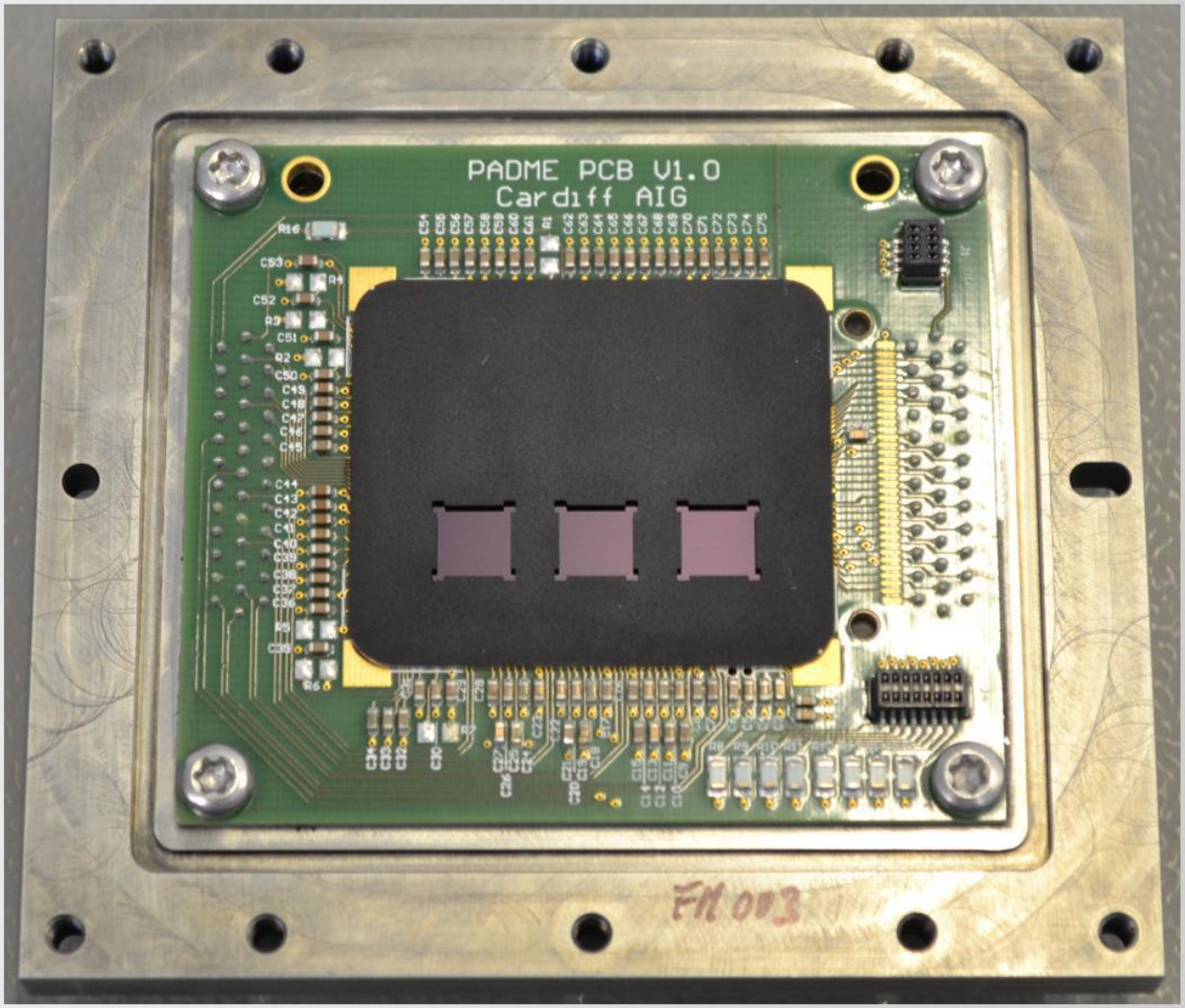

Test device for FPA assembly 2

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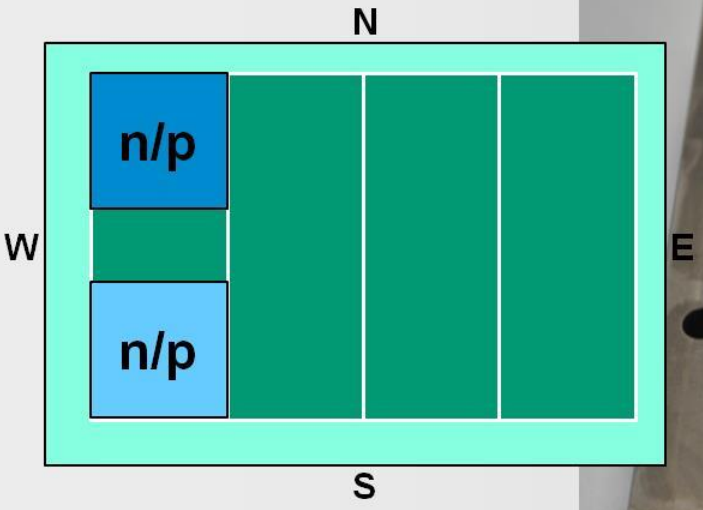
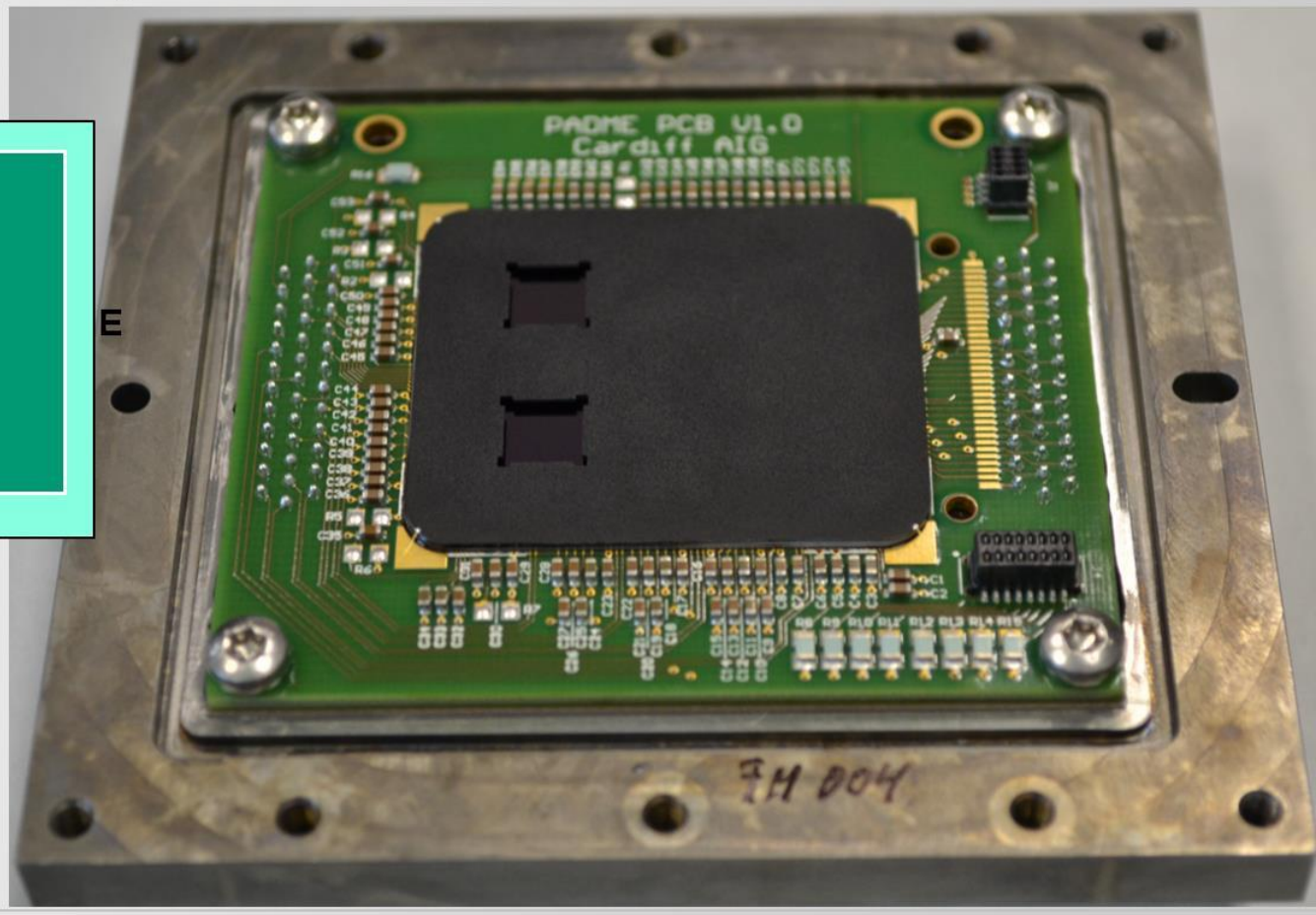
