Application of QWIP FPA Technology to the Integrated Multispectral Atmospheric Sounder (IMAS)

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AGENDA

- Overview of Sounder Science Mission
- Overview of IMAS System
- AIRS to IMAS Goals
- Quantum Well Infrared Detectors for IMAS
- Readout Integrated Circuits for VLWIR QWIPs
- Technology Status

IMAS QWIP/ROIC TEAM

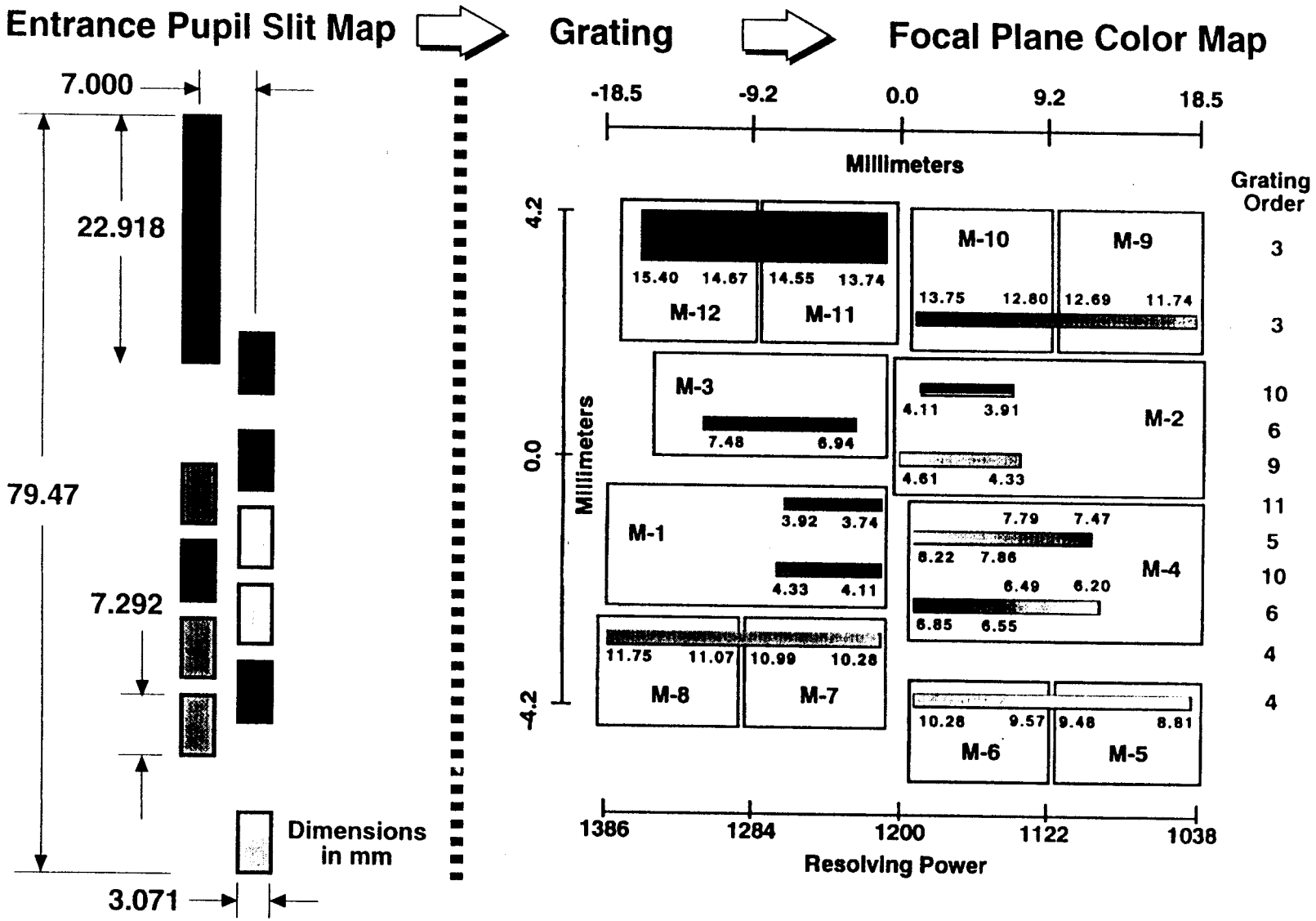
- **QWIPs**
  S. Gunapala
  S. Bandara

- **Microlens**
  F. Poole

- **ROIC**
  B. Pain
  G. Yang
  T. Shaw

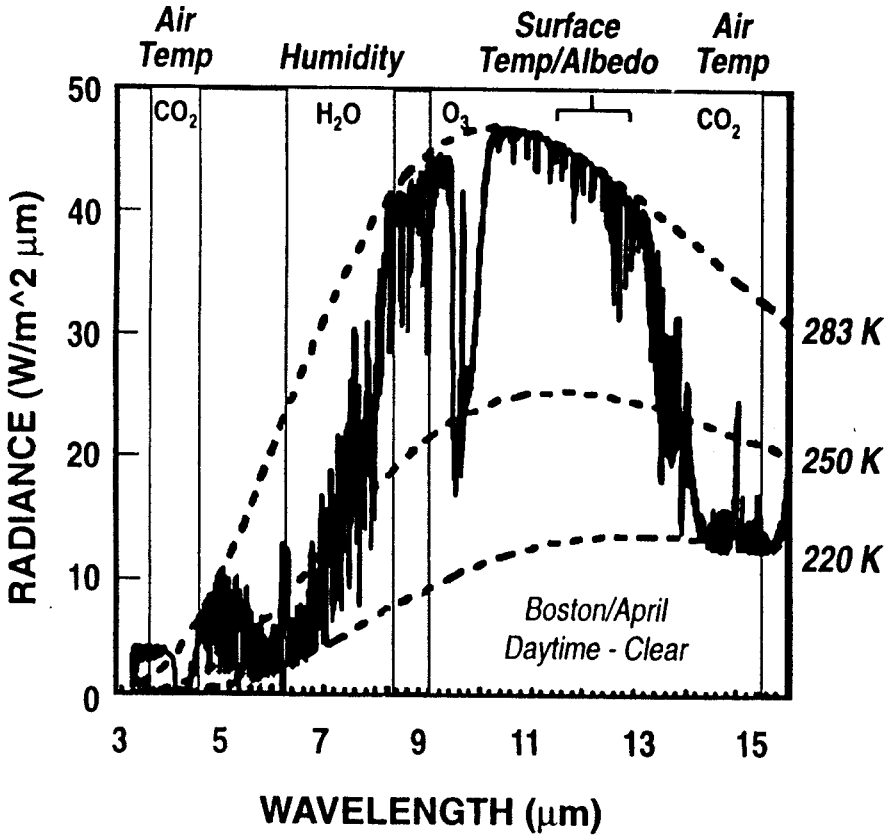
- **Packaging**
  M. Fitzsimmons
  R. Wilson

System Entrance Pupil/FPA Relationship



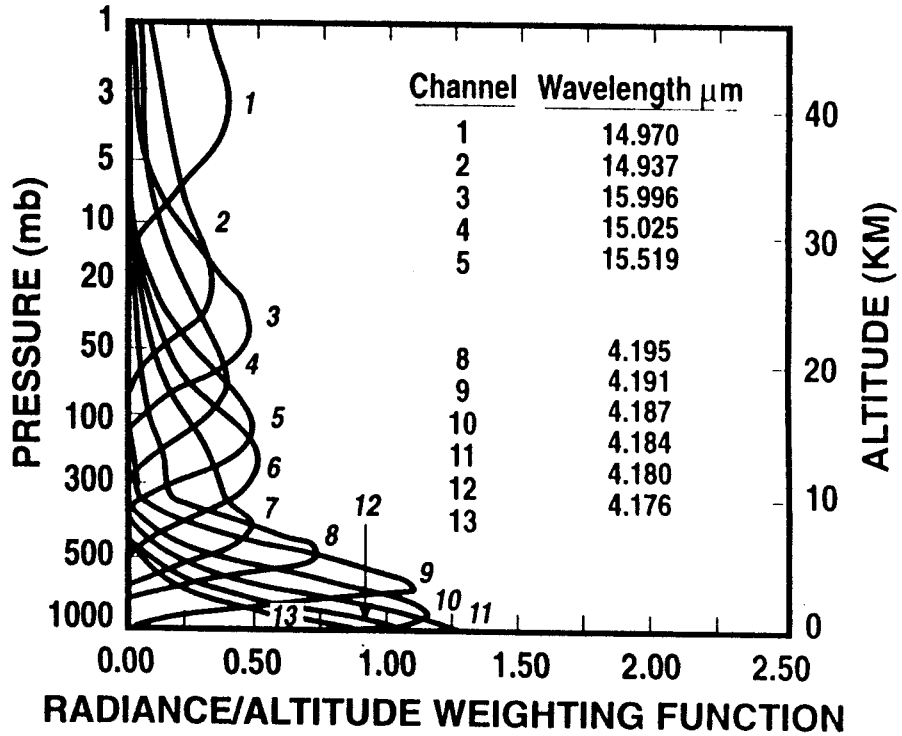
Atmospheric Temperature Retrieval
Obtained Through Passive IR Remote Sensing

