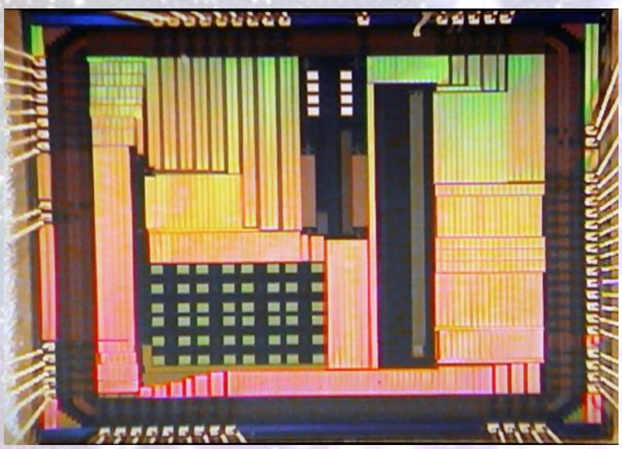
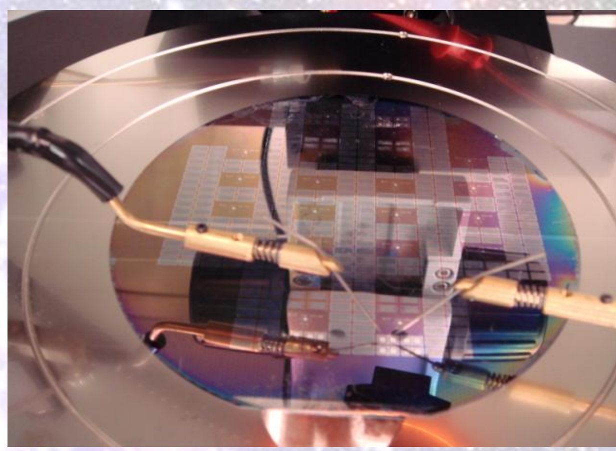
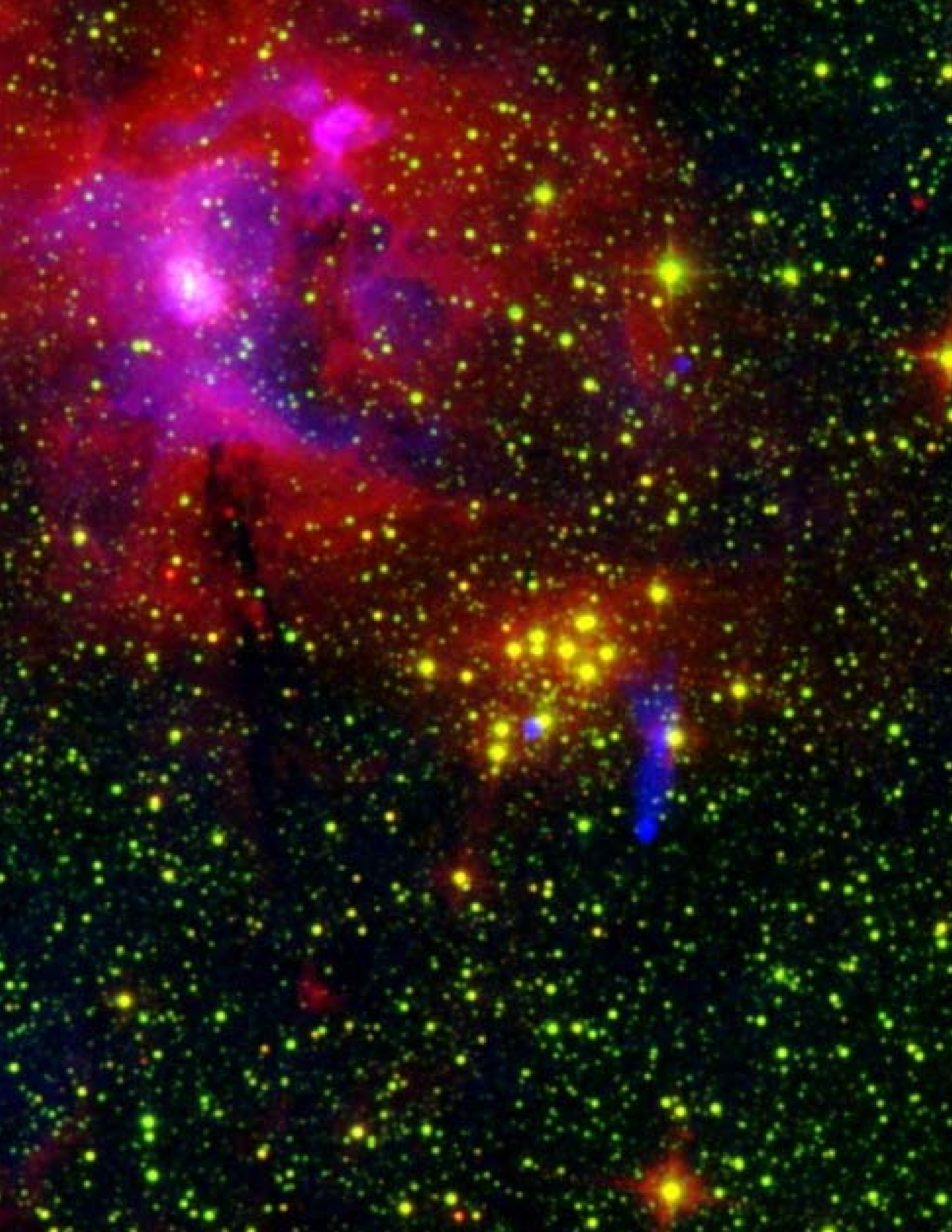


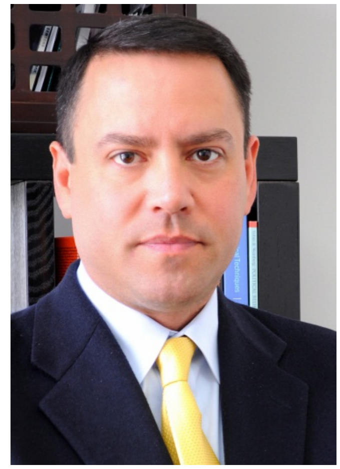


Center for Detectors
Annual Report 2012

Table of Contents



Director's Comments



Welcome to the Center for Detectors (CfD), a cross-Institute Academic Research Center in the College of Science at the Rochester Institute of Technology. CfD is in its third year of operation, and it continues to exceed its goals. In the past year, the Center has increased its performance in terms of research projects, student experiences and outcomes, and external research funding.

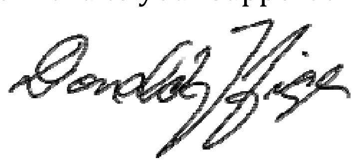
Of particular note, the CfD won a major new research grant from the National Science Foundation to develop the next generation of infrared detectors for Astronomy. IR detectors have been crucial to most astronomical discoveries over the past 30 years since they were initially introduced into the field; however, they remain relatively small and expensive. The Center's new research project, in collaboration with Raytheon Vision Systems, will break the current performance versus cost paradigm for IR detectors and open a much larger volume of "discovery space."

Students in the Center are deeply immersed in authentic research that is driven by answering pressing science questions. This approach leverages lecture-based curriculum by providing real-world experiences that require cooperation within a multidisciplinary team without the constraints of the academic calendar. Over the past year, students have come from a broad array of backgrounds and majors, *e.g.*, Electrical Engineering, Physics, Microelectronics, Design, Mechanical Engineering, Medical Illustration, and Accounting, to name a few.

On a final note, the CfD launched the Detector Virtual Workshop, a year-long speaker series sponsored by the National Science Foundation. The talks were recorded and placed on the CfD website; they have been used as the basis of class assignments for both undergraduate and graduate students. The series was especially timely for RIT in that the talks highlighted the need for overlap between science and engineering for progress in the field of detectors.

The following Annual Report describes the new and exciting activities of the Center of the past year. In it, you will find exciting descriptions of CfD research, education, and outreach programs in this report.

I welcome your interest in CfD and look forward to your support and feedback.



Dr. Donald Figer
Professor, RIT College of Science
Director, Center for Detectors

Highlights

Research

- Current projects are: A Zero Read Noise Detector for Thirty Meter Telescope (TMT), A Photon-Counting Detector for Exoplanet Missions, A NICMOS Survey of Newly-Identified Young Massive Star Clusters, and The Nature of GLIMPSE 81: A Star Cluster to Rival Westerlund 1.
- The CfD completed two projects in the past year: A LIDAR Imaging Detector for NASA Planetary Missions, and High School Student Explorations of Planetary Surfaces in Digital Immersive Worlds.

Detector Virtual Workshop

- The CfD presented over a dozen talks through the NSF-funded Detector Virtual Workshop. A continuation of the series is planned for this fall. The goal of DVW is to advance UV/O/IR detectors with primary benefit for astrophysics, and additional benefit to biomedical imaging, solar energy, and photonics. The workshop will consolidate the ideas into a report that summarizes promising detector developments over the next 10 years.

NASA Fellowship

- PhD student Christine Trombley completed a Fellowship with NASA/GSRP, High Mass Initial Mass Function, including a ten-week research experience at NASA's Goddard Space Flight Center.

