Research topics at Thales Research and Technology
Small pixels and 3rd generation applications

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TODAY CHALLENGES

- large FPA arrays, small pixel size
  - increased resolution
  - higher yield
- new (3rd generation) applications
  - true microscan
  - multi-spectral / broadband detection
  - polarimetry

$\Rightarrow$ pertinent physical / optical modelling

$\Rightarrow$ epitaxial growth mastering

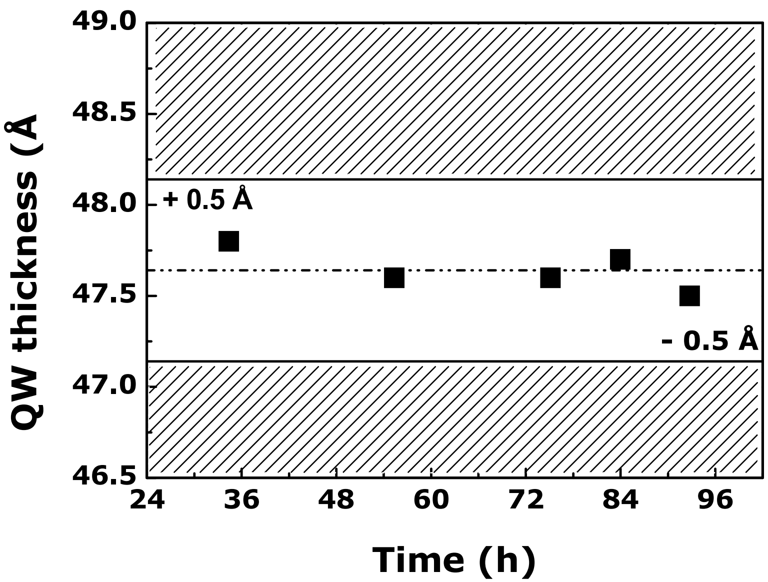
$\Rightarrow$ process mastering for small pixels

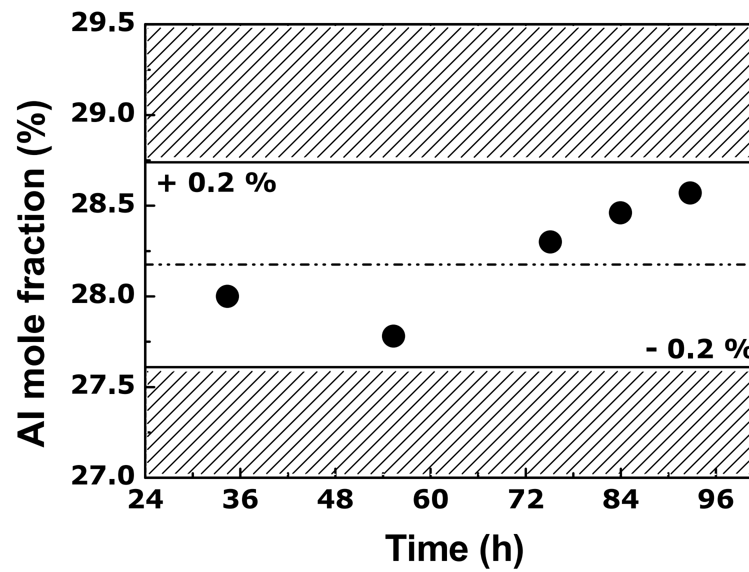
At Thales R&T research relies on production facilities

MBE FACILITIES AT TRT

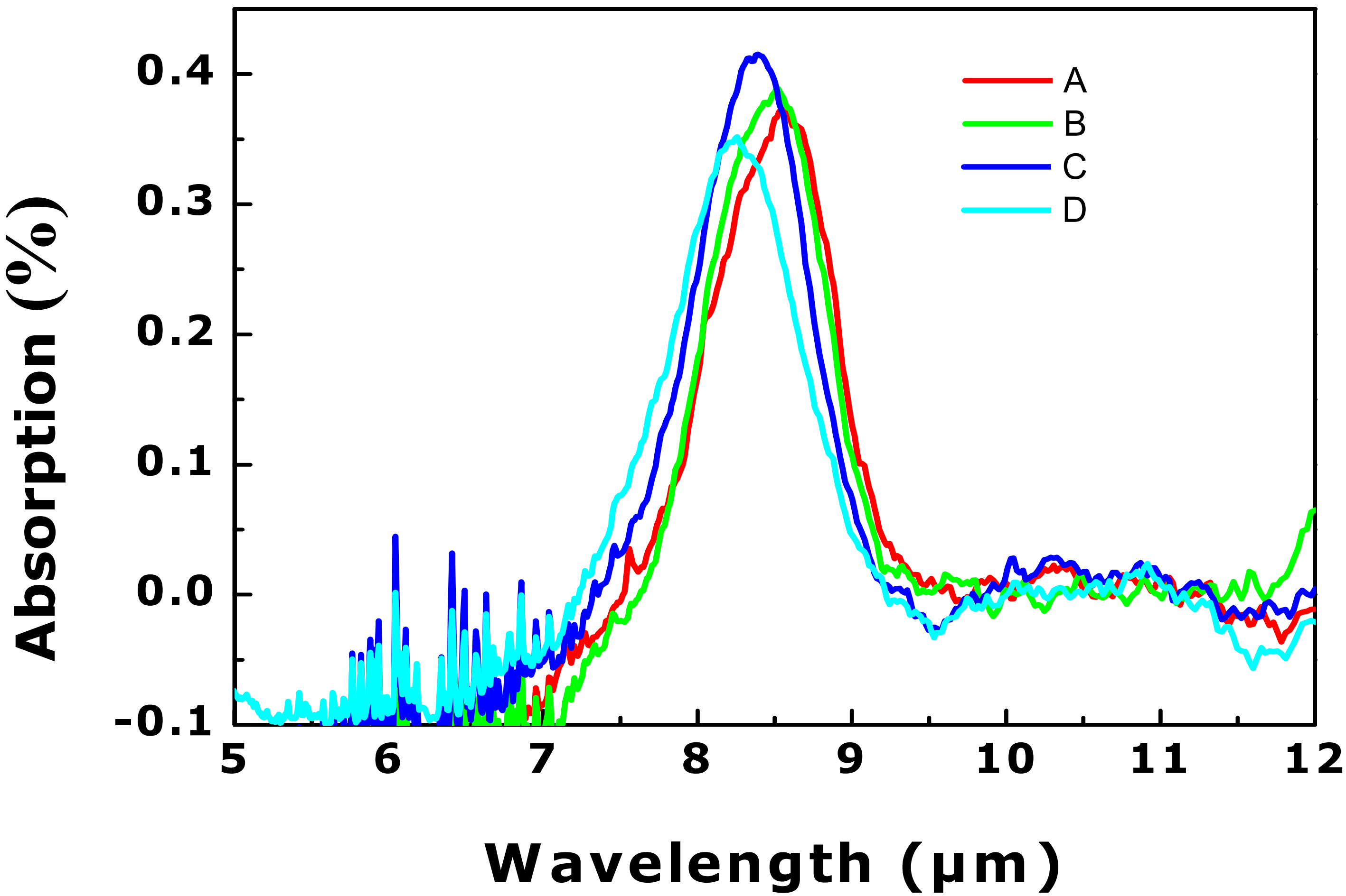
- RIBER 49 MBE growth system
  - multi-wafer: 5 x 3" / 3 x 4"
  - automated wafer charging
  - As / Sb based materials
  - GaAs, InP, GaSb, InSb substrates

