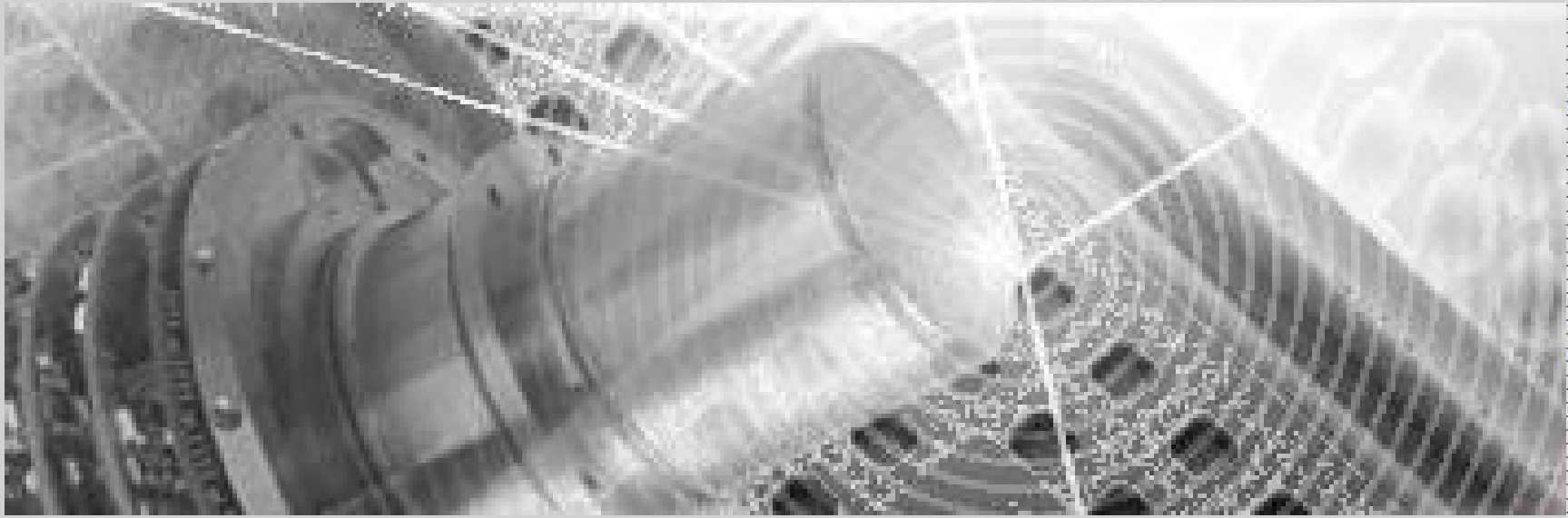
AIM Infrarot-Module GmbH



Space Application for MCT-based LWIR and VLWIR 2D High Performance Focal Plane Detector Arrays using p-on-n- Technology

Holger Höhnemann

7.6.2023, Infrared Detection for Space Applications Workshop, Toulouse

Company Introduction: Process and Value Chains of AIM

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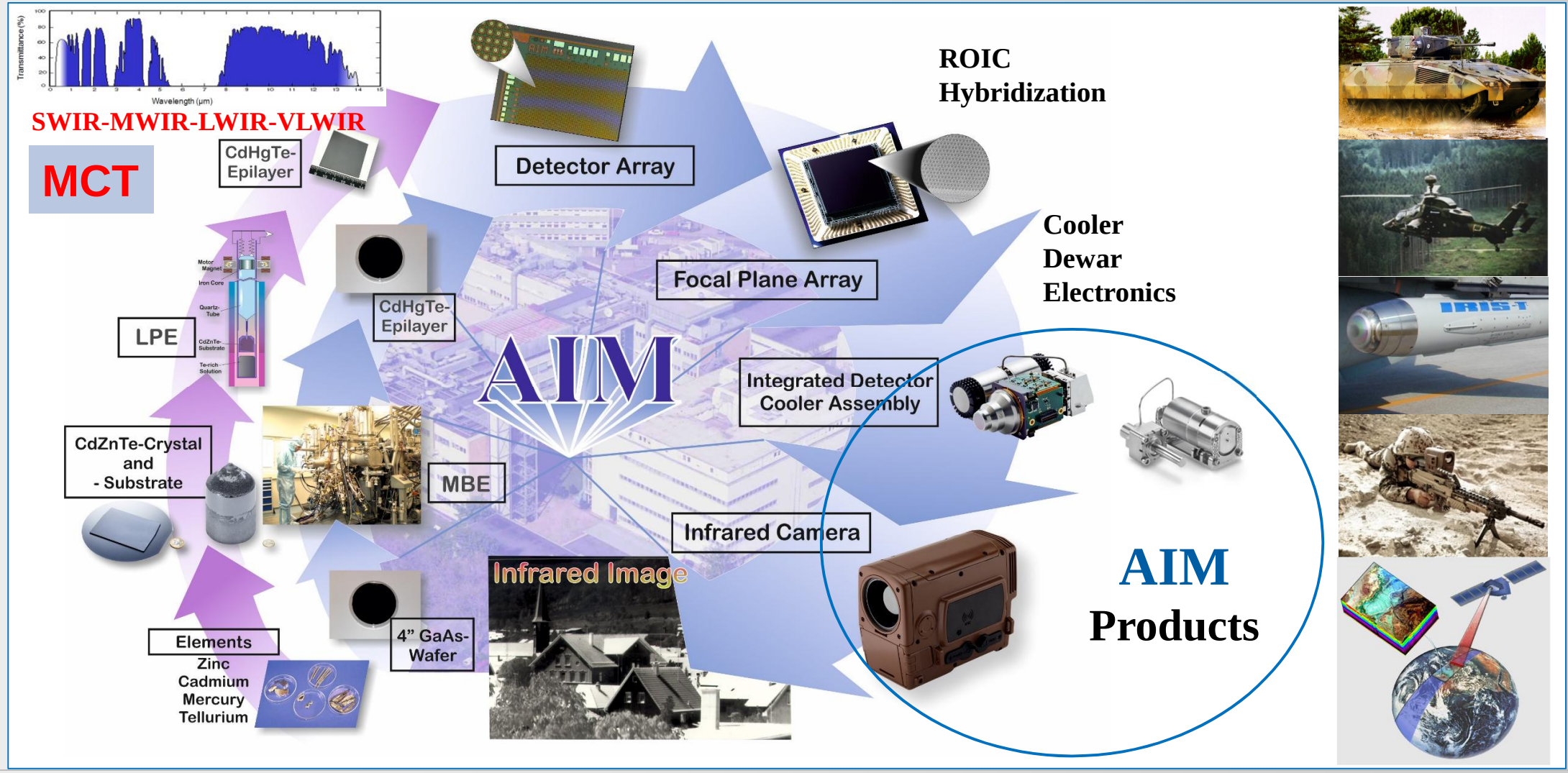
All main processes from crystal growth via detectors and coolers up to thermal sights under one roof