Publications and Presentations

- CfD team members published ten papers and presented six invited talks. In addition, CfD student Brian Glod completed his Master's thesis based on research completed at the Center.

Executive Summary

This report summarizes the activities of the Center for Detectors over the past year, spanning July, 2011 through June, 2012. The Center for Detectors was created in January, 2010. It is an Academic Research Center within the College of Science at the Rochester Institute of Technology (RIT). The purpose of the Center is to develop and implement advanced photon detectors to enable scientific discovery, national security, and better living. These objectives are met through leveraging multi-disciplinary and symbiotic relationships between its students, staff, faculty, and external partners, and by pursuing projects with personnel from multiple colleges, departments, companies, and national laboratories. The vision, mission, and goals are described in the Center Charter Document.

Personnel

Center for Detectors members come from a diverse range of academic programs and professional occupations. During the 2011-2012 academic year, the staff included two Professors, three engineers, one student lab assistant, four PhD students, one Master's student, and various other support staff.

Student Vignettes

Many of the Center's student workers apply the research they conduct in the Center's laboratory to their current academic programs at RIT. There are four employees conducting research for their PhD theses at the Center. Another student researcher published his Master's thesis this year based on his research at CfD to earn his MS in Electrical Engineering.

Publications

In the previous year, ten papers were published by CfD personnel. Two of these papers were published in the Monthly Notices of the Royal Astronomical Society, and presented findings that combined results of two of the Center's Astronomy grants. Other publication highlights include an article published in the prestigious *Nature* journal, and a new manuscript submitted in Summer, 2012 for future publication in the *Astrophysics Journal*.

Grants, Contracts, and External Funding

The Center is grant-funded, and has received more than $9.8 million in research awards. NASA and the Gordon and Betty Moore Foundation are the Center's primary supporters. In 2012, NSF also became a major sponsor with a research grant of $1.2 million for the development and testing of infrared detectors grown on silicon wafers.

Projects

The many projects in progress at the Center combine a variety of science topics. From the many branches of engineering, to imaging science, to physics, chemistry, and astronomy, the Center stands out from other academic research centers because of its diverse applications. Projects such as "The High Mass Initial Mass Function" use traditional techniques of observational astrophysics. Other projects, such as the NSF-funded New Infrared Detectors for Astrophysics, bring together microelectronic engineers, astronomy experts, and various other professionals in the engineering fields.

Press & Presentations

This year, CfD Director Don Figer was invited to speak at Northwestern University's Interdisciplinary Astrophysics Seminar. He also presented talks in San Diego, California, and Bad Honnef, Germany. PhD student Christine Trombley gave two invited talks at NASA's Goddard Space Flight Center and RIT's College of Imaging Science. In September 2011, RIT News released an article announcing the launch of the Detector Virtual Workshop speaker series. A November article highlighted Christine Trombley, describing her prestigious NASA fellowship and the corresponding visiting research experience at Goddard. Topping them all off, a June 2012 press release announced the Center's new $1.2 million award from NSF and described the advances in infrared detectors grown on silicon wafer substrates that the Center hopes to achieve through this project.

Detector Virtual Workshop

The Center launched the Detector Virtual Workshop during the past academic year. Over a dozen presentations were given, and more are planned for the coming fall. All presentations were streamed online to various locations around the world, and are archived on the Center's website for re-broadcast in the future. This series focuses on compiling input from the academic, industrial, and governmental sectors to highlight the most significant challenges, achievements, and promising developments existing in the detector field today.

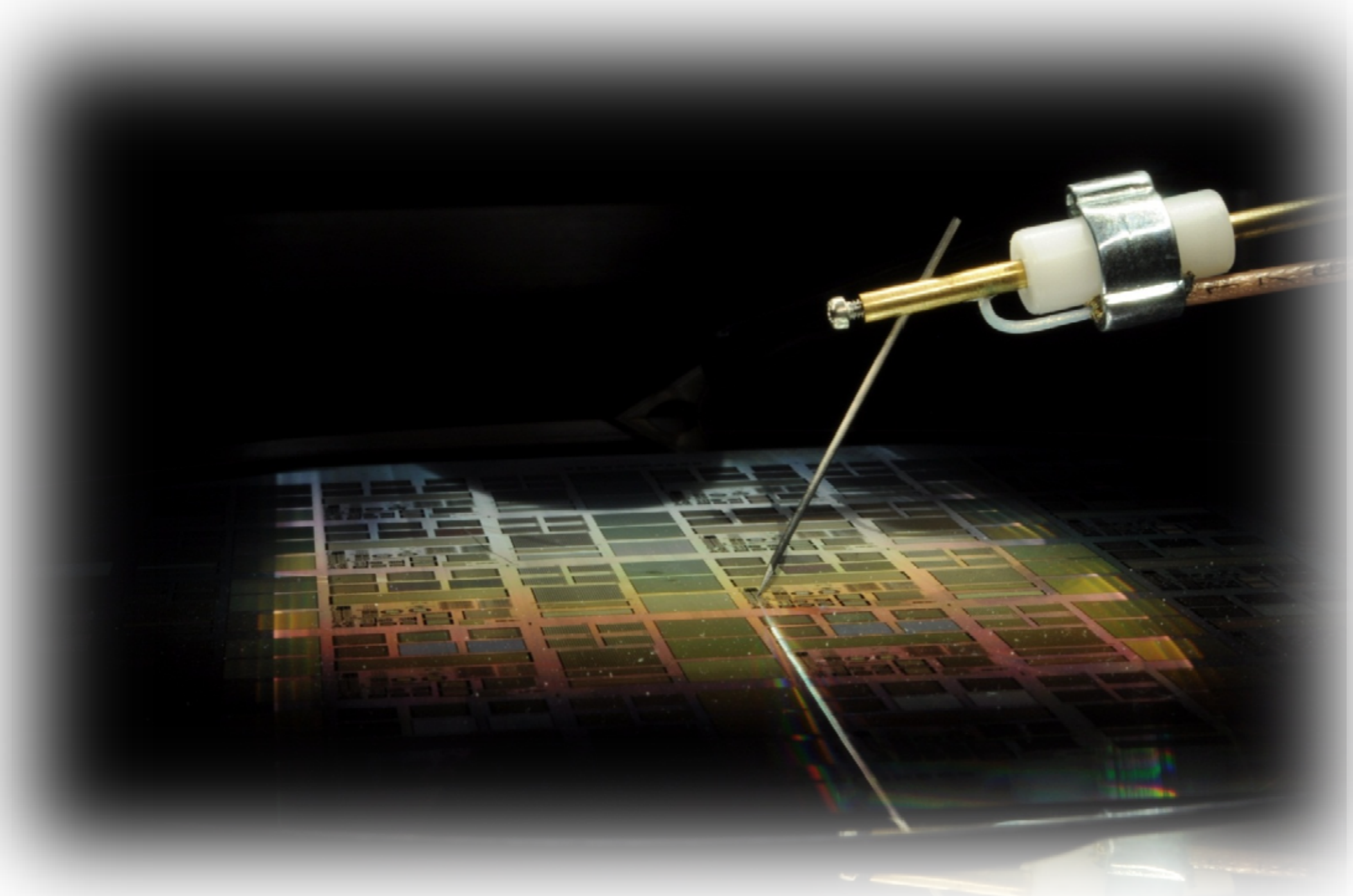
Educational Collaborations

Educational supplements to two of the Center's grants have allowed for some exciting projects involving students from local high schools over the past few years. This year, the second of the two projects, "Exploring Planetary Surfaces in 3D," was completed. In this project, high school students made use of an RIT-developed 3D projection system dubbed the "Planeterrainium" to explore features of the surface of Mars (and other planets) "as if they were really there."

