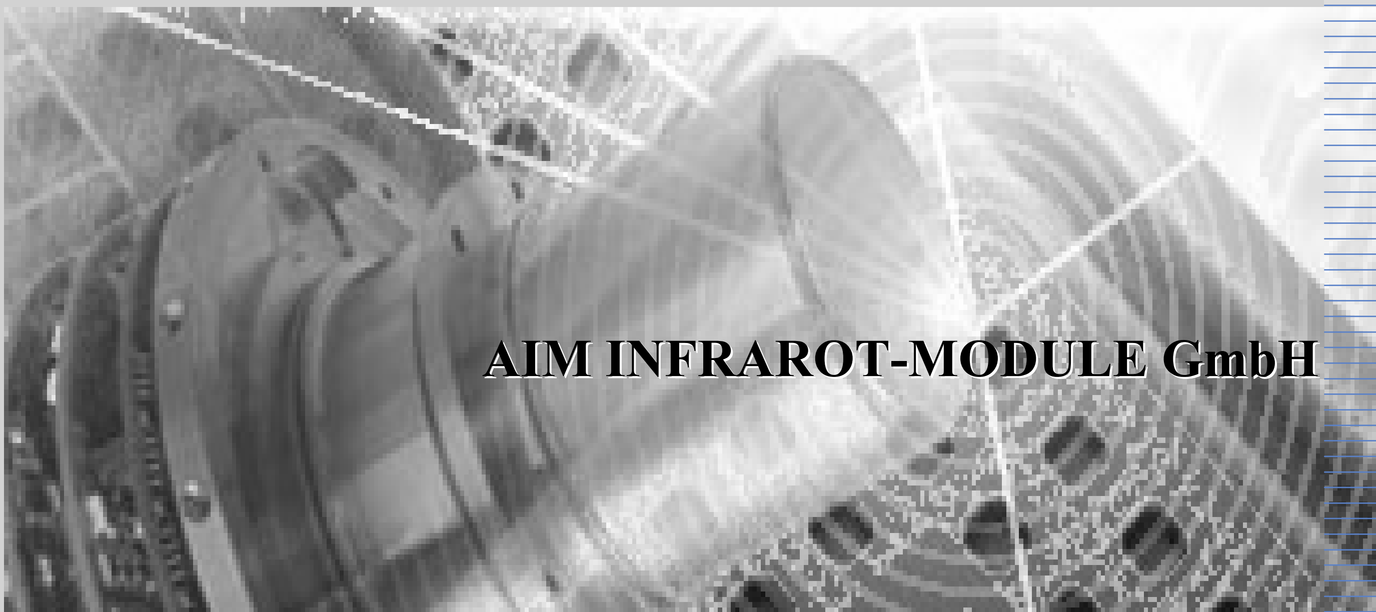
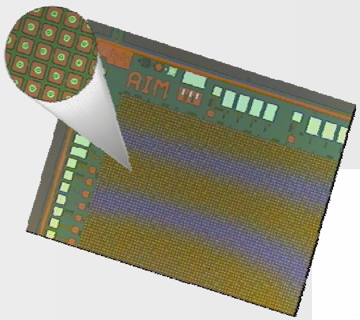
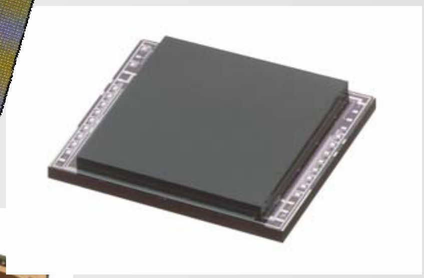
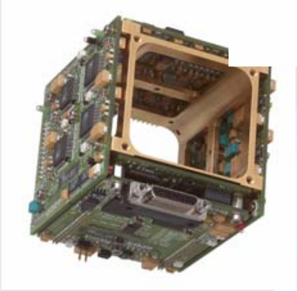
AIM INFRARED DETECTOR MODULES