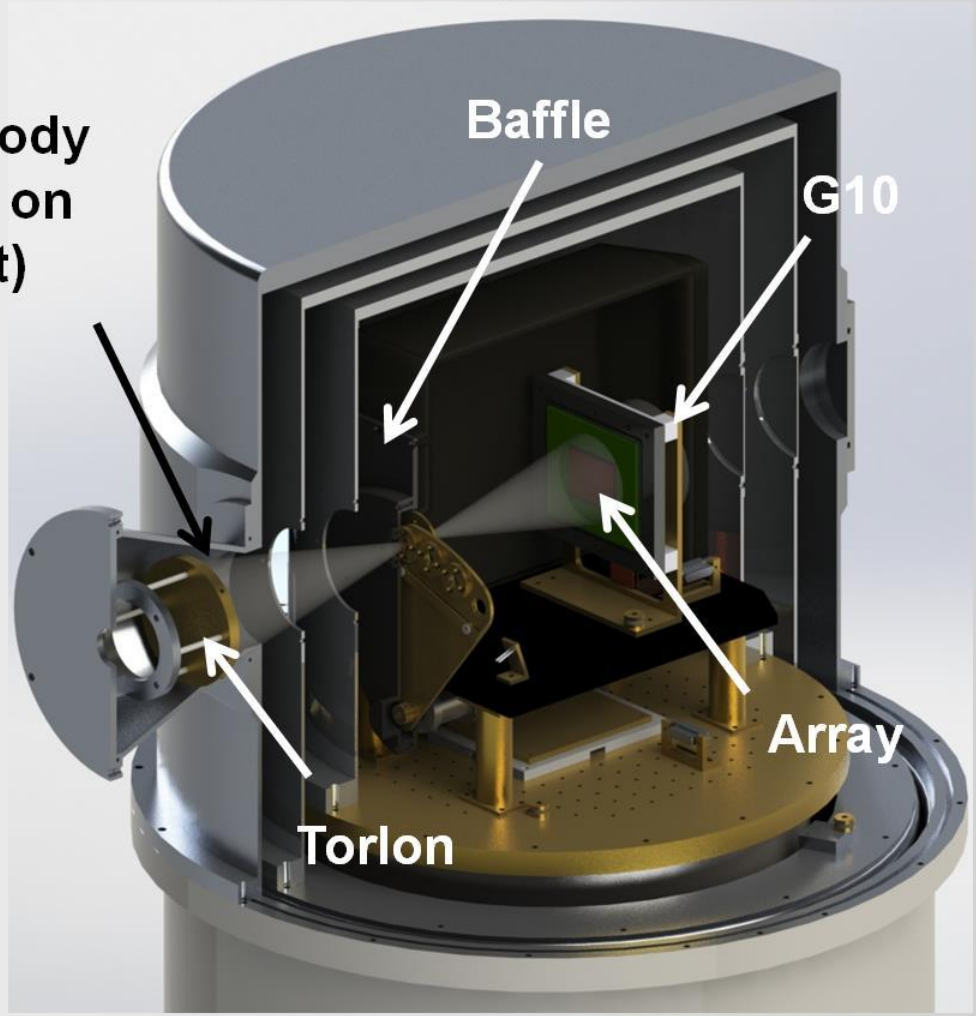
- For the FPA assembly 2 two different MCT samples with cut-off values at 12.5µm @ 40K having two different process modifications are assembled on one segment for direct comparison.