- **high stability of growth rate**
- **reproducibility**
- **uniformity**

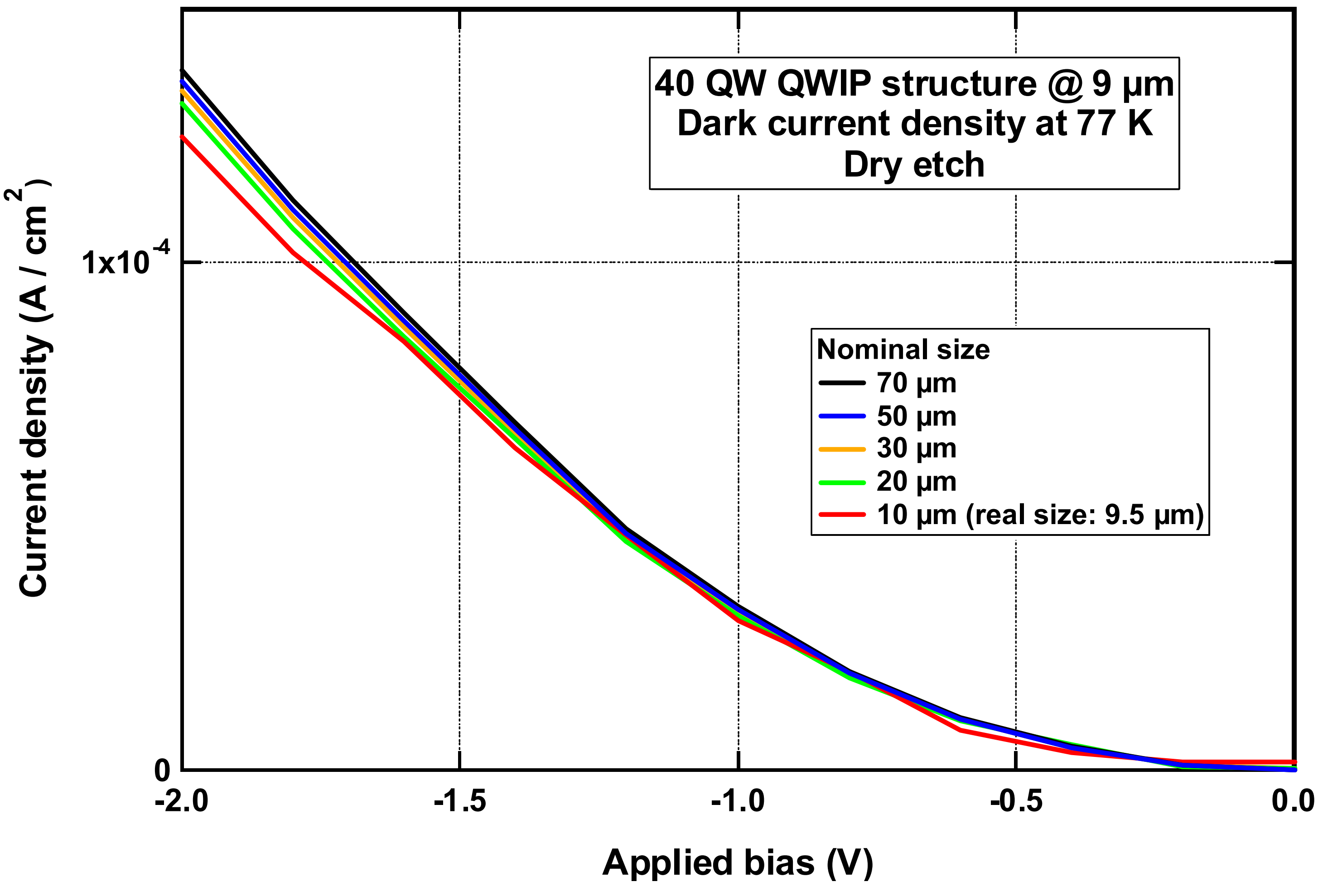




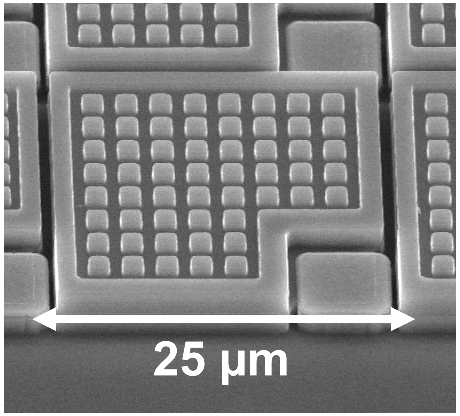
300 K absorption @ Brewser angle (1 pass)



