Imaging interferometer using dual broadband quantum well infrared photodetectors.

Francis Reininger, Sarath Gunapala, Sumith Bandara, Mike Grimm, Dean Johnson, Dan Peters[1], Scott Leland, John Liu, Jason Mumolo, Don Rafol, Ian Thomas[2], David Ting, and Dan Wilson

The Jet Propulsion Laboratory is developing a new imaging interferometer that has double the efficiency of conventional interferometers and only a fraction of the mass and volume. It uses a 512 x 640 pixel, dual broadband Quantum Well Infrared Photodetector (QWIP) array to scan interferograms digitally without moving any optical components. The interferograms can either be convolved with pre-programmed matched filters to detect chemical vapor signatures in real-time, or they can be Fourier transformed into observational spectra extending from 6 – 15 microns. The instrument is small enough to fly on an unmanned aerial vehicle, and it is stable enough to measure fluctuating target signatures from unstable platforms. The project is being funded by part of the Defense Advanced Research Projects Agency (DARPA) Photonic Wavelength And Spatial Signal Processing program (PWASSP).

The Spatially Modulated Prism Interferometer (SMPI) is a new type of imaging interferometer that has double the efficiency of conventional interferometers and only a fraction of the mass and volume. Its spectral resolution is independent of wavelength and slit width, an attribute made possible by generating interferograms at a pupil plane. It uses a large format, broadband Quantum Well Infrared Photodetector (QWIP) array to scan the interferograms digitally without moving any optical components. This enables the interferometer to make accurate measurements of target scenes that fluctuate during the scan period. Applications include detecting water sources on Mars, monitoring global warming and ozone depletion on Earth, monitoring pollution in cities, detecting chemical agents on the battlefield, and warning commercial aircraft of volcanic erruptions.

1. General Atomic Photonics Division.
2. Cardiff University

Program Objectives

- Develop and demonstrate a flash interferometer capable of detecting chemical agents at a spectral interval of 1.7 cm^{-1} across a 20° FOV.
- Develop a 512 x 640 pixel, dual broadband Quantum Well Infrared Photodetector (QWIP) that is simultaneously sensitive at 6 – 10 μm and 10 – 14.5 μm.

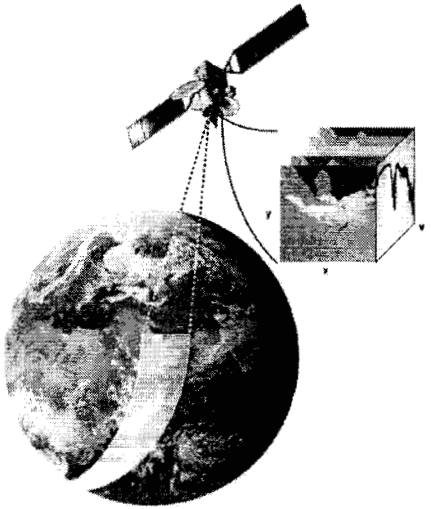
Technical Accomplishments

- Demonstrated the first dual broadband QWIP detector element.
- Increased the QWIP spectral bandwidth by a factor of 4.
- Increased the broadband QWIP detectivity by a factor of 3 with sharper wavelength cutoff using a new intermixed quantum well structure.
- Demonstrated the largest long-wavelength broadband (10 – 16.5 μm) and four-color narrowband detector arrays, each with 512 x 640 pixels.

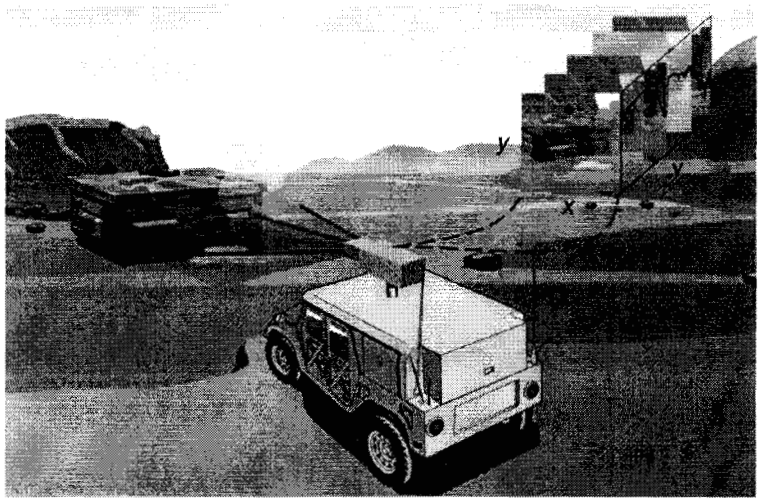
FY03 Milestones

- 1/31/03: Deliver the first dual broadband QWIP with 512 x 640 pixels.
- 9/30/03: Demonstrate a thermal infrared, flash interferometer with a factor of 10 resolving power improvement and factor of 4 FOV improvement over existing imaging spectrometers.