Upwelling Radiance Measurement

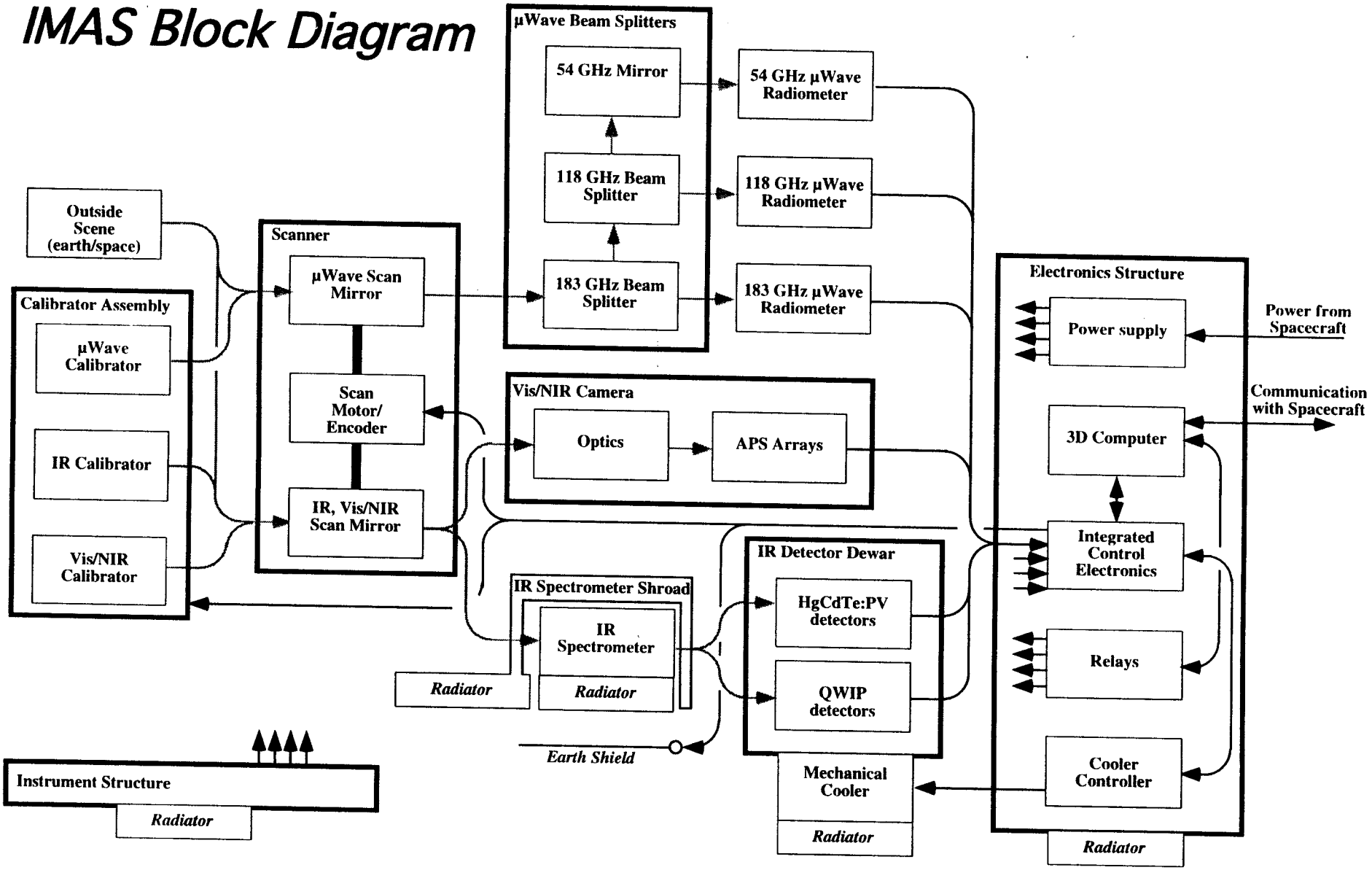


Note: Shaded Areas are NOT Covered by AIRS

High Spectral Resolution Sampling of CO_2 Signature Provides 1 km Height Resolution



IMAS Block Diagram



INTEGRATED MULTISPECTRAL ATMOSPHERIC SOUNDER (IMAS)

Goals:

- Develop Next Generation of Atmospheric Infrared Sounders (AIRS) via Integration, Technology Infusion and Spectrometer Optimization
- Satisfy Satellite Temperature and Humidy Sounding Requirements for the 21 st Century

Approach:

- Reduce Weight, Power, Size, Data Rate and Development Time
- Retain Critical AIRS Design Heritage

* *Inverstigate Promising Upgrade Technologies Such as Quantum Well Infrared Photodetectors (QWIPs)*

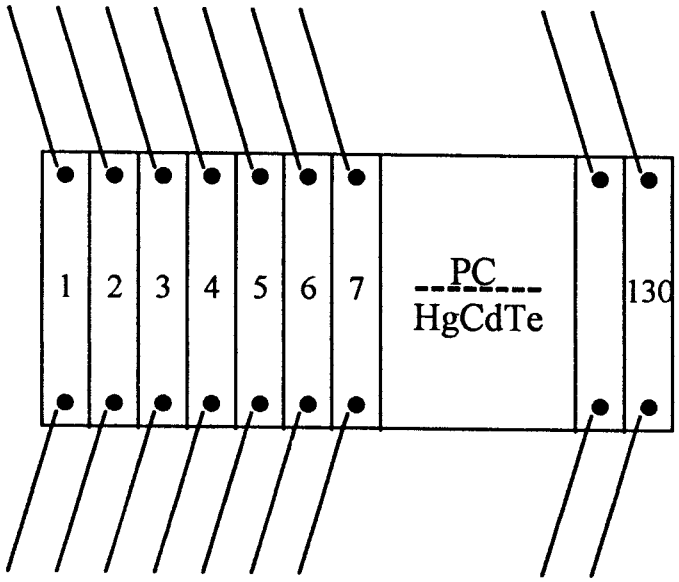
REPLACE PC HgCdTe DETECTORS with MULTIPLEXED FPAs

