Leibniz-Institut für
Astrophysik Potsdam

Overview and preliminary results of a near-infrared cross-dispersed spectrograph based on the arrayed waveguide grating technology

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Outline

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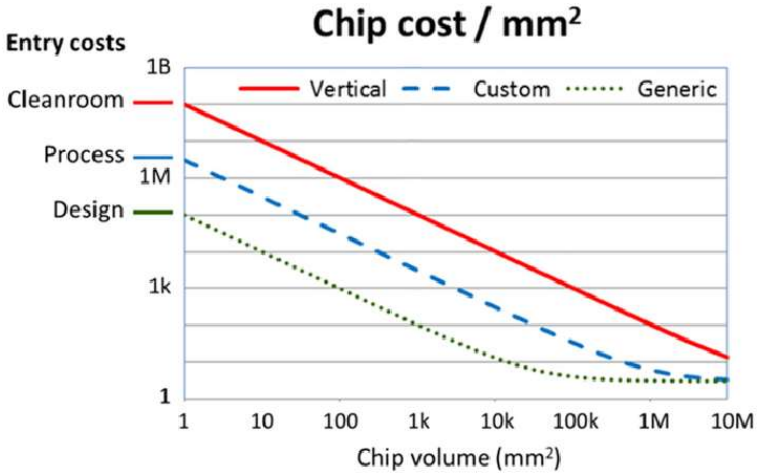
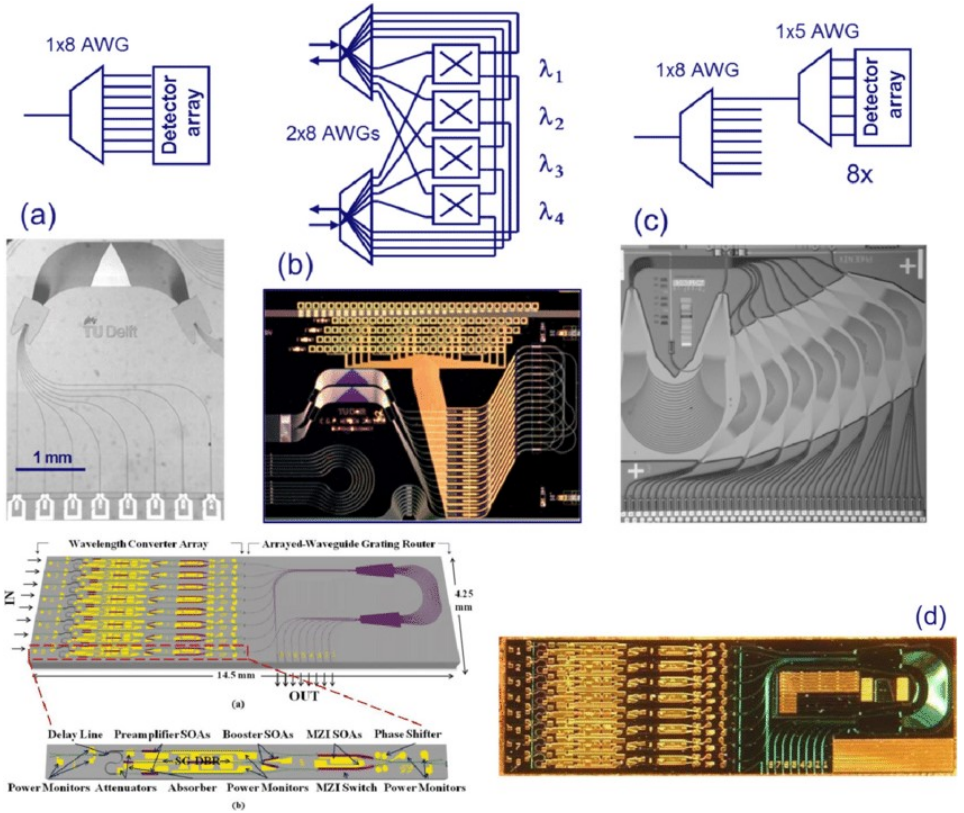
Innovative faseroptische Spektroskopie und Sensorik

1) PICs Overview
2) Applications in Astronomy
3) Astrophotonics at AIP – Arrayed Waveguide Gratings
4) The Potsdam Arrayed Waveguide Spectrograph (PAWS)
5) POCO Frequency Comb System – PAWS Calibration
6) Outlook

PICs Overview

- Development of chip complexity over the years
  - Similar to Moors-Law in transistors on microchips
- PICs are widely used
  - WDM receivers, Mach-Zehnder, etc...
- Dependence of chip cost
  - Chip cost on the production for three models