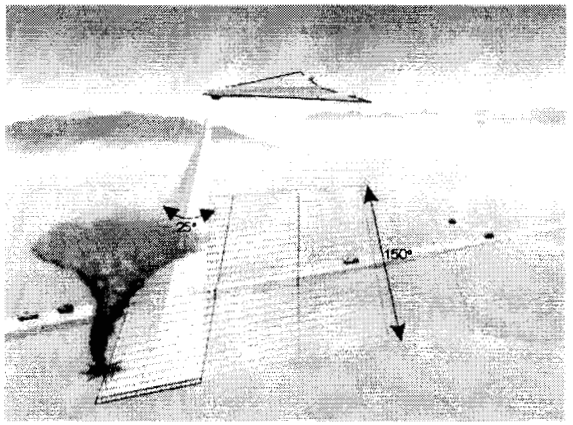
Chemical Effluents & Weather Prediction



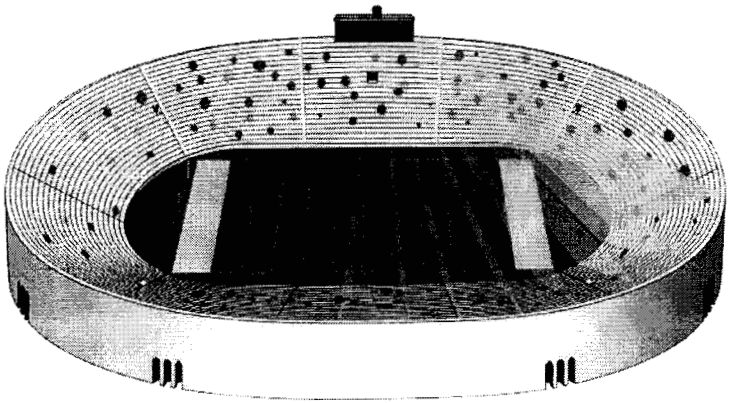
Liquid Nerve Agents



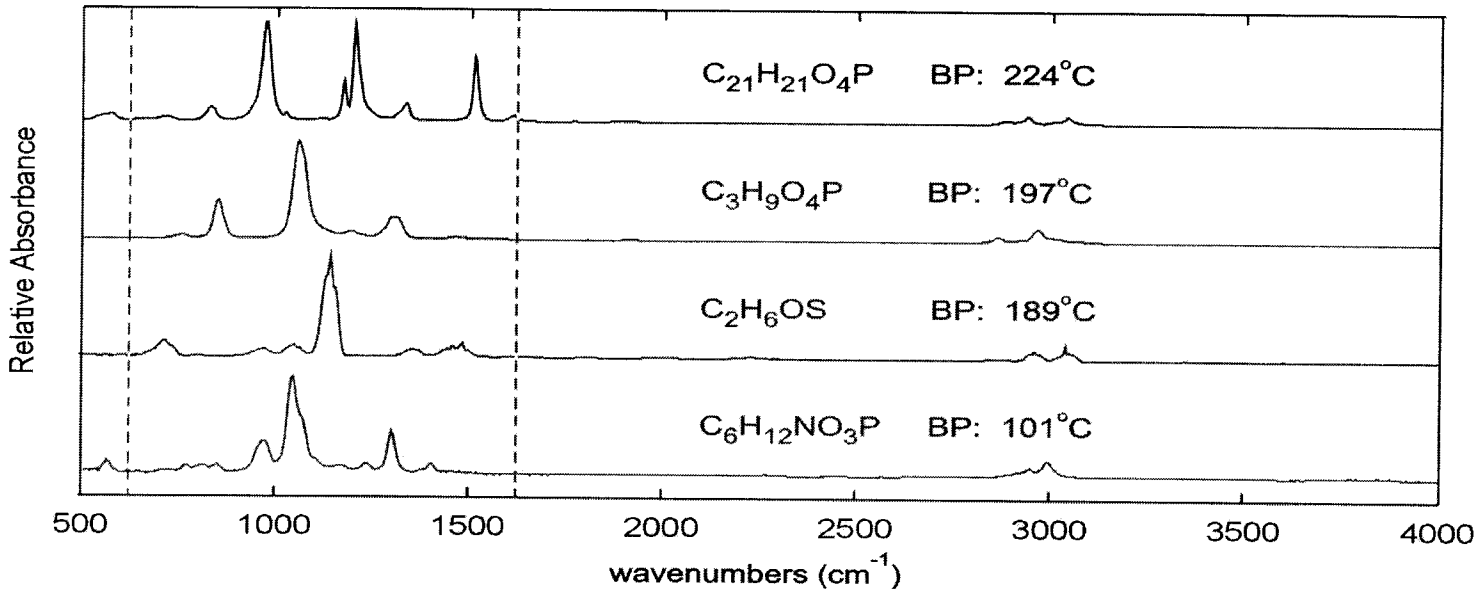
UAV: Chemical Explosives



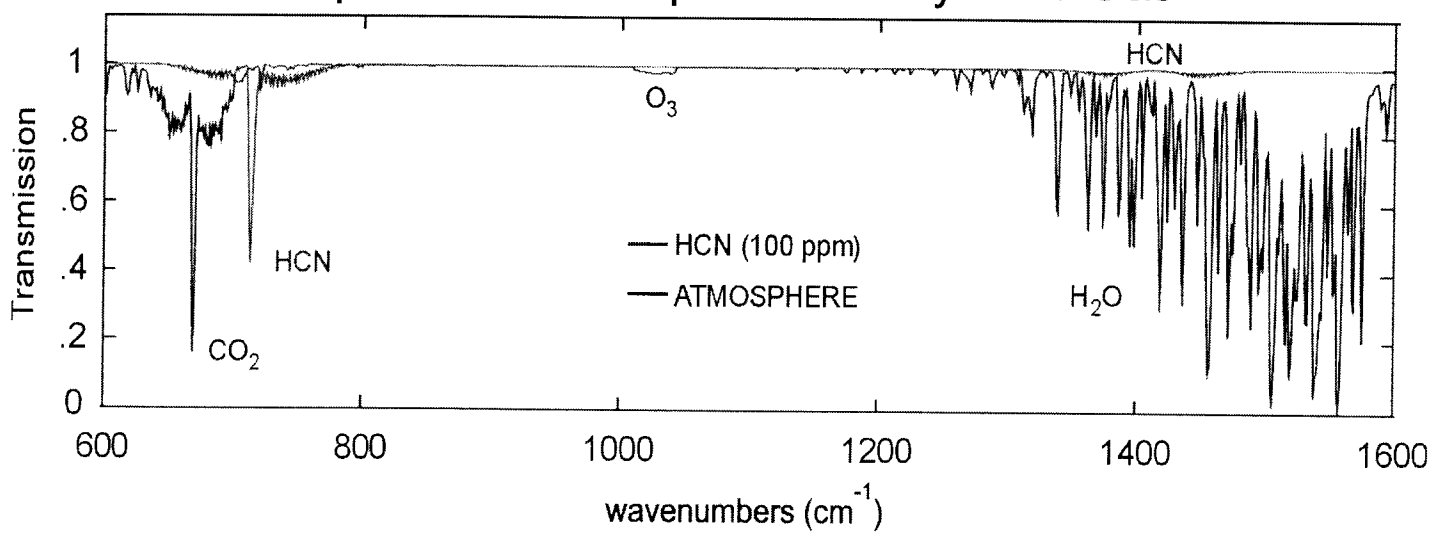
Homeland Defense

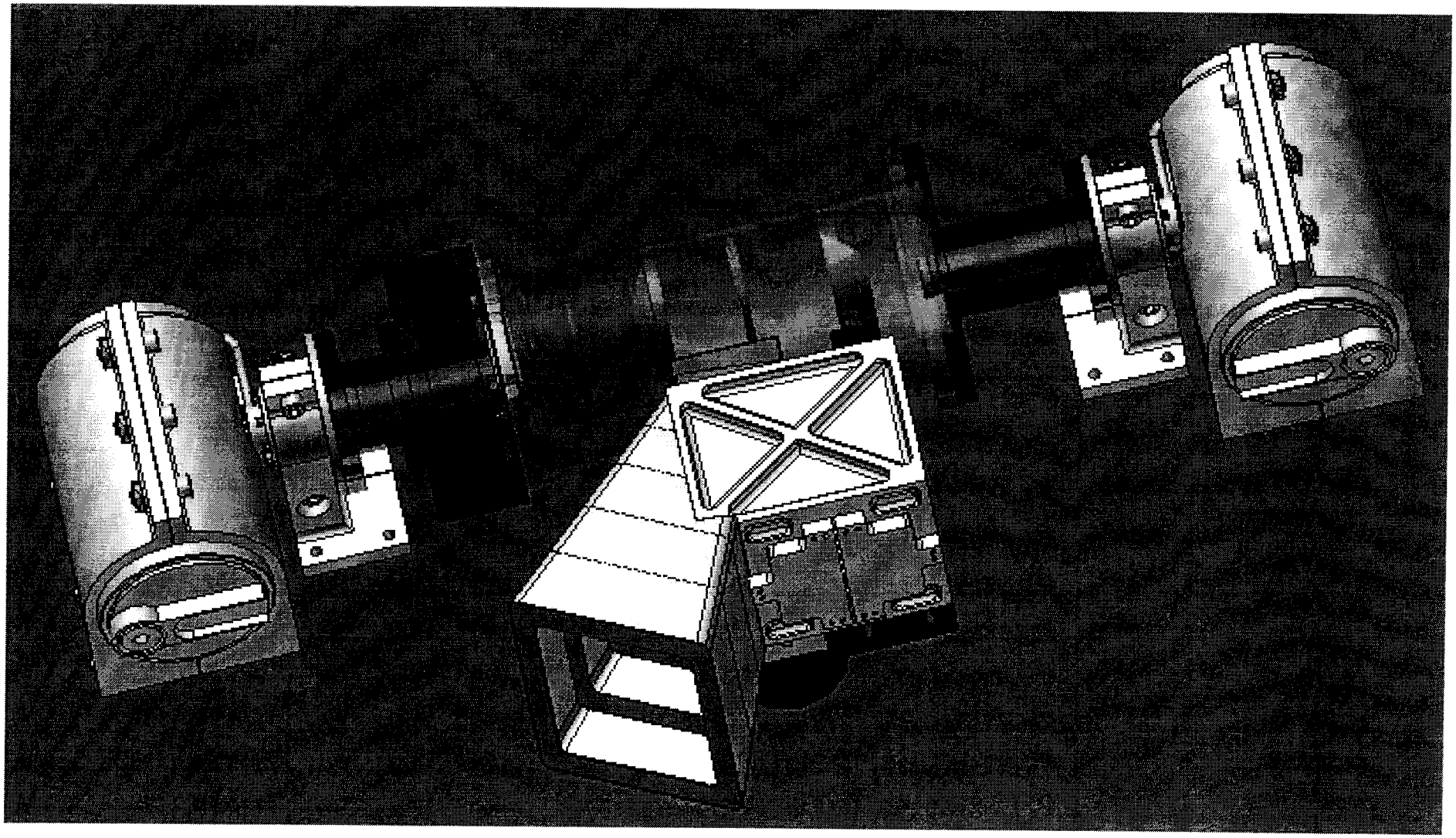


Spectra of Nerve Agent Simulants