- Utilize Hybrid Focal Plane Arrays
  - Indium Bump Interconnect
  - Preamp Under Detector Array

- Advantages
  - Replace ~ 300 Leads Off Cold Plate with ~ 20
  - Reduce Cooler Heat Load
  - Eliminate 6 PC Off FPA Preamp Cards
  - Reduce EMI Susceptibility
  - Eliminates 6 of 9 Cables into Dewar
  - Eliminates Chopper and Circuits
  - M11 and M12 Look Like Rest of IR FPAs

AIRS VLWIR PC HgCdTe Detector Arrays

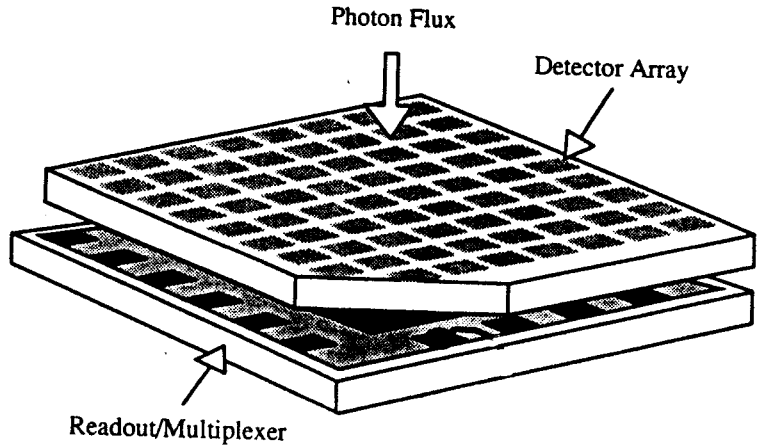
Module	Spectral Band (um)	Detector Material	Cutoff	Array
M11	13.74 - 14.55	HgCdTe	~16.5	1 x 144
M12	14.67-15.40	HgCdTe	~17.1	1 x 130



- 50 x 800 μm unit cells
- front side illuminated
- R ~ 700 ohm / detector
- chopper required
- 1 wire bond / detector
- > leads off FPA
- pre amps off cold plane

IMAS QWIP FPA

Module	Spectral Band (μm)	Detector Material	Cutoff	Array
M11	13.74-14.55	GaAs/ AlGas	~15	2 x 144
M12	14.67-15.40	GaAs/ AlGas	~16	2 x 130



QWIP FPA DEVELOPMENT APPROACH

- Enhance Quantum Well Infrared Photodetector (QWIP) Array Performance
  - Refine Device Design
  - Design/fab 2-dimensional Gratings
  - Develop and Incorporate Monolithic Microlens Arrays