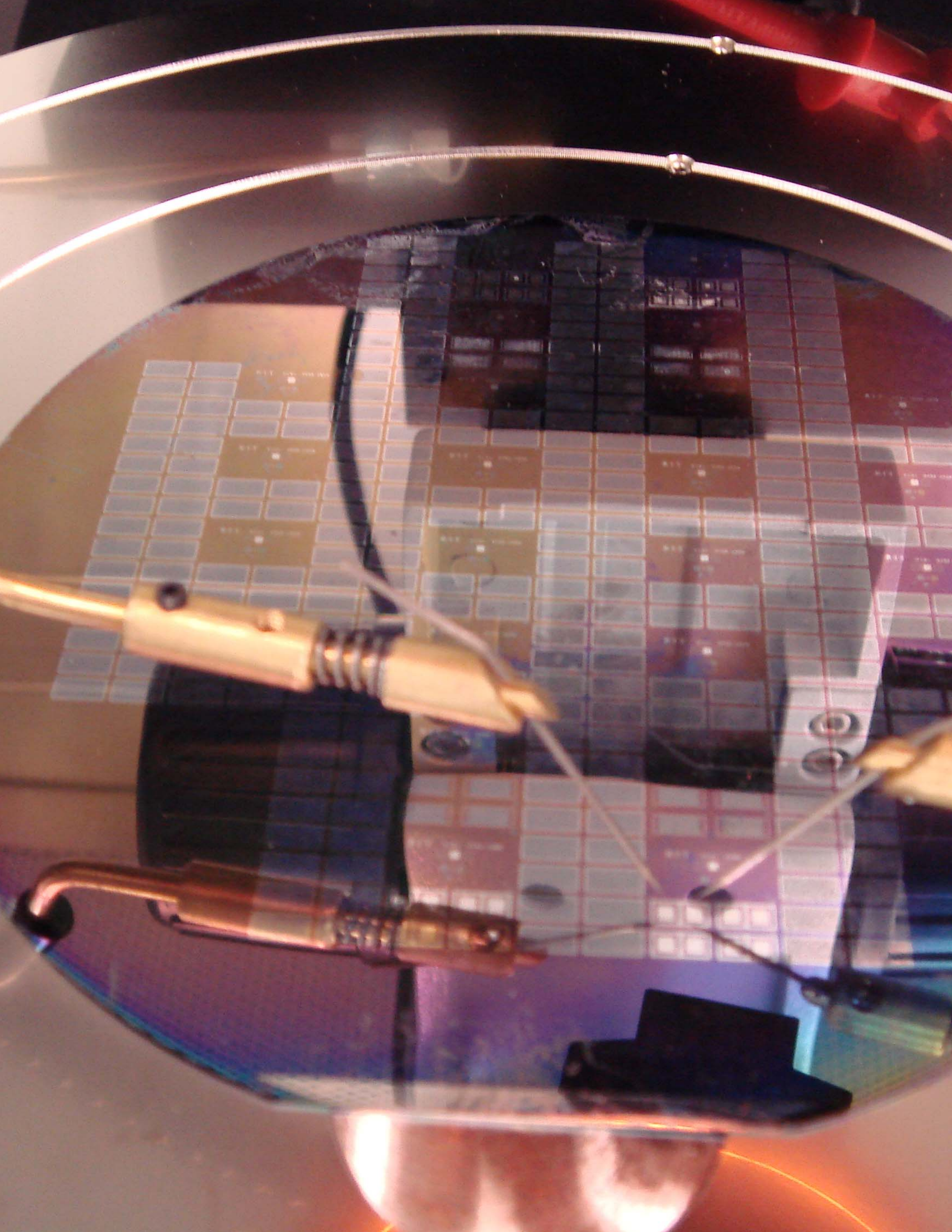
Equipment and Facilities

At the focal point of the CfD's detector-testing capabilities are three cylindrical cryogenic dewars. These dewars were designed at the Center, and are supported by temperature controllers, readout controllers, motion stability supports, integrating spheres, and data reduction PCs. The oldest dewar system, fabricated several years ago, is now undergoing a major upgrade to support a new research endeavor surrounding detectors grown on silicon wafer substrates.

The Center also has a class 1000 cleanroom, allowing for testing of detector parts in various stages of fabrication. The Center's capabilities are further enhanced by access to other access to other RIT facilities such as the Center for Electronics Manufacturing and Assembly, and the Brinkman Manufacturing Lab.



Research



New Projects

New Infrared Detectors for Astrophysics

NSF/Raytheon Vision Systems

Current infrared detectors are composed of a light-sensitive mercury cadmium telluride (HgCdTe) layer deposited on top of cadmium zinc telluride (CdZnTe) wafers. The CdZnTe substrates are expensive and limited in availability, which restricts the use of infrared detectors to just a few of the world's largest telescopes. In collaboration with Raytheon Vision Systems (RVS), CfD is designing and fabricating infrared detectors with silicon wafer substrates. Silicon wafers are commonly used in the high-volume semiconductor industry with standard sizes up to twelve inches. RVS has developed a method to deposit the HgCdTe light-sensitive layer on silicon using the technique of Molecular Beam Epitaxy (MBE). This fabrication method bypasses the defects traditionally caused by the lattice spacing mismatch between silicon and HgCdTe.

Figure 1: Picture of silicon wafers after having HgCdTe deposited using MBE growth

This project consists of three main objectives. First, CfD engineers will evaluate the existing HgCdTe material grown on silicon substrates by hybridizing the material to a large-format readout integrated circuit (ROIC). The existing detector material operates in the mid-wavelength infrared region. The CfD will then design and fabricate new detectors which will operate in the short-wavelength region. These new detectors will have HgCdTe deposited onto silicon wafers using MBE. The size of the infrared detectors will be 1,024 by 1,024 pixels and 2,048 by 2,048 pixels. Finally, Center engineers will evaluate the new detectors in the CfD laboratory as well as at a telescope, preferably the 2.1m telescope at Kitt Peak National Observatory (KPNO).

High Mass Initial Mass Function

NASA/GSRP

By examining a sample of young, massive stellar clusters in the galaxy (indicated in Figure 2 by circles), this project will place constraints on the high mass initial mass function as a function of stellar natal environment, lending insight into the life cycles of massive stars. We will also study evolutionary sequences of massive stars, and add new data points to help resolve the issues regarding the relationship between progenitor mass and end state of post-supernovae stellar remnants.

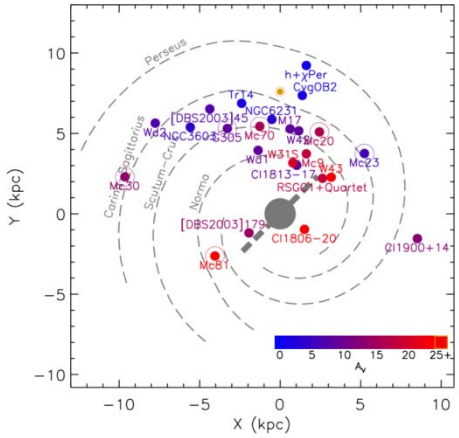


Figure 2. Locations of clusters in Ms. Trombley's sample in the Milky Way, circled, along with previously known young, massive clusters.

During the past academic year, CfD Graduate Student Christine Trombley obtained and began to analyze data from a variety of observational facilities on Earth and in space. These data will be transformed into quantitative information about massive stars, such as their birth masses, by using theoretical and empirical models of nuclear core burning and stellar winds. For his PhD thesis, graduate student Diego de la Fuente will use similar data to measure the chemical composition of massive stars in the Milky Way, in order to determine the chemical composition of the Galaxy.

Ongoing

A Zero Read Noise Detector for Thirty Meter Telescope (TMT)

Gordon and Betty Moore Foundation

The key objective of this project is to develop a new type of imaging detector that will enable the most sensitive possible observations with the world's largest telescopes, i.e. the Thirty Meter Telescope (TMT). The detector will effectively quadruple the collecting power of the TMT, compared to detectors currently envisioned in TMT instrument studies, for the lowest light level observations. It would have fundamental importance in ground-based and space-based astrophysics, Earth and planetary remote sensing, exo-planet identification, consumer imaging applications, and homeland safety, among many others. Measurable outcomes include being able to see further back into the infancy of the Universe, and to taking a better picture (less grainy) of a smiling child blowing out the candles at her birthday party. The detector will be quantum-limited (zero read noise), be resilient against the harsh effects of radiation in space, consume low power, operate over an extremely high dynamic range, and be able to operate with exposure times over one million times faster than typical digital cameras. The CfD is teaming with MIT/Lincoln Laboratory to leverage their Geiger-mode Avalanche Photodiode technology for developing the imaging detector. The project is funded through the Gordon and Betty Moore Foundation.

In the first year of the project, the visible (Si) and infrared (InGaAs) Geiger Mode Avalanche Photodiodes (GM-APDs) were fabricated. Two types of silicon GM-APDs were fabricated and tested: low-fill-factor (LFF), and high-fill-factor (HFF) devices. The electronics and packaging needed to operate the detectors at high vacuum and cryogenic temperatures were designed and fabricated over the past academic year. A block diagram of the system is shown in Figure 3, and includes a modified version of the version-one test board along with a cold electronics board and newly-designed detector flex package. This design enables parallel testing of up to four individual detectors at once.

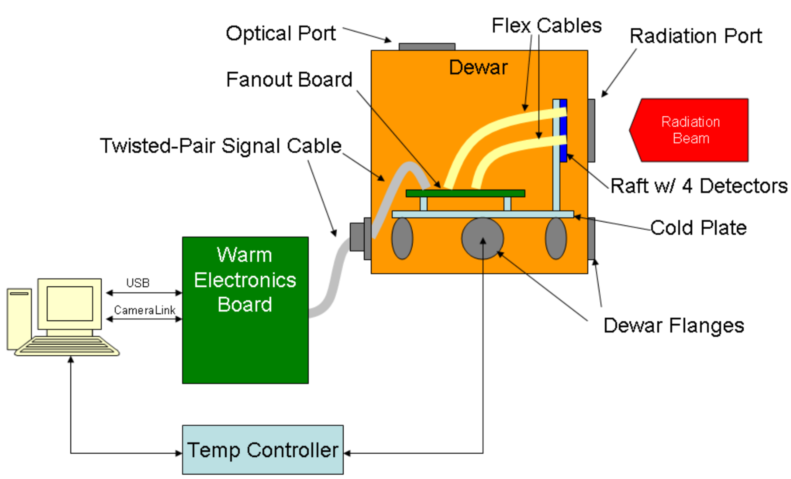


Figure 3. Cryogenic electronics system block diagram.