GENERIC SWIR-SENSOR GENSIS



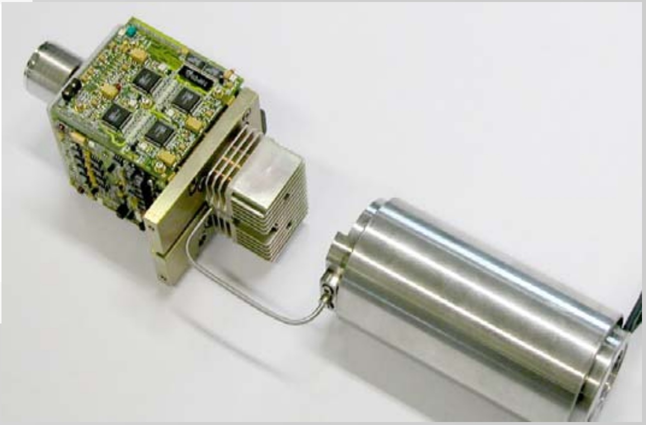






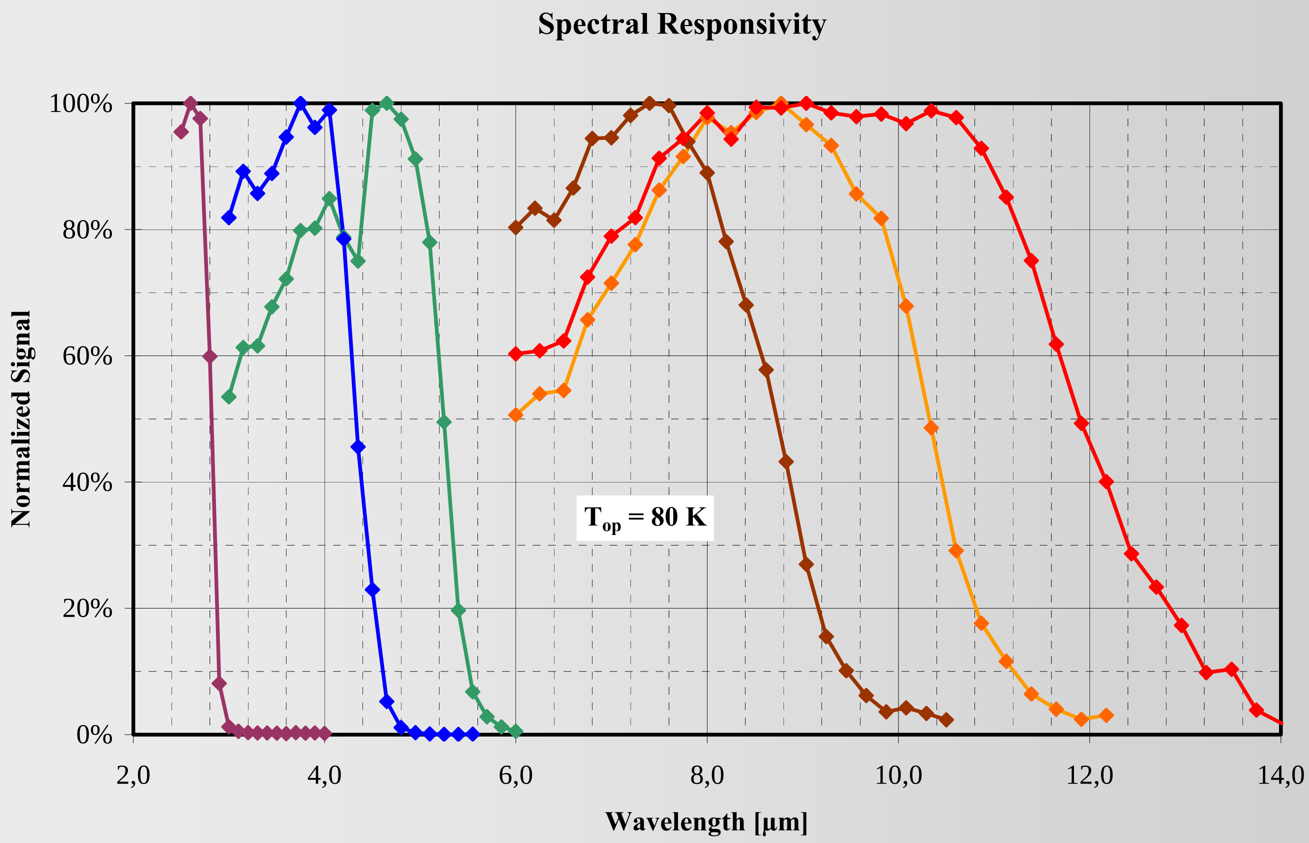
COMPONENTS

- Infrared Detector Arrays
- Readout Integrated Circuits, ROIC
- Focal Plane Arrays, FPA
- Dewar
- Frontend Electronics, FEE
- Cryogenic Stirling Cooler