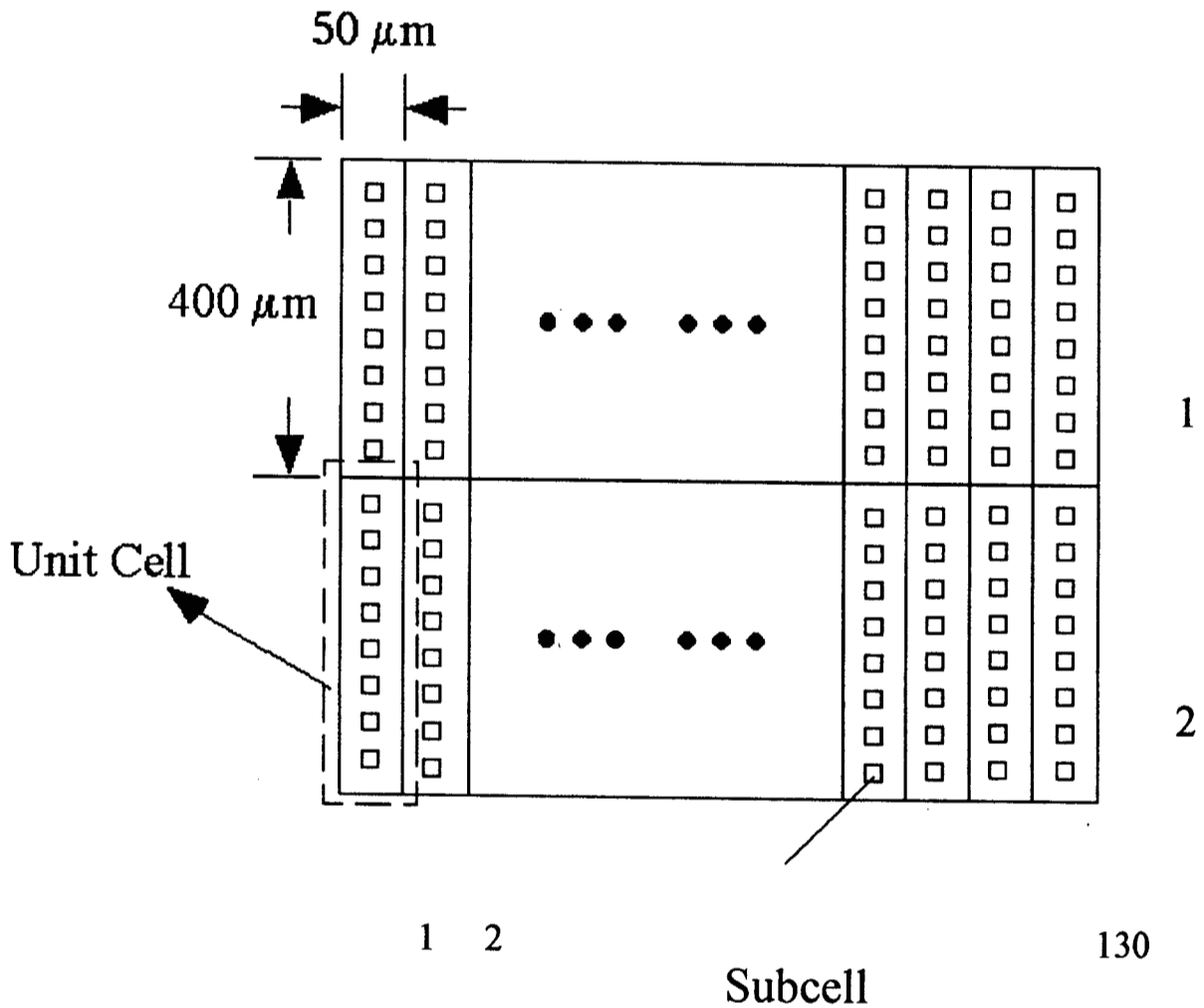
- Design QWIP Readout Integrated Circuit (ROIC)
  - Optimize for VLWIR QWIPs and High Photon Backgrounds
  - Utilize External Commercial CMOS foundry for IC fabrication

- Implement High Cell Count Indium Bump Interconnect Technique to Fab Direct Hybrid Focal Plane Array

IMAS QWIP FOCAL PLANE ARRAY

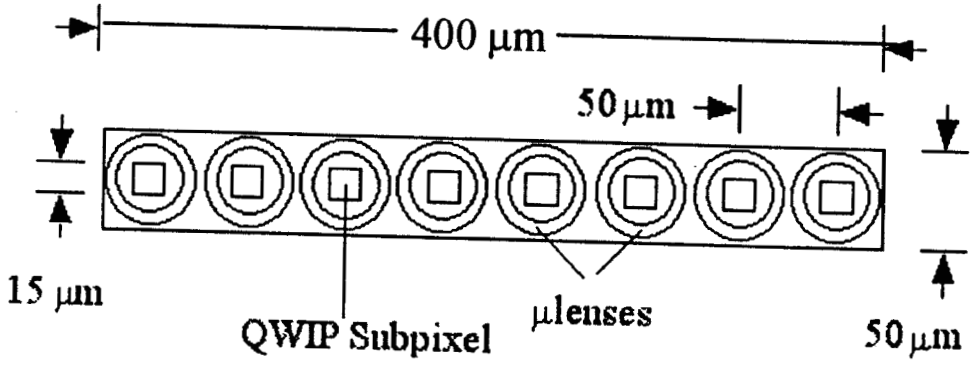
Detector Name:	Quantum Well Infrared Photodetector (QWIP)
Detector Type::	GaAs/AlGaAs Superlattice
Array Configuration:	2 x 130
Focal Plane Type:	Direct Hybrid
Wavelength Band:	14.67 to 15.4 μm
Detectivity	2 E11 cm rt Hz / W
Temp of Operation:	53 to 55 K
Unit Cell Size:	50 μm x 400 μm
Subcell Size:	50 μm x 50 μm
# Subcells / Unit Cell:	8
One Subcell :	One Detector with Frontside Microlens and Backside 2-d Grating
Detector Size:	15 μm x 15 μm