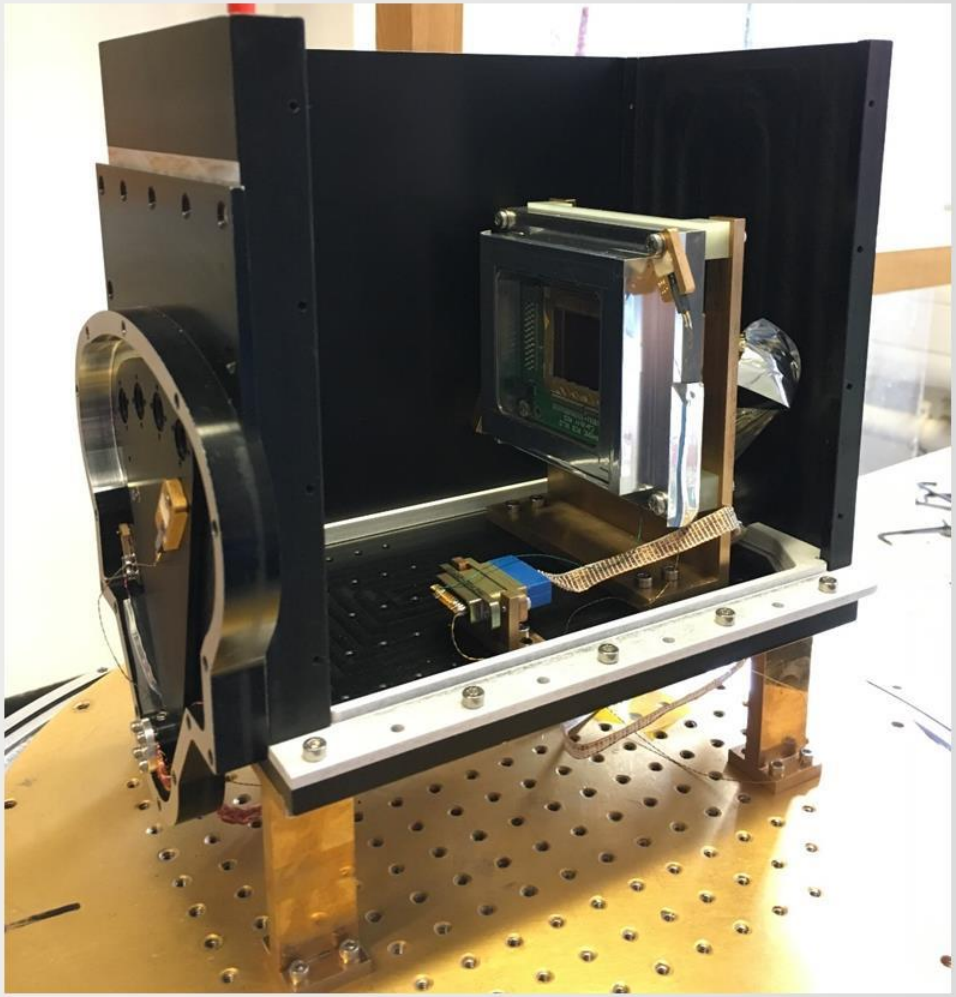


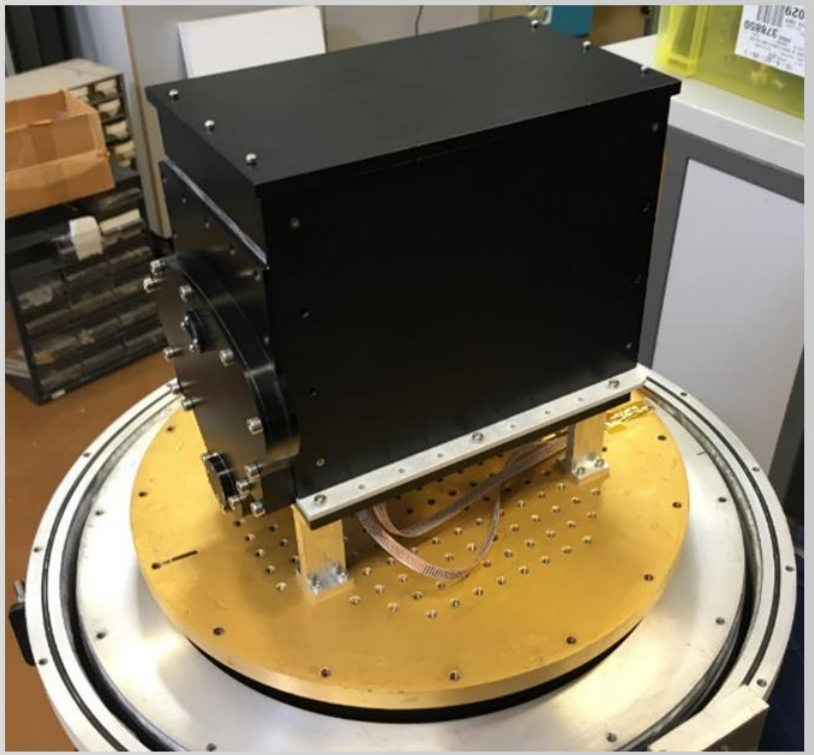
Test Cryostat setup

- Cross section of the liquid helium cryostat



Cryostat inner housing with assembled DUT