The flex package for the detector is shown in Figure 4. It consists of two rigid sections, joined in the middle by a flexible Kapton laminate.

Figure 4. Detector in flex package.

The detector and I/O connectors were mounted to the rigid sections and assembled onto a custom-machined raft designed to hold up to four detectors, shown in Figure 5. The flex package was specifically designed for use at high vacuum (10 nTorr) and cryogenic temperatures, and uses the same techniques that have been used in previous Lincoln Laboratory designs.

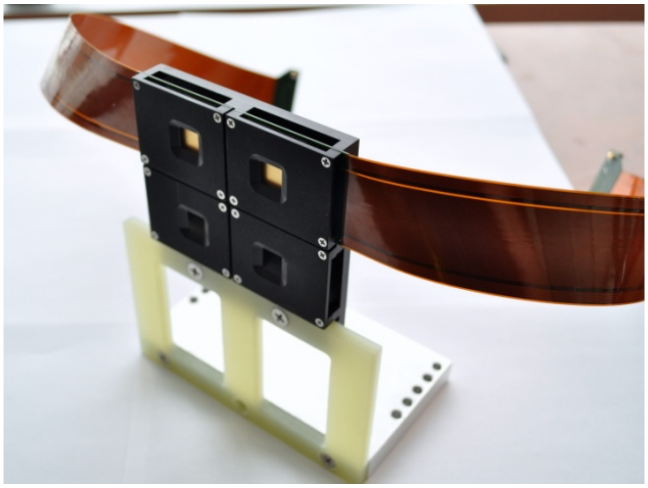


Figure 5. Example of the packaged detectors. The detectors are mounted to a raft and mount for cooling to cryogenic temperatures.

The cold fanout board is shown in Figure 6. In this image, the lower end of the 8"x8" board shows the three 100-pin micro-D connectors used for input, output and power. Near the top are four high-density connectors, which mate with the detector flex packages. In between are the LVDS receiver and driver chips, FPGA muxes, temperature sensors and test connector.

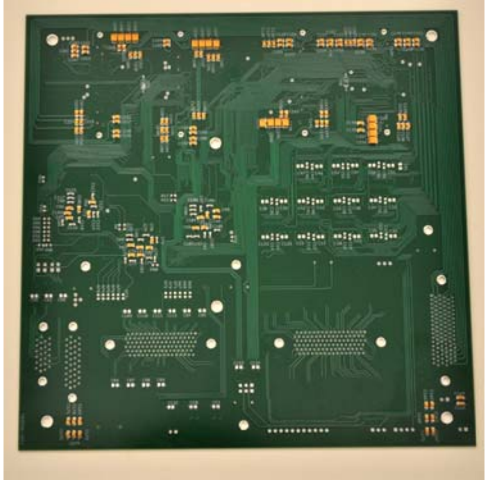


Figure 6. Cold electronics fanout board.

The fully integrated detector/electronics system inside the dewar is shown in Figure 7. The system went through a thorough testing process. The system allows operation of the detector in cryogenic temperature range in a high vacuum setting and is being used extensively to characterize the detectors.

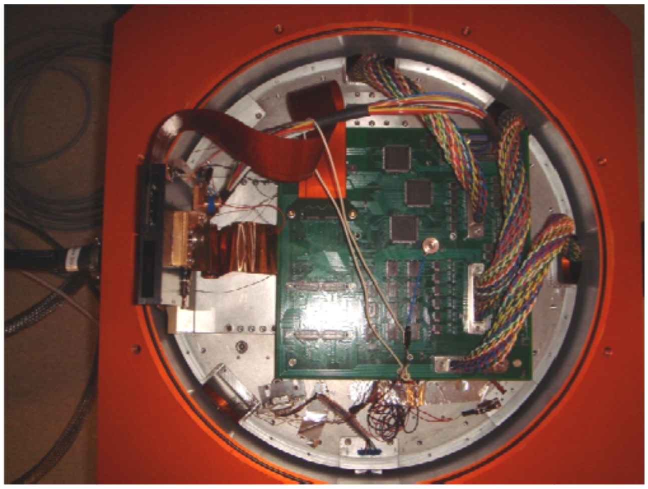


Figure 7. Top view of fully integrated detector electronics system inside the dewar. The detector is mounted on the raft (left) and connected to the cold fanout board (middle).

The LFF and HFF 256×256 APD hybridized to CMOS ROICs, fabricated at MIT/LL, have been tested extensively at the CfD. The clock patterns for the APD are shown in Figure 8. In Geiger mode, the APD is biased above the breakdown voltage before the APD can detect a photon. This “arming” of the APD takes place over the duration of the arm pulse (“a” in Figure 8). Once an avalanche takes place, the APD must be refreshed and “re-armed” in order to be able to detect photons again. This can be done in the single gate mode, in which each “re-arm” takes place when desired in a single shot, or the continuous gate mode in which the “re-arm” occurs at a regular interval, τ, as in Figure 8. The APD is ready to detect a photon over the gate width of τ–a. If a photon arrives during that time, it initiates an avalanche and the flip flop on the ROIC registers an event.

Other photons arriving during that time do not register an event, as the APD is already avalanching. Then, for a flux, ρ, on the APD, the trigger probability per gate is the Poisson probability of one or more photons arriving over τ, which is just 1–exp-ρτ.

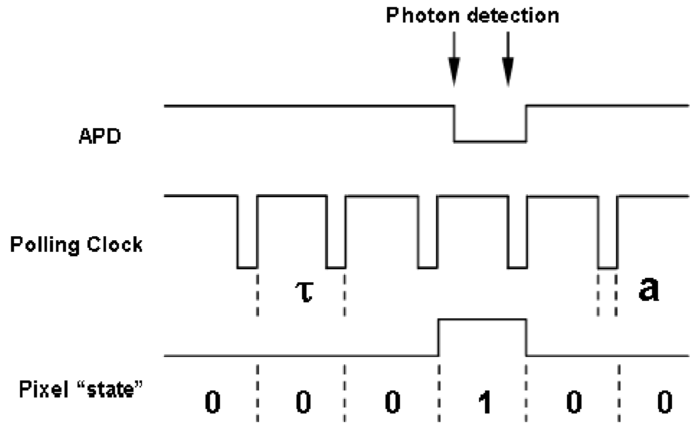


Figure 8. Clock patterns for the APD. This picture holds for both photons and dark events.

The poissonian nature of the triggering probability can be seen in *Figure 9* (*left*). A series of dark current exposures lasting 50,000 gates were taken in the single gate mode with a = 100 ns and τ = 0.5–4000 μsec with the LFF APD. The experimental event trigger probability, calculated by dividing the number of triggered gates by the total number of gates, closely follows the expected triggered probability of $1–\exp^{-\rho\tau}$. The event trigger probability grows linearly with the gate width for very small gate widths, and it begins to “saturate,” asymptotically reaching 1 as the gate width increases even further. The dark count rate for the pixels is calculated by fitting the data to $1–\exp^{-\rho\tau}$.

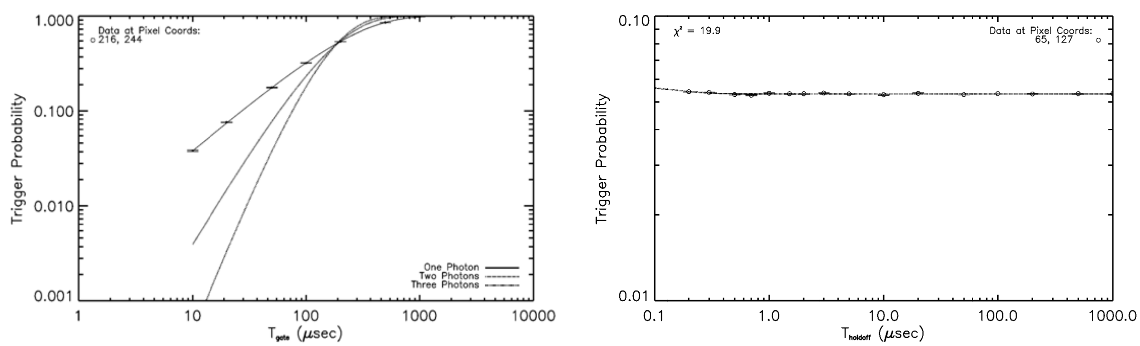


Figure 9. Event trigger probability for pixels on the APD with a = 100 ns, τ = 10 to 1000 μsec (left). Event probability is the number of triggered gates divided by the total number of gates. Data (horizontal ticks) are fitted to 1 – exp (-ρτ), which yields a very good agreement. To illustrate the validity of the poissonian single photon trigger probability model, best fits to p = 1–exp (-ρτ) – ρτ exp (-ρτ) and p = 1 – exp (-ρτ) – ρτ exp (-ρτ) – {(ρτ) 2 exp (-ρτ)}/2 are also plotted for comparison. The trigger probability changes very little as a function of hold off time, i.e. there is very little afterpulse.

An afterpulse is a false event caused by a charge carrier being trapped in a defect during an avalanche and subsequently being released after re-arming of the APD and initiating an avalanche. There is very little evidence of afterpulse in the HFF APD, as shown in Figure 9 (right).