MCT-IR-DETECTORS: λ CUT-OFF

AIM



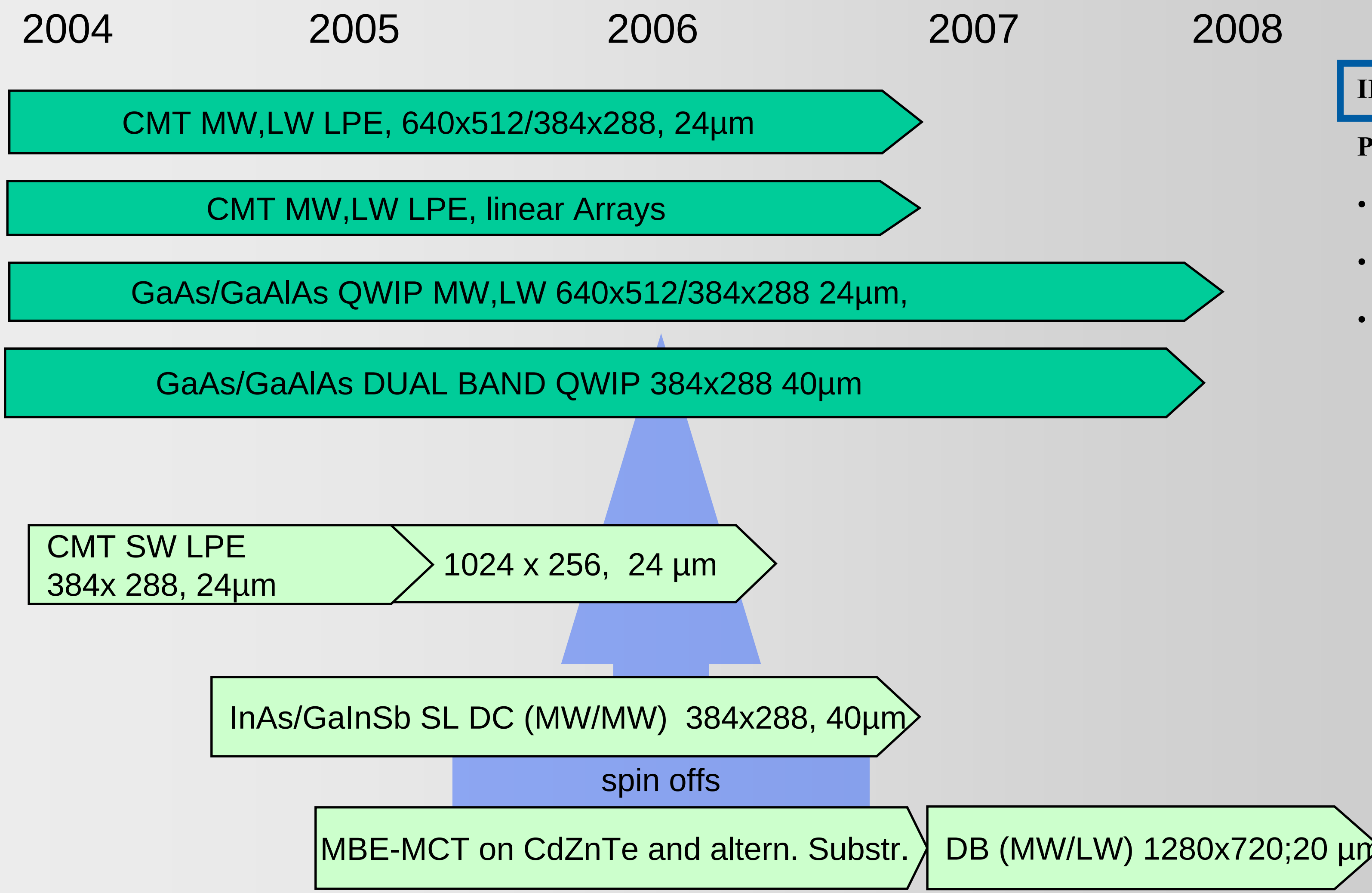
INTRODUCTION

PROGRAMMES

- German
- ESA
- AIM

TOWARDS 3rd GENERATION

AIM



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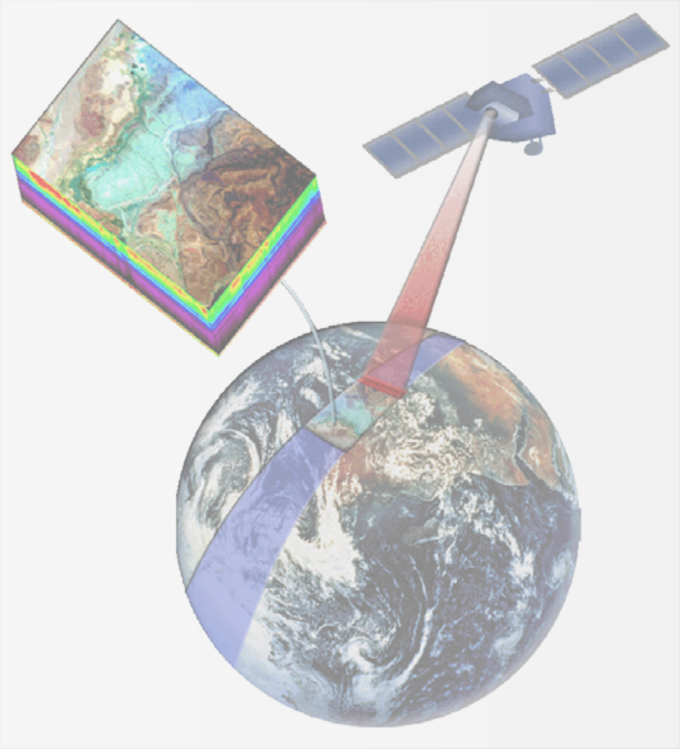
EnMap: ENVIRONMENTAL MONITORING and ANALYSIS PROGRAM



German Program:

- Application in Future Instruments for National and International Space Programmes
- AIM:
  Proof of Competence in the Area of Infrared Sensorics

Applications

- Earth Observations
- Meteorology
- Atmosphere and Climate Research
- spin-offs also in Terrestrial Applications

SWIR 1024 x 256 INFRARED DETECTOR MODULE

AIM

Infrared Requirement List		GENSIS
1.	Optical Inteface	Hyperspectral Imaging
1.1	Photon flux [photons•s^{-1}•cm^{-2}]	
1.2	Spectral wavelength range [µm]	0.95µm ≤ λ ≤ 2.45 µm
1.3	Arrays Configuration	1024x256
2.	Detector Material	MCT
2.1	Quantum efficiency η [%], Fill factor	> 60 %, ≥ 65%
2.2	Sensitive pixel area [µm x µm]	20 µm x 28 µm
2.5	Pitch [µm] [V x H]	24 µm x 32 µm
3.	CMOS - ROIC, number of outputs	8
3.1	Operating modes, readout modes: • Stare then read • Stare while scan readout • External frame start • Subframe readout capability • Individual gain adjustment for each line	✎ ✎ ✎ selectable lines user configurable 2-stages
3.4	Programmable integration times	1 ms ≤ Δt <≈ 4 ms
3.5	Detector-MUX-Interface	CTIA
3.6	Full charge well capacity/element [pC] Max. handling charge [e^-]	2 C's: Q1 = 6•10^5 e^- Q2 = 1.6 •10^6 e^-

SWIR 1024 x 256 INFRARED DETECTOR MODULE

AIM

	Infrared Requirement List	GENSIS
3.7	Maximum signal voltage range	2.0 V
3.8	Frame rate [Hz]	≤ 250 Hz
3.10	Dynamic range	> 76 dB
3.13	AD-conversion [bit]	14 bit
4.	Frontend Electronics, Elect. Interface	
4.4	Number of digital outputs	2
5.1	Responsivity [V/W]	≈ 3µV/e
5.2	NEP [W]	$6.8 \cdot 10^{-14}$ @ T_{op} (Det.) = 120 K
6.	Stirling Cryogenic Cooler	Pulse tube cooler, long life flexure bearing compressor
6.1	T_{op} (IR-Detector)	< 160 K (TBC)

