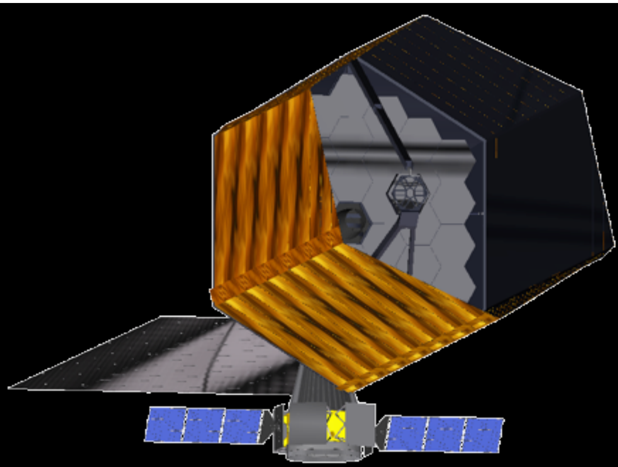
UNIVERSITY OF LEICESTER



UK Instrument Interests

Martin Barstow, Jon Lapington &
Chris Evans

Science & Technology Facilities Council
UK Astronomy Technology Centre

UNIVERSITY OF LEICESTER

Introduction

- University of Leicester – detectors
- Underpinned by industrial collaborations with
  - e2v, CCD/CMOS manufacturers
  - Photonis, MCP manufacturers
  - Photex, device packagers
- UK ATC – optomechanical design

UNIVERSITY OF LEICESTER

Detectors

- LUVOIR UV Detector requirements
- MCP UV-Imager demonstrator
  - Photocathode developments
  - ALD-enhanced MCPs
  - Square format MCP detectors
- High speed readout techniques
  - Capacitive division image readout (C-DIR)
  - Intensified CMOS detector
- Study goals

UNIVERSITY OF LEICESTER

LUVOIR UV Detector Requirements

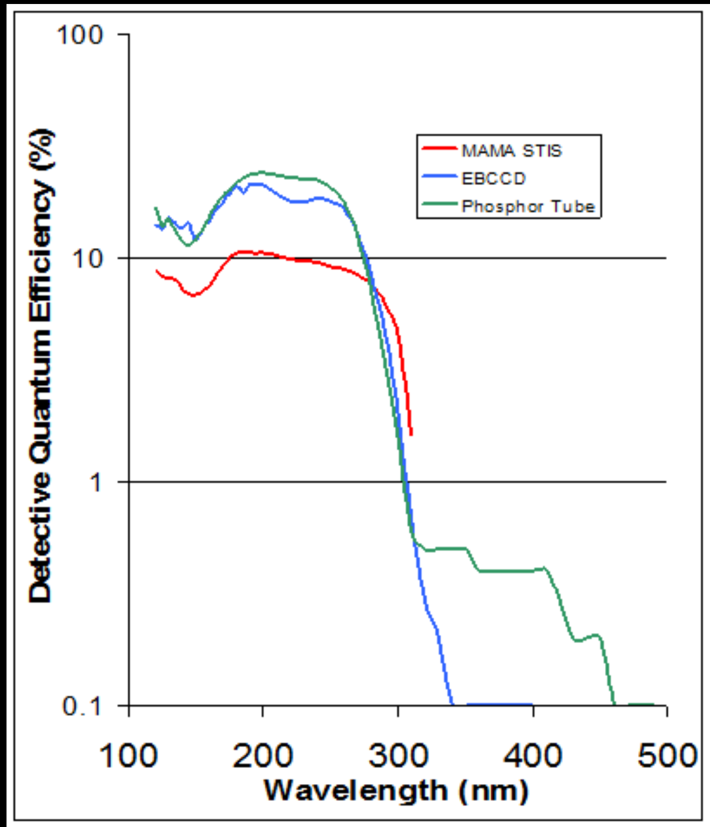
Parameter:	**Goal:**	**State-of-the-Art:**	
Operational Bandpass	90 nm – 400 nm	< 90 nm – 300 nm	MCP
		< 90 nm – 400 nm	EMCCD
		TBD	sCMOS
Read Noise	0	0	MCP
		N/A for multi. mode	EMCCD
		0.8 – 1.0 e^-	sCMOS
Dark Current and/or Spurious Count Rate	≤0.1-1 counts/cm^2/s ≤1-10e-3 e^-/resol/hr	0.05-0.5 counts/cm^2/s	MCP
		> 0.005 e^-/resol/hr	EMCCD
		> 0.005 e^-/resol/hr	sCMOS
Quantum Efficiency (Peak)	75% (Far UV – Near UV)	45-20% FUV - NUV	MCP
		30-50% FUV - NUV	EMCCD
		TBD	sCMOS
Resol Size	≤ 10 μm	20 μm	MCP
		20 μm	EMCCD
		10-20 μm	sCMOS
Dynamic Range (Max. Count Rate)	≥ 10^4 Hz / resol (as needed)	2kHz / resol 5 MHz global	MCP
		Readout dependent	EMCCD
		10^5 Hz / resol	sCMOS
Time Resolution	≤ 100 ms (as needed)	<< 1 ms	MCP
		< 10 ms	EMCCD
		< 10 ms	sCMOS
Format	≥ 8–16k pixels per side with high fill factor	8k × 8k	MCP
		3.5k × 3.5k	EMCCD
		3.5k × 3.5k	sCMOS
Radiation Tolerance	Good	Good	MCP
		TBD	EMCCD
		Good	sCMOS