There is, however, evidence for cross talk, i.e. a triggered pixel causes neighboring pixels to be falsely triggered, between pixels in the HFF APD. An example of this is shown in Figure 10. The nearest neighbors to the reference pixel are more likely to be triggered than the ones farther away. This behavior is seen regardless of length of the gate, bias, temperature settings, although there is less cross talk between pixels with a lower bias voltage. This behavior is problematic as this will cause pixels to be triggered by neighboring pixels and report false events. A redesign of the trenches between pixels is being undertaken at MIT/LL to mitigate cross talk.

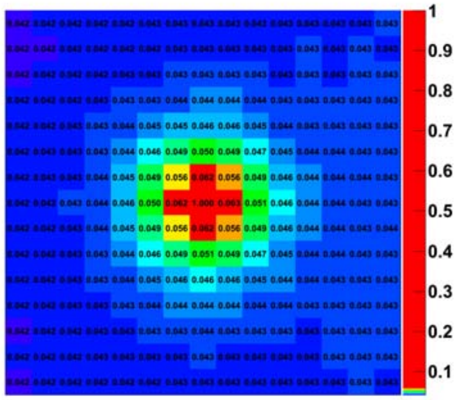
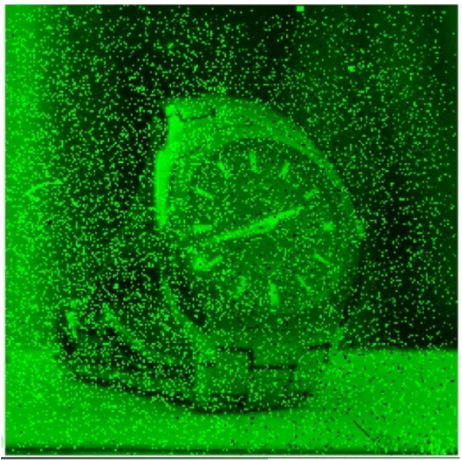


Figure 10. Conditional probability of neighboring pixels triggering given that a pixel is triggered. The conditional probability is averaged over a 32 x 32 pixel grid. Nearest neighbors are triggered with a higher probability than the neighbors that are far away from the reference pixel, indicating cross talk between pixels.

Figure 11 shows an image created by placing a watch on a table top, illuminating it with a light source, and focusing the light on the detector with a basic optics set up. The image was taken with the detector at 127 K and exposed to ambient light levels. It is the sum of 2000 gate exposure sequences in which only one photon is counted per gate. The event flip-flop for each pixel is read out after each gate and saved for later processing. The events generated by dark current are mitigated by setting a small gate time (30 μsec) in which the APDs are above breakdown and able to achieve a GM avalanche.



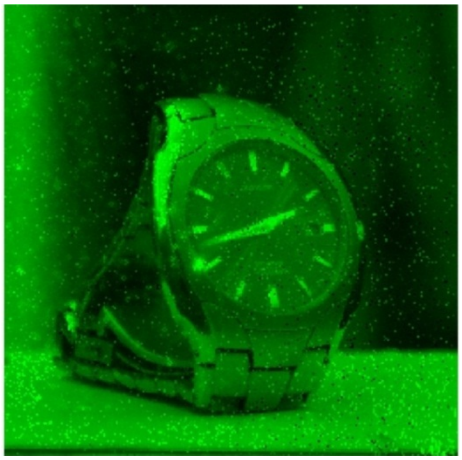


Figure 11. An image of a watch taken with a LFF GM-APD array biased above breakdown. Raw image (left) and after processing with basic filtering (right).

Figure 12 shows how the IV characteristic of the GM APDs changes with temperature. The breakdown voltage is estimated from this type of plot as the point on this surface plot where the anode current sharply increases.

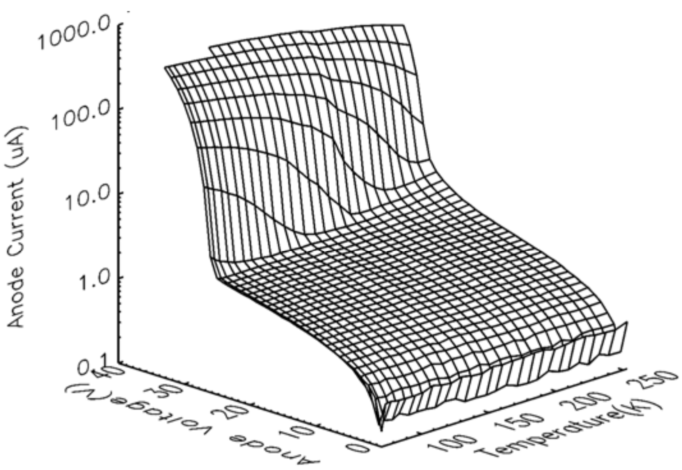


Figure 12. This is a plot of the anode current vs. anode voltage and temperature.

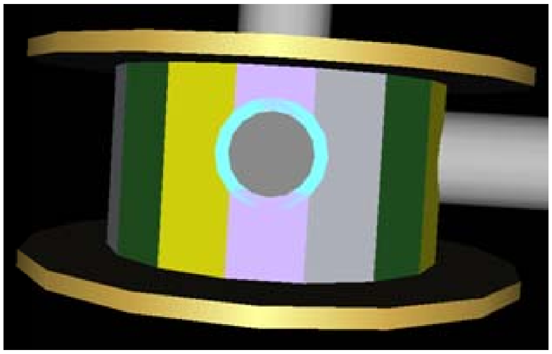
A Photon-Counting Detector for Exoplanet Missions

NASA

The objective of this project is to advance photon-counting detectors for NASA exoplanet missions. An "exoplanet" is a planet orbiting another star outside of our solar system. A photon-counting detector will provide zero read noise, ultra-high dynamic range, and ideal linearity over the relevant flux range of interest. The device always operates in photon-counting mode, and therefore it is not susceptible to the excess noise factor that afflicts other technologies. Its performance is expected to be maintained at a high level throughout mission lifetime in the presence of the expected radiation dose.

This project leverages the Moore project by using the same device design, but in higher quantities than needed for that project. By using multiple detectors, it will be possible to draw statistically significant conclusions about their performance and resilience in the presence of high energy radiation. This is important for predicting performance in a space mission.

In years prior, CfD Engineer Joong Lee designed the radiation testing program, defining the relevant mission parameters, and simulating the expected on-orbit radiation dose. It was determined that the radiation dose at the L2 orbit is expected to be ~ 5 krad (Si) over 11 years. For radiation testing, the device will actually be exposed to a dose ten times higher, or ~ 50 krad (Si), with 60 MeV proton beam. It was, then, necessary to determine the impact that such a radiation environment would have on the supporting electronics, as it is imperative they remain functional during radiation testing. To determine the survivability of the supporting electronics under such radiation environment at the radiation testing facility, a detailed simulation was undertaken. Using a GEANT4-based simulation called slic with a fully integrated 3-D geometrical model, the radiation dose seen by the electronics was mimicked. Figure 13 shows a rendering of the geometrical model of the radiation testing set up. The radiation dose seen by the electronics, estimated to be ~300 rad compared to the 50 krad exposure on the detector, is relatively benign, and the system is expected to be fully functional during radiation testing. We expect a radiation-induced dark current of ~0.5 e^-/pix/s/(total rad) one week after irradiation at -20 °C for a 25 μm pixel when exposed to 60 MeV protons. With cooling, the induced dark current can be reduced to acceptable levels for an exoplanet mission.



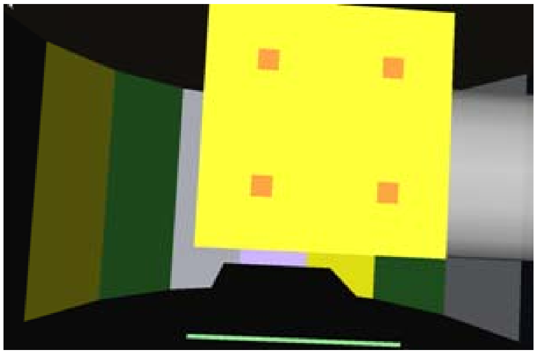


Figure 13. Rendering of geometrical model of the dewar (left), detector and electronics inside (right). This model is used in simulating the particle interactions as protons in the proton beam traverse the radiation port, the detector, and the inside volume.

The Nature of GLIMPSE 81: A Star Cluster to Rival Westerlund 1

CXC/Chandra

This project used Chandra Space Telescope/ACIS observations of a young star cluster. The X-ray emission from this cluster, already observed in previous low-resolution observations, was resolved by Chandra into many components. Analysis included separating the diffuse X-ray emission from the point-sources, and a spectral analysis of each source. The data from this project will be combined with those from other observations in order to perform a multi-wavelength analysis.

The research team published the first paper regarding Mercer 81 in the beginning of 2012. The paper, which was published in the Monthly Notices of the Royal Astronomical Society, is entitled "A newly discovered young massive star cluster at the far end of the Galactic Bar." This paper used the HST/NICMOS data to convincingly show that the cluster is young and massive. Notably, it is one of the first such clusters to be found at the far end of the bar of the Galaxy.