Costard et al., SPIE 6206 – 13, 2006

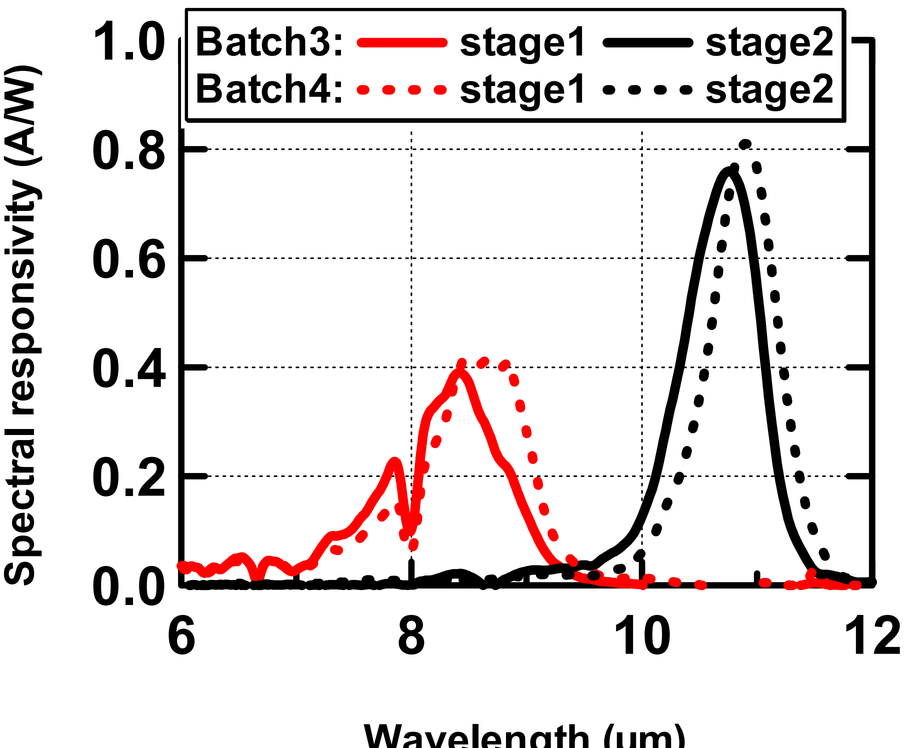

40 QW QWIP structure @ 9 µm
Dark current density at 77 K
Dry etch
Current density (A / cm²)
1x10⁻⁴
0
-2.0
-1.5
-1.0
-0.5
0.0
Applied bias (V)
Nominal size
70 µm
50 µm
30 µm
20 µm
10 µm (real size: 9.5 µm)

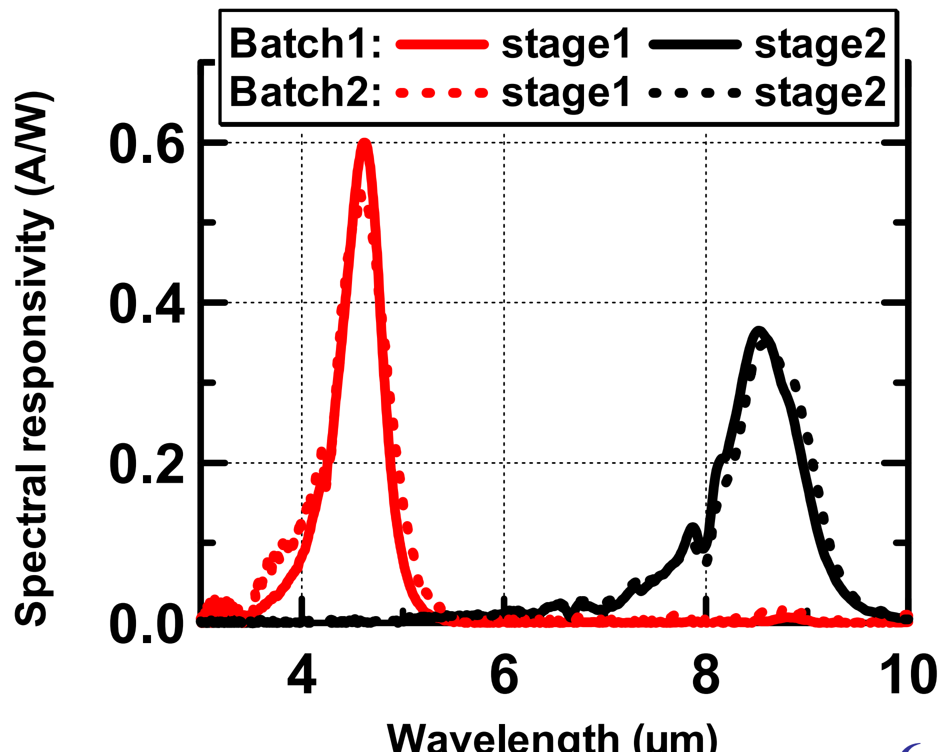
BI-SPECTRAL DETECTION



- 2-color, 25 µm pitch, 256^2 FPAs demonstrated
- 8.5 µm / 11 µm
- 4.5 µm / 8.5 µm

what about 4.0 µm / 4.5 µm ???