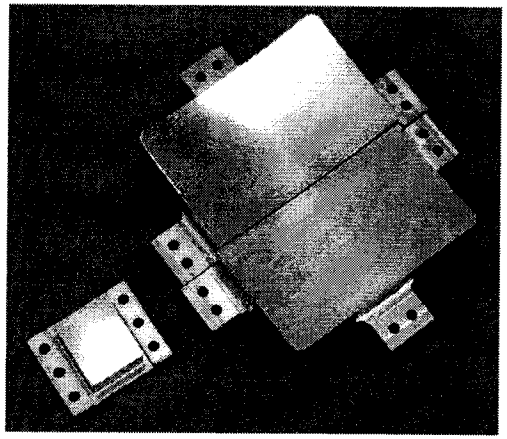


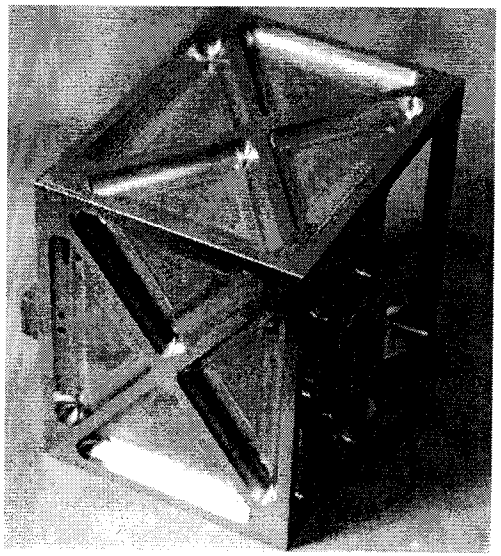
Spectra of Atmosphere and Cyanide Gas



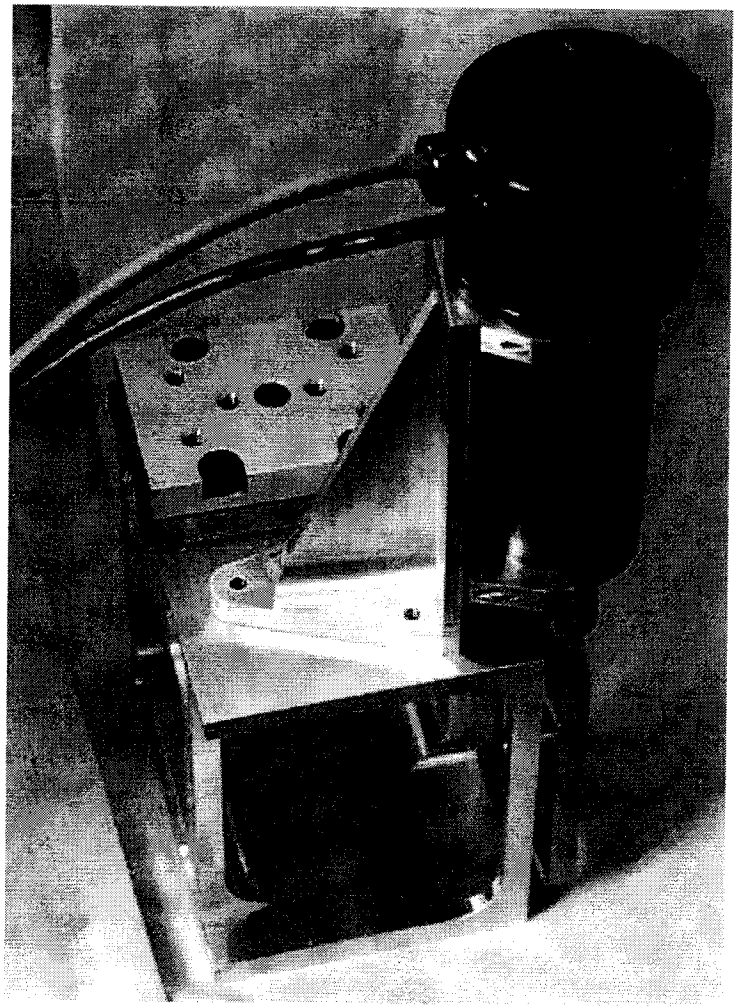


Mirror Blanks and Housing

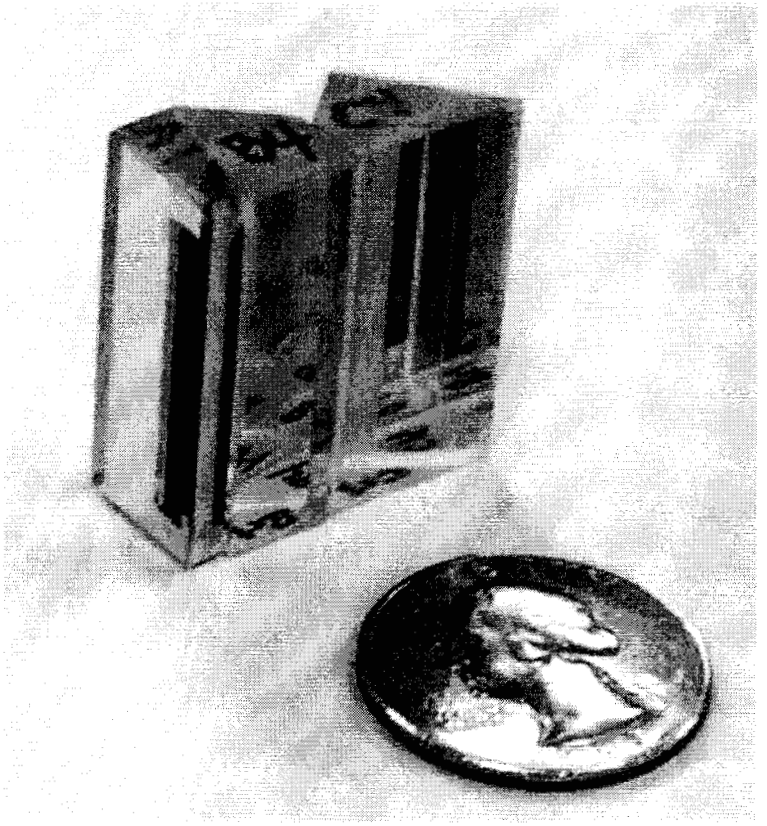




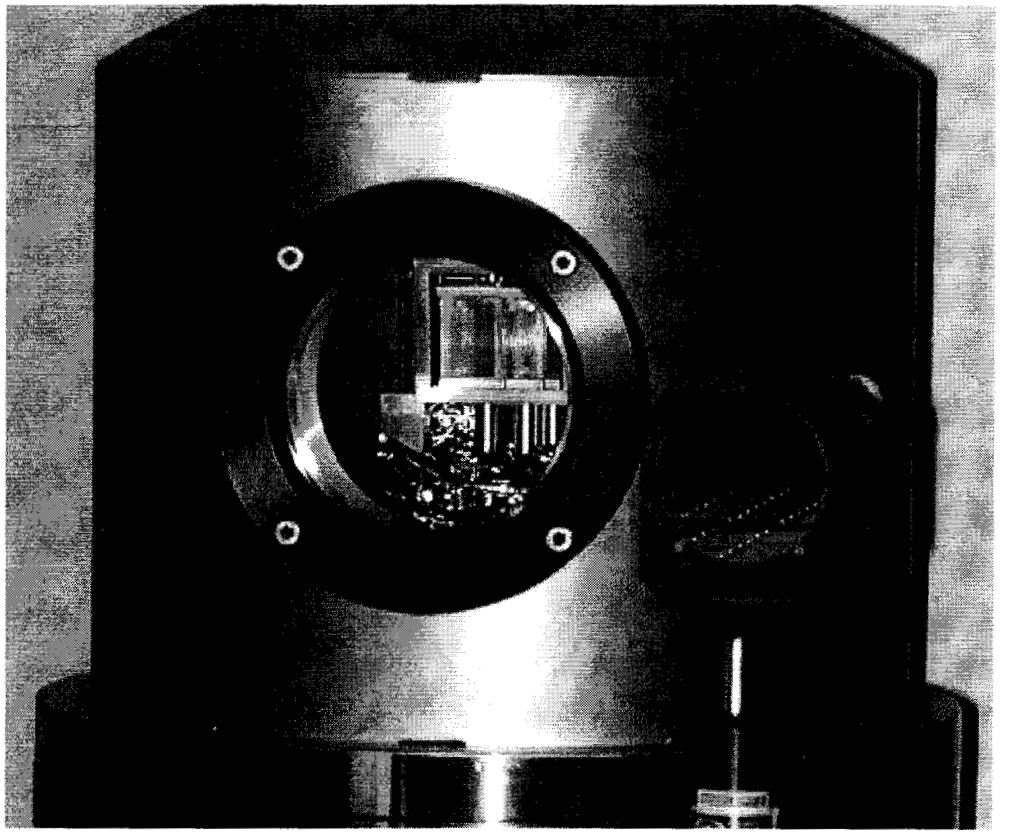
Telescope Assembled with Scanner



Prism Triplet Polished and Coated