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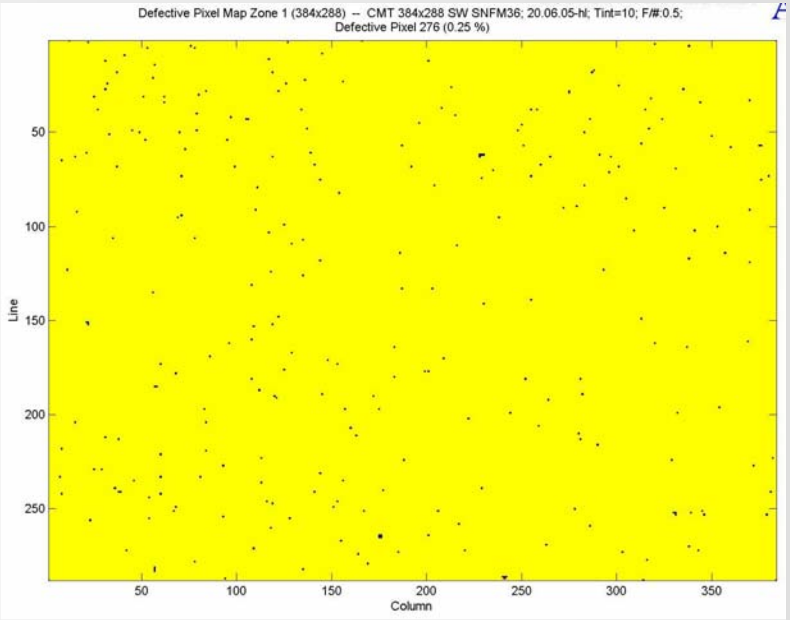
384 x 288 SWIR MCT-DETECTOR MODULE

AIM



Array: HgCdTe [1)]

Pixel: 384 x 288

Pitch: 24 x 24 µm^2

Cuton Wavelength: 0.85 µm

Cutoff Wavelength: 2.7 µm

Peltier Cooler:

Typical operating temperature 200 - 215 K

Tint = 10 ms

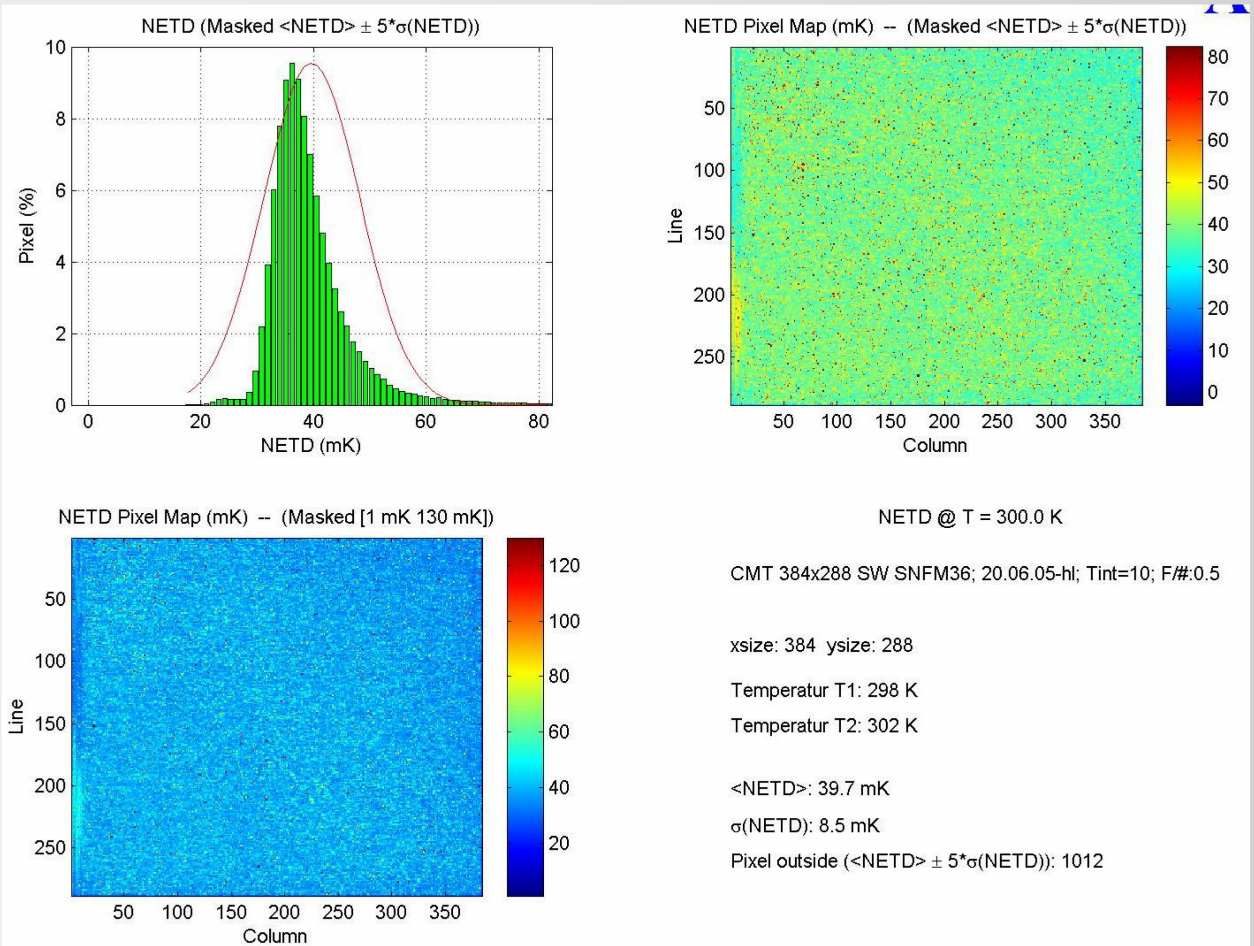
Detectivity (Band 0.85µm - 2.7 µm): > 3 x 10^{11} cmHz$^{1/2}$W^{-1}

Defective Pixels: 0.25%

[1)] Remark: SWIR-FPA still with Direct Injection!