2 x 130 QWIP Detector Array

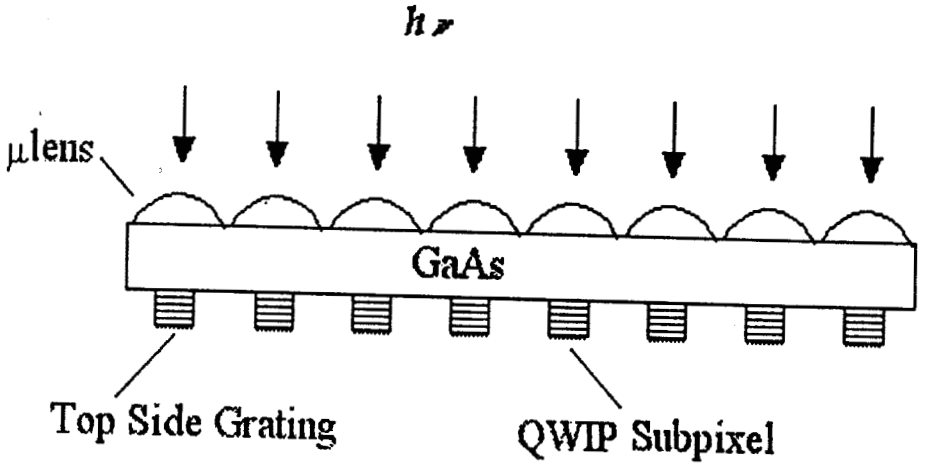


SINGLE PIXEL QWIP DESIGN

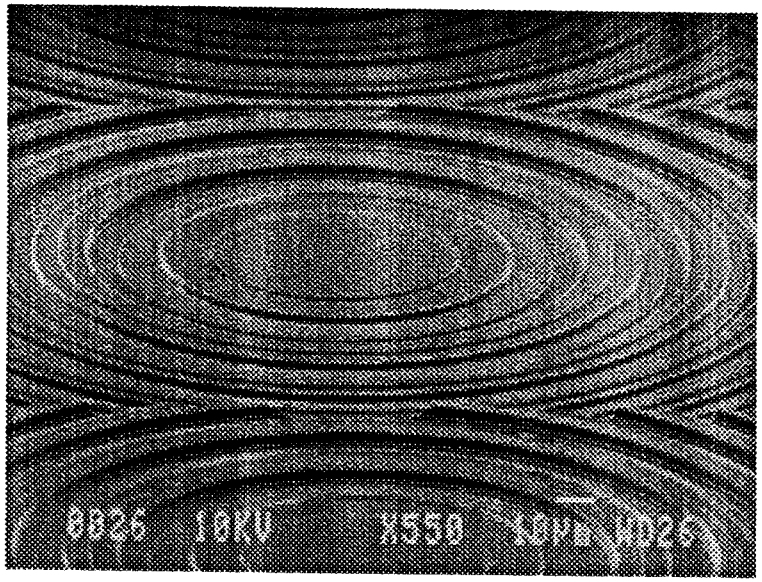
- Top View
  - Set of 8 QWIP Active Areas per Pixel
  - Active Area of Subpixel is 15 μm x 15 μm
  - Subpixels on 50 μm Centers

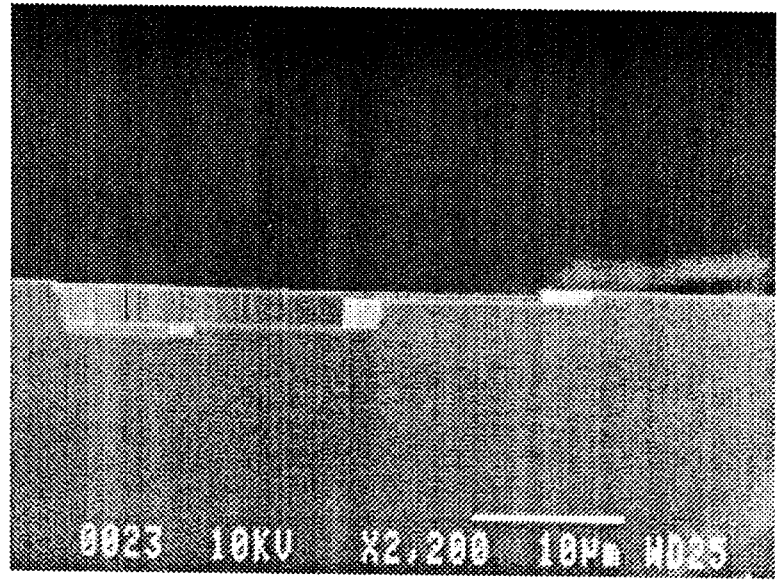


- Cross Section
  - μlens in GaAs on 50 μm Centers
  - Focuses on (15 μm)^2 QWIP Active Area
  - Gratings Improve QE