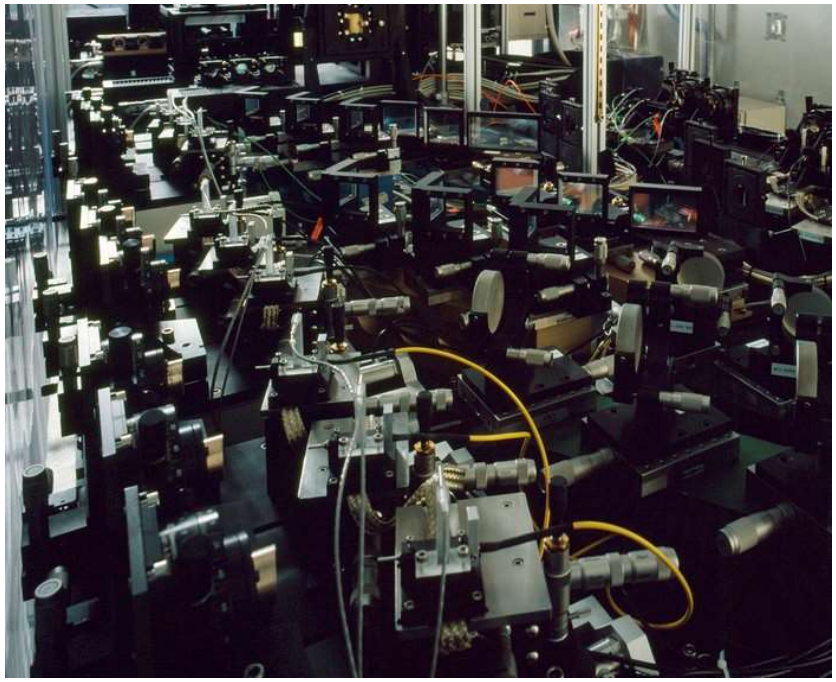


Example of different PICs

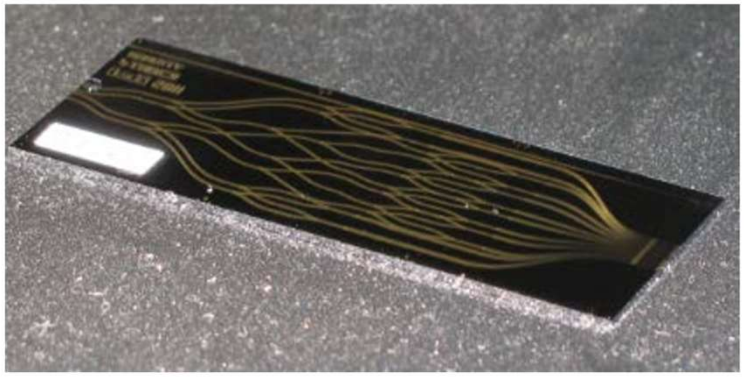
Images: Smit et al. 2014

PICs in Astronomy

- PICs benefits



Beam combination at the AMBER instrument, VLTI



Gravity beam combiner

1) Stability
2) 100 x size reduction (reduced payload)
3) Scalable, faster manufacture
4) Less mass and power

Images: ESO and GRAVITY collaboration

Astrophotonics at AIP

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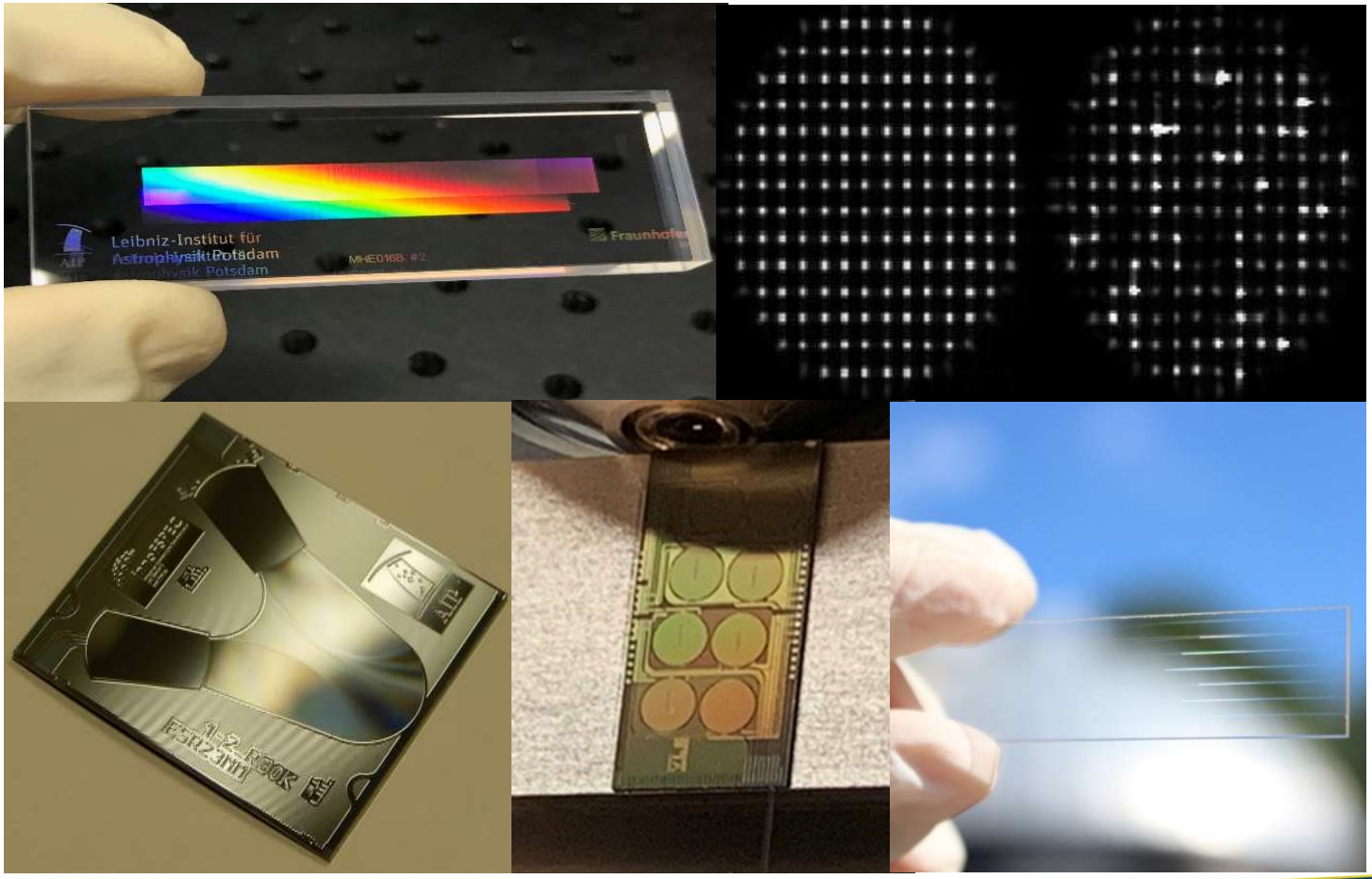
- Fiber and chip based photonics for near-infrared astronomy



1. OH Suppression Filters & Phase Masks
2. Adaptive Optics & Photonic Lanterns
3. Arrayed Waveguide Gratings
4. Frequency Combs
5. Pupil Remappers & Beam Combiners