Measurement: ROIC with test pixels

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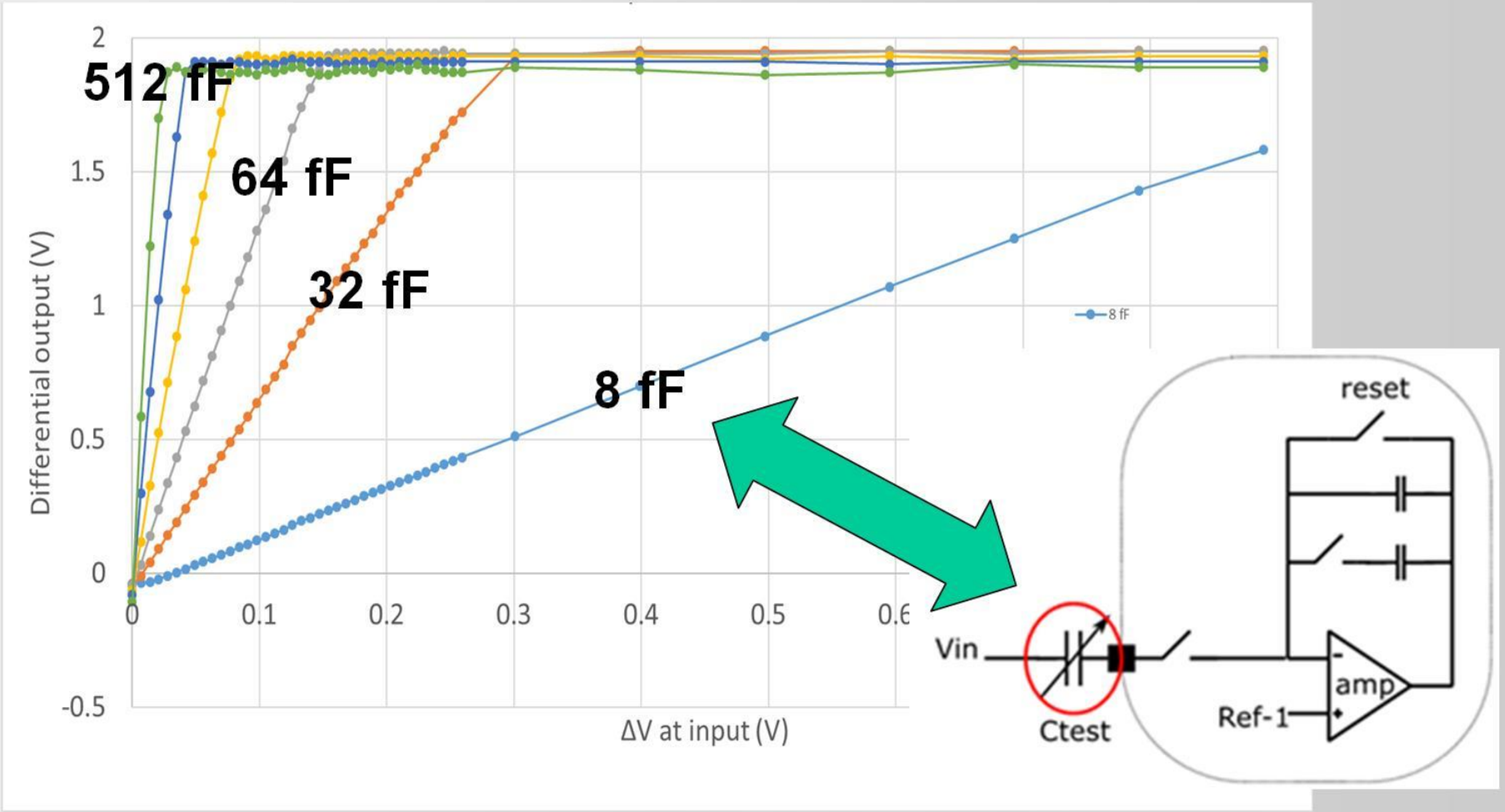
- Pixel response with capacitive input @ room temperature