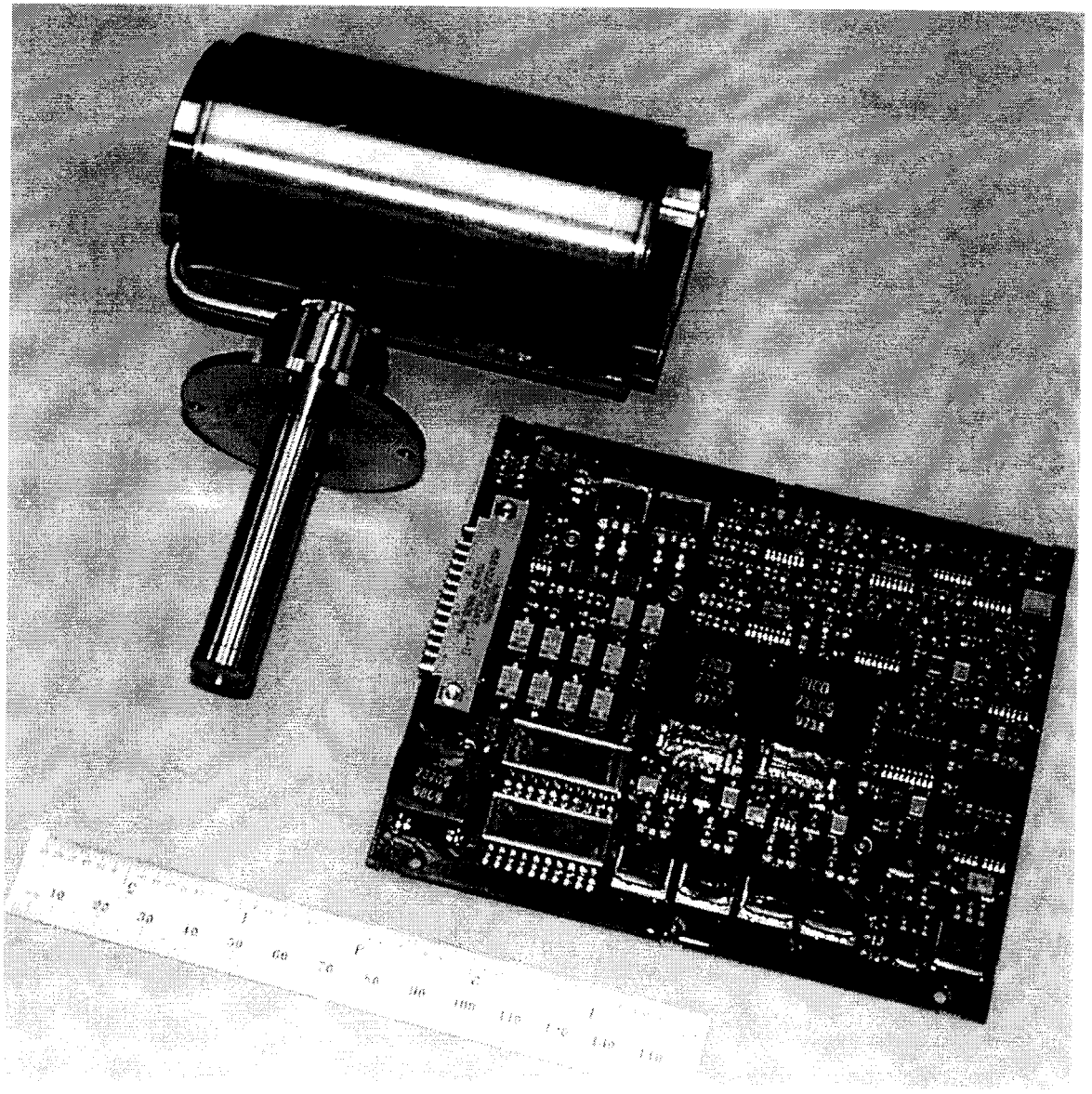
Prism Alignment Verification at 200 K



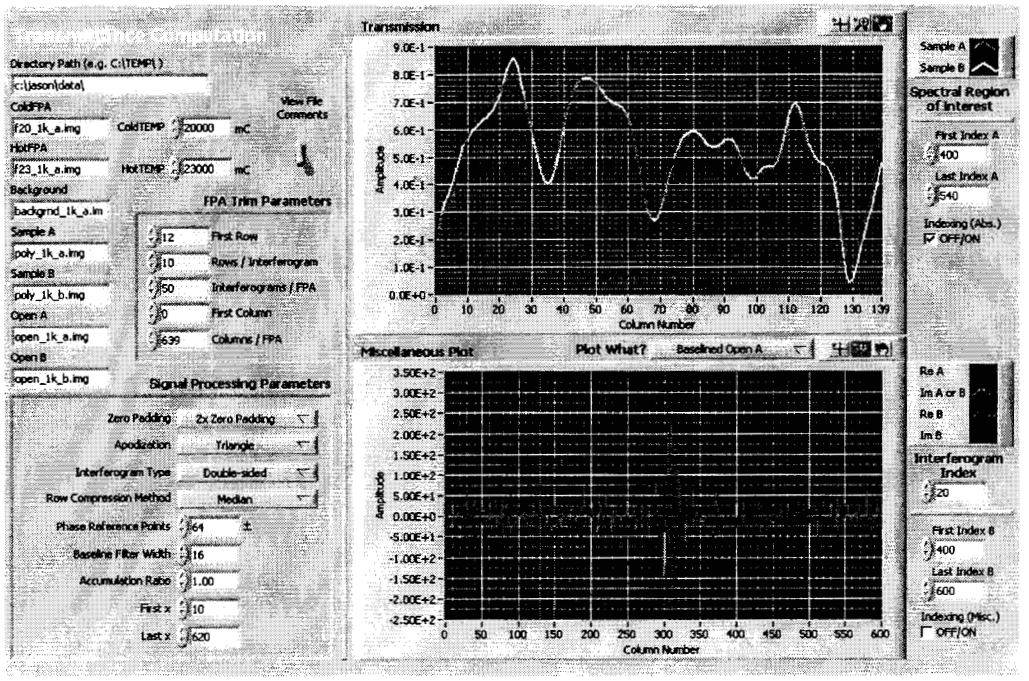
- One cryo-cooler will cool the QWIP FPA to 50 K.

- The other cryo-cooler will cool the interferometer optics to 200 K.

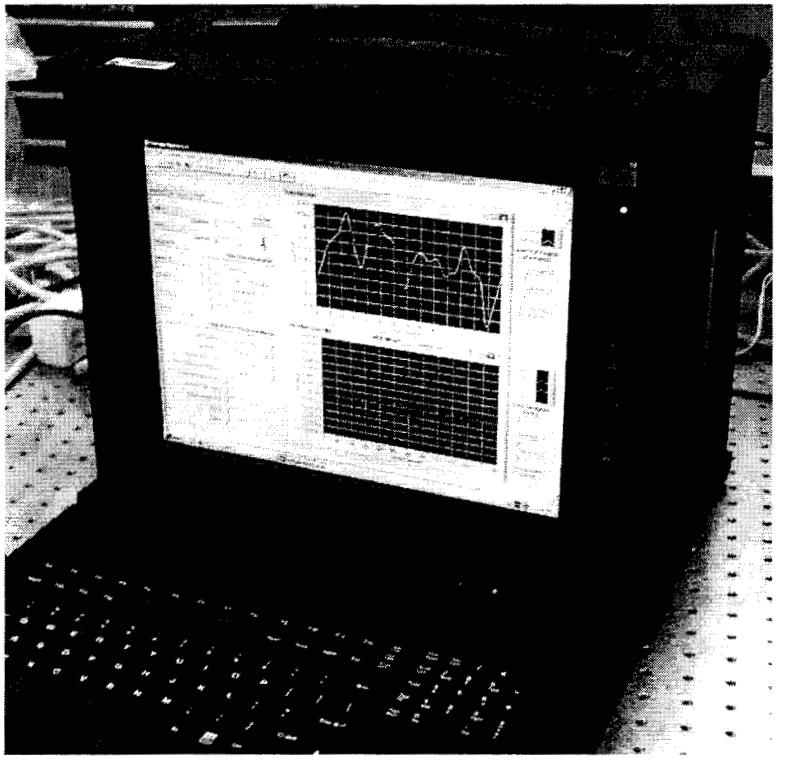
- Both cryo-coolers have undergone successful temperature cycling tests.