Images: innoFSPEC

Arrayed Waveguide Gratings

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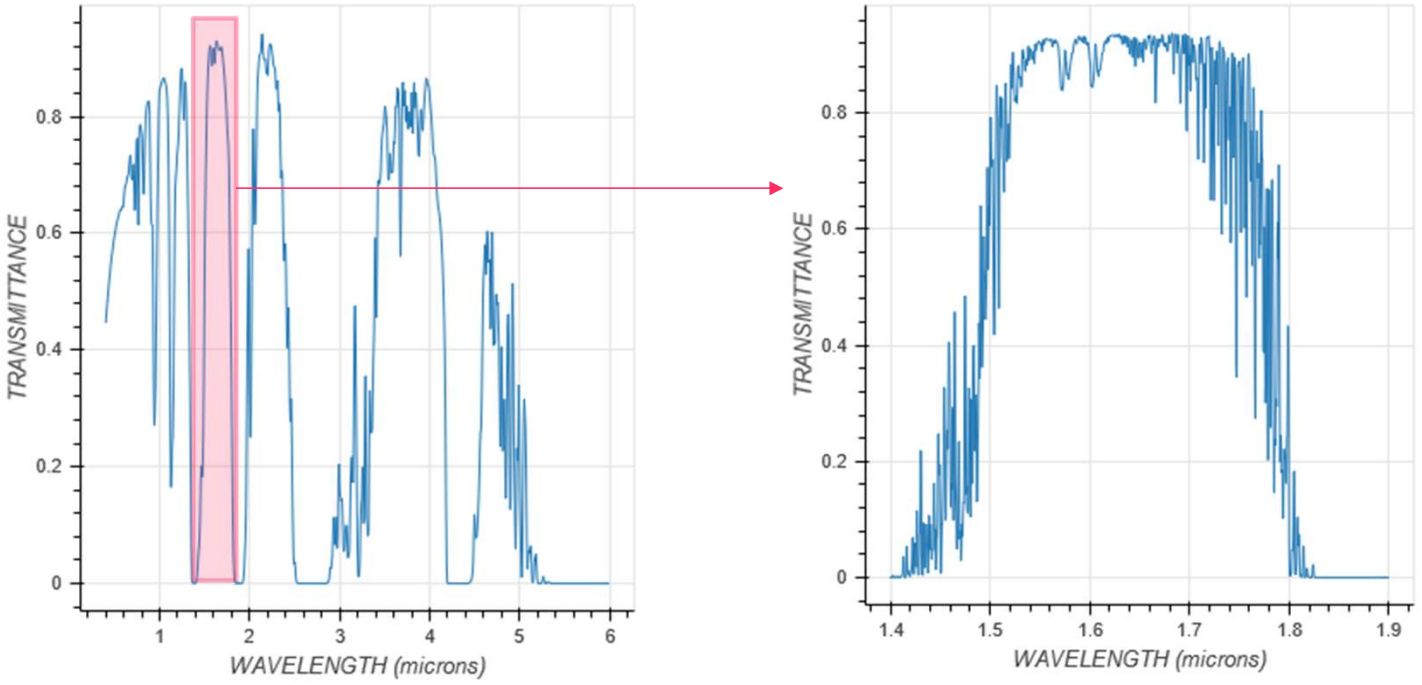
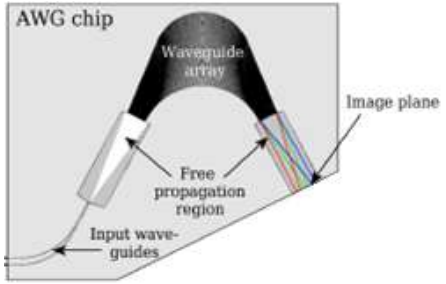
- AWG tailor made for astronomical instrumentation
  1) Tuned for a broad spectral range – H-Band
  2) Low insertion loss
  3) High resolving power





$\alpha_{losses,dB}$ ~ 0.2dB

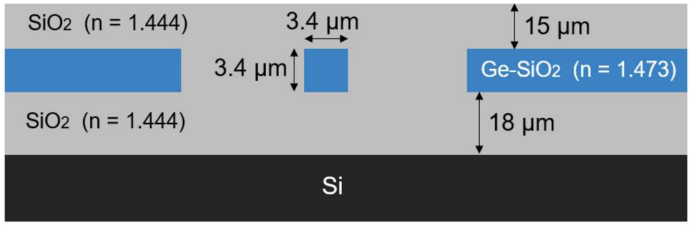
$R_{theoretic}$ ~ 65000

$R_{measured}$ > 15000

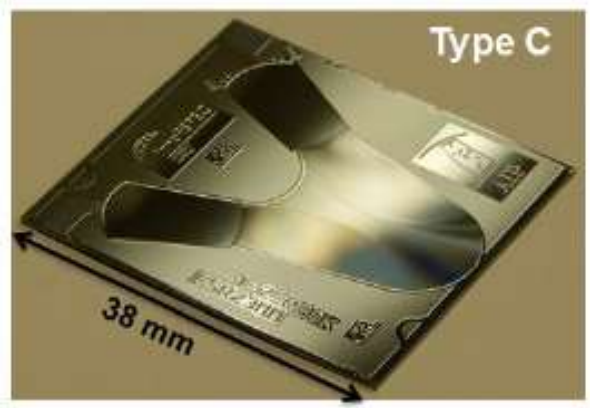
Images: http://modtran.spectral.com

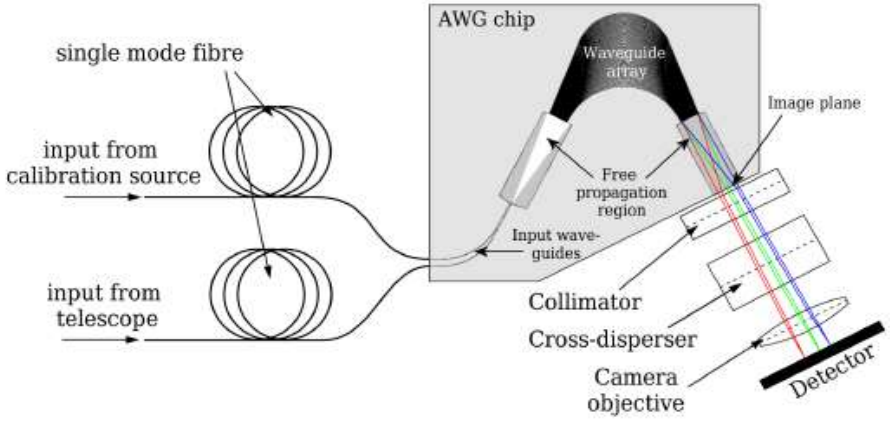
Integrated Photonic Spectrograph

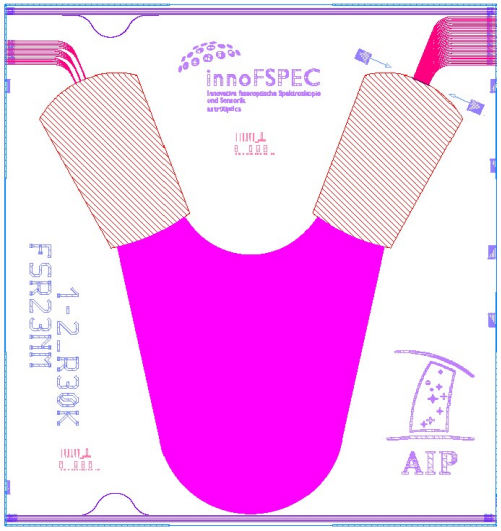
- Fabrication process
  1) UV-Photolithography
  2) Atmospheric pressure chemical vapor deposition (APCVD)
  3) SiO_2 substrate – Silica on silicon platform