Goal of the presented Detector design

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- The presented detector was developed in the frame of a predevelopment activity with ESA. The design was specified to support the main instrument concept for the LSTM instrument:
  - **L**and
  - **S**urface
  - **T**emperature
  - **M**onitoring
- The detector shall allow to operate in up to five different spectral channels (LWIR and VLWIR) as line detector with TDI capability and 100% operability.
- For the use in a brooming instrument the IWR (Integrate while read) operating mode is requested to allow fixed frame times even for different integration times.

DESIGN OF THE LSTM ROIC

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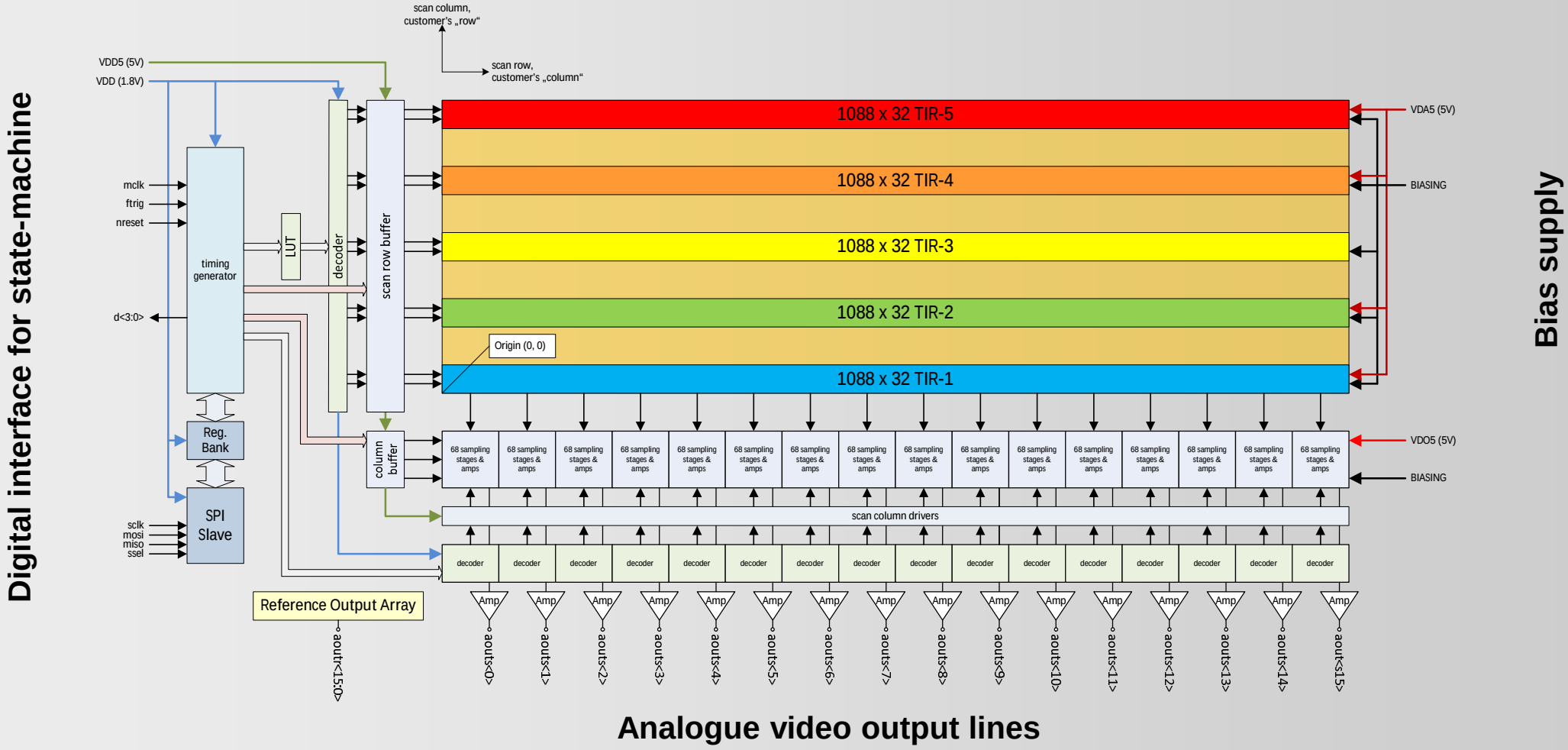
- The ROIC design is implementing the requirements with the following concept:



DESIGN OF THE LSTM ROIC

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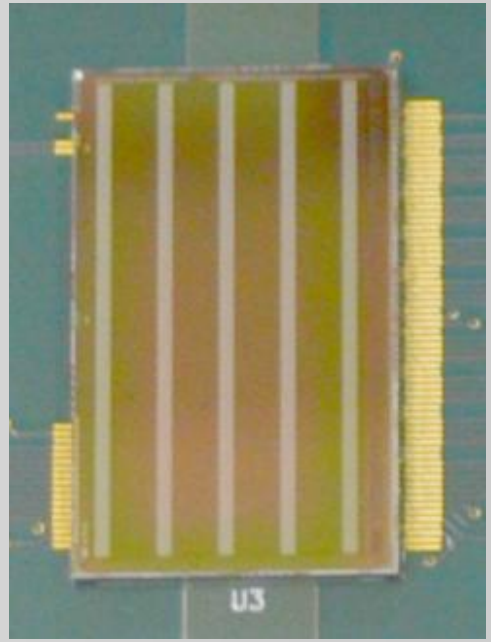
- The ROIC supports five detector stripes with 1088*32 pixels. Out of these 32 rows the lines used for TDI processing can be selected.
- In order to support the requested frame time 16 analogue outputs are used @10MHz master clock
- The pixel cell is designed as BDI input stage for p on n diode polarity.
- The resulting geometrical data are:

	Value	Units
Nominal Pixels	1088 x 160	Pixels
Pixel Size	25 x 25	µm²
Array Width	27200	µm
Array Height	14800	µm
ROIC Total Width	28770	µm
ROIC Total Height	18000	µm



SPECIAL FEATURES: MULTI SPECTRAL APPROACH

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- The ROIC is providing five stripes/segments to allow up to five separate spectral channels
- Each segment can be independently programmed for integration time and gain
- The PV interface design allows the usage of two different PV chips on one ROIC:
  - First PV on Segments 1,2,3
  - Second PV on Segment 4,5
- With this configuration an optimization with regard to photon flux, MCT cut-off and dark current is possible
- The PV-Selection for the LSTM-instrument is
  - PV1: approx. 11µm cut-off @65K
  - PV2: approx. 13.5µm cut-off @65K

OUTPUT SWING AND LINEARITY

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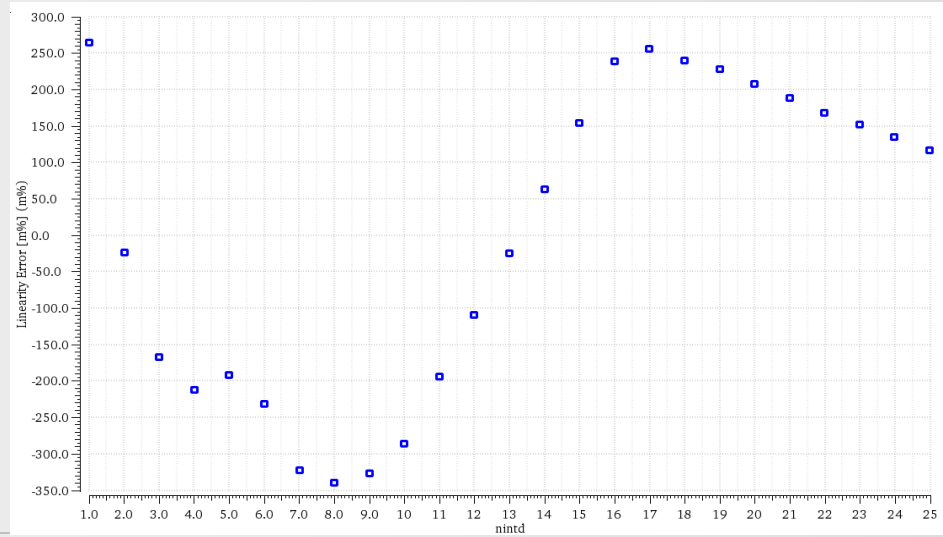
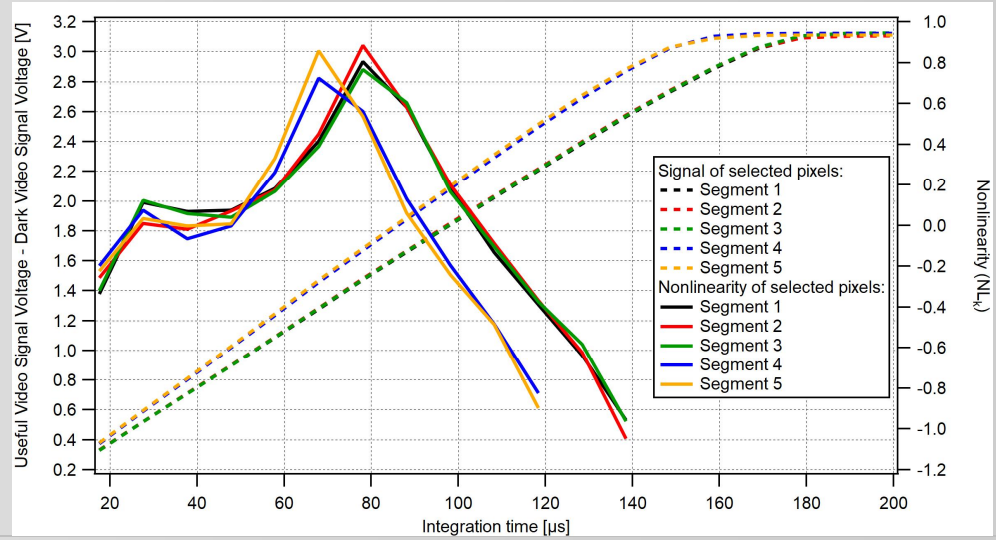
- The video output is designed for 5V supply current and a linear output range of 2.7V
- It is designed as single ended output with a reference line tied to ground.
- Each line can be fine tuned with an programmable internal serial resistance in order to match the output impedance.
- For the design output level the programmable CHCs are 3Me, 4.5Me and 7.5Me
- Linearity error for variation of integration time is approx. 0.6% by design, but 1.8% on hardware (due to shift of operating point)