MCP UV Imager for Space

- Leicester Technology demonstrator system
  - TRL 6 demonstrator already developed in UK-CEOI funded project
- Performance goals:
  - Resolution: ≤10 µm, rate: ≥5 Mcount/s, lifetime >10C/cm^2 ≡ ~10^{14} event/cm^2
- UV solar-blind photocathode technology
  - Demonstrator uses sealed window Cs_2Te photocathode
- Enhanced MCP performance using atomic layer deposition (ALD)
  - Enhanced lifetime, higher PDE, lower noise, higher dynamic range, lower HV
- Square format sealed tube, thin wall, low mass detector design
  - high fill factor detector arrays
- Image readout alternatives
  - Capacitive division centroiding image readout
  - Intensified CMOS device

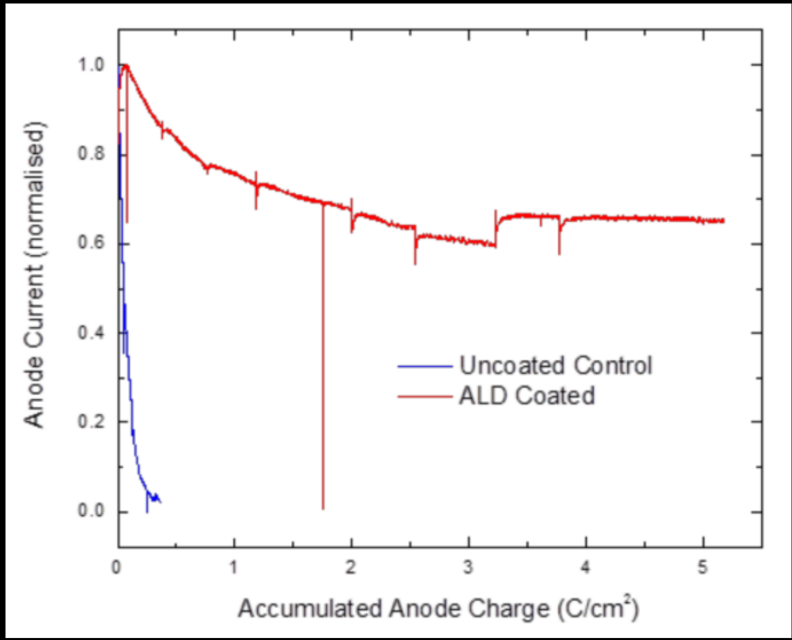
Photocathode developments

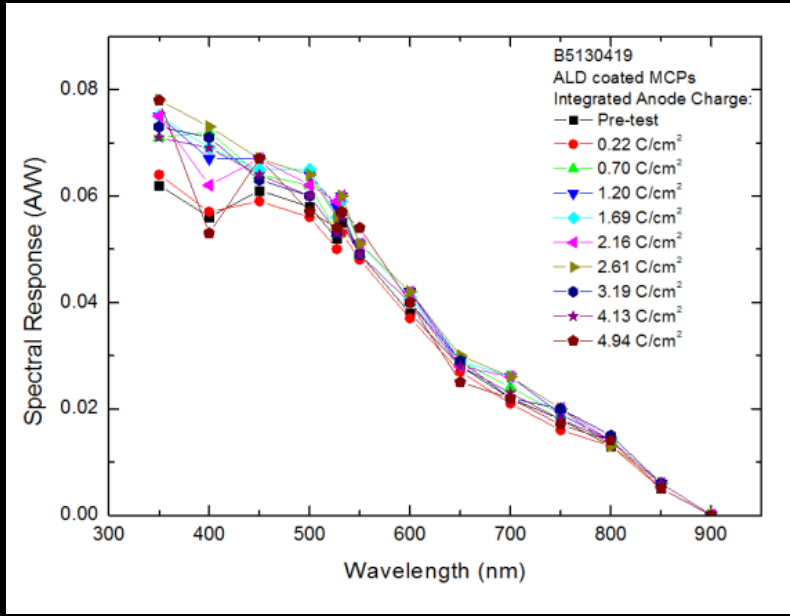
- Solar-blind Cs_2Te photocathode (Photek)
  - QE: 34% at 254 nm
    - cf. HST-STIS QE: 9%
  - Optical wavelength rejection
    - two orders of mag. >350 nm
    - zero red leak
  - Cut-off wavelength can be tuned
  - Sealed tube
    - No door mechanism or contamination
    - Lower mass, complexity, cost
    - Downside: 1100 Å window cut-off