Instrument Control Panel



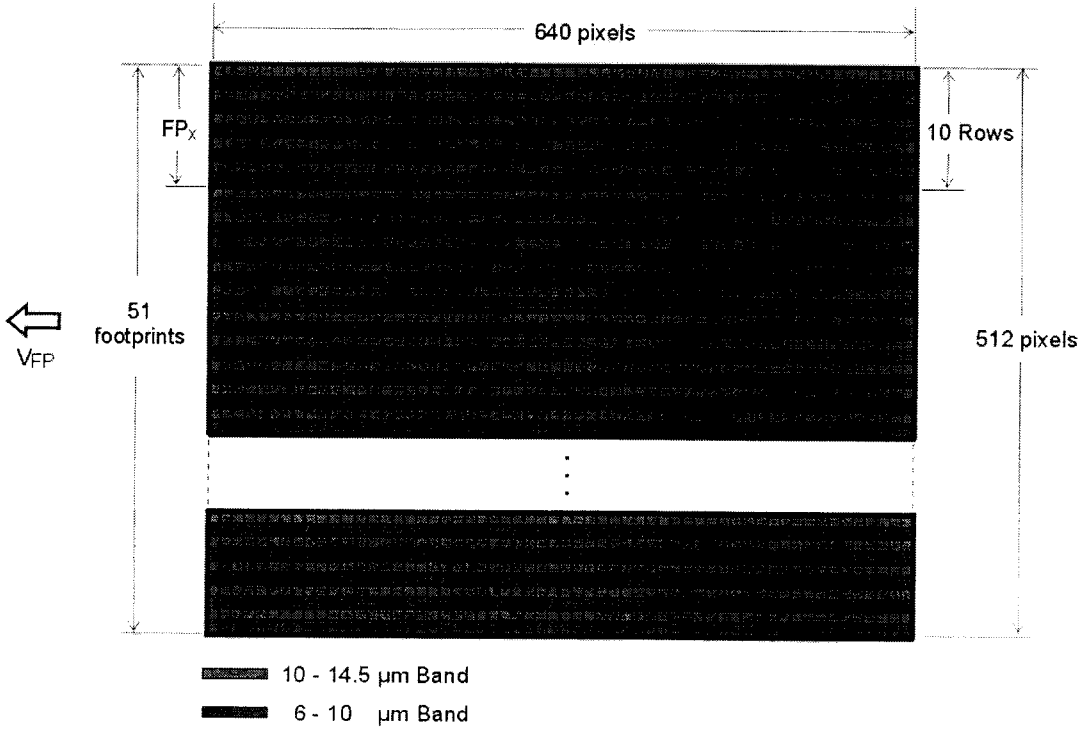
Hardened Field-Go Computer



State of the art LWIR detector arrays:

TES	GIFTS
HgCdTe	HgCdTe
15.4 μm cutoff	14.5 μm cutoff
1 x 16 pixels	128 x 128 pixels
0.75 x 1.2 mm^2	5.12 x 5.12 mm^2