- Best performing chips selected







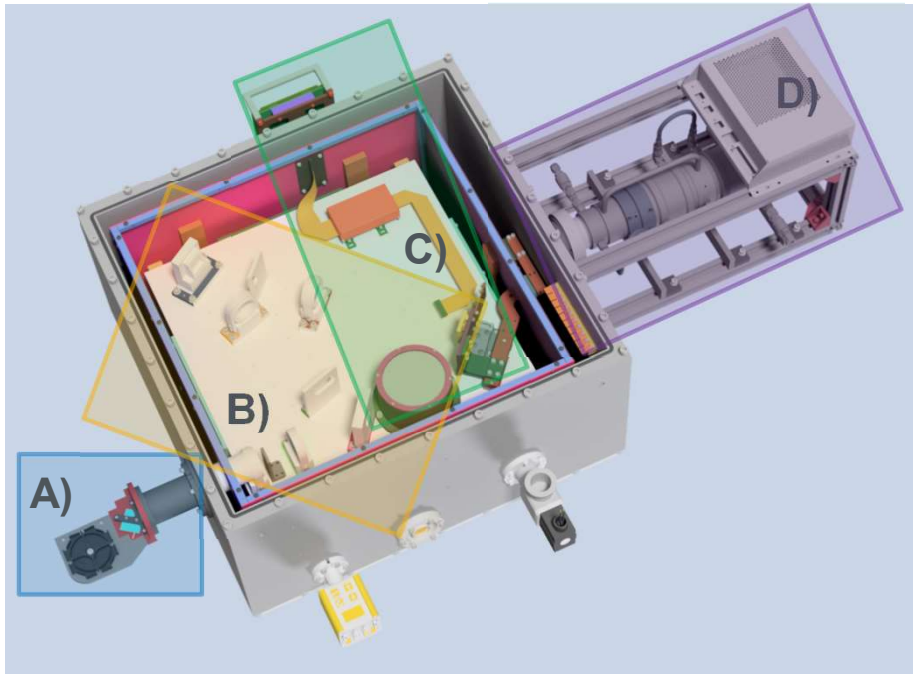
Layout 1-1-2

- Integrated photonic spectrograph (IPS)

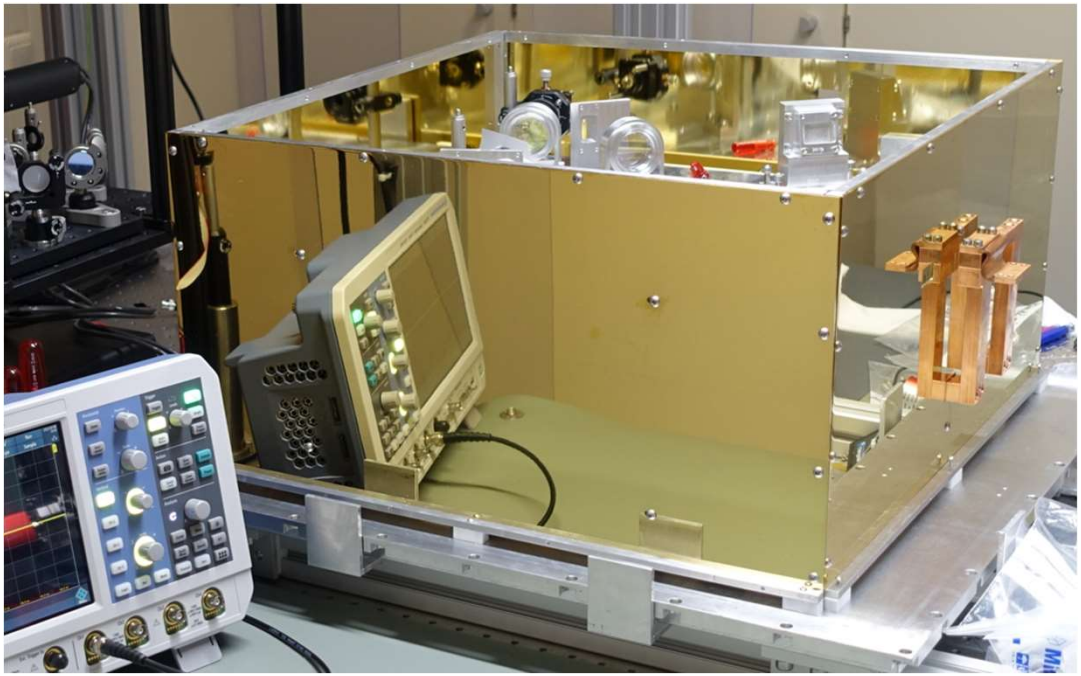
Images: innoFSPEC

The Potsdam Arrayed Waveguide Spectrograph

- Design of the cryostat



CAD of PAWS

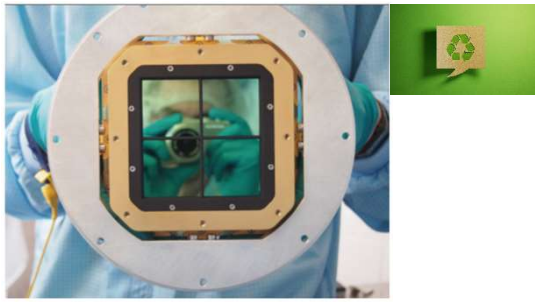


Radiation shield with optical system inside

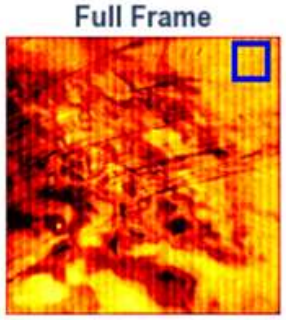
Images: innoFSPEC

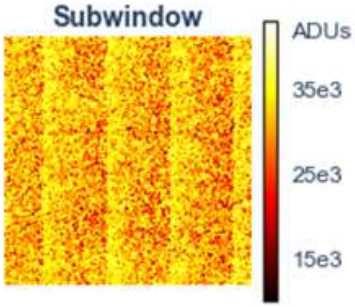
The Detectors

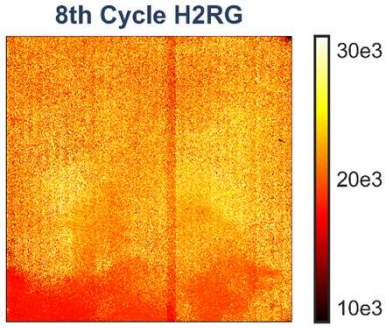
- The PAWS detector(s)