Measurement: Comparison of input stages

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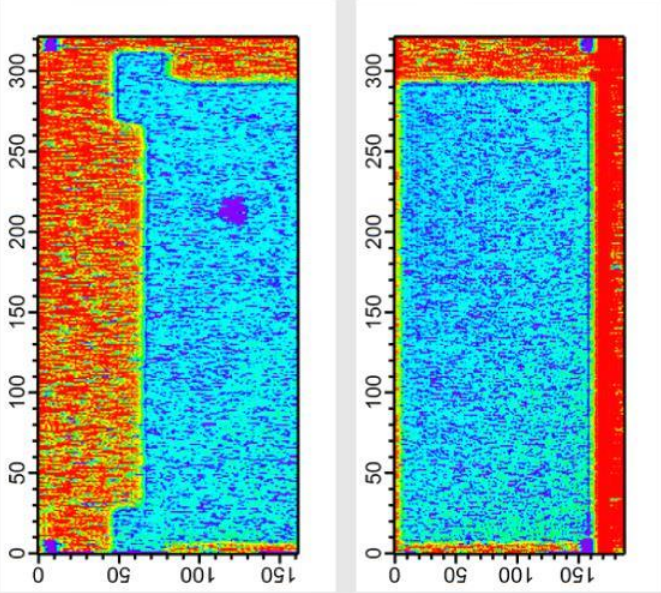
- Image representation of the center test MCT of assembly 1 under illumination is shown.
- This configuration allows direct comparison between input stage topology.

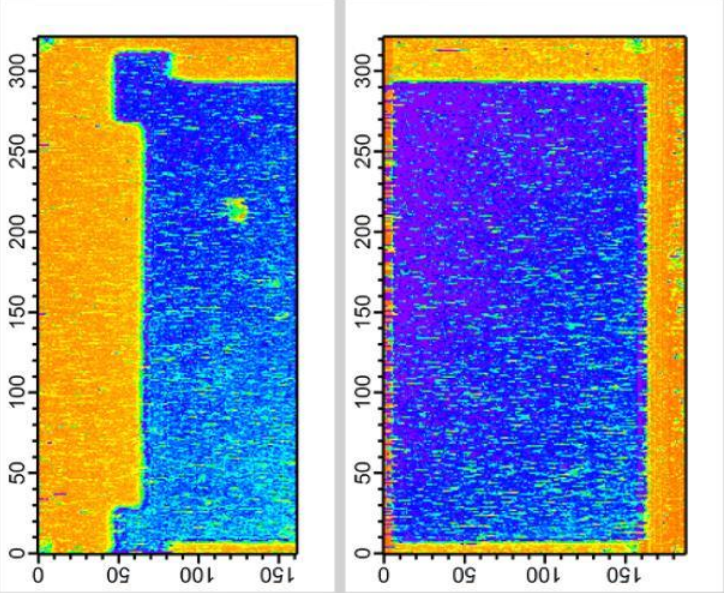
Signal response

segment 1 segment 2



Noise response

segment 1 segment 2



Measurement: Bias voltage characteristic MCT (1)