■ RESULTS: 384 x 288 SWIR DETECTOR MODULE

AIM



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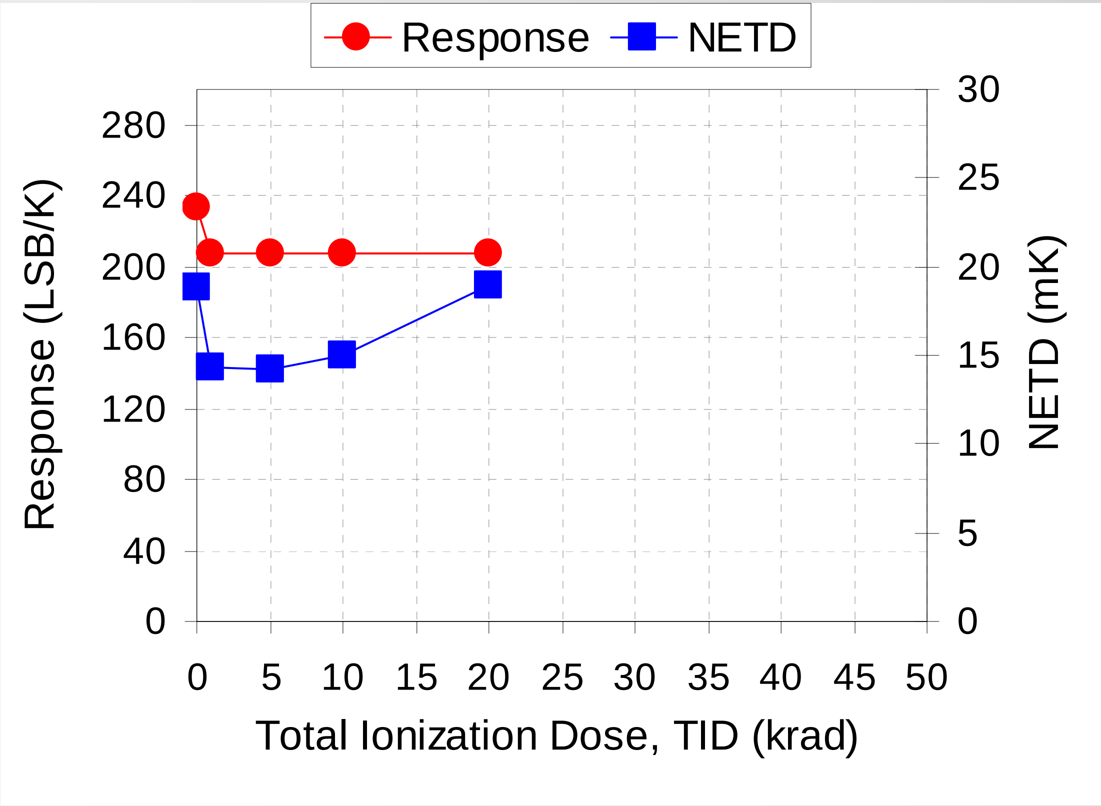
Tint = 10 ms

