Cosmic Origins (COR) Current Strategic Technology Development Portfolio

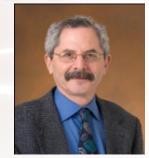
August 2013

Current COR Technology Development Portfolio

Funding	Technology Development Title	PI	Institution	Start Year and Duration	Area
Targeted	Heterodyne Technology For SOFIA	P. Goldsmith	JPL	FY10, 3 years	Far-IR Detector
SAT2010	Advanced UVOIR Mirror Technology Development for Very Large Space Telescope	P. Stahl	MSFC	FY12, 3 years	Optics
SAT2010	High Performance Cross-Strip Micro-Channel Plate Detector Systems for Spaceflight Experiments	J. Vallerga	UC Berkeley	FY12, 3 years	UV Detectors
SAT2010	Enhanced MgF2 and LiF Overcoated Aluminum Mirrors for FUV Space Astronomy	M. Quijada	GSFC	FY12, 3 years	UV Coatings
SAT2011	Ultraviolet Coatings, Materials and Processes for Advanced Telescope Optics	K. Balasubramani	JPL	FY13, 3 years	UV Coatings
SAT2011	Kinetic Inductance Detector Imaging Arrays for Far-Infrared Astrophysics	J. Zmuidzinas	JPL	FY13, 2 years	Far-IR Detectors
SAT2011	H4RG Near-IR Detector Array with 10 Micron Pixels for WFIRST and Space Astrophysics (2 merged SATs)	B. Rauscher and S. Anglin	GSFC and Teledyne	FY13, 3 years for Rauscher and 1 year for Anglin	UVOIR Detectors
SAT2011	High Efficiency Detectors in Photon Counting and Large Focal Plane Arrays for Astrophysics Missions	S. Nikzad	JPL	FY13, 3 years	UVOIR Detectors

Heterodyne Technology for SOFIA

PI: Dr. Paul Goldsmith/JPL



Description and Objectives:

- Heterodyne technology is necessary to answer fundamental questions including - How do stars form? How do circumstellar disks evolve and form planetary systems? What are the flows of matter and energy in the circumgalactic medium? And what controls the mass-energy-chemical cycles within galaxies?
- We will develop local oscillator (LO) and receiver subsystems that will allow for the implementation of multi-pixel high spectral resolution imaging in the all important 1.9-2.06 THz range.

Key Challenge/Innovation:

- Lack of solid-state sources in the THz range is perhaps the single most important challenge towards implementing array receivers
- Lack of broad IF band Hot Electron Mixers is issue at higher freqs.

Approach:

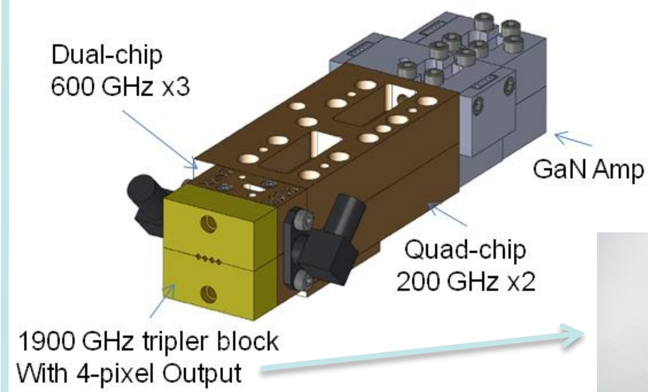
- Utilize JPL developed membrane diode process to construct compact tunable sources in the 1.9-2.06 range
- Utilize novel waveguide based active device power combining schemes to enhance power at these frequencies
- Work with collaborators in Russia to demonstrate wide IF band Hot Electron Mixers
- Build and test multi-pixel receivers to investigate stability and demonstrate performance

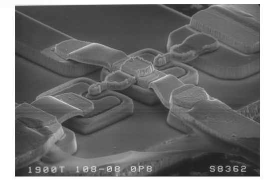
Key Collaborators:

- Imran Mehdi, Jon Kawamura, Jeff Stern, Boris Karasik, Jose Siles, Choonsup Lee, Robert Lin (all JPL)

Development Period:

- Oct 2010 – Sept 2013 (no cost extension intended)





1.9 THz diode

1.9 THz all solid-state LO source for pumping a 4-pixel heterodyne receiver

Accomplishments and Next Milestones:

- Demonstrated solid-state LO source at 1.904 THz that puts out 50 microwatts of power
- Demonstrated a biasable 1.9 THz LO source
- Demonstrated a 2.7 THz receiver with SOA performance
- Demonstration of 4-pixel LO chain (FY13)
- Development of waveguide based 4-pixel HEB mixer array (FY13)
- Demonstration of 4-pixel array receiver (FY14)
- Final design of 16-pixel array receiver (FY14)

Application:

- Array receivers for SOFIA
- Heterodyne array receivers for future suborbital and space missions
- Array receivers for CCAT

TRLin = ***3*** *TRLcurrent* = ***3*** *TRLtarget* = ***4***

Advanced Mirror Technology Development

PI: Phil Stahl/MSFC

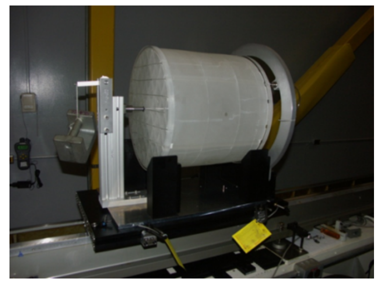
Description and Objectives:

- Mature the TRL of 6 key technology challenges for the primary mirror of future large-aperture Cosmic Origin UVOIR space telescopes
- Include monolithic and segmented optics design paths
- Conduct prototype development, testing and modeling
- Trace metrics to science mission error budget

Key Challenge/Innovation:

- Deep core concept design traceable to 4m mirror
- 4m to 8m mirror and support structure point design that would meet launch vehicle and science requirements

Subscale Deep Core Mirror Testing at MSFC XRCF



Subscale Deep Core Mirror Static Load Testing at Exelis

Approach:

- Provide guidance for science community architecture down select in 2015.
- Advance key technology required to enable 4 different implementation paths.
- Develop science and engineering requirements for traceable mirror systems and determine their associated mass. Then select a launch system or down-size the mirror systems and science requirements.

Key Collaborators:

- Dr. Scott Smith, Ron Eng and Mike Effinger/ NASA MSFC
- Bill Arnold/Defense Acquisition Inc., Gary Mosier/GSFC
- Dr. Marc Postman/STScI, Laura Abplanalp, Keith Havey, Roger Dahl, Steve Maffett/ITT Excelis

Development Period:

- Sept 2011 – Sept 2014

Accomplishments and Next Milestones:

- Modeled and validated by test at MSFC the deep core mirror's thermal performance
- Modeled and validated by test at Exelis the deep core mirror's static load performance
- Updated mirror & spacecraft modelers and generated point design
- Submit 9 papers to the SPIE Optics & Photonics conference/ August 2013
- Test AMSD type mirror/Dec 2013

Application:

- Flagship optical missions
- Explorer type optical missions
- Department of Defense and commercial observations

TRLin = varies from TRL3 to TRL5.5 pending technology
TRLcurrent = varies from TRL3 to TRL5.5 pending technology
TRLtarget = half step increase

Cross Strip MCP Detector Systems for Spaceflight

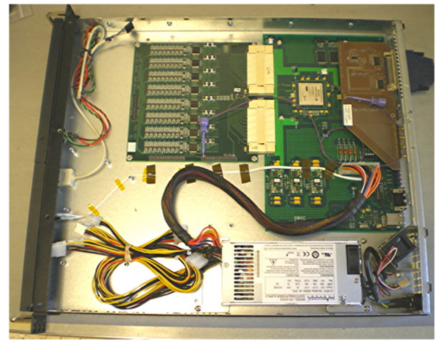
PI: John Vallerga/ U.C. Berkeley

Description and Objectives:

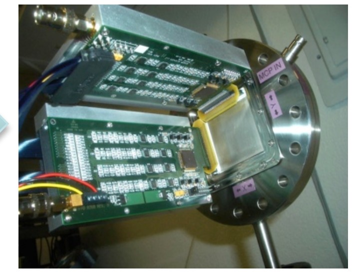
- Cross strip (XS) MCP photon counting UV detectors have achieved high spatial resolution (12µm) at low gain (500k) and high input flux (MHz) using laboratory electronics and decades old ASICs. We plan to develop a new ASIC ("GRAPH") that improves this performance, which includes amps and ADCs in a small volume, mass and power package crucial for spaceflight and demonstrates its performance to TRL 6.

Key Challenge/Innovation:

- A new ASIC with amplifiers a factor of 5 faster yet with similar noise characteristics as existing amplifier ASIC
- GHz analog sampling and a low power ADC per channel
- FPGA control of ASIC chip



Existing 19" rack mounted XS electronics



Two small, low mass, low power ASIC and FPGA boards qualified for flight

Approach:

- We will develop the ASIC in stages, by designing the four major subsystems (amplifier, GHz analog sampler, ADC and output multiplexor) using sophisticated simulation tools for CMOS processes. Small test runs of the more intricate and untested designs can be performed through shared access of CMOS foundry services to mitigate risk. We plan 2 runs of the full up GRAPH design (GRAPH1 and GRAPH2). In parallel, we will design and construct an FPGA readout circuit for the ASIC as well as a 50mm XS MCP detector that can be qualified for flight use.

Key Collaborators:

- Prof. Gary Varner, U. Hawaii
- Dr. Oswald Siegmund, U.C. Berkeley

Development Period:

- May 1, 2012 – Apr 30, 2015

Accomplishments and Next Milestones:

- 50 mm detector design and fabrication complete
- Commissioned detector with PXS electronics
- Designed and fabricated ASIC amplifiers
- Design and fabrication of FPGA board (Nov 2013)
- Design and fab of half-GRAPH1 ASIC (Nov 2013)
- Design and fab of GRAPH2 ASIC (Nov 2014)

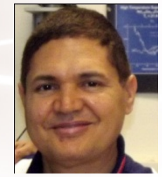
Applications:

- High performance UV(1-300nm) detector for astrophysics, planetary, solar, heliospheric, or aeronomy missions
- Particle or time of flight detector for space physics missions
- Fluorescense lifetime imaging (FLIM) for biology
- Neutron radiography/tomography for material science

*TRLin = **4*** *TRLcurrent = **4*** *TRLtarget = **6***

Enhanced MgF_2 and LiF Over-coated Al Mirrors for FUV Space Astronomy

PI: Manuel A. Quijada/GSFC

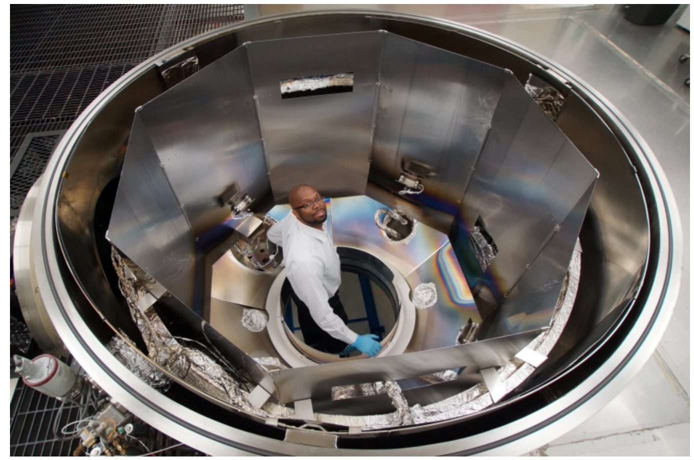


Description and Objectives:

- To develop on a large scale (up to 1 meter diameter) coating of mirrors using a Al+MgF_2 coating process to enhance performance in the Far-Ultraviolet spectral range
- Study other dielectric fluoride coatings and other deposition technologies such as Ion Beam Sputtering (IBS) that is known to produce the nearest to ideal morphology optical thin film coatings and thus low scatter

Key Challenge/Innovation:

- Improved reflective coatings for large optics, particularly in the ultraviolet part of the spectrum, could yield dramatically more sensitive instruments and permit more instrument design freedom



Inside 2-meter coating chamber after installation of thermal shroud and halogen-quartz heater lamps.

Approach:

- Retrofit a 2 meter coating chamber with heaters/thermal shroud to perform coating iterations at a high deposition temperatures (200-300°C) to further improve performance of protected Al mirrors with either MgF_2 or LiF overcoats
- Optimize deposition process of lanthinide trifluorides as high-index materials that when paired with either MgF_2 or LiF will enhance reflectance of Al mirrors at Lyman-alpha
- Establish the IBS coating process to optimize deposition of MgF_2 and LiF with extremely low absorptions at FUV wavelengths

Key Collaborators:

- Steve Rice and Felix Threat (551)
- John Lehan (SGT)
- Jeff Kruk and Charles Bowers (665)

Development Period:

- FY12 – FY14

Accomplishments and Next Milestones:

- Established the short wavelength transmission cutoff of GdF3 and LuF3 films grown by physical vapor deposition method.
- Systematic study of MgF_2 films grown with the IBS process as function of growth temperature and other coating parameters.
- Re-optimized the growth process of Al+MgF_{2+} to realize additional reflectance gains below 1200 A.
- Initial coating run of Al+MgF_2 slide distribution in 2 meter chamber: August 2013
- Design and fabricate a narrow-wavelength reflector using a dielectric stack in the 1200-1500A range: November 2013

Application:

- This technology will enable FUV missions to investigate the formation and history of planets, stars, galaxies and cosmic structure, and how the elements of life in the universe arose

TRLin = 4 ***TRLcurrent = 4*** ***TRLtarget = 5***

Ultraviolet Coatings, Materials and Processes for Advanced Telescope Optics

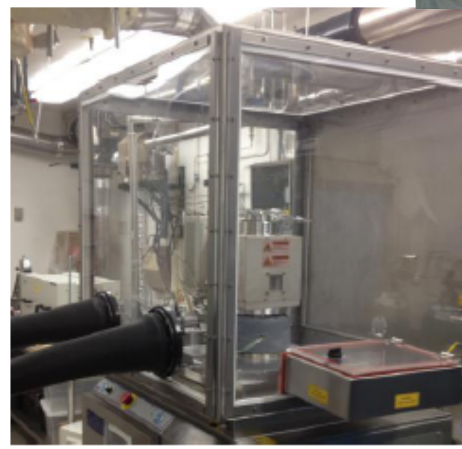
PI: K. Balasubramanian/JPL

Description and Objectives:

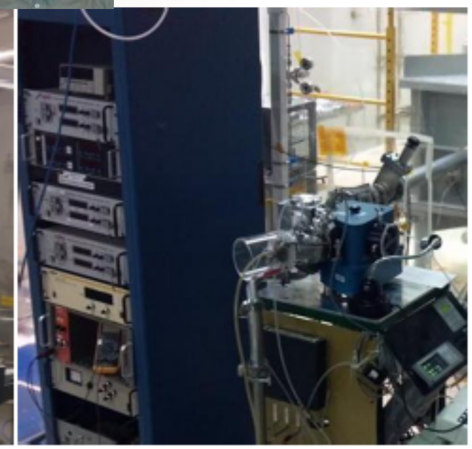
- "Development of UV coatings with high reflectivity (>90-95%), high uniformity (<1-0.1%), and wide bandpasses (~100 nm to 300-1000 nm)" is a major technical challenge as much as it is a key requirement for cosmic origins program and for exoplanet exploration program. This project aims to address this key challenge and develop feasible technical solutions.