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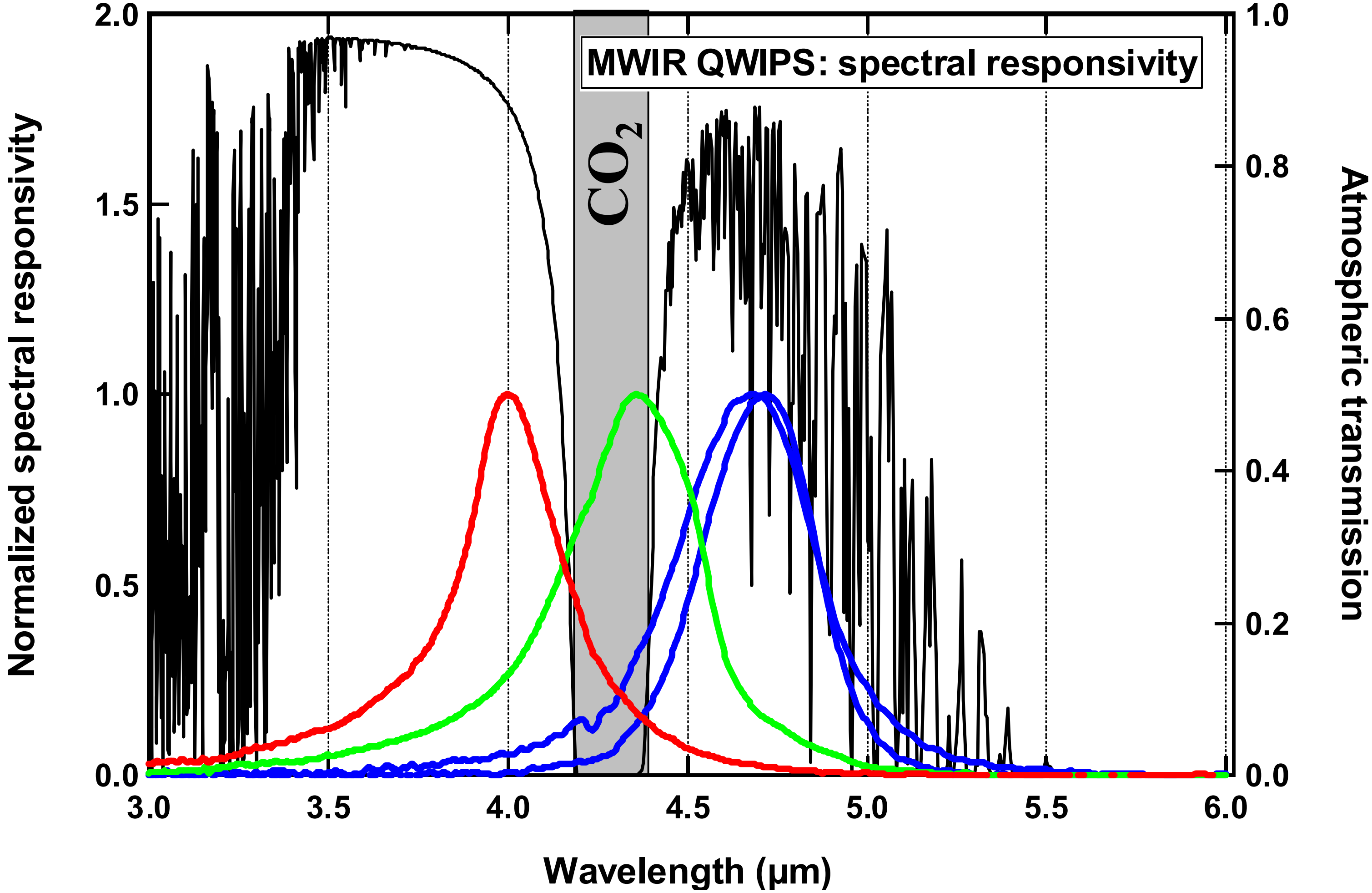