NETD < 40mK

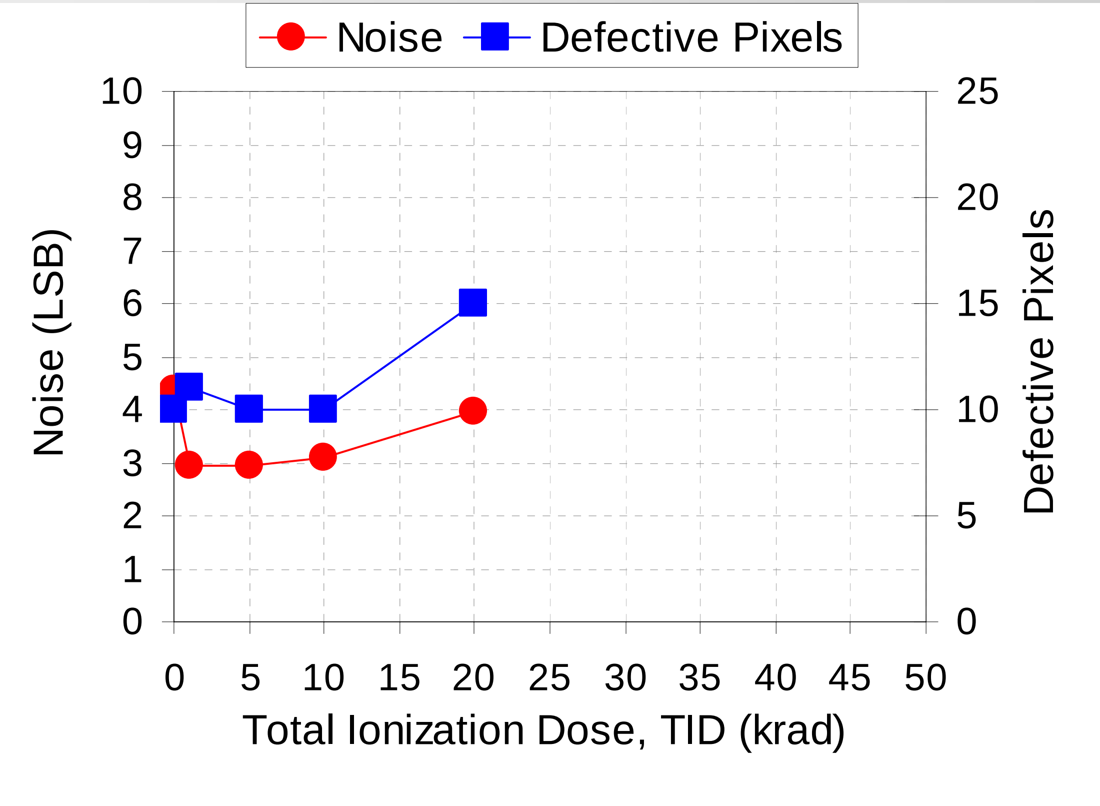
γ-TDI IRRADIATION TESTS



384x288 MWIR-MCT-Reference Detector: Tests carried out at ESTEC

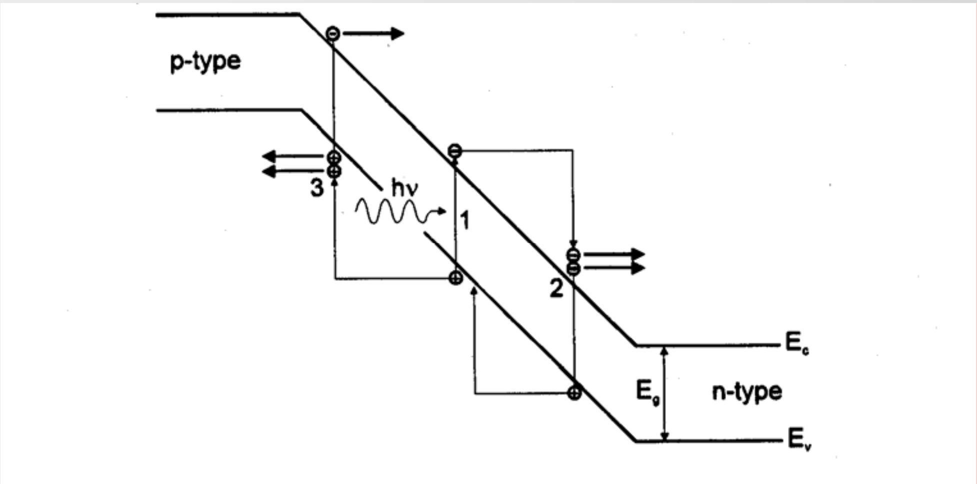
γ-TDI IRRADIATION TESTS

AIM



384x288 MWIR-MCT-Reference Detector: Tests carried out at ESTEC

■ AVALANCHE PHOTODIODES



Ionisation Coefficients

holes: α_h

Electrons: α_e

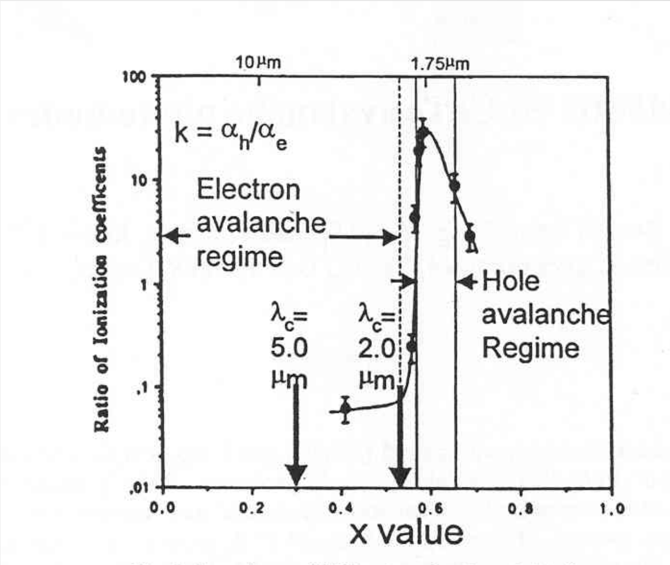
$$k = \frac{\alpha_h}{\alpha_e}$$

$k \approx 1$: same contribution e^- und h^+, avalanche Process will not stop

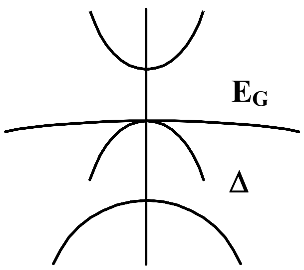
$k \ll 1$: Only e^- will contribute, avalanche Process is ceased

■ MCT AVALACHE PHOTODIODES

AIM



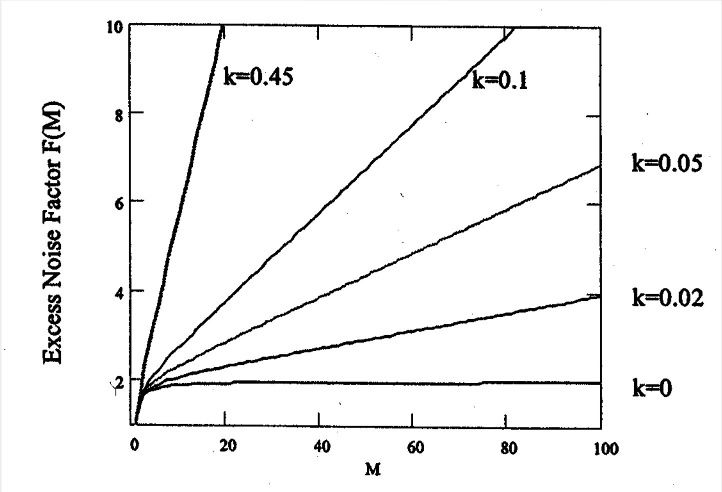
Bandstructure of $Hg_{1-x}Cd_xTe$ (MCT)



λ_{CO} > 2 µm :	k<<1 well suited for low-noise APDs in Proportional Range
x ≈ 0,6 :	Resonance of E_G and Δ; k > 1 suited for APDs in Geiger modus?

■ MCT AVALACHE PHOTODIODES

AIM



Noise current density: $$I_N^2 = 2eI_{Ph}M^2F$$

Additional noise figure: $$F = M\left[1-(1-k)\left[1-\frac{1}{M}\right]^2\right]$$

for k = 0 and high Gain M: $$F = 2-\frac{1}{M} \approx 2$$

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- German
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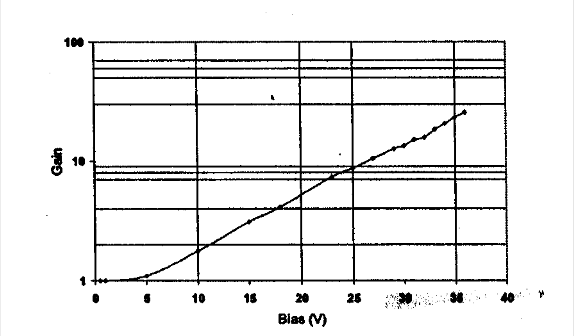
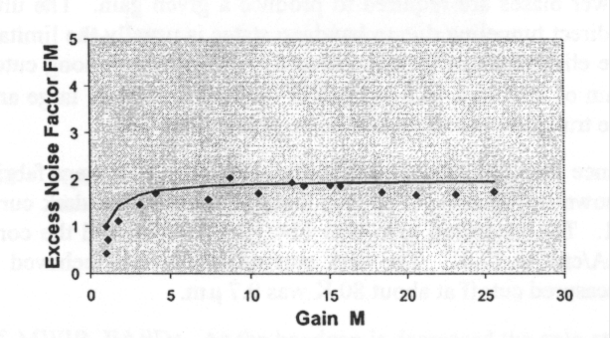
Measurement results for MCT-APDs with λ_{CO} = 2,2 µm at 297 K