Noise and Homogeneity

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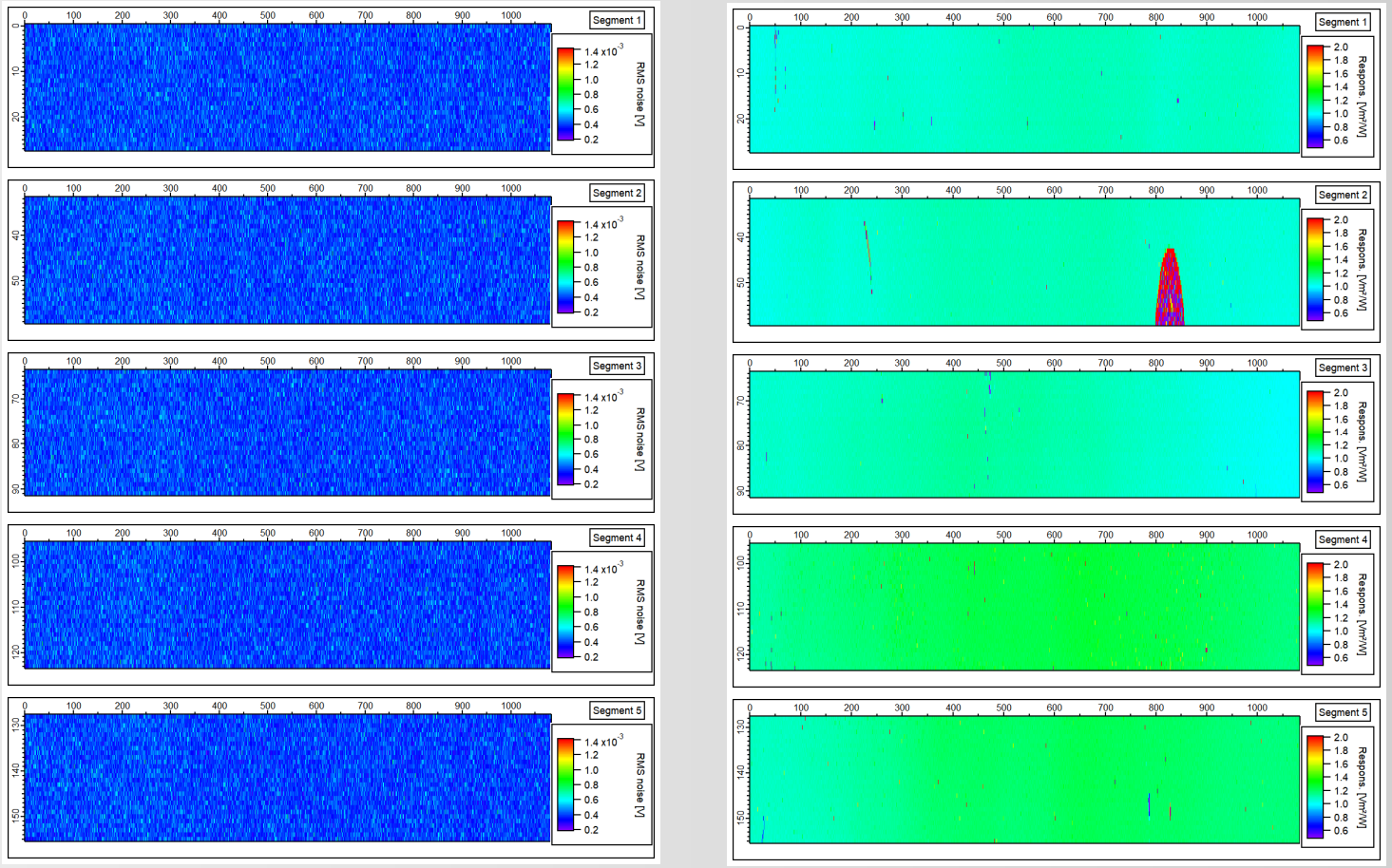
- The noise map(left) of each segment shows a homogenous ROIC noise of 400 µV
- The photo response @ 65K (right) shows a good homogeneity too with an artifact in segment 2



PRNU: 2.12%

PRNU: 2.39%

PRNU: 3.57%

PRNU: 3.89%

PRNU: 4.03%

ROW SELECTION MODES

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- The detector has four main operating modes, which can be combined by the two major settings:
  - Integration mode: IWR or ITR
  - Data output: „Full Frame“ or „Row Selection“
- For the full frame readout all pixel cells will be read out in one frame, limiting the frame rate to approx. 800 fr/s @ 10MHz master clock
- In the row selection mode the number of possible readout rows is limited to 32. This allows a full readout of one segment.
- Number of rows and order of readout is fully programmable and can be adjusted to the current needs.
- With 32 rows read out, the frame rate is approx. 3800 fr/s @10 MHz master clock
- Reducing the number of read out frames will increase the possible frame rate.