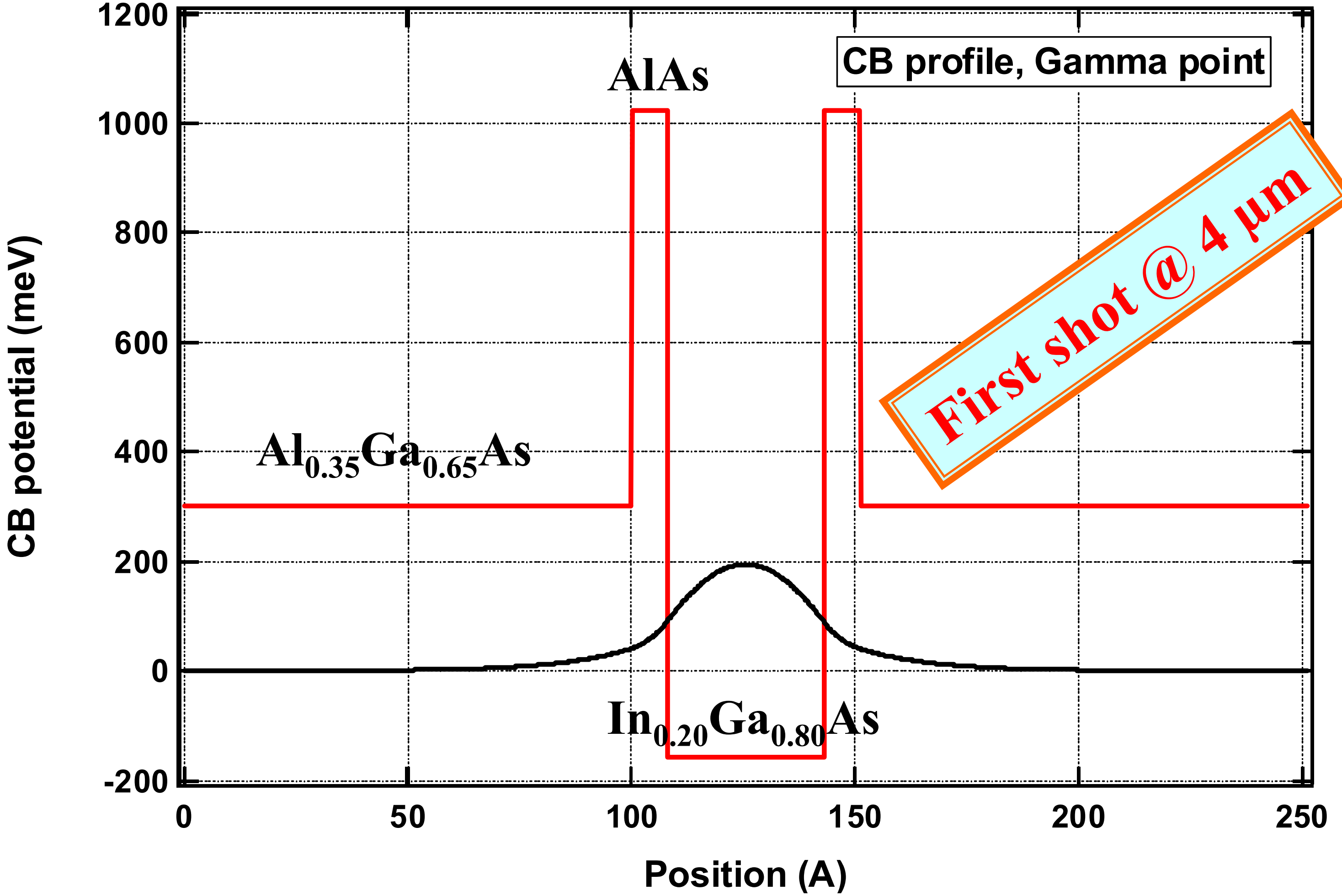

- AlAs layers to increase confinement
- elastic strain control: 20 % Indium, 5 QW
- applied bias compatible with existing read-out circuitry
- high doping ($1 \cdot 10^{12}$ cm^{-2})

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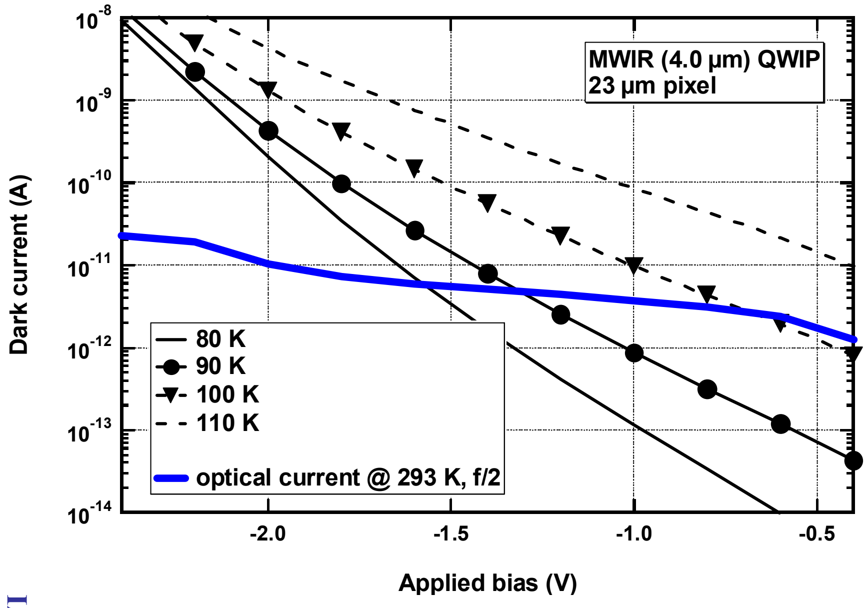

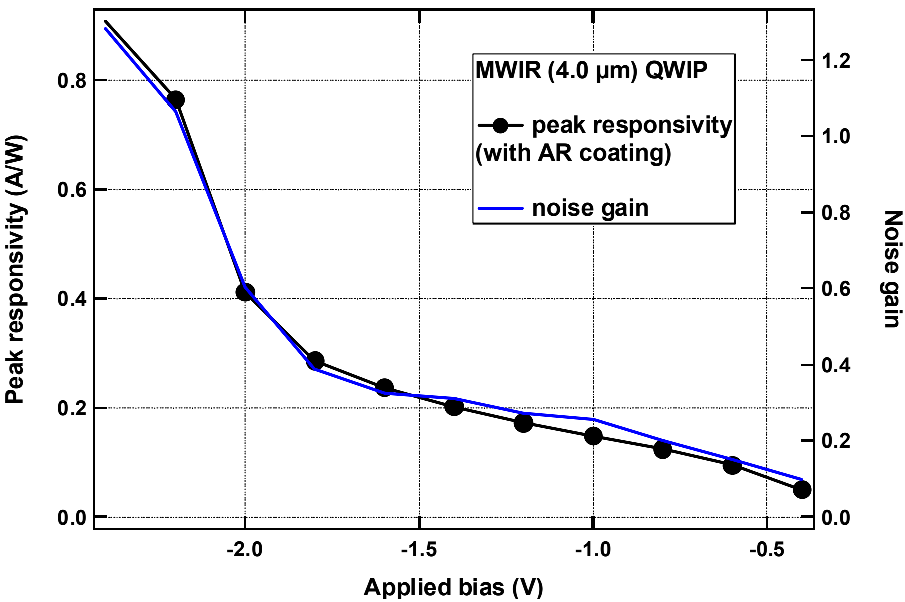

- reproducible IV characteristics
- activation energy at zero bias: 260 meV ≈ peak energy – Fermi energy
- optimum FPA performance at –1.2 Volts
- BLIP temperature at 293 K & f/2: 95 K