Team member Diego de la Fuente obtained new spectroscopic data from ISAAC/VLT in April, 2012. These data will be analyzed and combined with the Chandra data in order to determine the physical properties of the most massive stars in the cluster. In addition, the data will be used by team member Christine Trombley to aid in determining the effect of binarity on the high end of the initial mass function for the cluster as part of her PhD thesis.

A NICMOS Survey of Newly-Identified Young Massive Clusters

NASA/Space Telescope Science Institute

We are on the cusp of a revolution in massive star research triggered by modern infrared surveys such as 2MASS, Spitzer/GLIMPSE, UKIDSS, and VVV, and this undertaking capitalized on these projects by performing the first survey of massive stars in young stellar clusters throughout the Galactic plane. A search of these surveys has produced over 1000 newly-identified massive stellar cluster candidates in the Galactic plane which are hidden from our view at optical wavelengths due to extinction. In this project, CfD researchers Ben Davies and Christine Trombley used 29 HST (Hubble Space Telescope) orbits to image the most promising candidate clusters in broad and narrow band filters using NICMOS. The observations will be complemented with approved Spitzer and Chandra programs, numerous approved and planned ground-based spectroscopic observations, and state-of-the-art modeling. We expect to substantially increase the numbers of massive stars known in the Galaxy, including middle-aged and evolved massive stars in the Red Supergiant, Luminous Blue Variable and Wolf-Rayet stages. Ultimately, this program will address many of the fundamental topics in astrophysics: the slope to the initial mass function (IMF), an upper limit to the masses of stars, the formation and evolution of the most massive stars, gamma-ray burst (GRB) progenitors, the chemical enrichment of the interstellar medium, and the nature of the first stars in the Universe.

Most of the work in the data analysis plan has been completed. This includes manual reduction with the NICMOS pipeline and mosaicking each of the four wavebands observed. It also includes extraction of photometry using aperture photometery and PSF-fitting, and estimates of completeness through synthetic image simulations. We have assembled color-magnitude diagrams and luminosity functions for each cluster. Both of these require accurate knowledge of the field-star contamination, which we have obtained from each cluster's control-field.

Remaining work includes determination of the extinction to each cluster from the near-IR colors. When possible, using radio data in the literature, we have obtained each cluster's radial velocity and hence kinematic distance. With the reddening and distance known, we then fit each CMD with model isochrones to get cluster ages. We then use this information, combined with the latest stellar evolutionary models, to convert each cluster's background-subtracted luminosity function into an initial mass function. At this point, we can estimate the cluster's mass, the masses of the most massive stars, and detect the presence of an upper-mass cutoff.

During the 2011-2012 academic year, the team published two papers related to this research in the Monthly Notices of the Royal Astronomical Society: "The G305 star-forming complex: the central star clusters Danks 1 and Danks 2," and "A newly-discovered young massive star cluster at the end of the Galactic Bar."

Completed this year

LIDAR Imaging Detector for NASA Planetary Missions

NASA/PIDDP

In collaboration with MIT/Lincoln Laboratory, CfD worked to develop an imaging Light Detection and Ranging (LIDAR) detector for NASA planetary space missions. The device has a pixilated array of independent Geiger-mode Avalanche Photodiodes that can asynchronously measure laser light time of flight. The output is three-dimensional images providing distance measurements for each pixel. The device has a timing accuracy of ~100 picoseconds, thus enabling a ranging accuracy ~1 cm, or roughly two orders of magnitude, better than existing LIDAR instruments.

MIT Lincoln Laboratory delivered a 32x32 hybridized, bump-bonded LIDAR detector for testing at RIT. We assembled the test system for the detector and characterized the device. CfD Student Researcher Chris Maloney designed a camera enclosure for the detector and supporting ROB in order to facilitate imaging, as well as the execution of characterization experiments. The enclosure was designed to be light-tight, providing a simple and effective means of achieving a dark environment for the detector.

We then evaluated the properties of the LIDAR detector. In preparation, MIT Lincoln Laboratory provided a wafer of LIDAR-style GM-APDs for preliminary testing at a probe station. This wafer contains a variety of test structures with a range of size and geometry. IV curves for the diodes were plotted from the obtained measurements, and the lack of an R/G region in the forward-bias indicated a minimal number of traps within the GM-APDs.

In order to measure the intrapixel response, a test system was developed to scan the pixel area and measure the detector response across the pixel. This was done using a spot projector that creates a 1.5 μm spot and is mounted to 3 linear stages as shown in Figure 14.

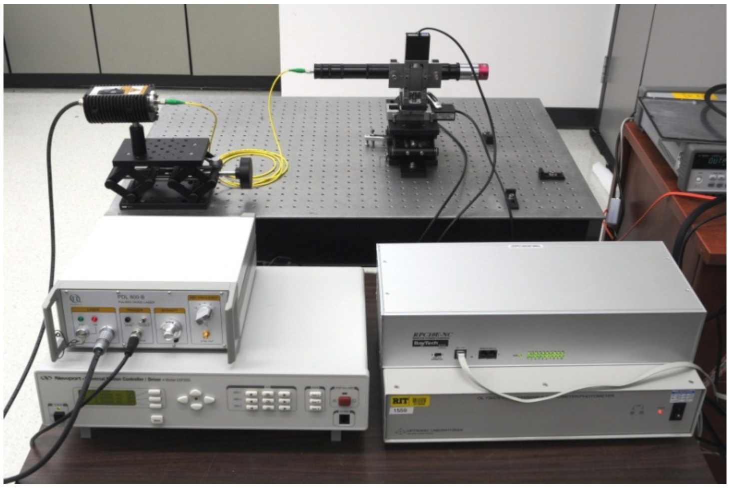


Figure 14. Spot projector used to make intrapixel response measurements.

By moving the spot projector along the z-axis, the laser was precisely focused on the detector. Next, the x and y axes were scanned, and the response of the pixel under test was measured. Once the pixel was fully scanned, a picture was assembled showing the intrapixel response as shown in Figure 15. Since this was a low fill factor device, there was a large difference between the response in the center versus the response at the edges.

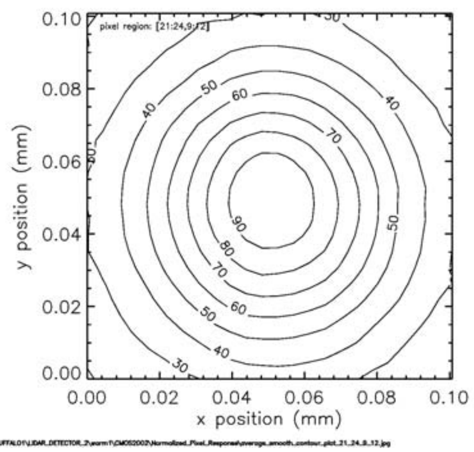


Figure 15. Intrapixel response on the LIDAR detector. This plot shows the average relative response for a single 100 μm x 100 μm pixel.

Christine Trombley

Christine Trombley is a graduate student member of the Center for Detectors who is pursuing a PhD in the Astrophysical Sciences and Technology program at RIT. She completed a BS degree in Astrophysics and Physics at Michigan State University in 2007.

Her first involvement with CfD was in 2007, when she joined the Rochester Imaging Detector Laboratory as a data analyst, reducing and analyzing Spitzer Space Telescope Infrared Array Camera observations of young, embedded stellar cluster candidates. Over her five year term with the Center, Christine has experience reducing and analyzing a variety of multiwavelength astrophysical observations, from radio to X-ray.

Ms. Trombley is investigating the slope of the high end initial mass function (IMF) in a sample of 8 young, potentially massive stellar clusters for her PhD thesis; the positions of these clusters are indicated in Figure 16. She will utilize spectroscopic observations from northern and southern facilities, as well as imaging from the Hubble Space Telescope, in order to determine the masses of bright stars in each stellar cluster. Following the method outlined in the Nature article written in 2005 by Dr. Figer, she will calibrate the mass-magnitude relation of stars in each cluster, then construct IMFs. The IMF has been shown to be nearly universal at lower mass ranges, and Christine's work will investigate whether that relation holds at the high mass range.

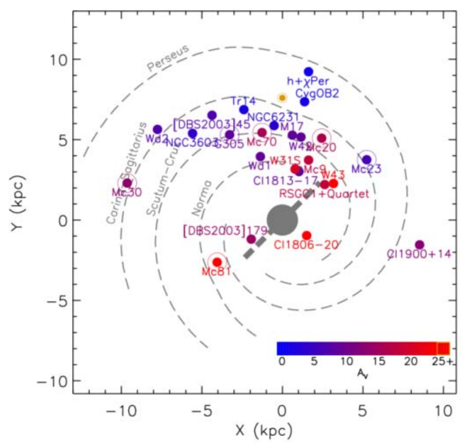


Figure 16

After winning the NASA Graduate Student Research Fellowship, Christine spent 10 weeks in Fall of 2011 at NASA's Goddard Space Flight Center in Greenbelt, MD, under the supervision of Dr Sara Heap. During this time, she examined near-IR spectra of candidate massive stars observed by colleague Diego de la Fuente, a PhD student at INTA/CSIC, comparing the spectra with atlases and models. These spectra, taken with ISAAC at the Very Large Telescope in Chile, represent the southern clusters in her sample of young, potentially massive stellar clusters. In the fall of 2012, Ms Trombley will carry out her NASA Infrared Telescope Faculty near-IR spectroscopic program over 2.5 nights.