ALD enhanced MCPs

- ALD coated conventional MCPs
- Enhanced secondary electron emission
  - Higher QE due to higher photoelectron detection efficiency
  - Lower operating voltage due to higher gain per bounce
- Increased detector lifetime due to reduced MCP outgassing
  - ALD seals in MCP adsorbates
  - Reduces ion feedback events
  - Reduces photocathode QE fatigue
  - Reduces MCP gain loss

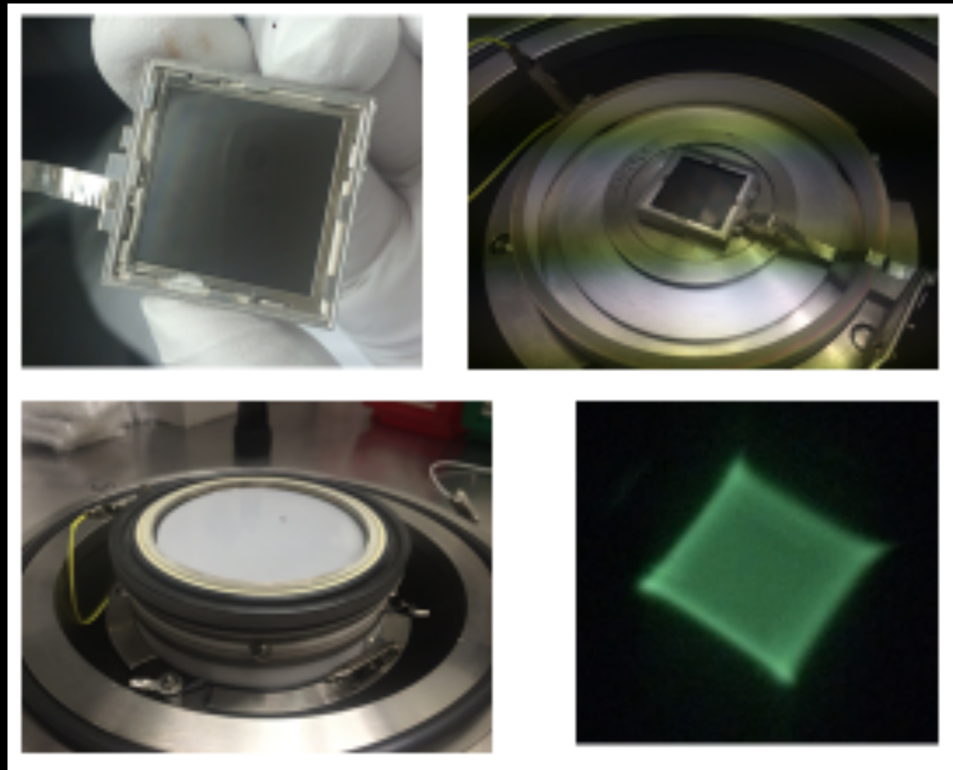




UNIVERSITY OF LEICESTER

Square format MCP detector

- Thin-walled square tube developed for LHCb upgrade
- Allows close packing of tube arrays
- Minimal dead space between active regions
- LHCb programme has enhanced TRL