SUCCESSFUL DEMO OF MICROLENS TECHNOLOGY IN GaAs

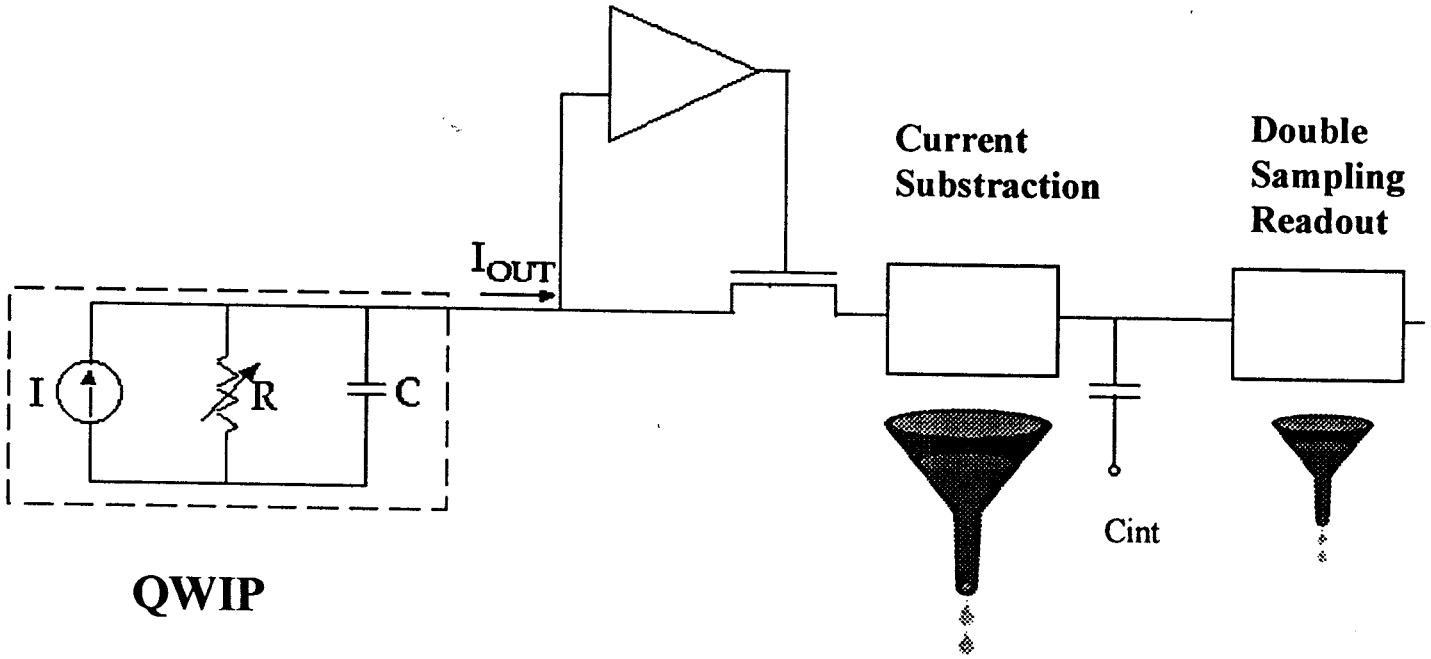




- 250 μm μlenses on Backside of GaAs QWIP Detectors

- 4 Level Binary Lens Cross Section

BACKGROUND SUBSTRACTION for QWIPs



CURRENT MODE PEDESTAL SUBSTRACTION

- Calibration Mode
  - Memorize Dark and Background Current While Looking at Space

- Signal Read Mode
  - Sensor is Looking at the IR Signal, QWIP Output Includes Dark Current, Background Photon Flux, and IR signal
  - Substract the Memorized Current from Input Signal

- Subsample Charge at an Integration time of 1.401 msec

Dark Current (Q_d):	1.2×10^9 electrons
Background Photon Flux (Q_{ph}):	3.0×10^7 electrons
IR Signal (Q_{sig}):	1.8×10^5 electrons

QWIP DEVELOPMENT PROGRAM STATUS

- Test QWIP Devices Fabricated and Evaluated from 2 Lots
  - Lot 1 Calibration Material Run
  - Lot 2 Initial Design Iteration