- research directions
  - increase peak reponsivity
  - decrease peak wavelength

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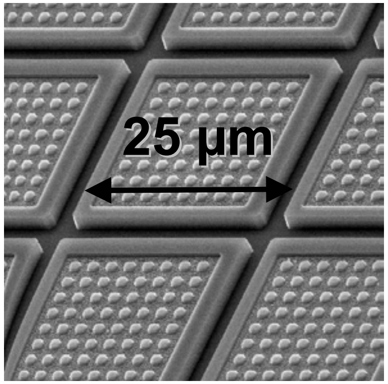
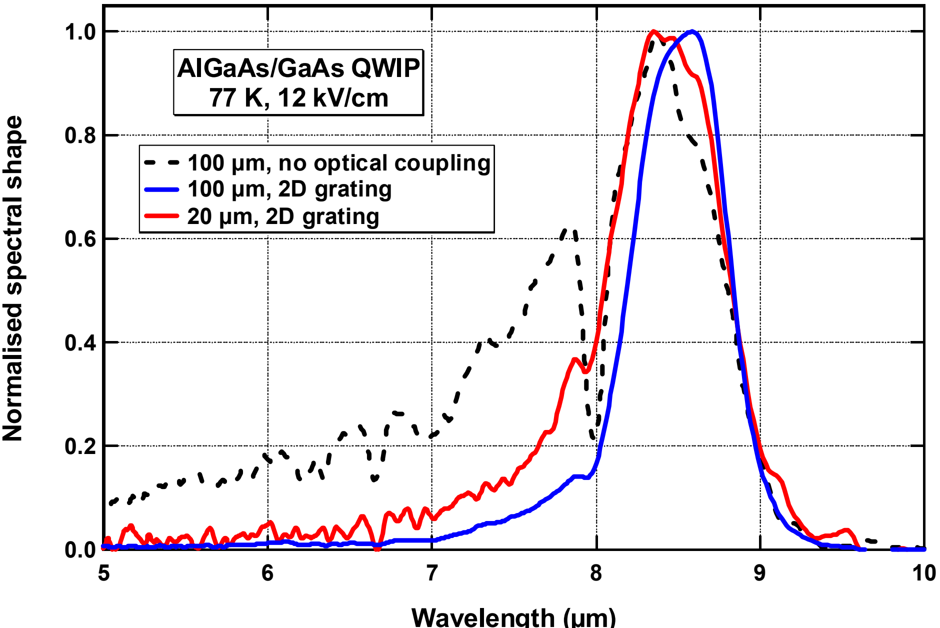
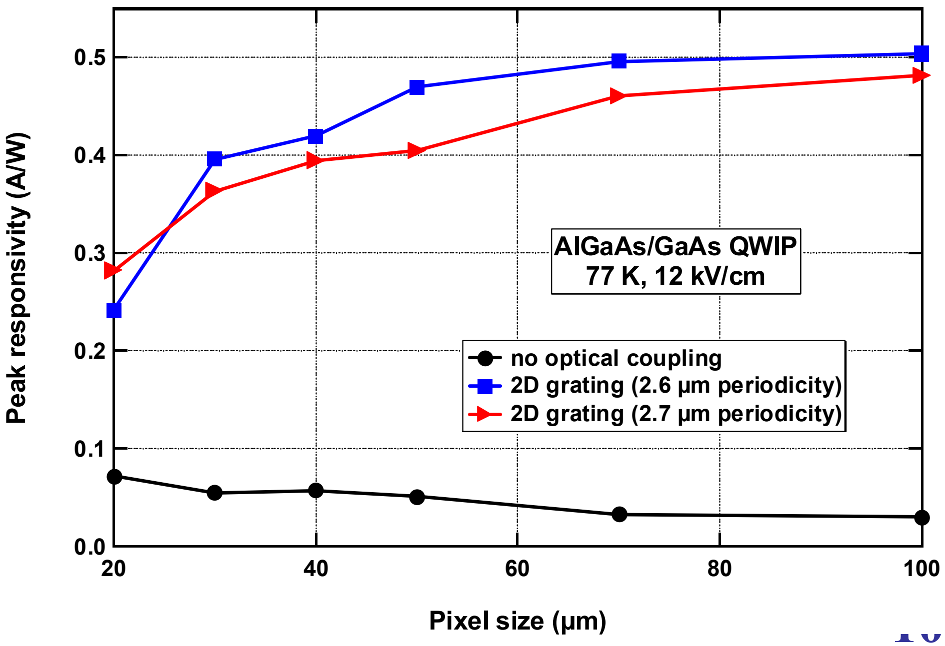
- pertinent parameter: pixel size / peak wavelength
- spectral shape = f(size)
- peak responsivity = f(size)

regular QWIP, 9 μm







- How to model the optical coupling ?
- How to improve the active layer ?

Global conclusions extracted from experimental data:

- optimum active layer for large pixels ≠ optimum active layer for small pixels
- optimum optical coupling for large pixels ≠ optimum optical coupling for small pixels

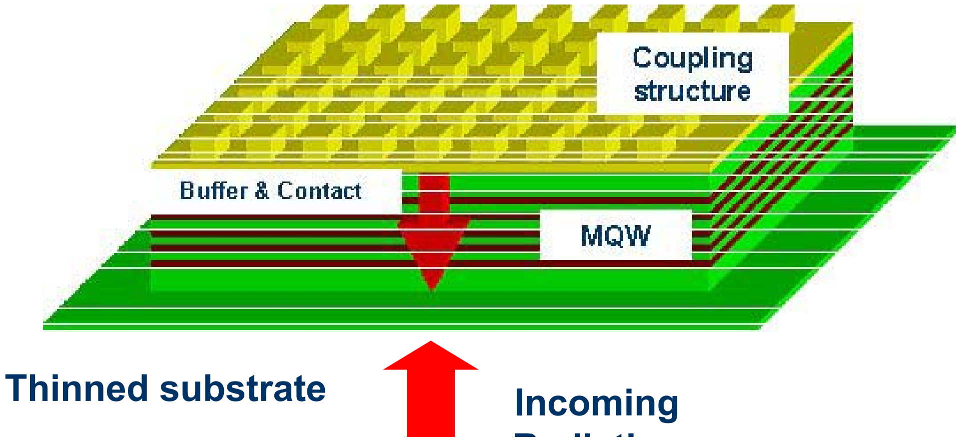
Optical coupling, pixel geometry and active layer cannot be dissociated

⇒ self-consistent treatment

OPTICAL COUPLING MODELLING

The "elementary" FPA pixel is:

- small compared to λ_{PEAK}
- complex
- 3D structure

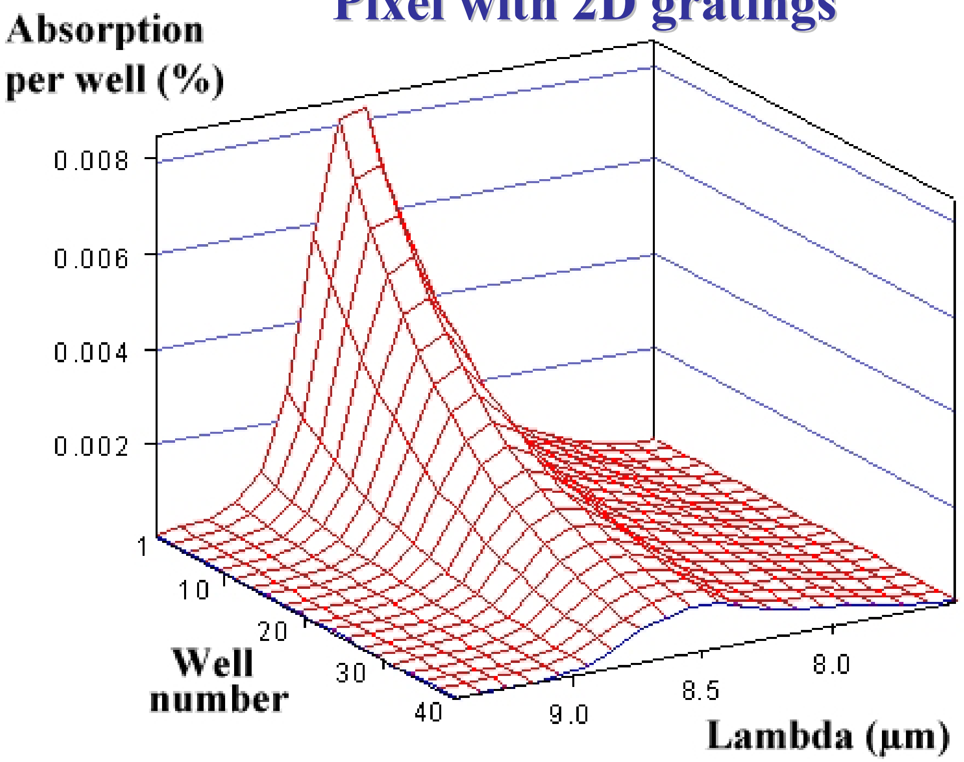


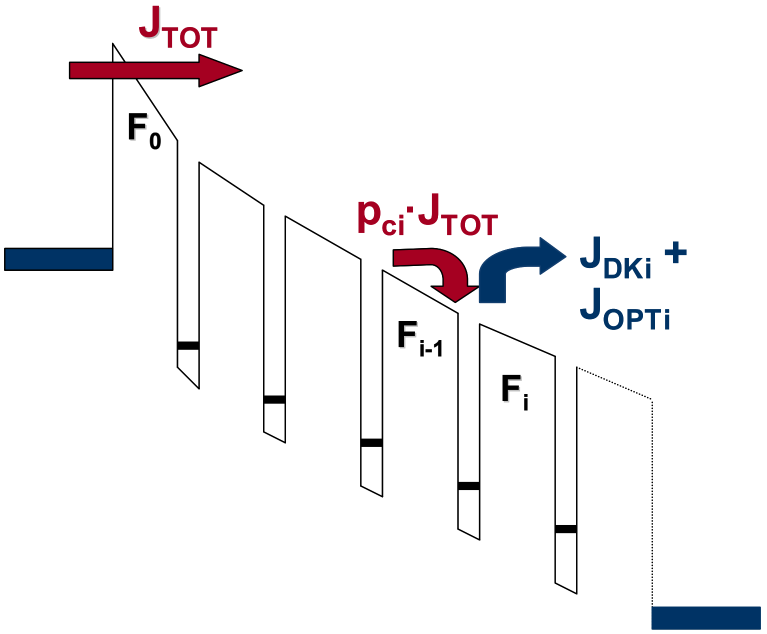
- Near-field optics
- Finite size effects ➔ 2D modelling is only qualitative

- Parameters (simultaneous optimisation):
  - Pixel width, height
  - Substrate thickness
  - Grating period, filling factor, depth and topology
- Full experimental way ? Expensive, time-consuming and no information on the near field, no physical insight

- Develop 3D rigorous EM modelling capability: Finite Difference Time Domain method
- Parallel computing

Pixel with 2D gratings



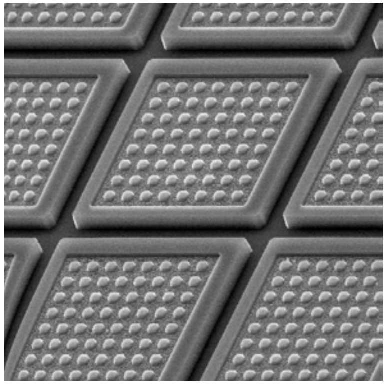


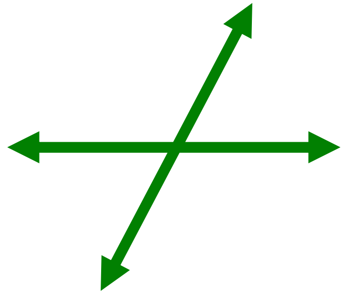
- QWs are not equivalent
- the closer to the gratings, the better

High temperature operation

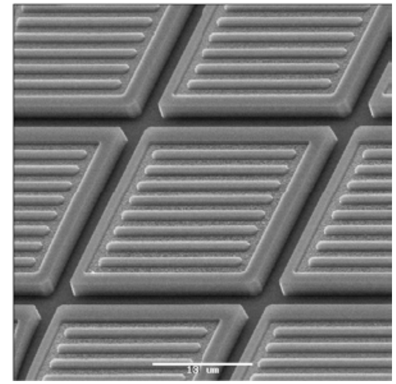
- number of quantum wells ??
- barrier width ??
- doping ??