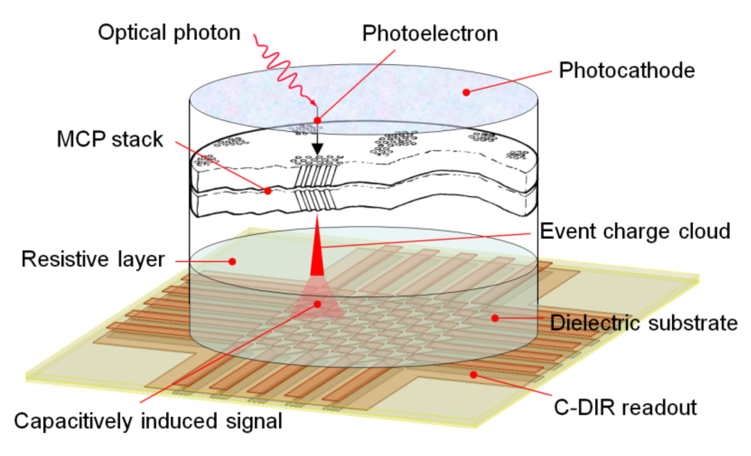
UNIVERSITY OF LEICESTER

High Speed Image Readouts

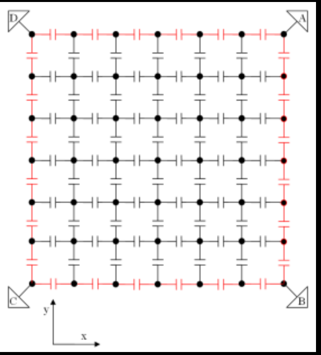
- Capacitive division image readout with adaptive digital electronics
  - Proposed for ESA-JUICE UV Imager
  - High speed, low noise centroiding readout
  - Combines high spatial/time resolution & count rate capability
  - Low cost/complexity for sealed or open-faced MCP detector
  - Digital filtering provides real-time count rate vs image resolution trade-off
  - Adaptive electronics allow scene dependent optimisation
- Intensified CMOS readout
  - Uses low power, high frame rate CMOS imager
  - ASTROSAT-UVIT iCMOS detector developed in the UK
  - Sub-pixel centroiding →large pixel formats
  - 6 µm pore MCPs → high spatial resolution
  - Photon counting & analogue modes → high dynamic range
  - CMOS windowing allows higher rate ROI observations

Capacitive division image readout

- Charge signal divided by capacitor array
- Charge readout at 4 nodes
- Capacitance array intrinsic in geometry
- Typical pattern capacitance < 8 pF
  - No resistive or partition noise
  - low noise, high spatial/time resolution
- Very low readout noise
  - Less than 200 e- rms at τshape = 250ns
- Spatial resoslution
  - 4000 × 4000 pixel2 at 5x106 electrons
- Simple linear encoding algorithm
  - minimal digital processing
- Excellent linearity
  - utilize >80% of anode
- Optimal performance
- → adaptive digital electronics

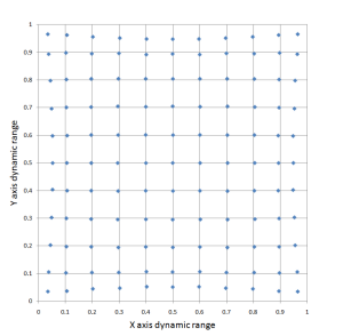


- Event charge is localized on resistive layer
- Transient signal induced through dielectric
- Dielectric substrate part of vacuum housing
- Induced signal sensed by C-DIR readout
- C-DIR - a capacitively coupled electrode array