Kimberly (Manser) Kolb

Kimberly (Manser) Kolb is a graduate student member of the Center for Detectors who is pursuing a PhD in the Imaging Science program. She completed her MS degree in the same program during summer, 2011. She completed a BS degree in Microelectronic Engineering in 2008. Her combination of degrees and experience is useful in the field of high-end detectors, giving her a knowledge base that encompasses detector development through fabrication, characterization, and implementation.

Her first involvement with CfD was in 2007, when she began process development work for fabrication of silicon p-i-n diodes for hybridization (a NASA project) as a senior in the Microelectronic Engineering BS program. This work later culminated in her capstone project for that degree. After a brief stint in industry in 2008-2009, Kimberly returned to RIT and CfD to pursue her MS degree, funded by the prestigious BAE Systems Fellowship. BAE Systems is the world's second-largest defense company, and the two-year fellowship program at RIT included tuition, travel support and a stipend. She continued to participate in ongoing projects, including the hybridization portion of the NASA project to which she had previously contributed, leading to an SPIE paper and conference presentation (summer, 2010) of her work. Kimberly also completed an internship at BAE Systems in the summer of 2010, working on infrared detector fabrication and process improvement.

Kimberly used specialized test circuitry with a customized data acquisition technique, developed a method for parameter extraction from the raw data, and examined device characteristics derived from experimental results. She also developed a simulation program to approximate the dark count rate (among other parameters) of a device based on semiconductor characteristics and testing conditions. Her thesis makes conclusions about the dependence of dark count rate on device architecture and how individual noise mechanisms affect device performance.

Ms. Kolb investigated the dark count rate of these detectors and reported the results in her thesis. There are a number of mechanisms that produce dark counts, the most prominent being thermal excitation of carriers. Thermal carrier generation rates are generally only dependent on the temperature of the diode and may be constant under certain controlled conditions. Afterpulsing results from the release of carriers trapped in intermediate energy states (states with energy less than the band gap of the material). Unlike thermal carrier generation, afterpulsing is dependent on the dead time of the device (the time during which the device is unable to detect a carrier). Another mechanism, called self re-triggering, occurs when relaxing carriers emit photons during an avalanche. These photons can be absorbed in the substrate and generate dark carriers. Self-retriggering is also dependent on the dead time of the device.

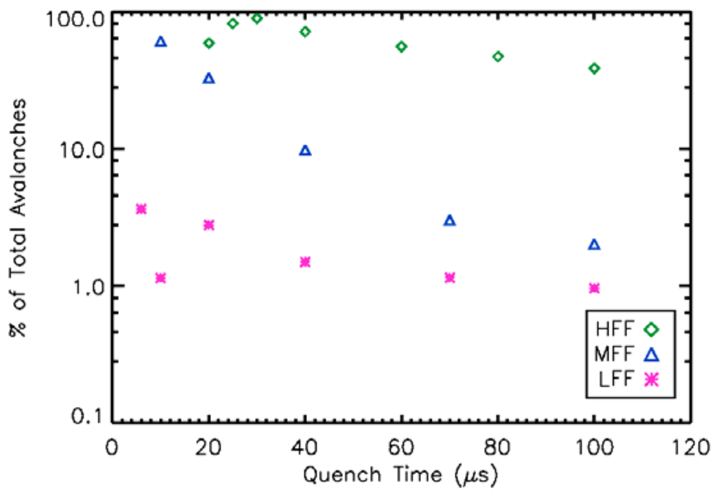


Figure 17. Experimental Results for Self-Retriggering Noise Contributions; LFF, MFF, and HFF represent different device types.

Brian Glod

Brian Glod earned his MS in Electrical Engineering in 2012, and his BS in Computer Engineering in 2010 from RIT. Brian is currently a Lab Engineer at the Center for Detectors. He assists with the design and modification of the detector electronics. He is also highly involved with FPGA development and interface software for communication between the acquisition computers and imaging electronics.

Brian's career at the Center for Detectors started in March of 2009 as a lab technician responsible for general lab tasks and simple software development. During the summer of 2009, Brian transitioned to co-op status, and was responsible for designing the FPGA DDR memory interface and buffering schemes used for controlling the NASA-funded Low-Noise CMOS Imaging Detector project. After the co-op experience, Brian continued to develop FPGA acquisition code and started to become involved in hardware design. Early on, this involved the design of several printed circuit boards for simple cable-to-detector signal routing, and mechanical fixtures for the NASA detector. The circuit boards and fixtures were intended to be operated within a dewar with exposure to temperatures and pressures as low as one nanotorr and 30 Kelvin. After success in this area, his PCB design skills were further developed through the schematic capture and layout of a data acquisition board for the same CMOS detectors. The acquisition board was designed to interface with a TerASIC DE3 Development System featuring a Stratix III FPGA. The goal was to significantly reduce detector acquisition noise, and was achieved using careful layout techniques and ultra-low-noise surface mount components. When completed, the board successfully reduced acquisition noise by 73%. With additional modifications, the board has potential for further noise reduction.

Brian completed his MS thesis under the direction of Dr. Donald Figer at the Center for Detectors. His research characterized a digital data acquisition and control system for the simultaneous operation of four Geiger-mode avalanche photodiode array detectors. Because the electronics had been recently designed, the goal of characterization was to understand their behavior and limitations to ensure the accuracy and reliability of the imaging data prior to exposure to secondary radiation. Through the course of his research, Brian developed bit error rate tests that verified data accuracy over a wide range of temperatures. He also spent significant time performing signal integrity analysis simulations on the system cabling and PCB traces for critical clock paths. The simulations proved similar to hardware measurements, and were therefore used to make suggestions for improving future design iterations.

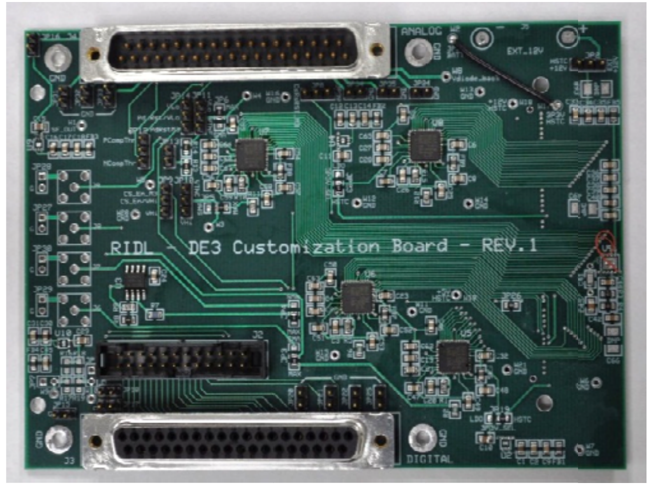


Figure 18. Low-noise data acquisition board for use with the NASA Low-Noise Imaging Detectors

After graduating, Brian continues to work at the Center for Detectors developing electronics and software for cutting-edge "noiseless" imaging detector arrays for astrophysics applications. These detectors will ultimately be used in the world's largest telescopes to peer deeper into space, discover Earth-like planets, and enhance our understanding of the universe.

Diego de la Fuente Guillen

Diego de la Fuente Guillen is a graduate student pursuing a PhD at the National Aerospace Technical Institute in Madrid, Spain. He also holds a BS in Physics from Universidad de La Laguna (2009), and an MS in Astrophysics from Universidad Complutense de Madrid (2011). Diego worked at the Center for Detectors as a Visiting Research Scholar in March and April of 2012. His visit to collaborate with Dr. Figer was sponsored by a grant from Spain's Ministry of Economy and Competitiveness.

Adapting code originally written by Dr. Figer, Diego spent the majority of his time with the CfD reducing spectra of massive, evolved stars observed as part of his successful ISAAC/VLT proposals. The next steps in his PhD thesis project involve extensive modeling, along with measuring the metal content of these stars. In the spirit of collaboration and networking, Diego also attended journal club, afternoon coffee discussions, and lunch seminars given by professors, post-docs, and graduate students of RIT's astrophysics program during his stay in the United States.

Ross Robinson

Ross Robinson is a graduate student who is pursuing a PhD in the Imaging Science program.

Ross's research focuses on enhancing focal plane array quantum efficiency with quantum dots. Current silicon CMOS- or CCD-based detectors used in standard digital cameras do a poor job of recording UV images. The ability to detect UV light may be improved by switching to exotic materials or by polishing the detector until it is so thin that it is flexible and almost transparent. Both of those options are very expensive to fabricate. A different approach is to apply a coating of nanometer-scale materials to the surface of a detector chip to convert the incoming UV light is to visible light, which is more readily recorded by standard detector chips. This research has developed a method of coating detector arrays with nanomaterials and applied it to improve the ability of detectors to record UV and blue light.