ROW SELECTION SAMPLES

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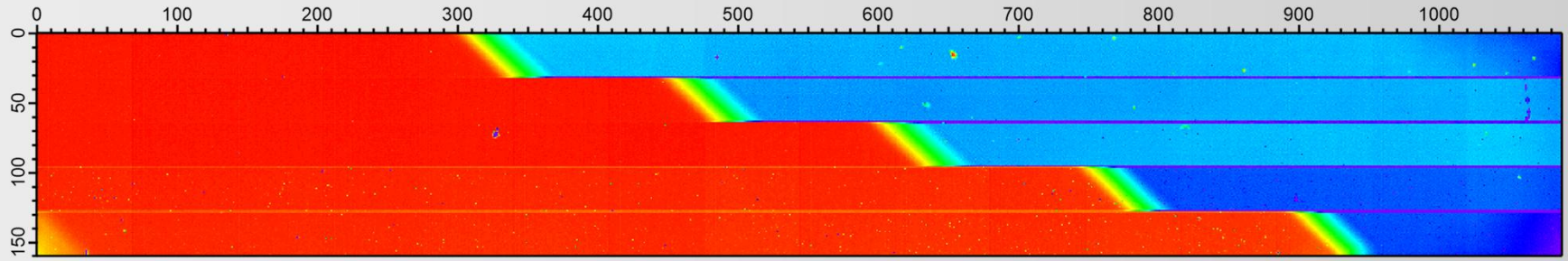
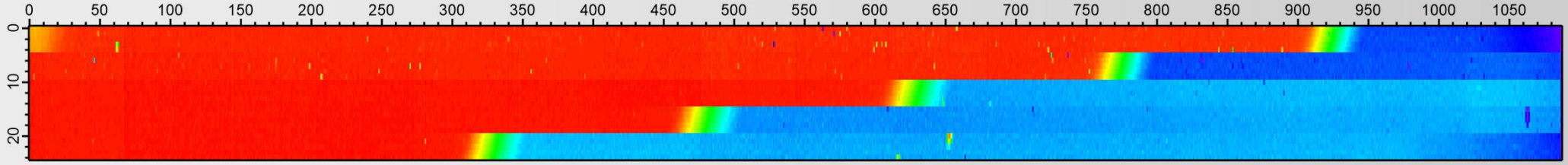
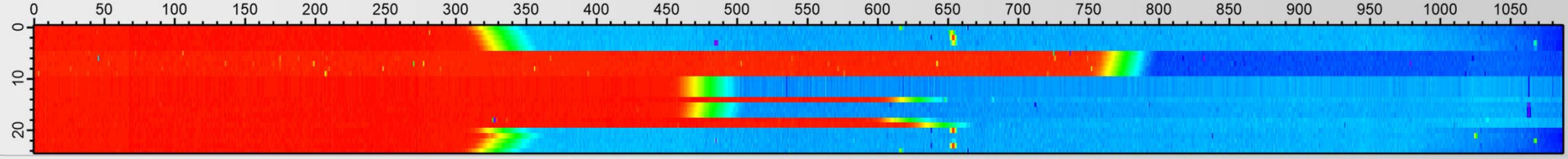
- Sample picture „slanted edge“ in full frame mode



- Row selection by lookup table gives unrestricted capabilities:
  - e.g. 5x5 rows in reverse order



  - e.g. mixing and repeating any rows



SPECIAL FEATURE: 100% OPERABILITY

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- The operability is a well known challenge especially for PV chips designed for long wavelength cut-off.
- From statistical point of view always a few pixel in each row will have some deviations, which makes them not usable for measurement.
- This becomes more critical in case these pixels will be used for TDI-Summation
- To achieve a 100% operability for the TDI pixel the presented row selection mechanism is used to select additional TDI rows.
- These additional rows are used to select the proper combination of pixels and discard defective pixels.
- Example: 3 pixel required for TDI summation

SPECIAL FEATURE: 100% OPERABILITY

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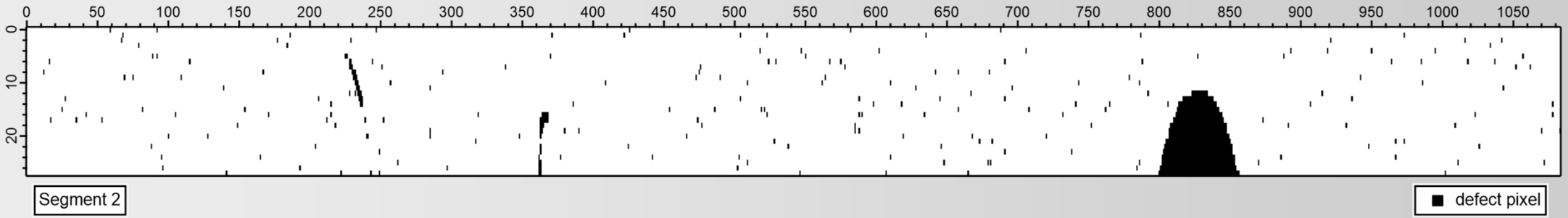
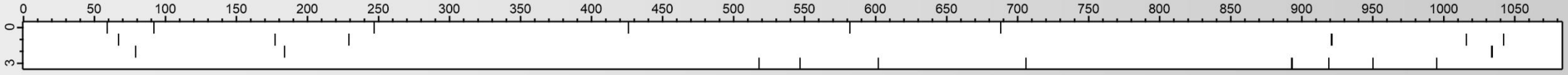
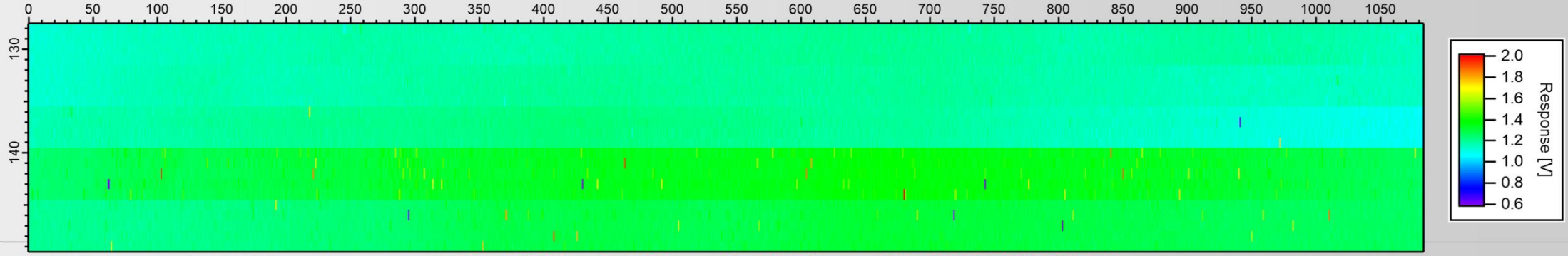
- Defect pixel map of segment 2