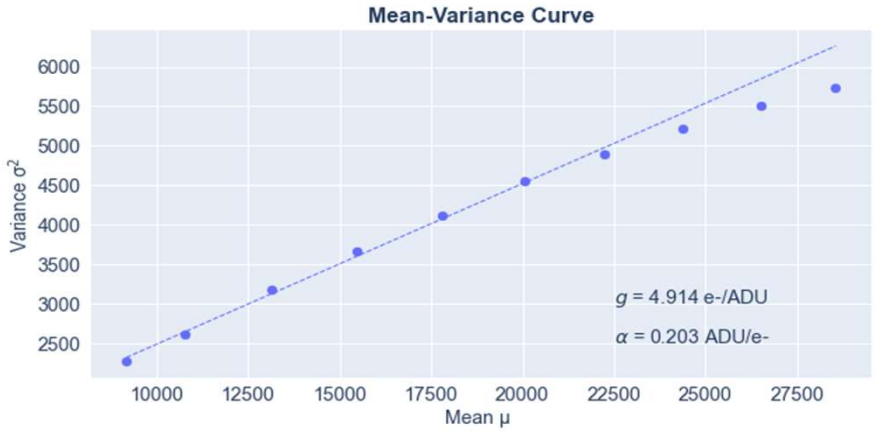
PANIC: 4 H2RG mosaic







Operational temperatures



PTC

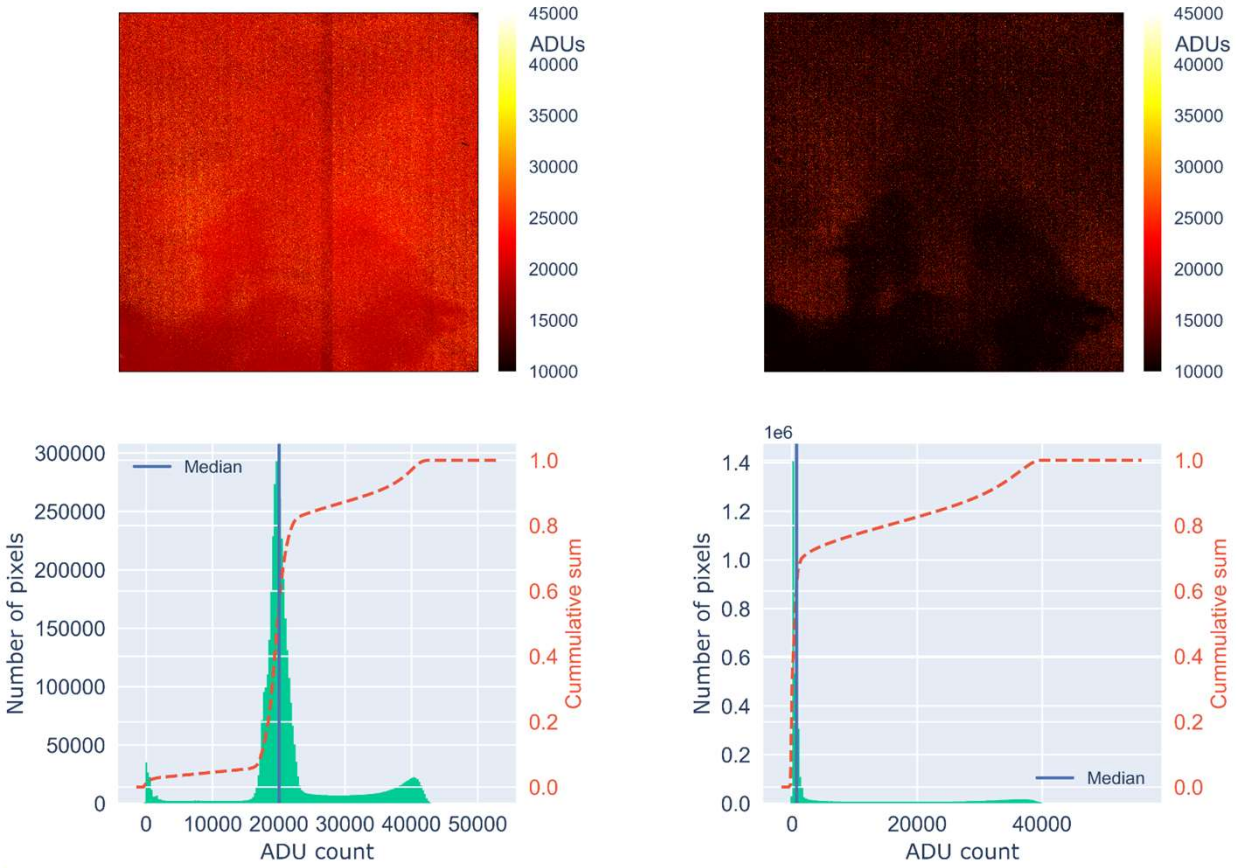
9th cycle on-going

Images: innoFSPEC, PANIC from the MPIA

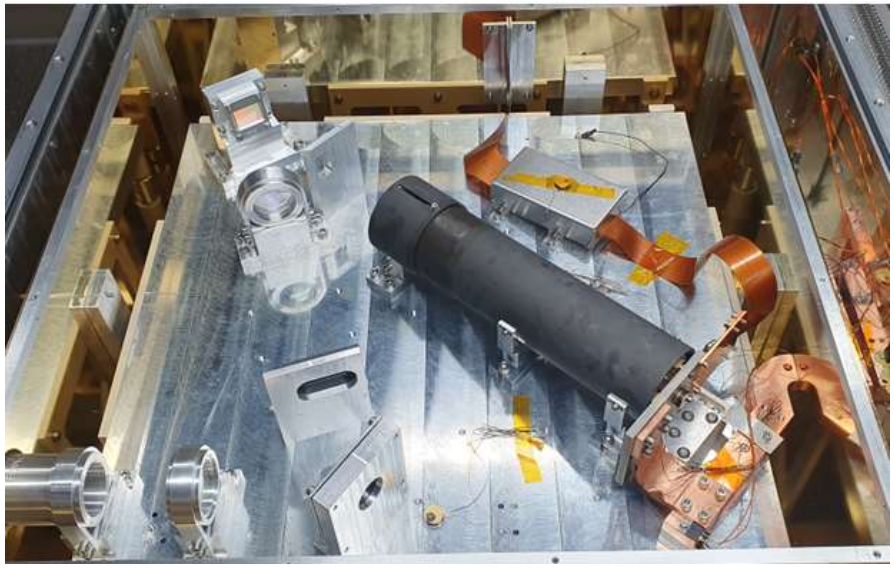
Improvement in Current Cylce

- CDS frames with minimal integration time = 2.7 seconds

8th Cycle



9th Cycle

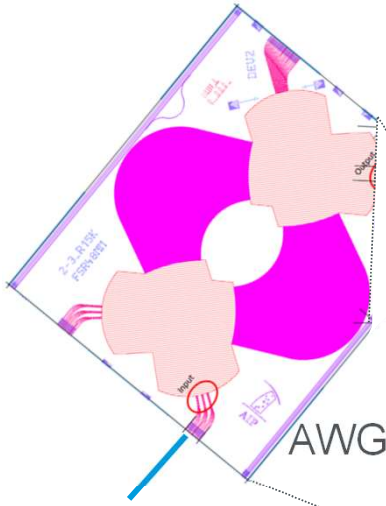


Baffled detector

Images: innoFSPEC, PANIC from the MPIA

First Lab Light