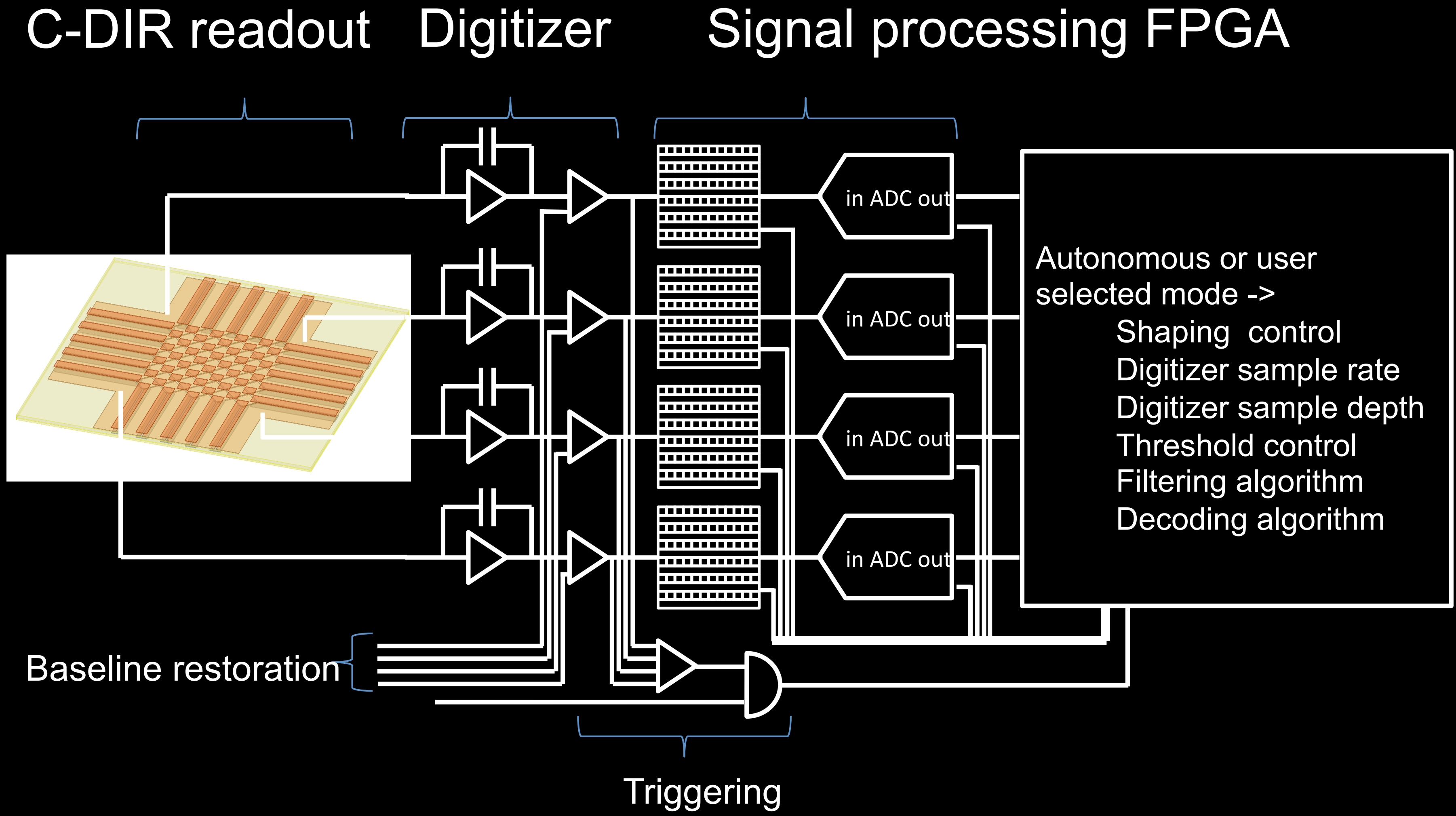


Equivalent circuit

Linearity

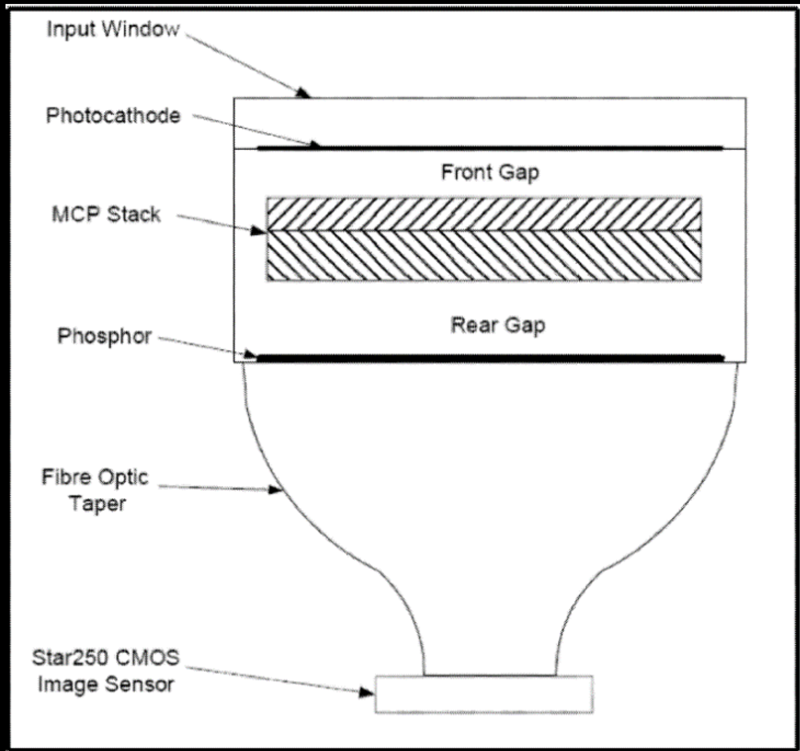


C-DIR Adaptive Electronics



Intensified CMOS detector

- Many benefits shared with iCCD
  - sub-pixel resolution
  - flight heritage (XMM-OM, SWIFT etc.)
- Advantages of CMOS technology
  - no charge transfer
  - no shutter
  - no blooming
  - rad-hard
  - high frame rate
  - low power
- Easy integration
  - image acquisition & DPU functionality on FPGA
- Designs already space qualified
  - Astrosat UVIT (Photek)
  - Solar Orbiter SPICE



Study questions

- Tradeoff between MCP and the various CMOS/CCD approaches
  – E.g direct imaging vs intensified imaging
  – Matching spatial resolution to telescope
  – Dynamic range of sensors
  – Quantum efficiency