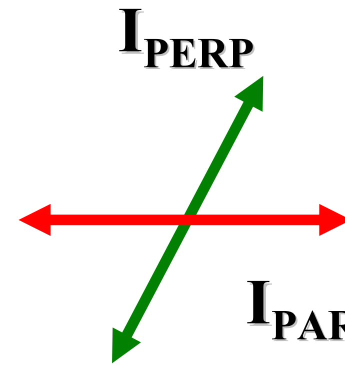
2D gratings





1D gratings

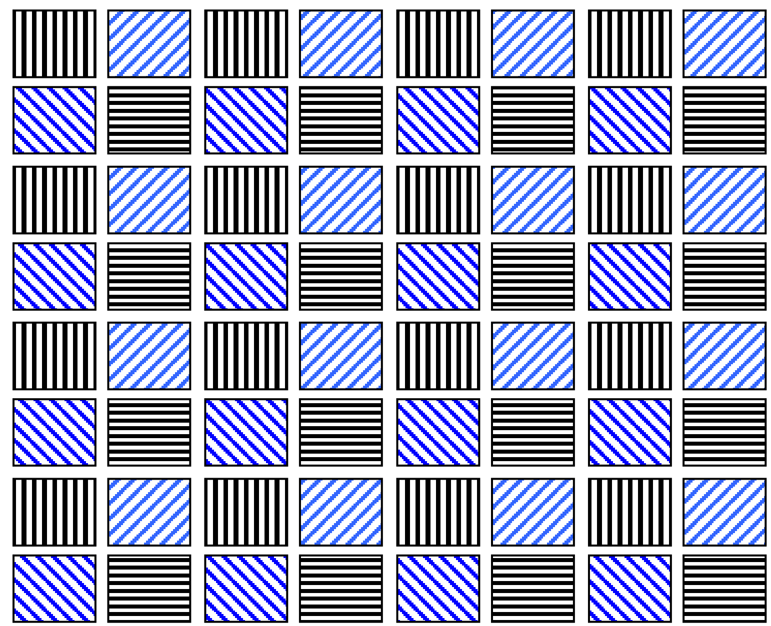




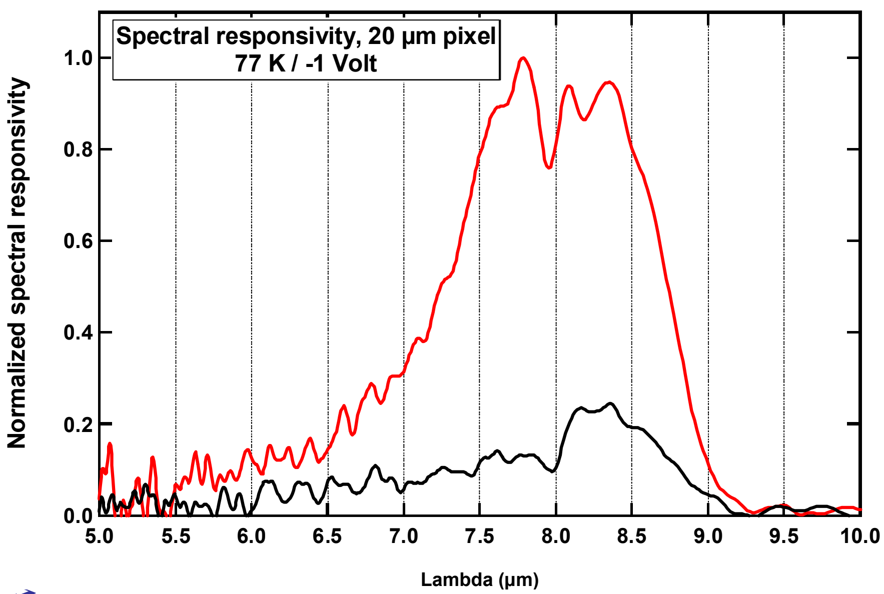
Polarisation ratio

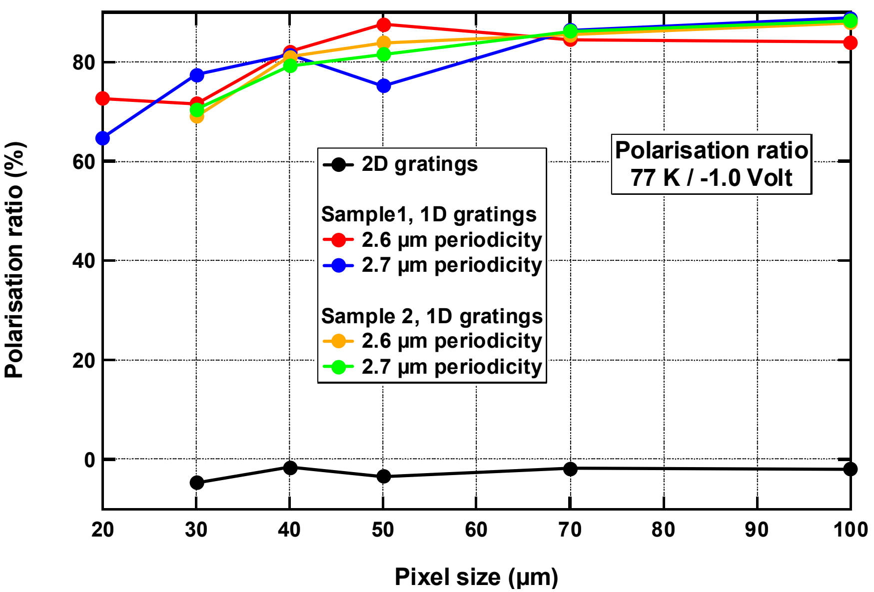
$$\frac{I_{PAR} - I_{PERP}}{I_{PAR} + I_{PERP}}$$

$$I \,\alpha \int R(\lambda) \cdot d\lambda$$



POLARIMETRIC DETECTORS





- setup tested on 2D gratings: residual polarisation ratio < 3 %
- reproducible results
- high polarisation ratio even for 20 µm pixels

- research directions
  - FPA design and fabrication
  - goal: 20 µm pitch, 640x512 FPA

Alexandru NEDELCU, ATL III-V LAB, France - QW