- Experimental Set-up



AWG Type F

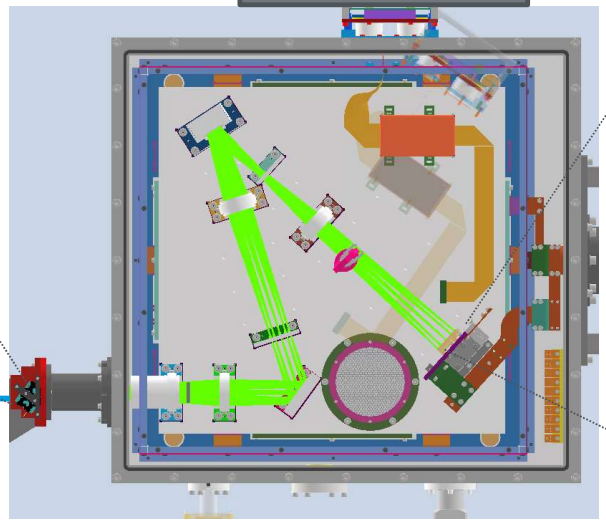
Tuneable Laser
1400 – 1680 nm

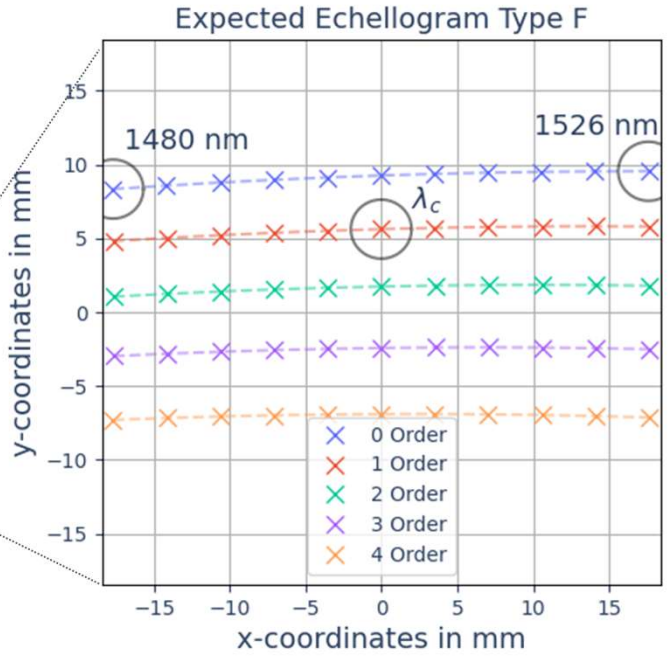
Super-K
1400 – 1800 nm

Fibre

Luminos
6 Axis Positioner

RoE/GEIRS



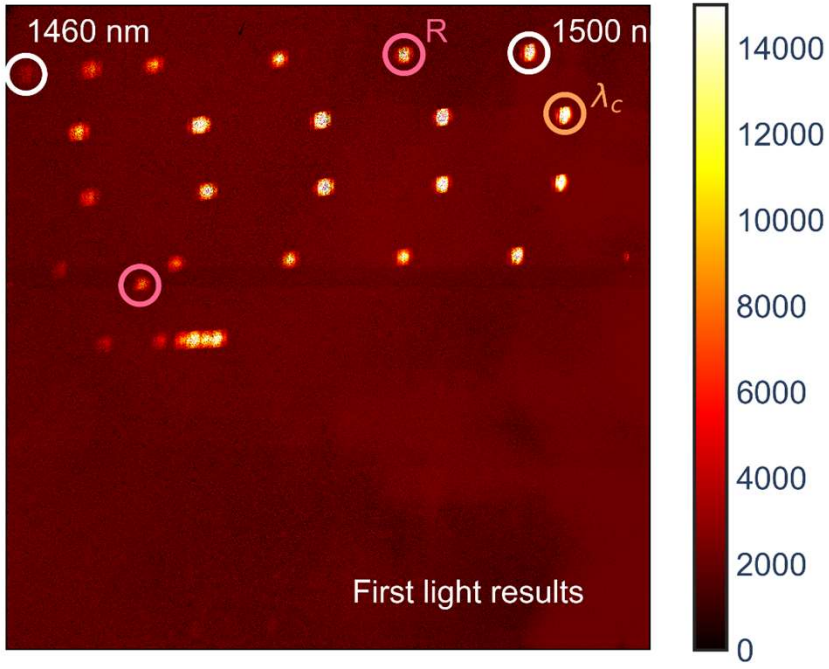


Images: innoFSPEC

First Lab Light

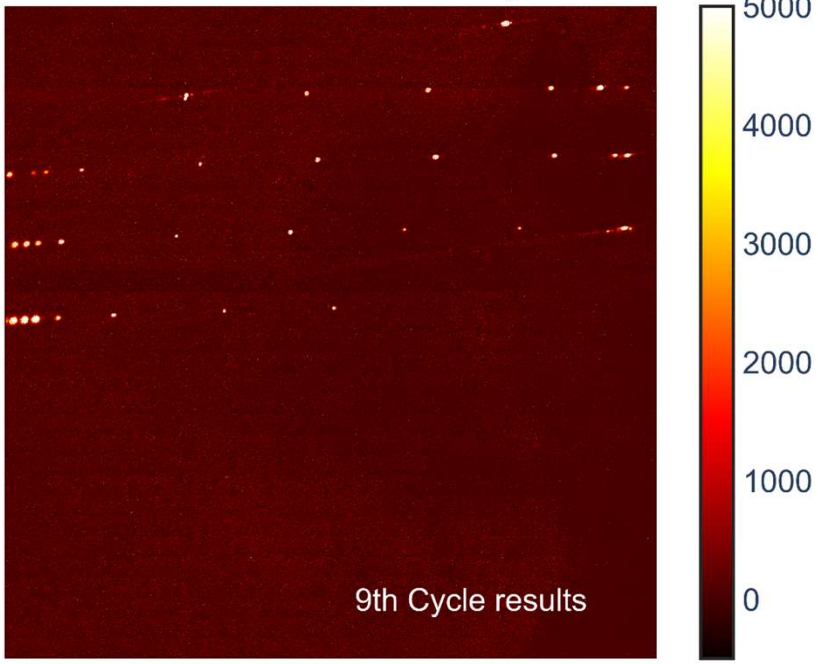
- Tunable Laser and Super-K results

Tunable Source Echellogram



8th cycle rms spot size = 55.1 pixels

Tunable Source 9th Cycle



Measured:

Δλ = 0.27 nm
R = λc/Δλ = **5796**

9th cycle rms spot size = **17.43 pixels**
Improvement of factor **3.16**

Images: innoFSPEC

Chip-based Frequency Comb (Astrocomb)

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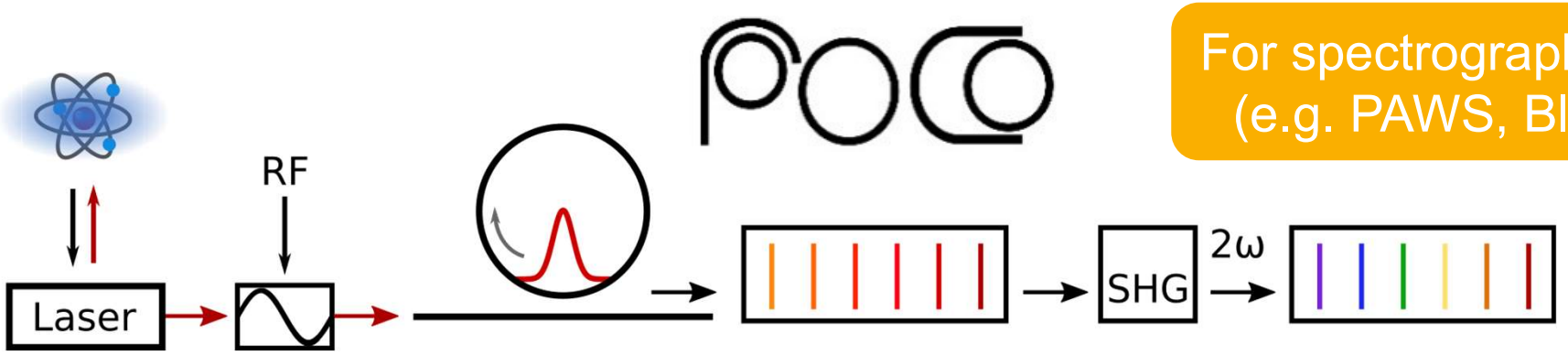
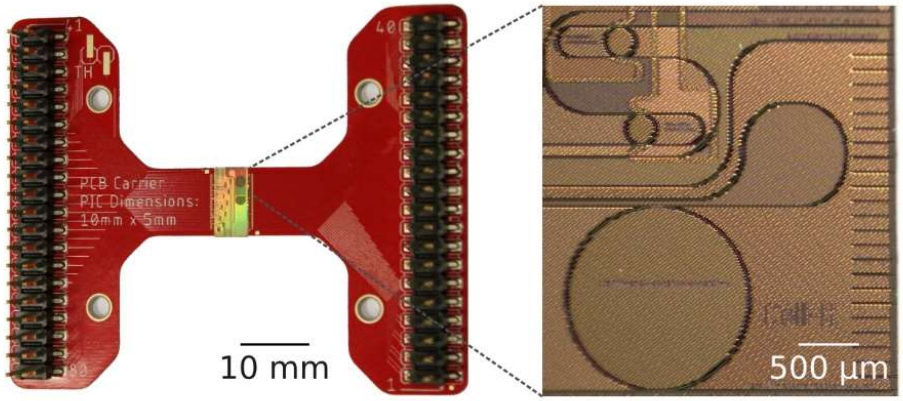
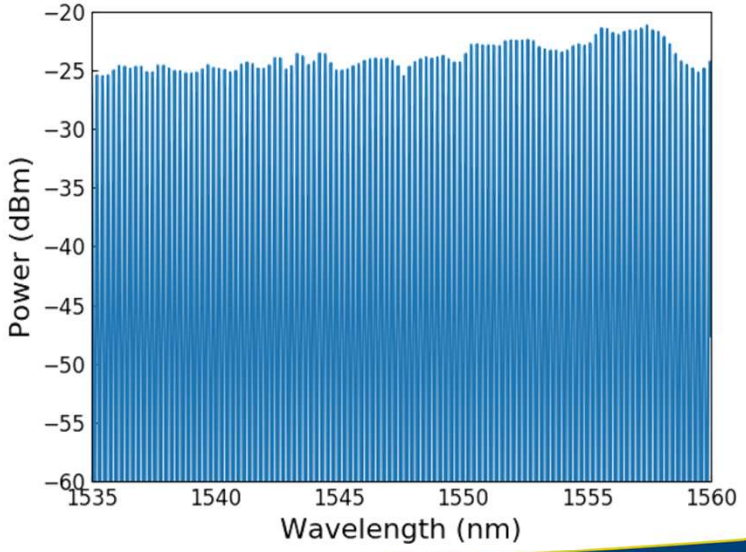
For spectrograph calibration
(e.g. PAWS, Blue MUSE)