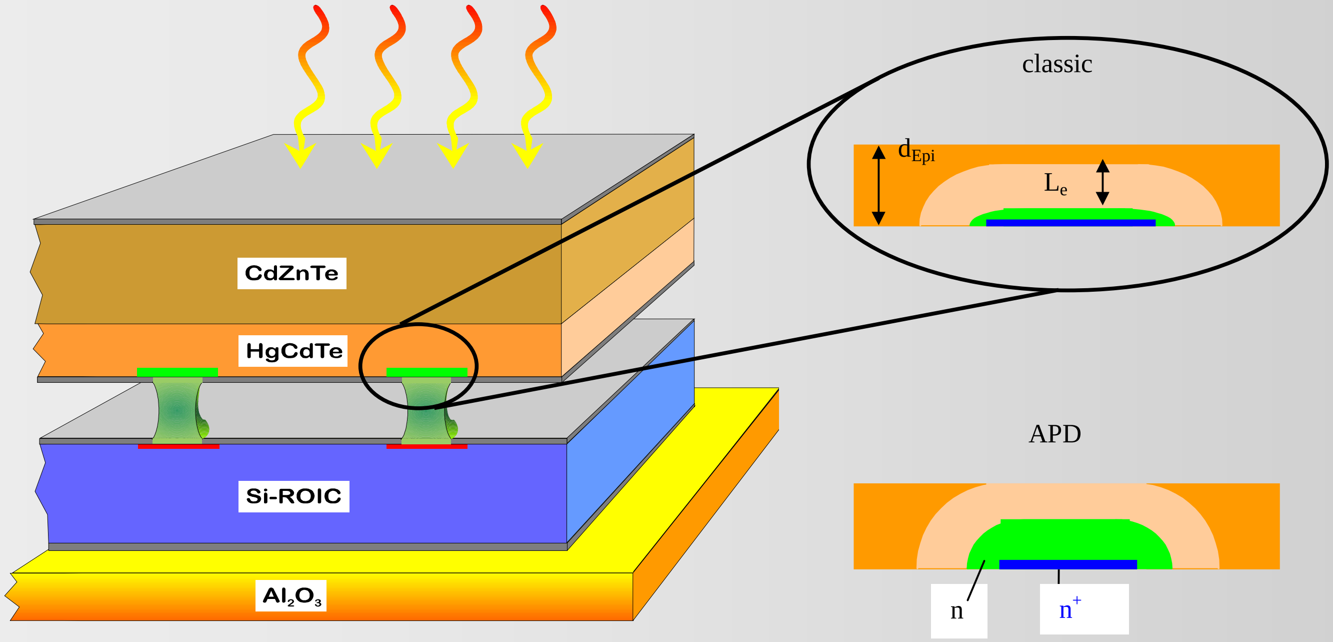
J.D. Beck et al., Proc. SPIE 4454, 188 (2001)

Gain for Bias between 0 and 40 V

Additional noise figure for Gain between 1 and 25

AIM FLIP-CHIP-TECHNOLOGY

AIM



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Classical Photodiode: n^+ - n - p