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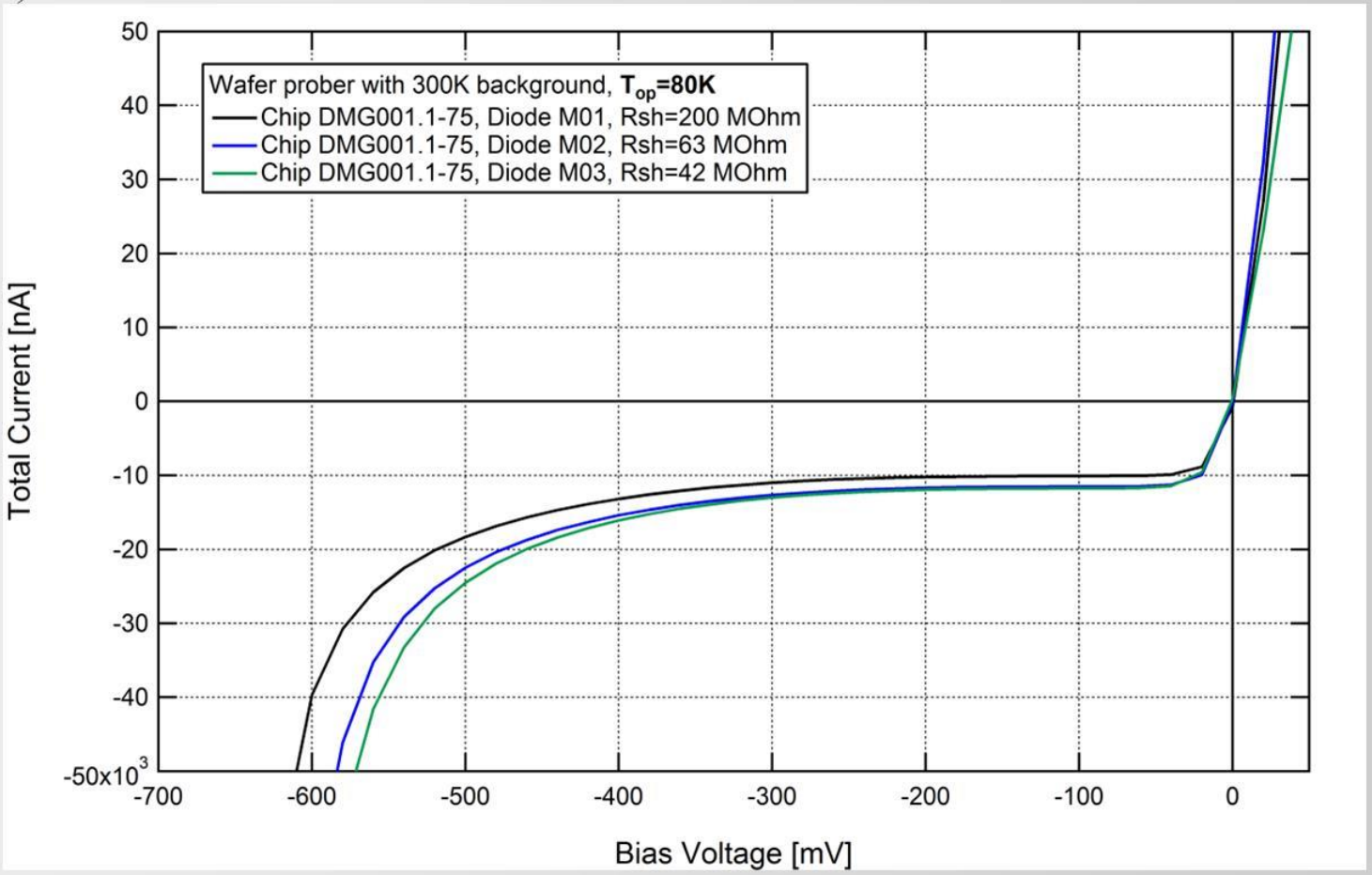
- MCT reverse bias characteristic for N - on - P material (cut-off 12.5µm @ 40K)



Measurement: Bias voltage characteristic MCT (2)

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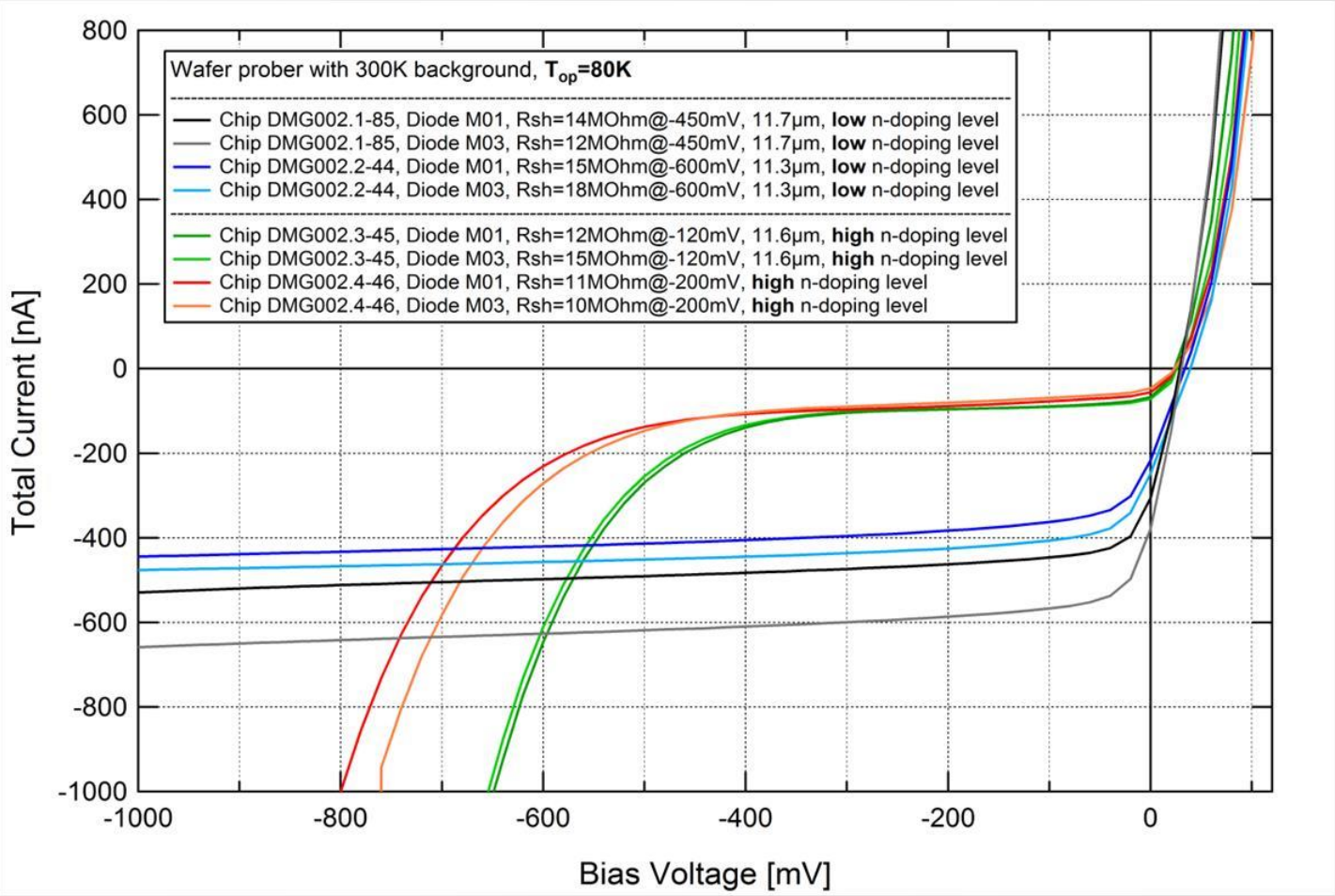
- MCT reverse bias characteristic for P - on - N material. Cut-off values at 12.6 µm @ 40K. Here an impact of the doping level on the reverse breakdown voltage can be observed