Study questions

- Tradeoff between MCP and the various CMOS/CCD approaches
  - E.g direct imaging vs intensified imaging
  - Matching spatial resolution to telescope
  - Dynamic range of sensors
  - Quantum efficiency

UK Astronomy Technology Centre

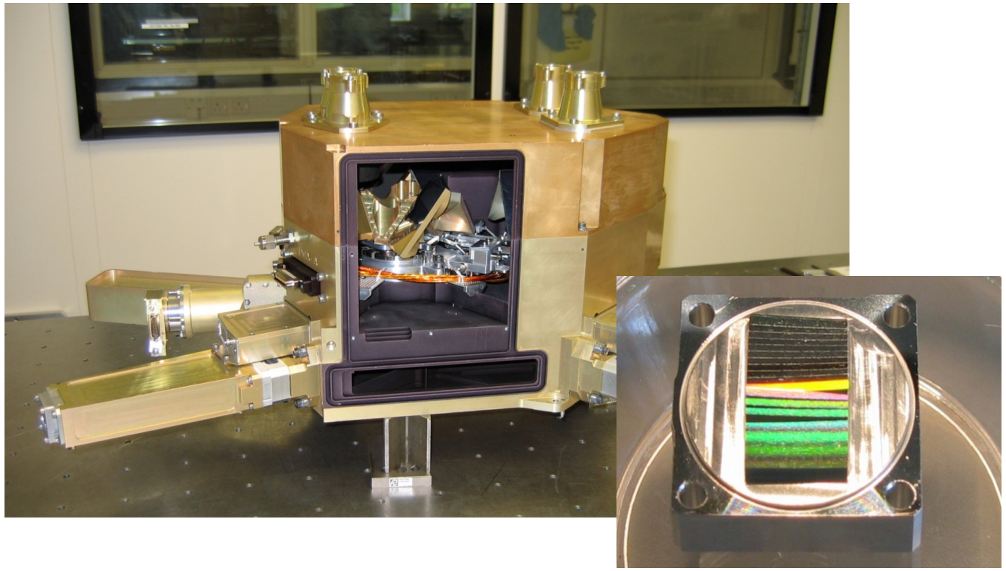
- ~ 70 staff – engineers, managers, scientists
  - Matrix management structure
  - Staff allocated to projects as needed
- Long heritage in delivery of state of the art, “facility class” instruments and telescopes.
- Current ground-based projects:
  - Lead institute for VLT-MOONS
  - Lead on IR camera for VLT-ERIS
  - Coordinating institute for UK E-ELT programme
  - Lead technical institute for E-ELT HARMONI
  - LM-band spectrograph lead for E-ELT METIS
  - Significant roles in E-ELT MOSAIC & HIRES studies
  - Lead for ALMA observing software (& toward SKA)