Interlaced Dual Band Layout



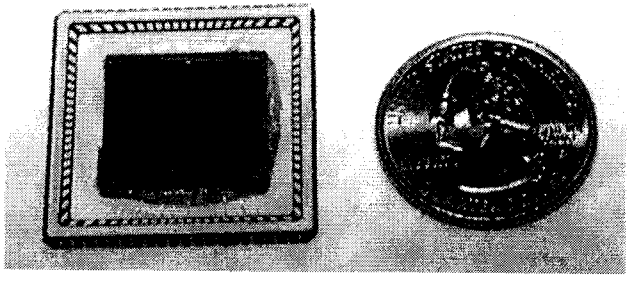
Broadband QWIP

InGaAs

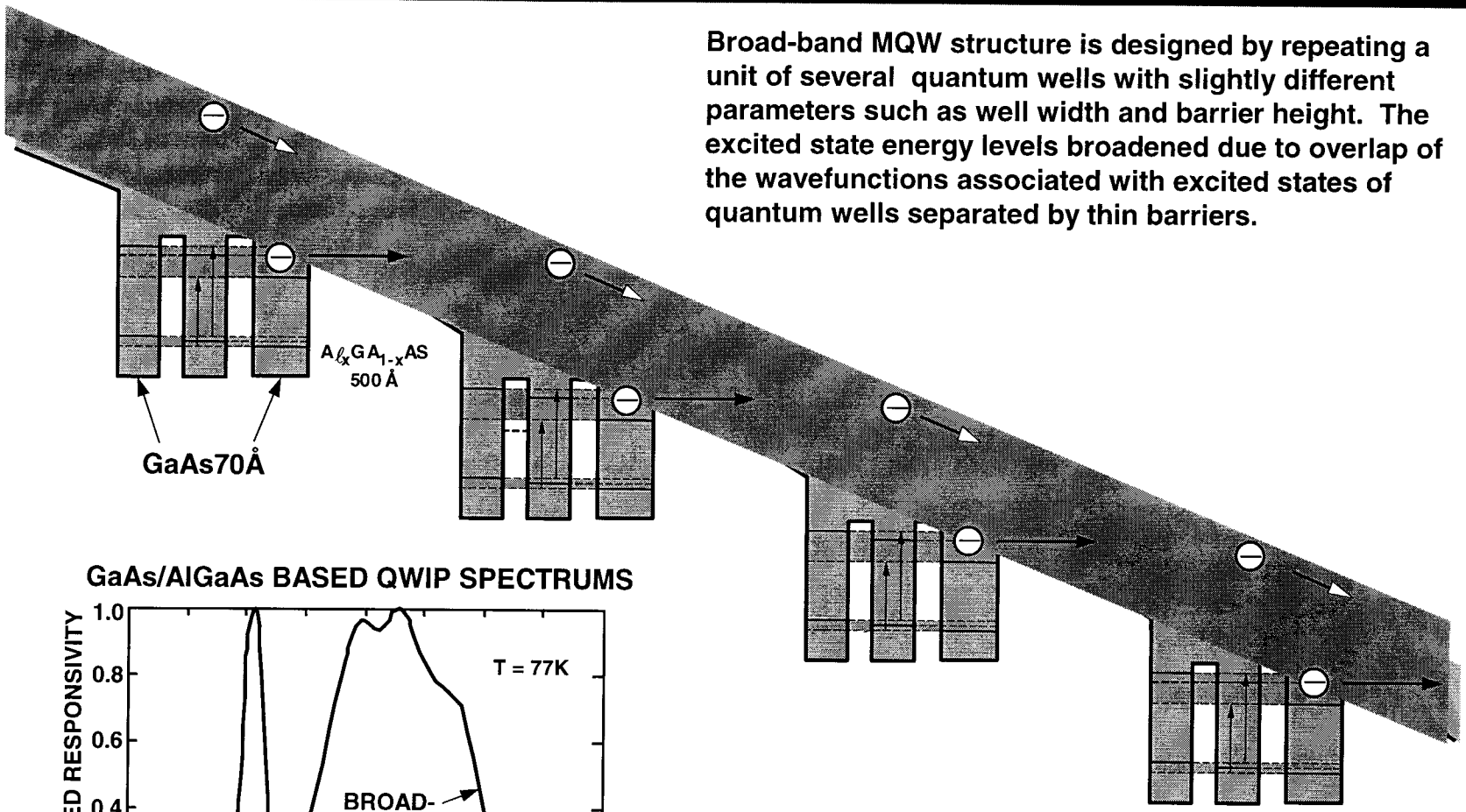
10 - 16.5 μm

512 x 640 pixels

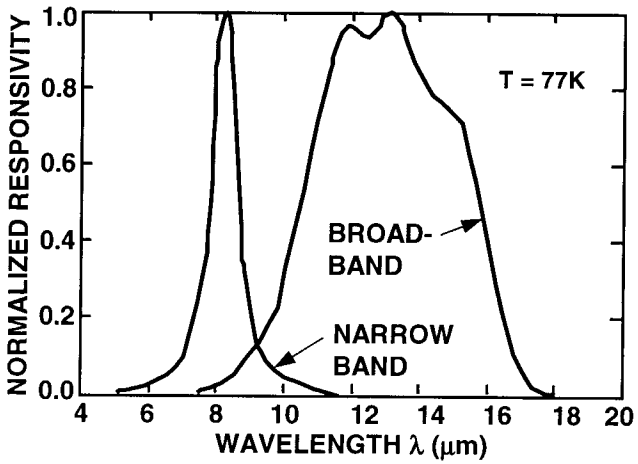
12.8 x 16 mm^2



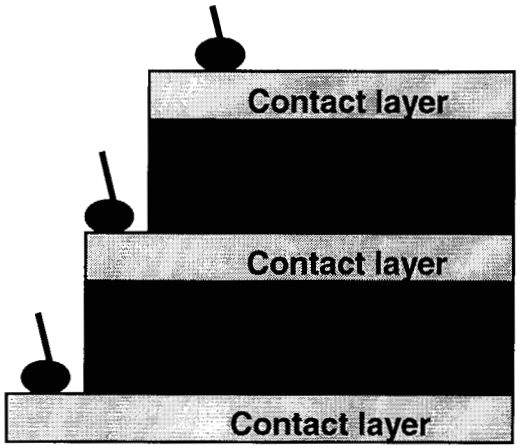
Broad-band MQW structure is designed by repeating a unit of several quantum wells with slightly different parameters such as well width and barrier height. The excited state energy levels broadened due to overlap of the wavefunctions associated with excited states of quantum wells separated by thin barriers.