Measurement: Dark current (1)

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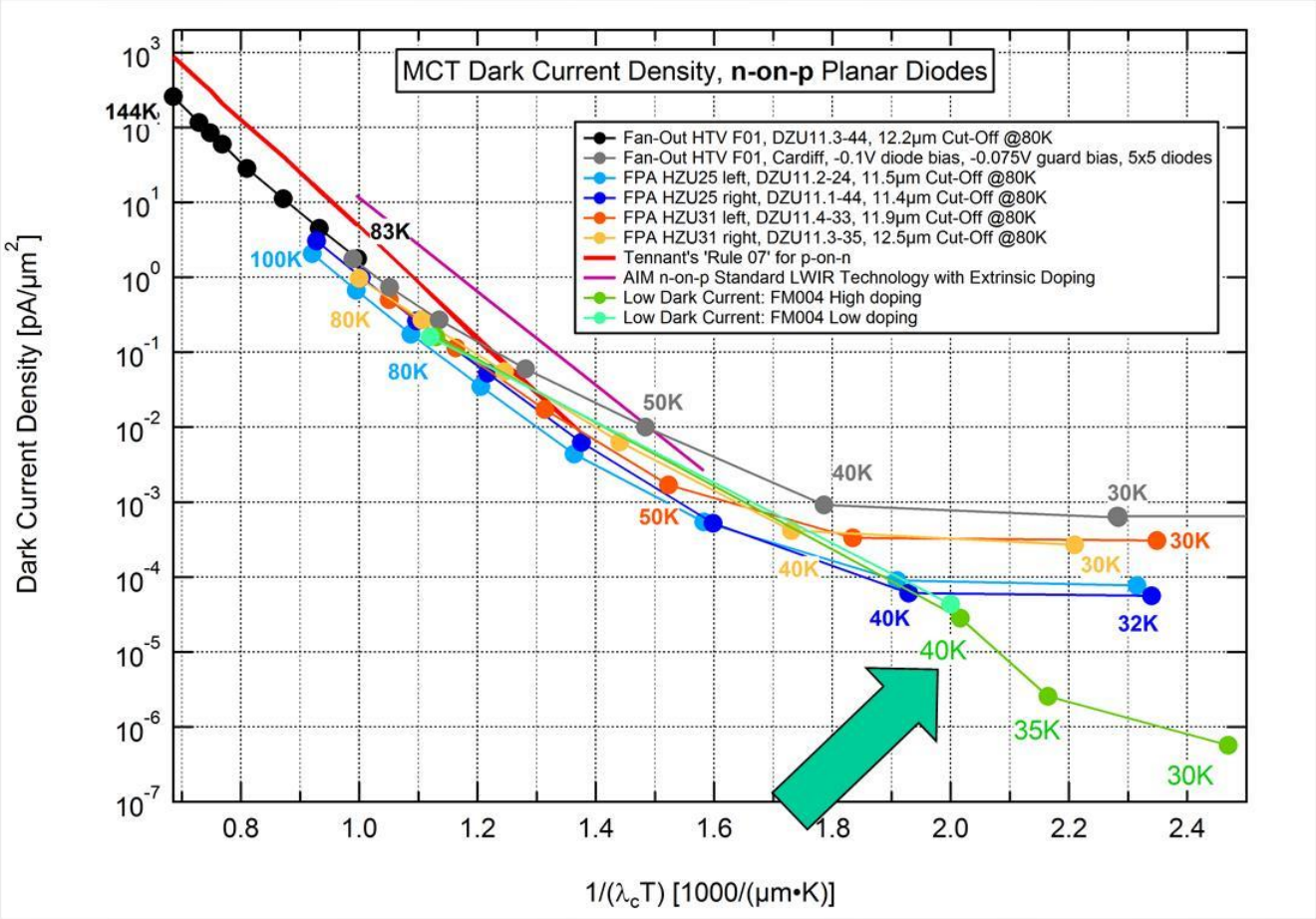
- MCT electrical results: N – on P
  - Eqivalent dark current is comparable to former results at LN2 temperatures and **lowest known dark current values reported ever for lower temperatures.**