Science & Technology Facilities Council
UK Astronomy Technology Centre

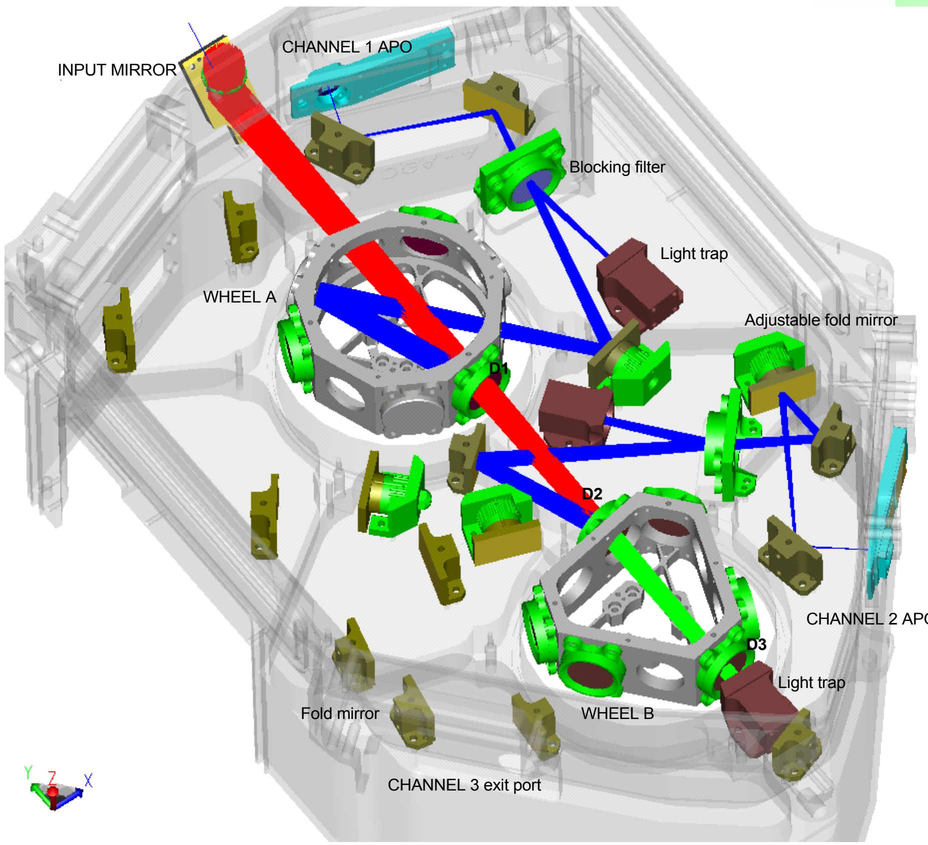
UK ATC: Instrumentation for NASA & ESA

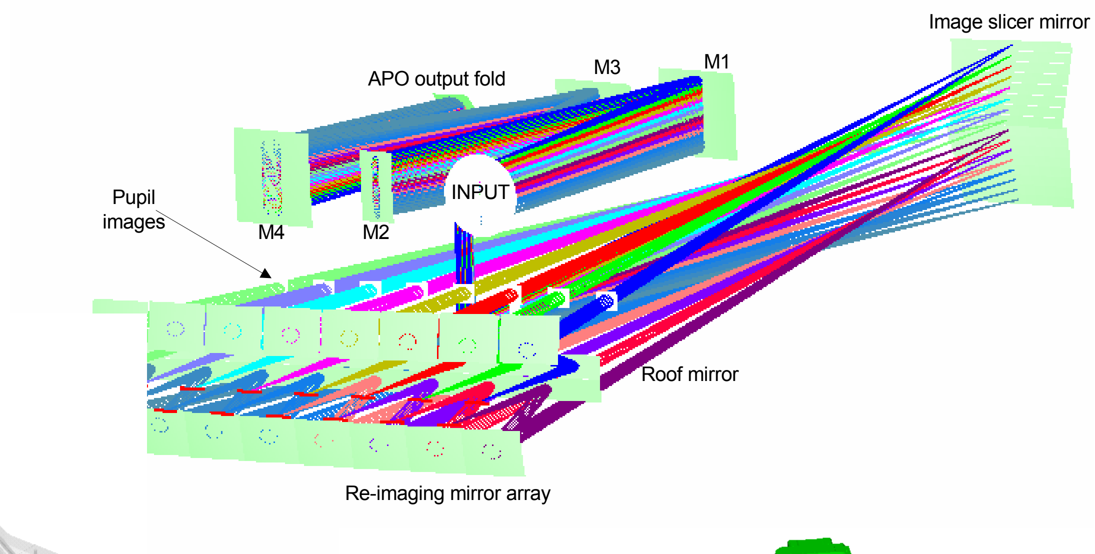
JWST MIRI

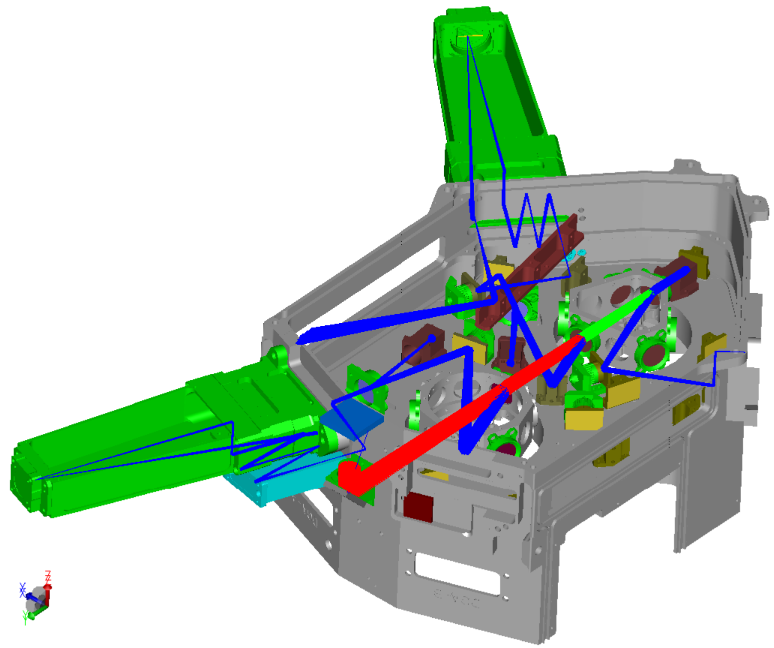
- 27 European institutes (incl. Leicester) + JPL
- UK ATC – overall project lead, optical system design, Spectrometer Pre-Optics
- Now working closely with STScI to develop user support tools and & calibration pipeline