Key Challenge/Innovation:

- Materials and process technology are the main challenges. Improvements in existing technology base and significant innovations in coating technology such as Atomic Layer Deposition will be developed.



ALD chamber at JPL



Deep UV Test station at U of Colorado

Approach:

- A set of experimental data will now be developed with MgF_2, AlF_3 and LiF protected Al mirrors in the wavelength range 100 to 1000 nm for a comprehensive base of measured data to enable full scale developments with chosen materials and processes.
- Enhanced coating processes including Atomic Layer Deposition (ALD) will be studied; Characterization and measurement techniques will be improved.

Key Collaborators:

- Stuart Shaklan (JPL), Nasrat Raouf (JPL), Shouleh Nikzad (JPL), Frank Greer (JPL), Paul Scowen (ASU), James Green (Univ of Colo)

Development Period:

- Jan 2013 – Dec 2015

Accomplishments and Next Milestones:

- A coating chamber has been upgraded with sources, temperature controllers and other monitors to produce coatings of various fluorides; measurement tools are also established now at JPL and U of Colo.
- Preliminary coatings with various fluorides will be produced and characterized during Aug-Dec 2013.
- Enhancements to conventional coating techniques will be developed; ALD coating process tools and process will be established at JPL (2014)
- ALD and other enhanced coating processes for protected and enhanced aluminum mirror coatings will be developed and improved (2015)
- Test mirror coupons representing a meter-class mirror to be produced and characterized (2015)

Application:

- The technology developed through this project will enable future astrophysics and exoplanet missions that aim to capture key spectral features from far UV to near infrared.

*TRLin = **3***   *TRLcurrent = **3***   *TRLtarget = **5***

Kinetic Inductance Detector Arrays for Far-IR Astrophysics

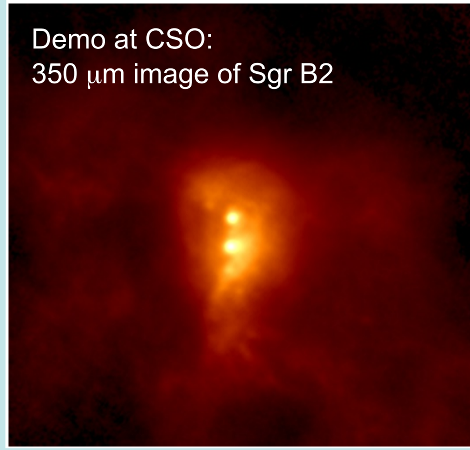
PI: Jonas Zmuidzinas/Caltech

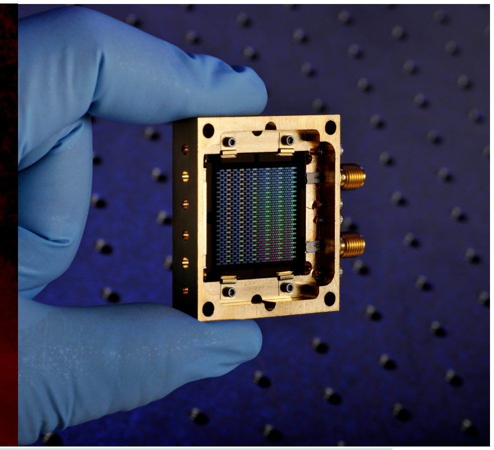
Description and Objectives:

- Half of the electromagnetic energy emitted since the big bang lies in the far-infrared. Large-format far-infrared imaging arrays are needed for studying galaxy formation and evolution, and star formation in our galaxy and nearby galaxies. Polarization-sensitive arrays can provide critical information on the role of magnetic fields.
- We will develop and demonstrate far-IR arrays for these applications.

Key Challenge/Innovation:

- Far-infrared arrays are in high demand but are difficult to fabricate, and therefore expensive and in short supply. Our solution is to use titanium nitride (TiN) absorber-coupled, frequency-multiplexed kinetic inductance detectors.