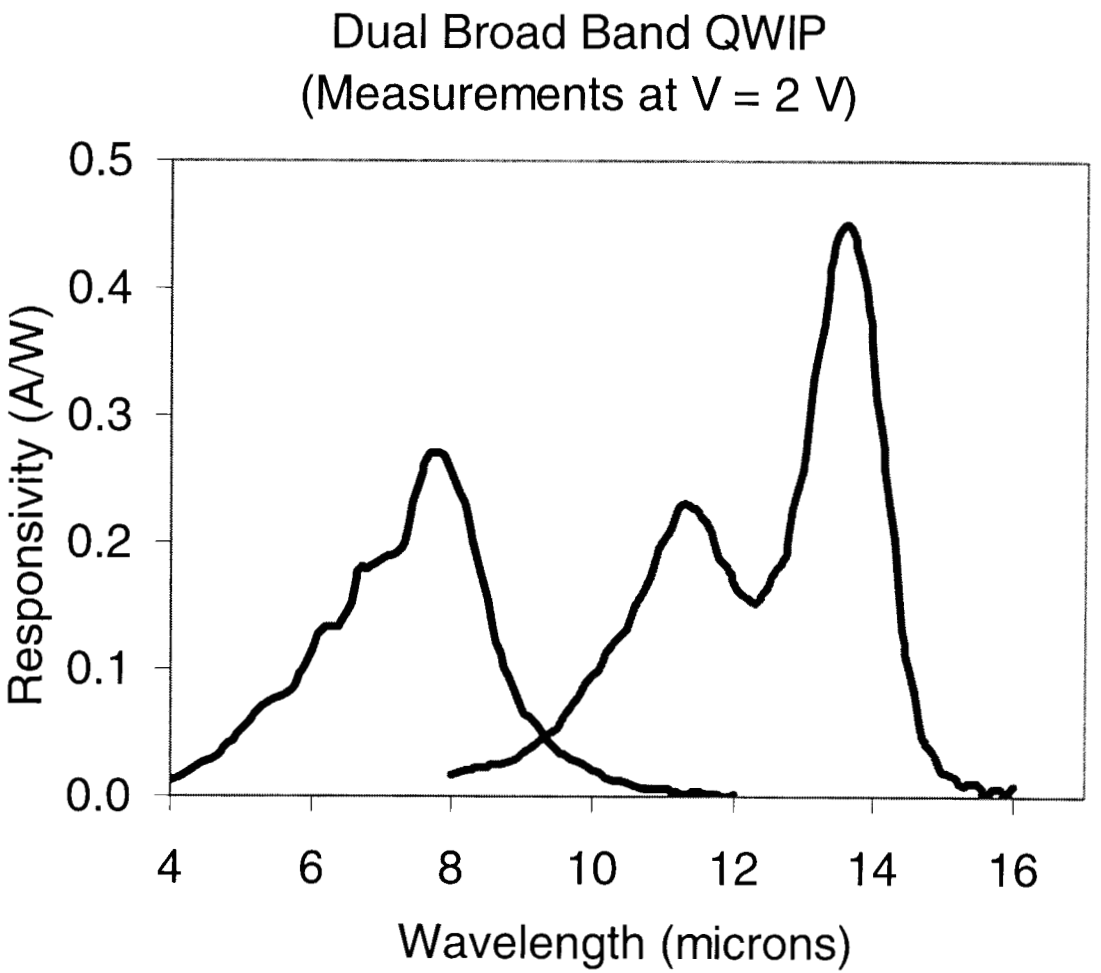


GaAs/AlGaAs BASED QWIP SPECTRUMS

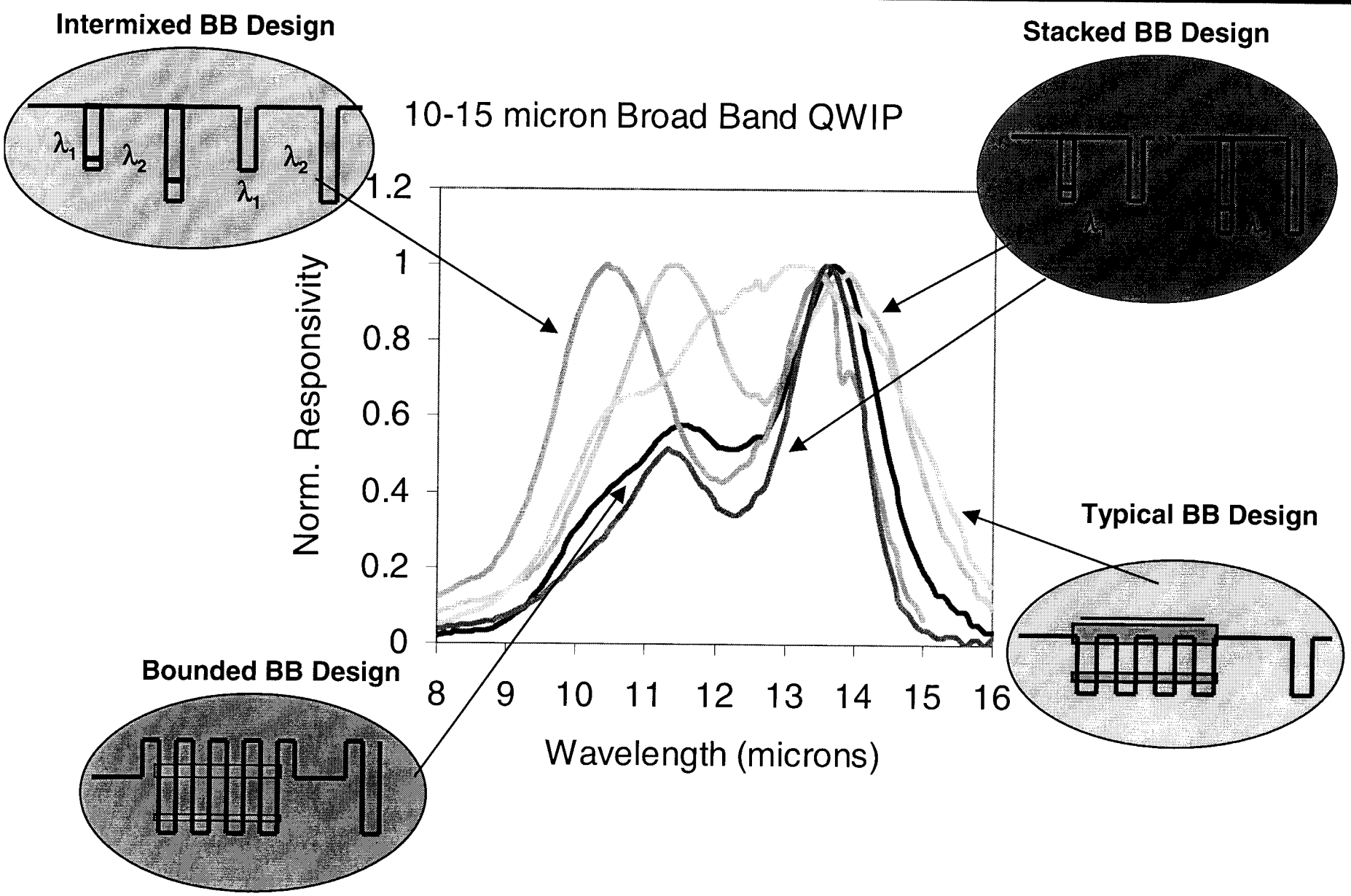


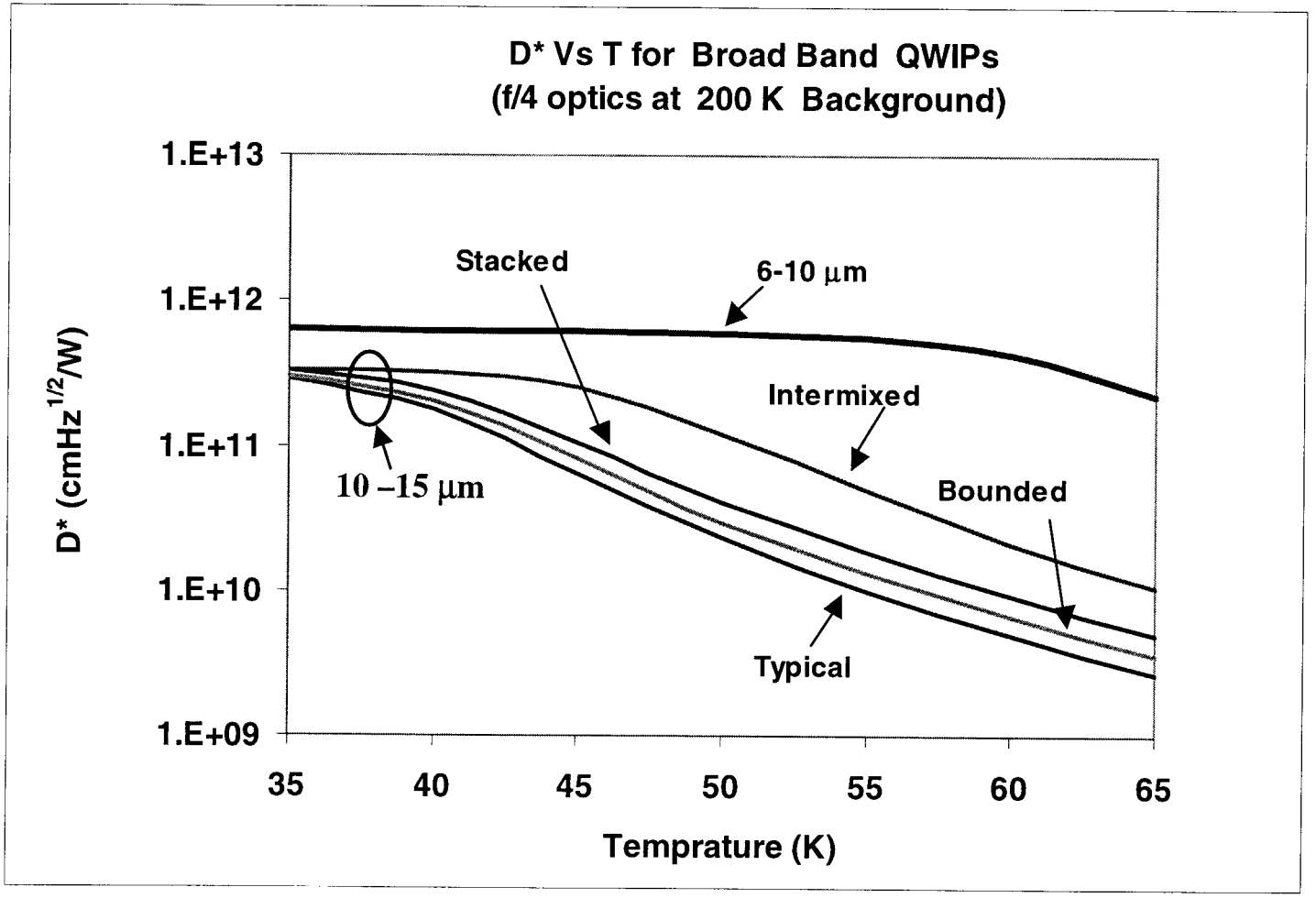
GaAs/AlGaAs BASED QWIP CAN COVER A VERY BROAD INFRARED (3-25 μm) REGION



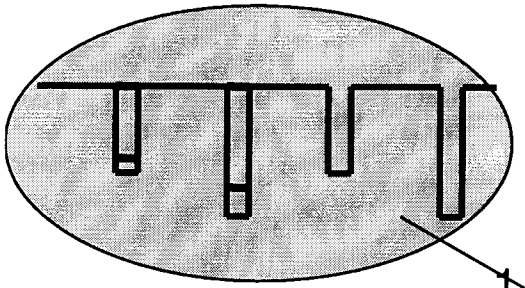


- Fabricated on a 3" GaAs Wafer.
- Use the stacked Broad-band Design.
- Need adjustment in the peak wavelengths

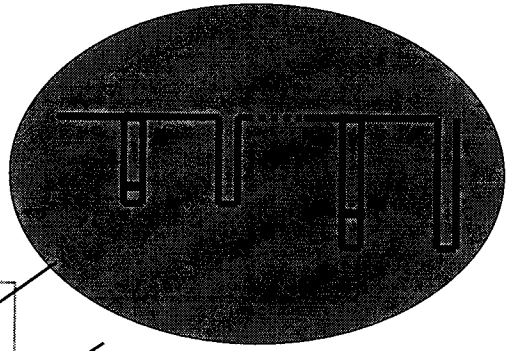

Intermixed BB Design
Stacked BB Design
10-15 micron Broad Band QWIP
Typical BB Design
Bounded BB Design
Norm. Responsivity
1.2
1
0.8
0.6
0.4
0.2
0
8
9
10
11
12
13
14
15
16
Wavelength (microns)


D* Vs T for Broad Band QWIPs
(f/4 optics at 200 K Background)
1.E+13
1.E+12
1.E+11
1.E+10
1.E+09
D* (cmHz^1/2/W)
Stacked
6-10 μm
Intermixed
Bounded
Typical
10 –15 μm
35
40
45
50
55
60
65
Temprature (K)