- Additional Iterations of QWIP Detector Material/Device Fab Planned

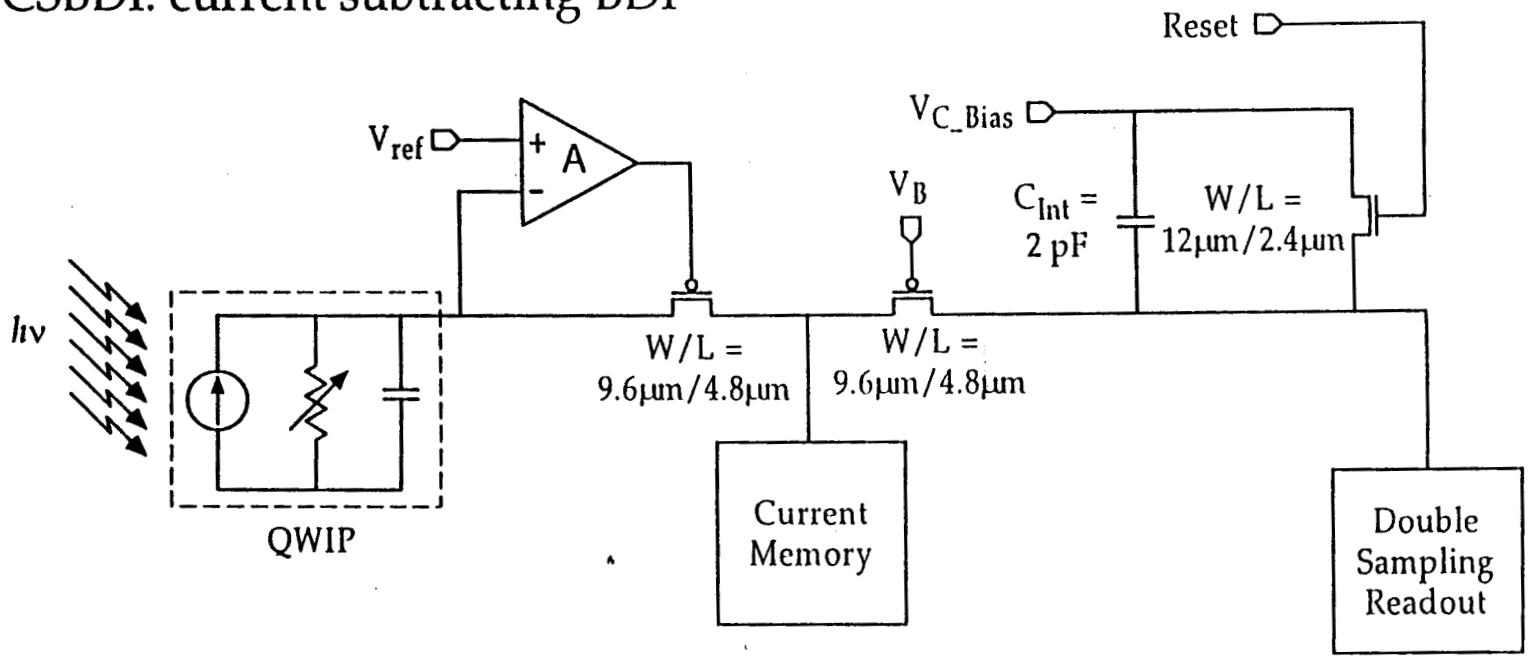
- Readout Current Memory/Substraction Concept Implemented into CMOS Test Devices
  - Concept Demostrated Qualitatively
  - Quantitative Measurements in Progress

- 1 x 65 Readout Test Array in Fabrication

- Full QWIP/ROIC Focal Plane Evaluations Planned for Early FY98

CSBDI CIRCUIT DESIGN

CSBDI: current subtracting BDI



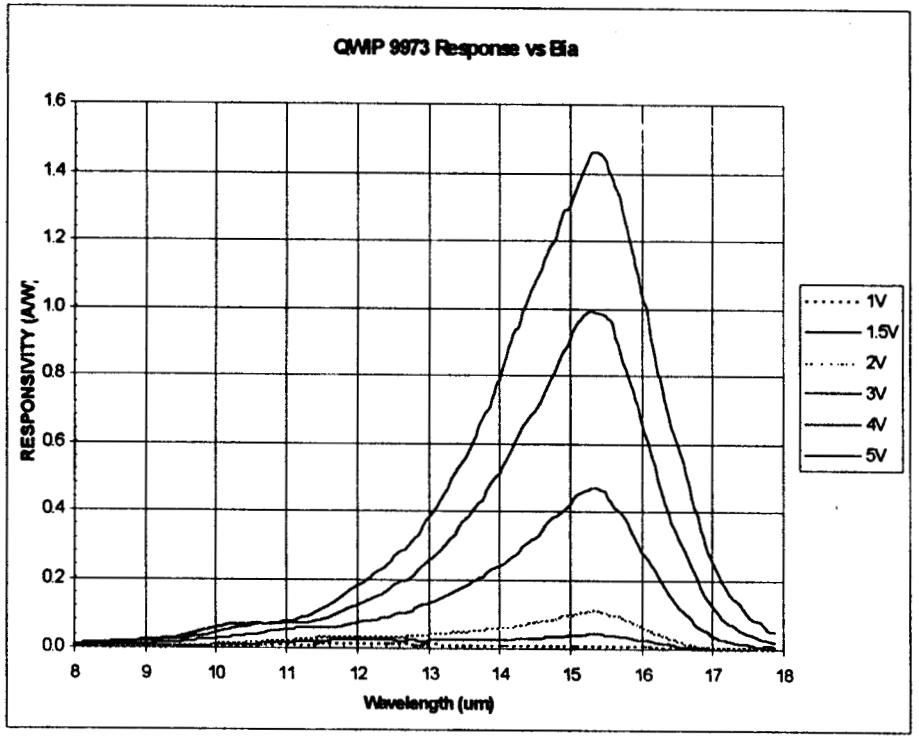
- **Pedestal removal:**

  current mode - before integrtion ~ 99%

  voltage mode - after integration ~ 99.9%

- **Shot Noise increases by 1.4**

RECENT QWIP WITH PEAK RESPONSIVITY AT 15.4 μm



- Lot 2 Detectivities Range from 2E10 to 2E11 cm√Hz /W
- Peak λ Range from 14 μm to 15.4
- λ Cutoffs Range from 14.7 to 16.3 μm