Silicon-Nitride Chip (SiN-Chip) with micro-ring resonator



POCO and PAWS – PICs for Astronomy

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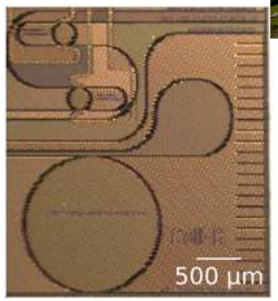
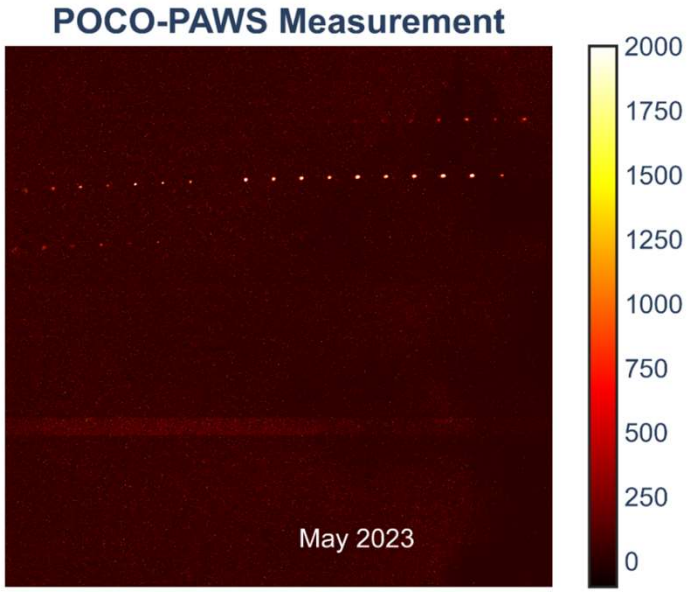
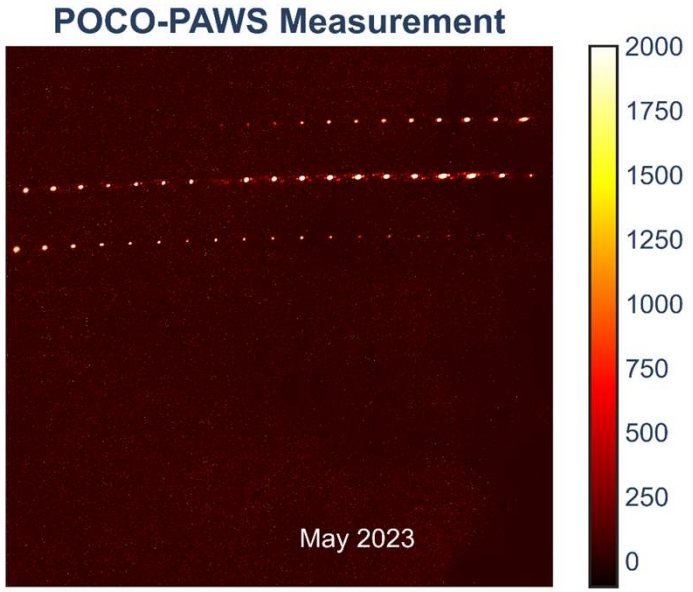
POCO



Optical Fibre

PAWS





Images: innoFSPEC

POCO and PAWS – PICs for Astronomy

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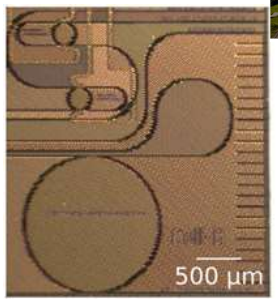
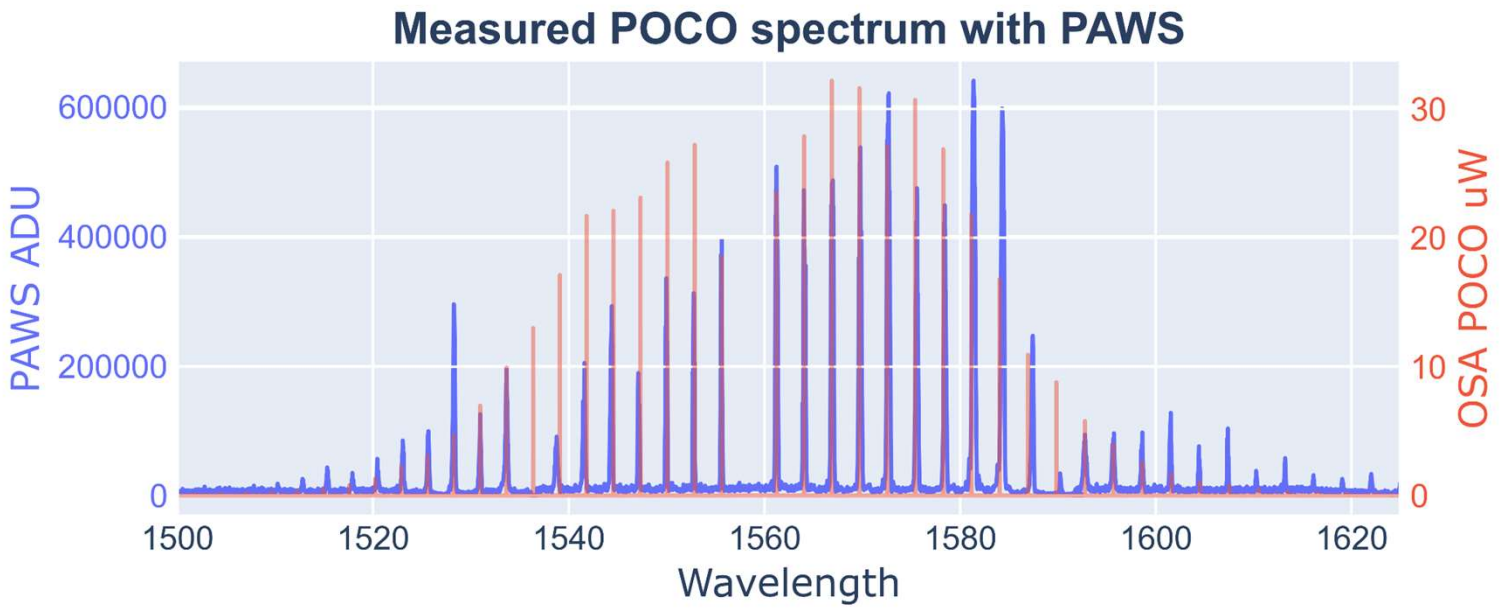
POCO



PAWS

Optical Fibre



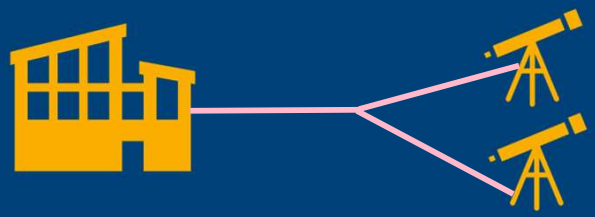
Images: innoFSPEC

Outlook

- Improvements:
    1) Least degraded H2RG
    2) Better Focus
- Analysis on AWG performance
    1) Test multiple fibres simultaneously
    2) Warm AWG limitations
- Test at the Calar Alto Observatory
- Goal: compact cryo-cooled end-to-end system
- Future possibilities of detector integration in PICs for astronomy?

Conclusions

- PICs are used widely in different fields and are constantly improving
- Several benefits for astronomical instrumentation:
  1) Stability
  2) 100 x size reduction (reduced payload)
  3) Scalable, faster manufacture
  4) Less mass and power
- Development of Astrophotonic devices on-going:
  - Arrayed waveguide gratings
  - Frequency combs
- Development and first tests of PAWS
- Calibration of PAWS with POCO
  - Interfacility distributed calibration system!
- Goal: compact cryo-cooled end-to-end system



Thanks for listening

PAWS


Dr. Eloy Hernandez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POCO


Daniel Bondenmüller


Haydar Altuğ Yıldırım


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