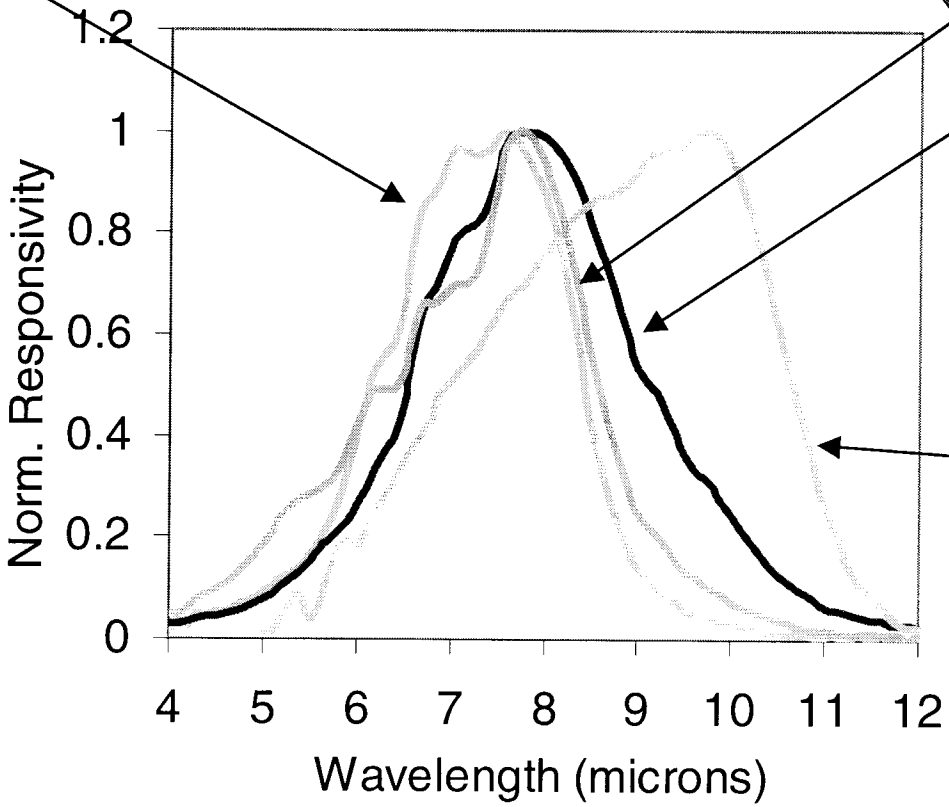
Intermixed BB Design



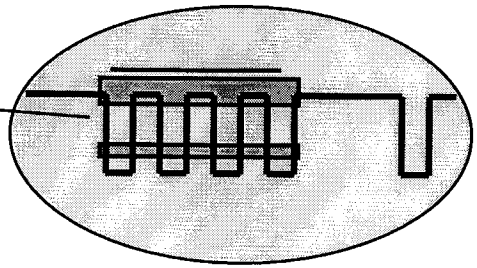
Stacked BB Design

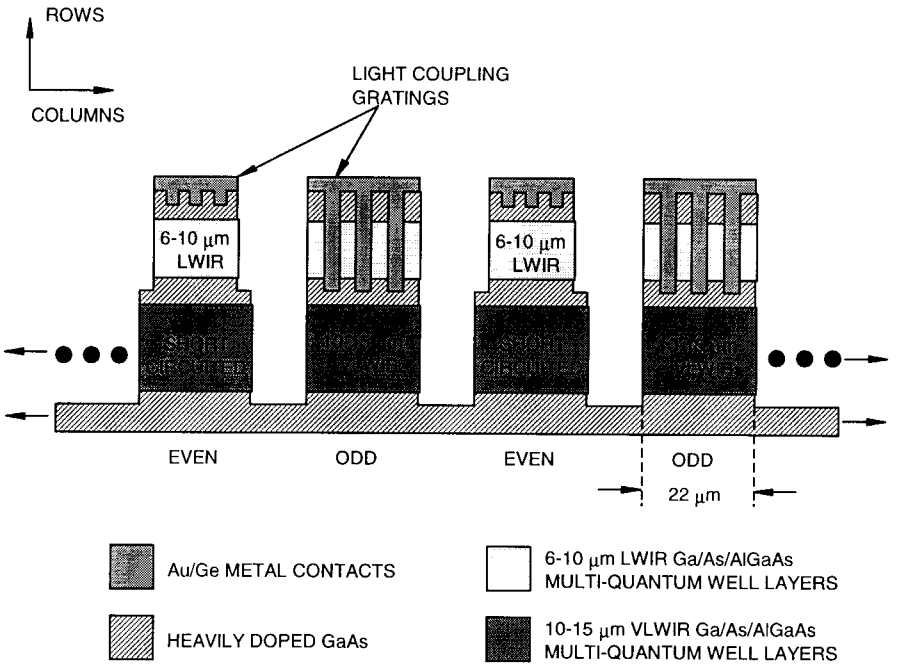


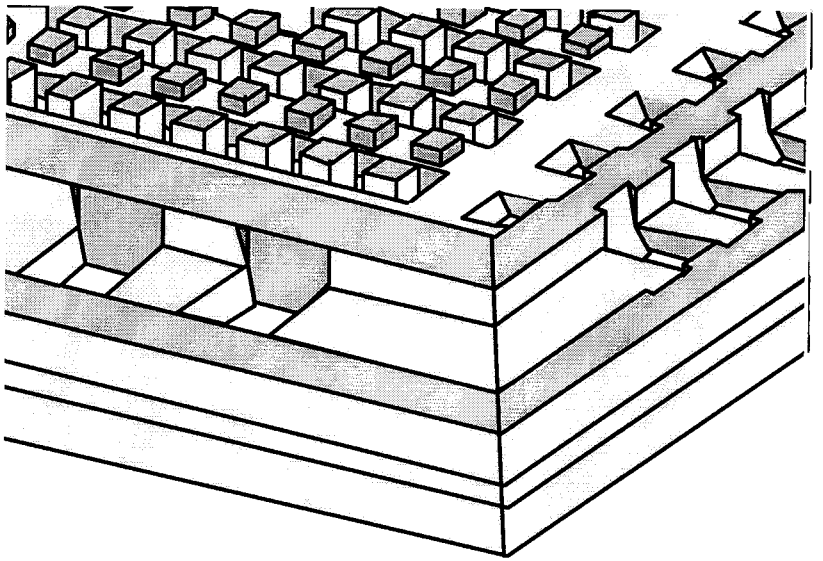
6 -10 micron Broad Band QWIP



Typical BB Design

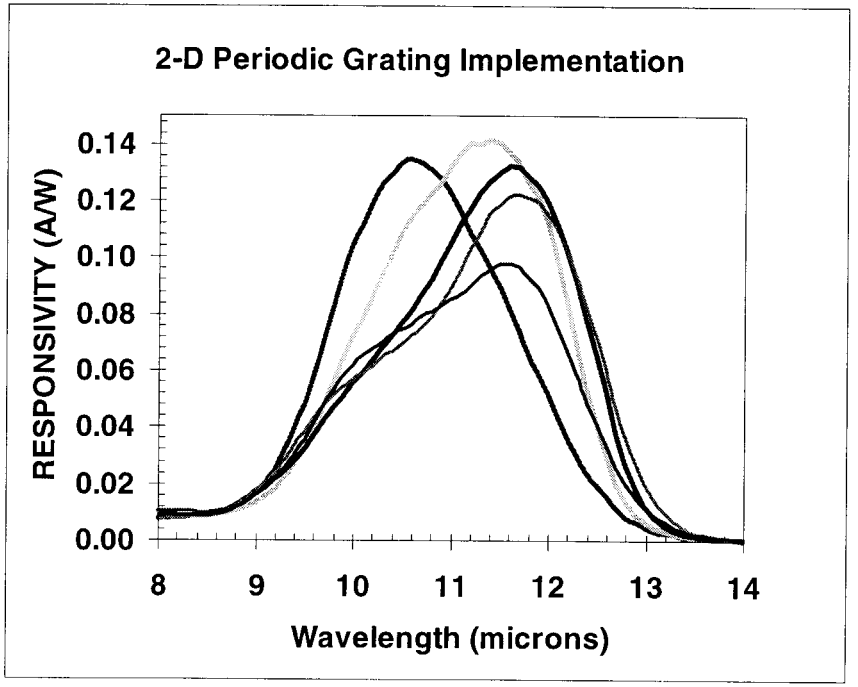


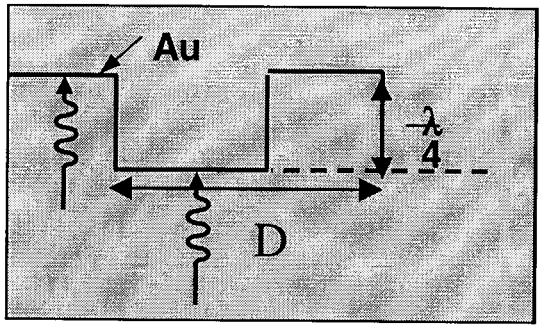
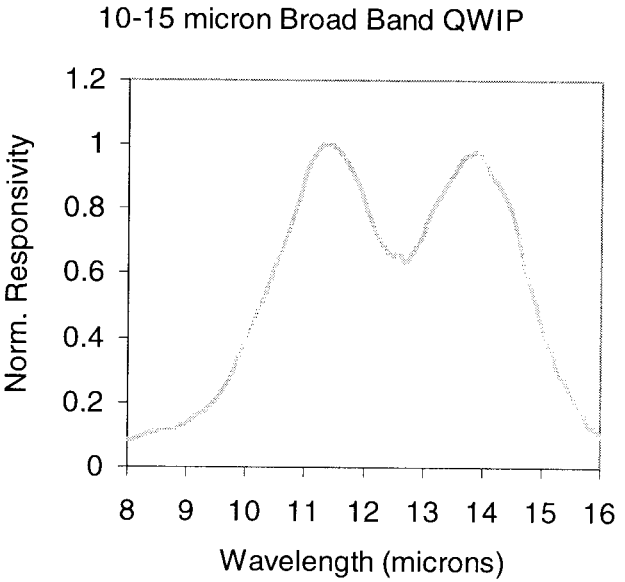




Deep groove gratings make ohmic contact to the lower QWIP (10-15 μm) while deactivating upper QWIP (6-10 μm).
Both Ground layers (middle contact of the even rows & bottom contact) are connected at the end of rows.

Use 2-D Gratings to tailor the wavelength





Minimize 90 deg. reflection