- After row selection: one additional row to be read out to get 100% operability for 3 TDI pixels



- Depending on the PV quality one or two additional rows need to be read out to achieve 100% operability for each segment



MULTILAYER CERAMICS DESIGN

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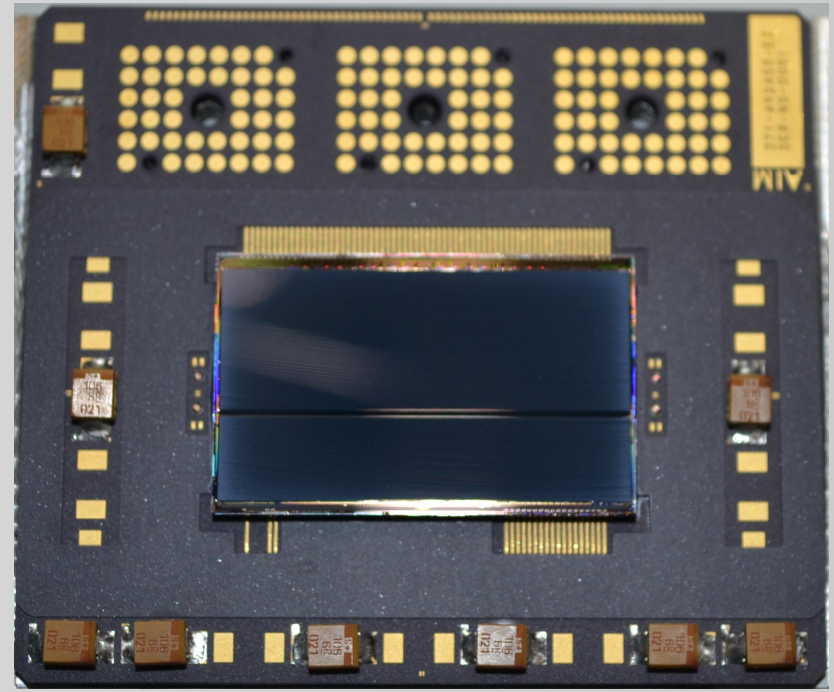
- In order to handle the electronic parts properly a dedicated multi-layer ceramics was designed.
- This ceramics is used to
  - Spread the supply lines with low ohmic resistance
  - Link the Hybrid pads to the z-axis pads
  - Link the hybrid pads to the IDCA
  - Provide optional blocking capacitors as near as possible to the Hybrid in order to reduce distortions on the supply lines
- Assembly is tested down to 50K operating temperature
- Operating temperature in LSTM instrument is 65K