Measurement: Dark current (2)

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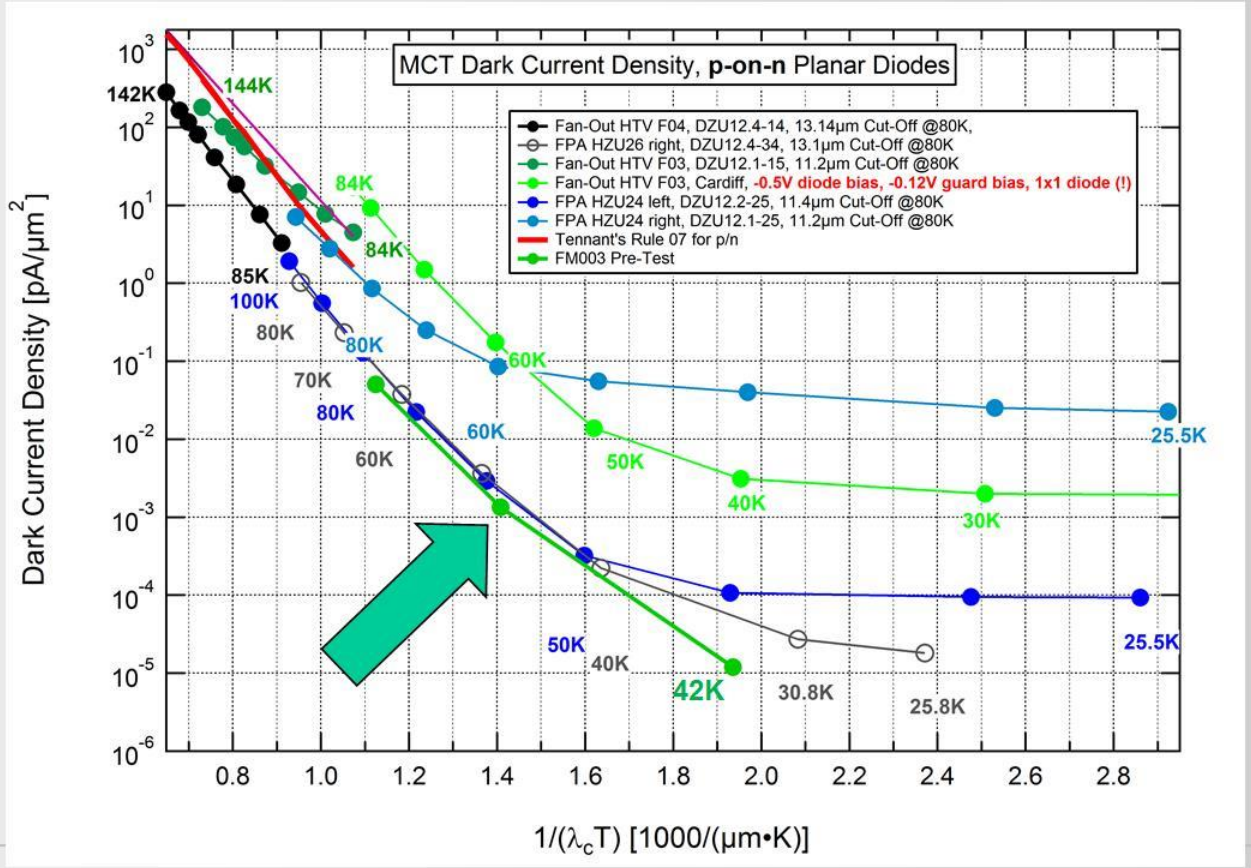
- FM003 MCT electrical results: P - on - N
  - Eqivalent dark current is comparable to former results for low dark current materials at higher temperatures.
  - Best results achieved ever for 42K operating temperature. Tests are ongoing.



Summary

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- Within this project a new design and test approach for low flux MWIR and LWIR MCT detectors was set up.
- New ROIC and improved MCT detector devices were prepared and tested.
- Initial ROIC design is fully functional. High flexibility in operating modes by programming capabilites via fast SPI interface.
- A test equipment was build up to ensure complete dark test environment.
- **The lowest known dark current value ever reported was measured for operating temperatures at 40K and below.**
- Measurements are ongoing, further highlights are expected.

Acknowledgements

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