Approach:

- The goal is to raise the TRL of these detectors so that investigators may confidently propose them for a variety of instruments:
  - Ground telescope demo, 350 mm, 3×10^{-16} W Hz$^{-1/2}$
  - Lab demo for SOFIA, 90 mm, 1.7×10^{-16} W Hz$^{-1/2}$
  - Lab demo for balloon, 350 mm, 7×10^{-17} W Hz$^{-1/2}$
  - Lab demo for space, 90 mm, 5×10^{-19} W Hz$^{-1/2}$

Key Collaborators:

- G. Chattopadhyay, JPL
- Peter Day, JPL
- Darren Dowell, JPL
- Matt Holllister, Caltech
- Rick Leduc, JPL
- Chris McKenney, Caltech

Development Period:

- Jan 2013 – Dec 2014

Accomplishments and Next Milestones:

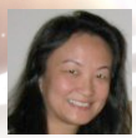
- Fall 2012: Lab demonstration at 350 μm
- Spring 2013: Successful 350 μm telescope demo at the Caltech Submillimeter Observatory (CSO) (see image above)
- Summer 2013: Lab tests of 350 μm lens-coupled arrays
- Fall 2013: First lab tests of high-sensitivity arrays

Application:

- SOFIA instruments
- Balloon payloads
- Future space mission, e.g., SAFIR/CALISTO
- Ground-based telescopes
- Applicable to both cameras and spectrometers (low NEP lab demo)
- Potential impact on mm-wave CMB instrumentation

TRLin = ***3*** *TRLcurrent =* ***3*** *TRLtarget =* ***4-6***

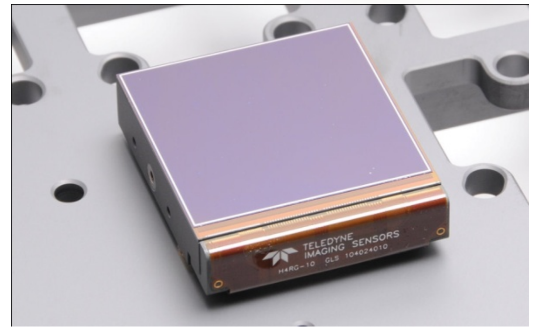
H4RG Near-IR Detector Array with 10 micron pixels for WFIRST and Space Astrophysics



PI: Bernard J. Rauscher/GSFC
Co-PI: Selmer Anglin/Teledyne Imaging Sensors

Description and Objectives:

- Develop the 16 megapixel H4RG-10 near-IR detector array to TRL-6 for WFIRST in time for the Astrophysics Mid-Decadal Review
- WFIRST Science Definition Team identified the H4RG-10 as the critical enabling technology that is needed for achieving the aims of the Astrophysics Decadal Survey *New Worlds, New Horizons*
- Mature this technology to minimize risk, cost, and schedule
- Reduce the persistence and noise of large format high resolution infrared array detectors



This H4RG-10 is identical to one that was tested in the Goddard DCL in 2011. It consists of a 4K x 4K pixel array of HgCdTe pixels mated to a silicon readout. It met all WFIRST performance requirements except: (1) pixel operability and (2) read noise

Key Challenge/Innovation:

- Hybridization improvements to meet WFIRST pixel operability requirements in 4K x 4K, 10 μm/pixel format
- Pixel design improvements to meet WFIRST read noise requirements and reduce persistence

Approach:

- Teledyne study to improve pixel interconnect yield
- Teledyne study to optimize process and improve read noise
- Fabricate lot splits of H4RG-10s at Teledyne
- Characterize H4RG-10s vs. WFIRST requirements in Goddard Detector Characterization Laboratory (DCL) and Teledyne
- Characterize H4RG-10s for WFIRST weak lensing and persistence at JPL/CalTech
- Environmental testing for TRL-6

Key Collaborators:

- Jason Rhodes (JPL: Institutional PI)
- Donald N.B. Hall (University of Hawaii)
- Bryan Dorland (U.S. Naval Observatory)
- Ed Cheng (WFIRST)
- Roger Smith (CalTech)

Development Period:

- FY13 – FY15

Accomplishments and Next Milestones:

- Demonstrate pixel interconnect operability yield >98%: Sept 2013
- Demonstrate an H4RG-10 that meets WFIRST performance requirements: Dec 2013
- Demonstrate an H4RG-10 that meets WFIRST environmental requirements: Dec 2014
- Complete TRL-6 demonstration: End of performance period

Application:

- WFIRST
- Explorer class near-IR missions
- Ground and space based astrophysics programs
- This is a broadly enabling technology for astrophysics

TRLin = ***4*** *TRLcurrent =* ***4*** *TRLtarget =* ***6***

High Efficiency Detectors in Photon Counting and Large FPAs

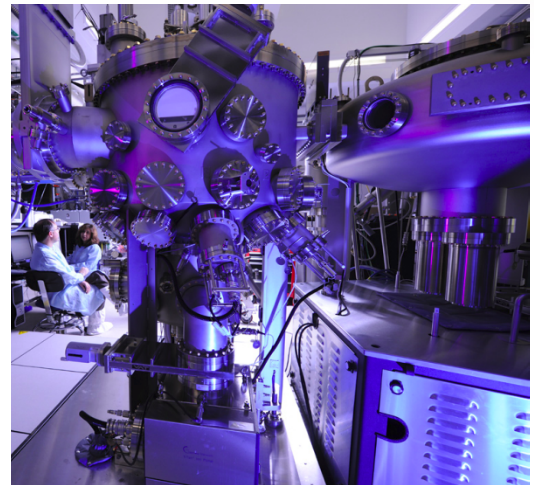
PI: Shouleh Nikzad/JPL

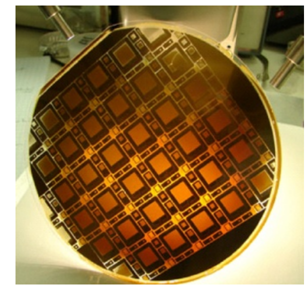
Description and Objectives:

- High efficiency, high stability imaging arrays that are affordable and stable are an efficient and cost effective way to populate UV/Optical focal planes for spectroscopic missions and 4m+ UV/Optical telescope as stated in the NWNH 2010

Key Challenge/Innovation:

- Atomic-level control of back illuminated detector surface and detector/AR coating interface produces high efficiency detectors with stable response and unique performance advantages even in the challenging UV and FUV spectral range





Approach:

- Develop and produce 2 megapixel AR-coated, delta doped electron multiplied CCDs (EMCCDs) using JPL's 8-inch capacity silicon molecular beam epitaxy (MBE) for delta doping and atomic layer deposition (ALD) for AR coating. Perform relevant environment testing, perform system-level evaluation on sky to validate performance over a wide range of signal level.

Key Collaborators:

- Chris Martin, Caltech, David Schiminovich, Columbia University, Paul Scowen, Arizona State University, Michael Hoenk, JPL

Development Period:

- Jan 2013 – Dec 2015

Accomplishments and Next Milestones:

- Wafers of 2Kx1K devices have been received and back - illumination process is underway. Wafers have been bonded to handle wafer. One wafer has been thinned to 8-10 micron. Wafer is ready for delta doping and next process steps. Complete first wafer in FY13Q4
- Characterize & validate the performance. (iterative, first in FY14Q1)
- Evaluate environmental performance. (FY14Q2 - FY15Q4)
- Evaluate performance in astrophysics-relevant and mission-relevant environments. (FY15Q3 – Q4)

Application:

- Large aperture UV/Optical Telescope, Explorers, Spectroscopy missions, UV/Optical imaging

*TRLin = **4***   *TRLcurrent = **4***
*TRLtarget = **5-6***