DETECTOR IN IDCA

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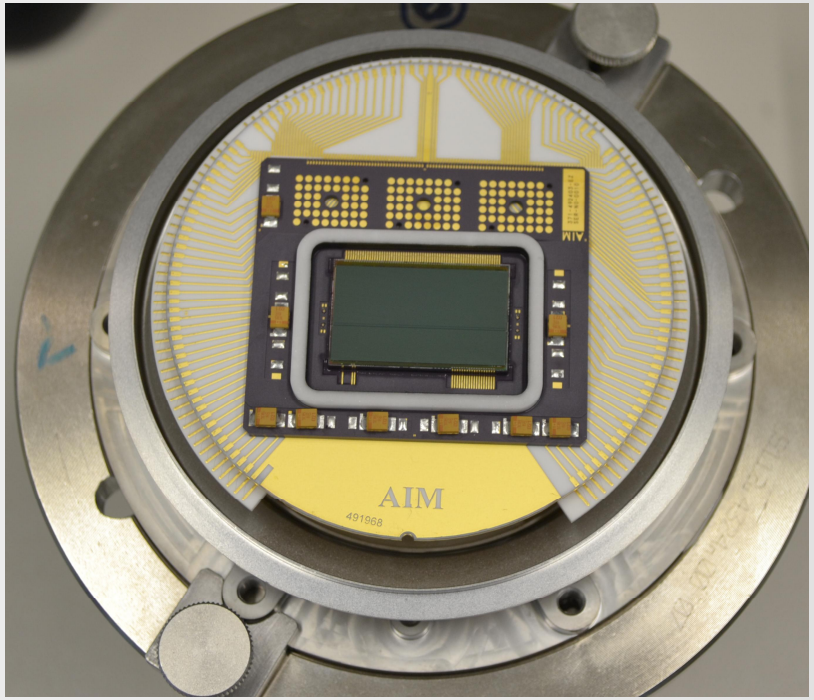
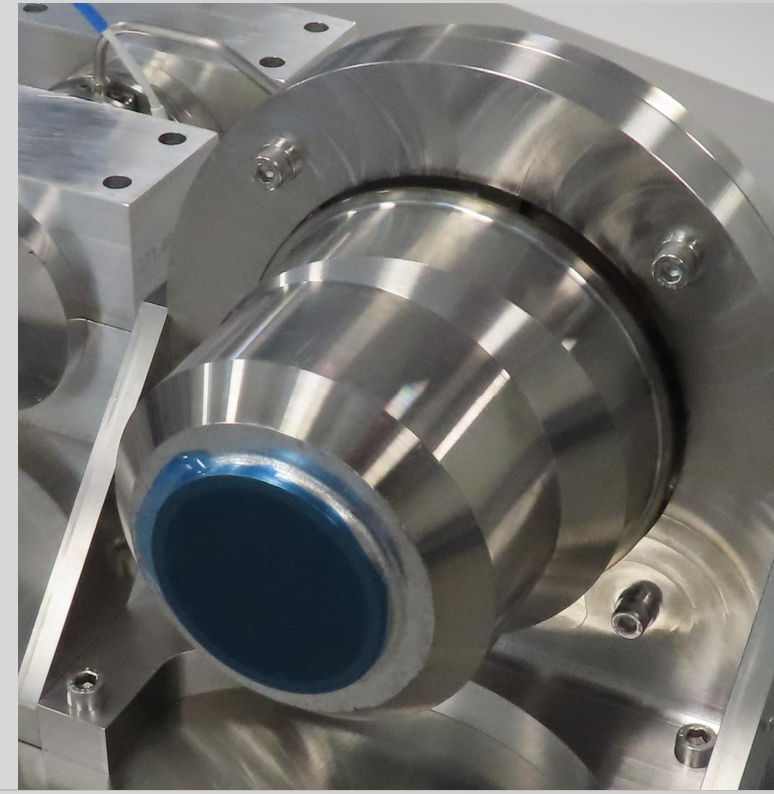
- In this configuration the detector can be used in IDCA configuration too. The multilayer ceramics can be mounted in a large scale AIM IDCA.
- Customer can use a pulse tube cold finger with SF400 compressor, a combination, which is already active in a current space mission.

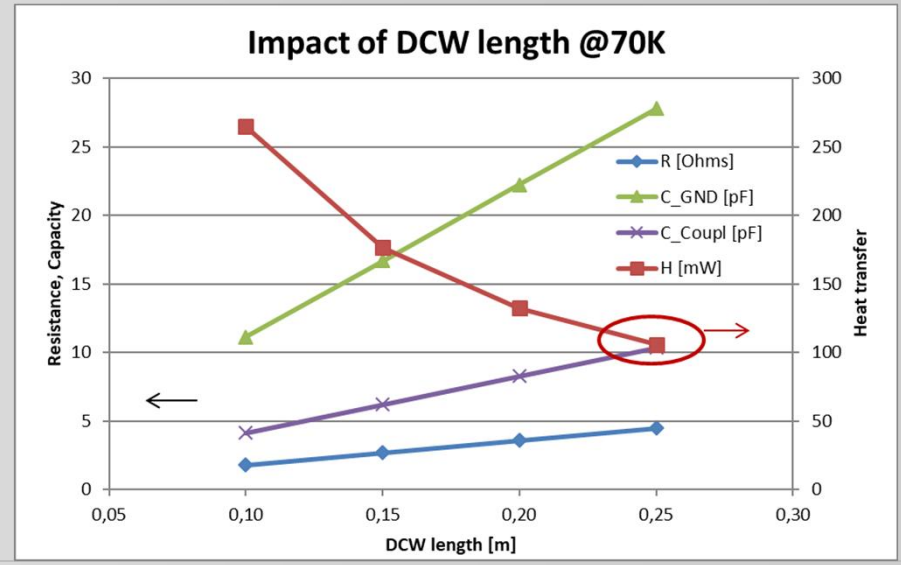




CRYOGENIC FLEX CABLE

AIM

- For operation in open detector configuration the electrical interface between detector cold end and electronics warm end needs to be linked with a cryogenic flex cable.
- The technology was taken from a former mission, the design was made specially for the usage of the multilayer ceramics and the z-axis connectors.
- The mechanical design of the flex cable has to be carefully adjusted, since it will impact several other parameters like thermal heat load, inductivity and capacitance, which will have an impact on signal integrity too.