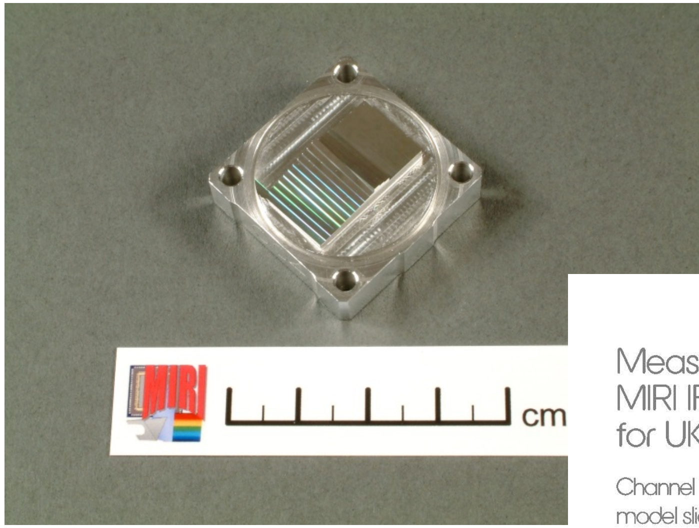
JWST-MIRI: Spectrometer & image slicers

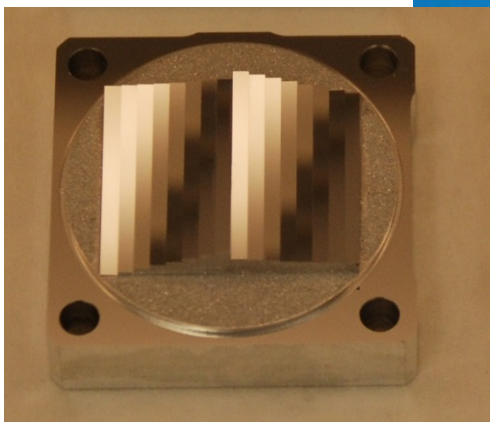






JWST-MIRI: Spectrometer & image slicers

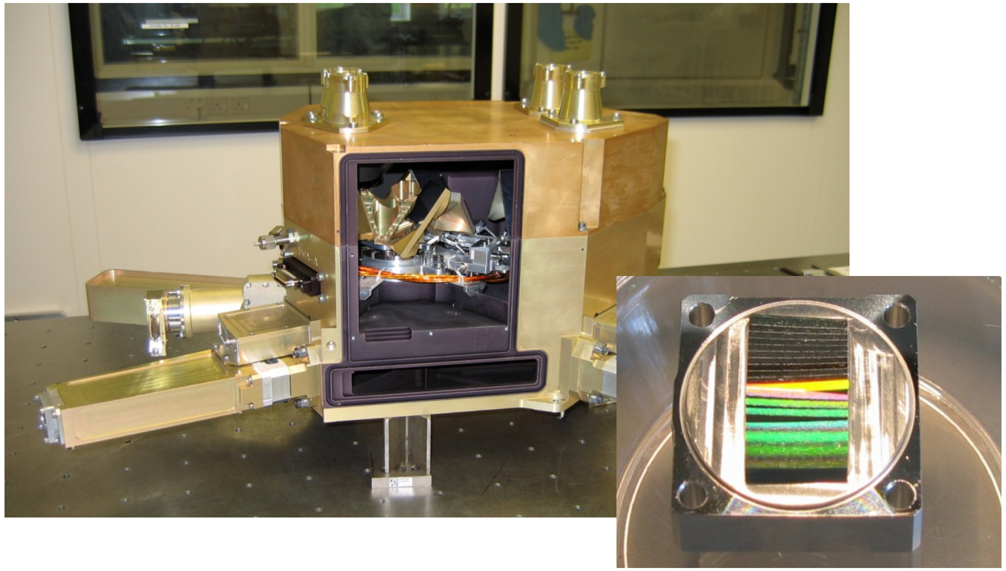




UK ATC: Instrumentation for NASA & ESA

JWST MIRI

- 27 European institutes (incl. Leicester) + JPL
- UK ATC – overall project lead, optical system design, Spectrometer Pre-Optics
- Now working closely with STScI to develop user support tools and & calibration pipeline



Herschel SPIRE

- Initial opto-mechanical design of photometer channels
- Development of beam-steering mirror for chopping

Current Development Studies

- European IR detectors for future missions with Selex UK
- Ariel exoplanet study for ESA (M4)
- NSTP funded cubesat design studies (mostly EO focussed)