$n^+ \approx 0{,}5$ µm

n ≈ 0,5 - 1,0 µm

Le = 5 - 10 µm

$d_{Epi} \approx 8$ µm

Avalanche Photodiode: n^+ - n - p

$n^+ = 0{,}0 - 0{,}5$ µm

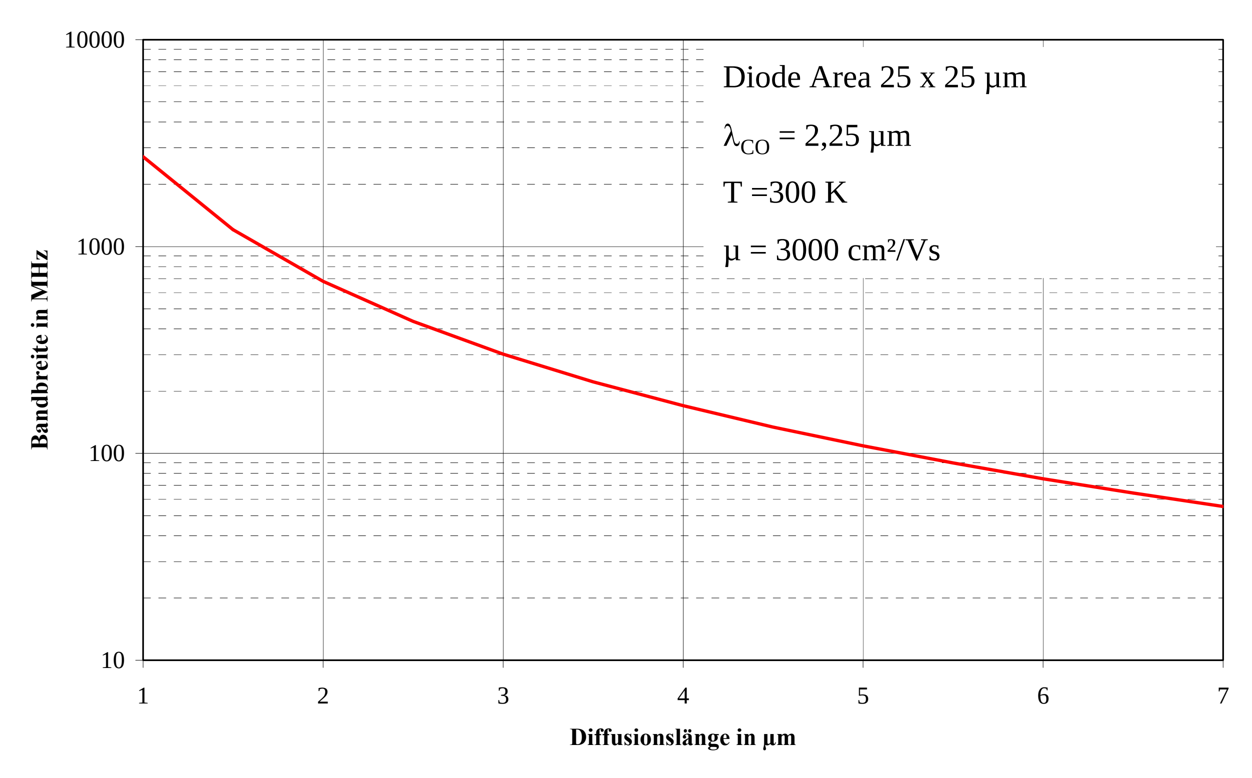
n ≈ 1,0 - 5,0 µm

Le = 5 - 10 µm

$d_{Epi} \approx 6 - 8$ µm

BANDWIDTH ESTIMATION

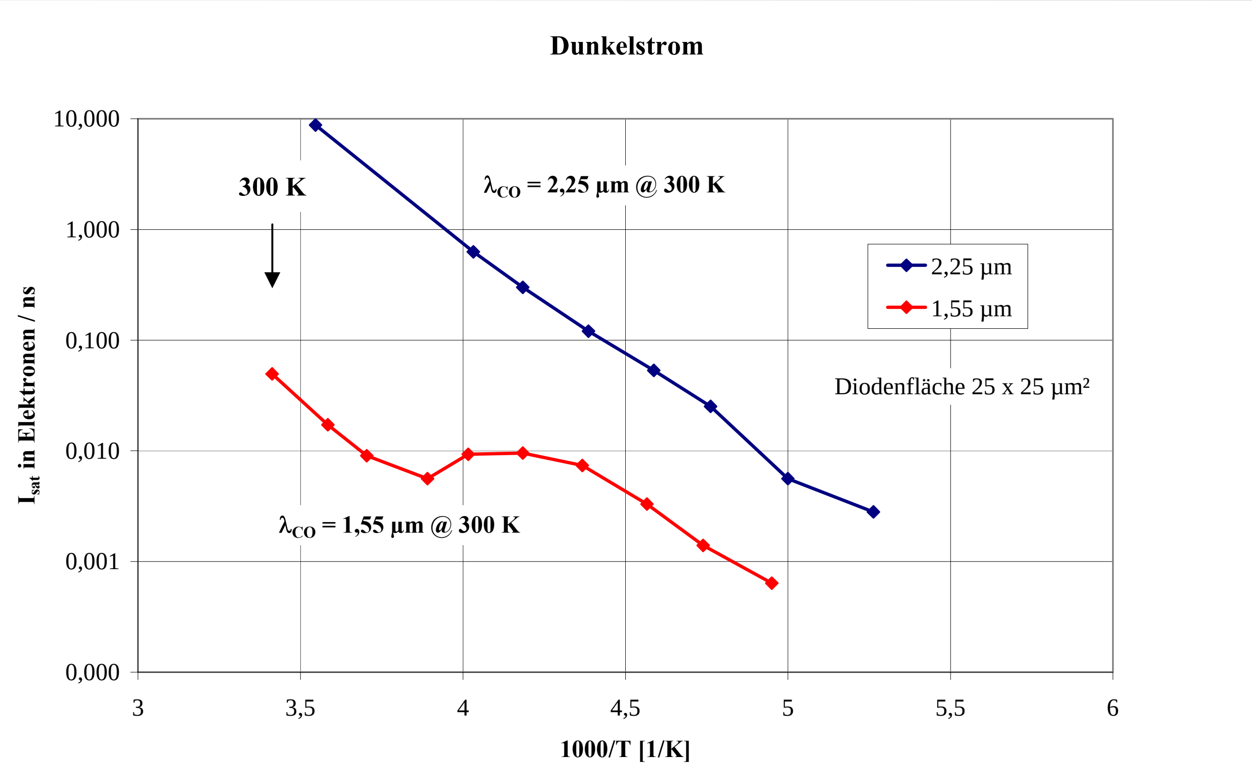
AIM



- Required Bandwidth 500 MHz critical
- Corrective Action:
  - deeper depletion region
  - Lower Operation Temperature

AIM EXPERIENCIES

AIM



Dark Current at RT

λ_{COi} = 1,55 µm : 0,05 e$^-$ / ns

λ_{COi} = 2,25 µm : 10 e$^-$ / ns

Expected Photon Number: 8 - 80 / ns

■ REQUIRED DEVELOPMENTS

AIM

- Technology Development for Extended Depletion Region
  (for Example Diffusion Instead of Implantation, Extrinsic Doping)
- Reduced Epitaxial Layer Thickness to Achieve Higher Bandwidths
- Characterisation of Manufactured Diodes wrt
  Gain, Noise, Responsivity, Noise Behaviour, and Homogeneity at various Operation Temperatures
- Analysis of the Feasibility of MCT-Diodes Operating in the Geiger Modus
- Generation of Effective Electrical Potential Equalization to Prevent "Debiasing" for Matrix-APDs
- Eventually Using Micro-Lenses for Matrix-Arrays
  Pitch ca. 200µm x 200µm
- Hybridization Technology for Arrays for Larger Array Dimensions
- Adaptation of the Dewar Technology, if Cooling Requiured