OPEN DETECTOR APPROACH

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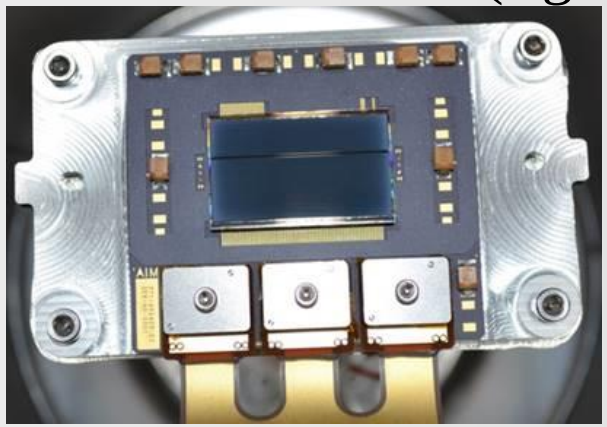
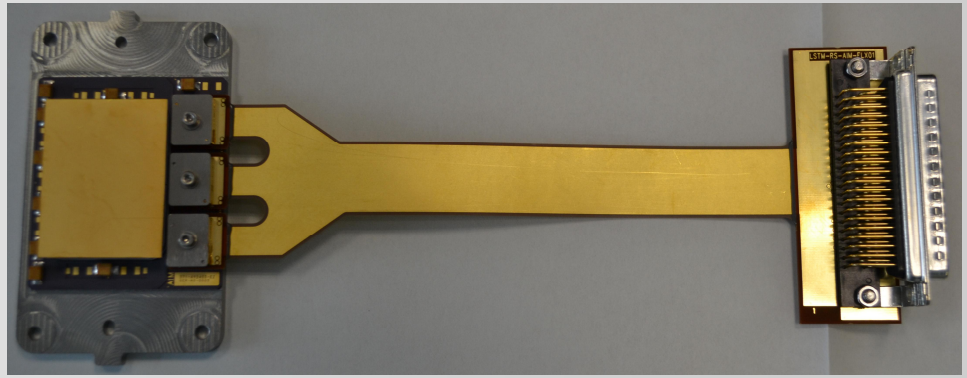
- Having all the key elements in place the reference design from the predevelopment was manufactured and tested (right: assembly for dark current test)





- For the LSTM instrument the open detector design is slightly modified, maintaining the main building blocks.

RADIATION HARDNESS

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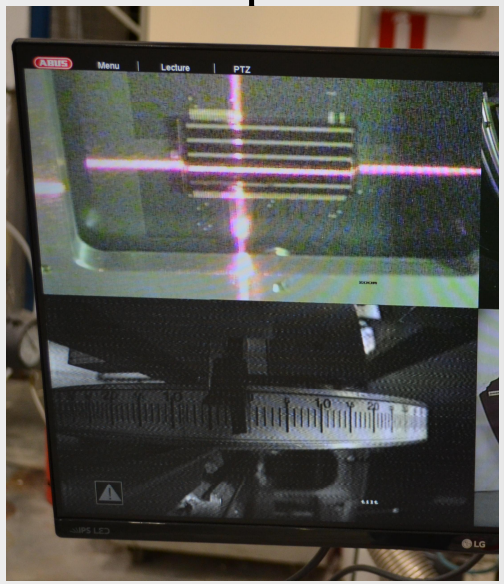
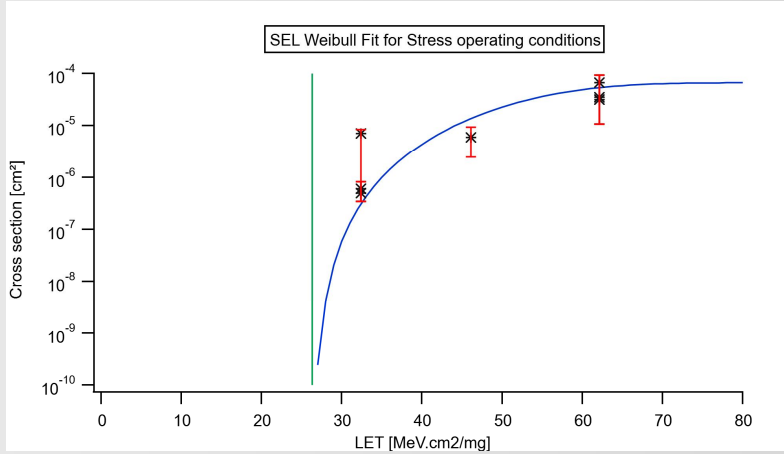
- Heavy ion test have been performed on the LSTM ROIC. The ROIC is hardened by design, however, one supply line was found sensitive to radiation induced latch up (non-destructive).
- Test setup

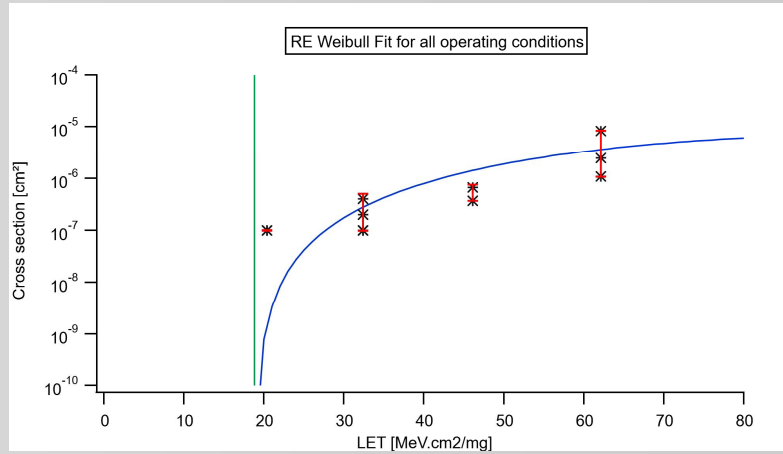


SEL statistics

» (Stress condition)



Register Event Statistics



- **With the given statistics the expectation on the LSTM instrument is none or one heavy ion event during the mission.**

Conclusion

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- Within the predevelopment activity for the LSTM mission a detector design was created, which is not only matching the needs of the LSTM instrument but which offers several options and a high flexibility for many other approaches.
- It can be used for a wide range of spectral channels by adjusting the PV design to the customers need
- The detector is used in the LSTM instrument design, having a customized set of two different PV chips and tailored interfaces.

- Acknowledgments:
  - This work was supported by ESA contract 4000125484/18/NL7LF
  - Many thanks to Airbus Defense and Space to release the content of the Instrument details
  - Many thank to all participants and contributors to this presentation