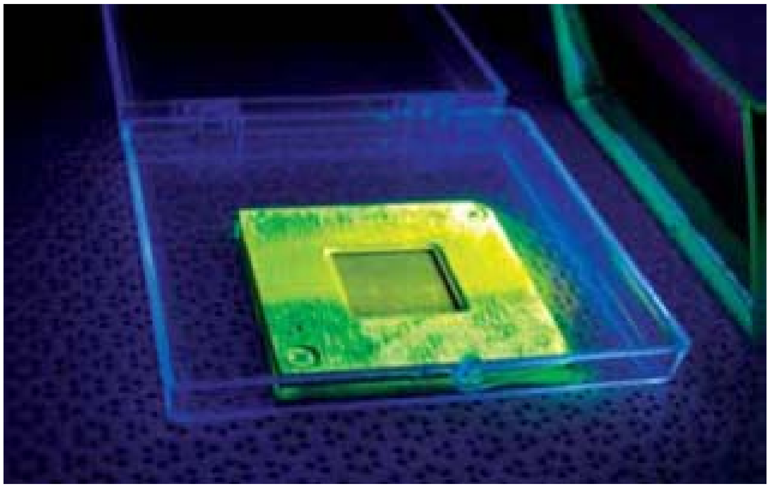


Figure 19. Quantum Dot coated detector in aluminum mask under UV

Kenny Fourspring

Kenny Fourspring is a graduate student who is pursuing a PhD in the Imaging Science program.

Last year, he was awarded a NASA Graduate Student Research Fellowship. He spent part of the year at NASA's Goddard Space Flight Center, involved in low temperature testing of DMD for the W-FIRST space telescope program. W-FIRST (Wide-Field IR Space Telescope) is planned to advance the ability to find earth sized planets, and also investigate dark matter. The telescope will contain an infrared spectrometer. For a DMD to work effectively the device must be cooled to minimize the background. A packaged DMD was placed within a dewar (see Figure 20), and the flatness across the array measured as the device was cooled. A functionality test was also performed before and after the cooling procedure to ensure that all pixels still functioned.

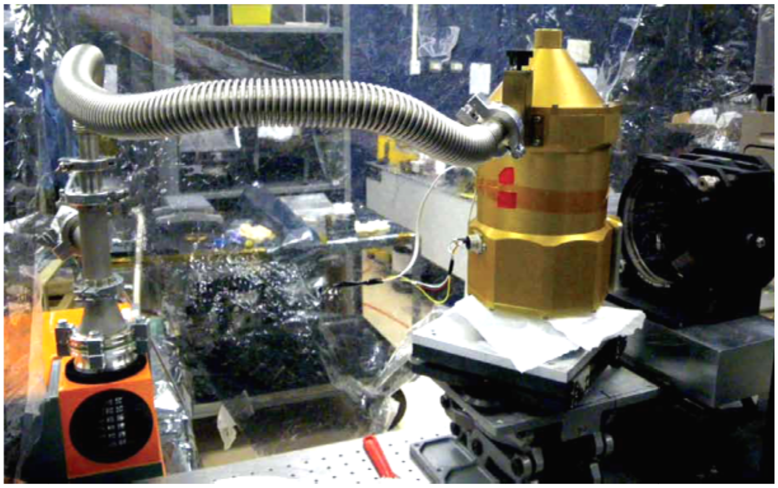


Figure 20 shows interferometer measurements of surface at two different temperatures (ambient left and -100 °C right).

External Funding and Collaborating Partners

Figure 21 shows funding per year since the inception of the Rochester Imaging Detector Laboratory in 2006. Colors correspond to projects. A breakdown of current individual grants and contracts is given in the following pages.

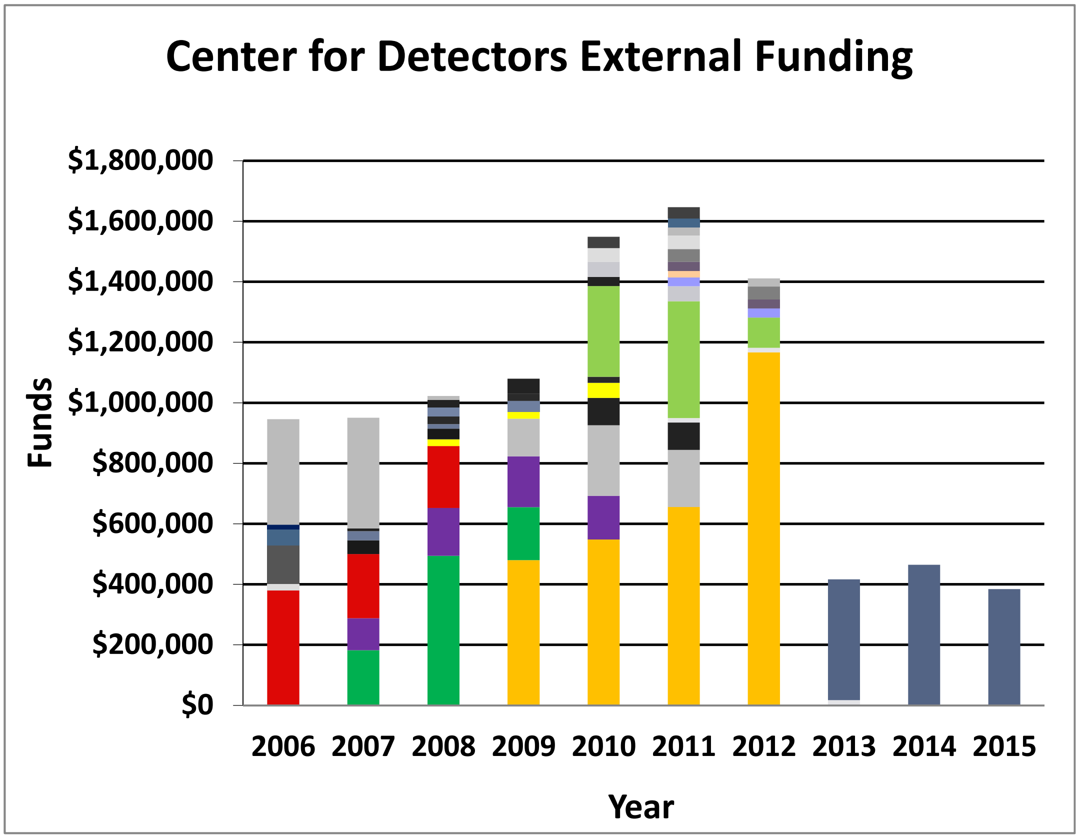


Figure 21. Since its inception in 2006, the Center for Detectors has secured over $9.8 million in research funding. The largest contributions are from the Moore Foundation and NASA. The Moore Foundation has invested $2.8 million to support the development of a zero noise detector, while NASA awarded close to $5 million in research grants. In 2012, NSF also became a major sponsor with a research grant of $1.2 million for the development and testing of infrared detectors grown on silicon wafers.

Grants and Contracts- New

Title	Funding Source	Dates	Amount
New Infrared Detectors for Astrophysics	NASA	6/01/12- 5/31/15	$1,246,799
NASA GSRP	NASA/GSRP	9/15/11- 9/14/12	$30,000

Grants and Contracts - Ongoing

Title	Funding Source	Dates	Amount
Next Generation Imaging Detectors for Near- and Mid-IR Wavelength Telescopes	Gordon and Betty Moore Foundation	10/01/08- 9/30/13	$2,839,191
A Photon-Counting Dectector for Exoplanet Missions	NASA/TDEM	2/19/10- 2/18/13	$783,981
Detector Virtual Workshop	NSF	7/01/11- 6/30/13	$19,999
The nature of GLIMPSE 81: a star cluster to rival Westerlund1	CXC/Chandra	6/21/10- 6/20/13	$35,768
A NICMOS Survey of Newly Identified Young Massive Clusters	NASA- STcl/HST	1/01/09- 12/31/12	$180,449

Grants and Contracts - Completed within the Past Year

Title	Funding Source	Dates	Amount
A very low noise CMOS Detector Design for NASA	NASA/APRA	2/08/07- 5/06/11	$847,000
Radiation Tolerant Detector for NASA Planetary Missions	NASA/PIDDP	6/25/07- 6/24/11	$807,681
The Journey of a Photon: High School Student Involvement in Developing their Community's Understanding of Detector Science	NASA	6/25/07- 7/24/11	$74,977

Collaborating Partners

The Center for Detectors has a rich history of collaboration with organizations outside of RIT. These include partners in academia, such as the University of Rochester, at national laboratories, such as NASA, and in industry, such as ITT and Raytheon. Our desire to collaborate flows from the fact that no single organization could accomplish all the goals of our projects. Instead, the project teams are distributed across several organizations, each with its own world-class expertise and often significant infrastructure developed over decades of past projects.

As a side benefit of this collaboration, our students are exposed to a wide range of research and development environments. In some cases, they visit partner organizations for extended periods of time. Students also sometimes decide to start a career at these sites after their graduation.

In Fall 2011, CfD PhD student Christine Trombley traveled to Maryland to spend ten weeks working in Goddard's Exoplanets and Stellar Astrophysics Laboratory. The research experience was part of Trombley's year-long NASA Graduate Student Researchers Fellowship that supports her research on massive stars. Also during this past year, a new NSF grant was awarded jointly to RIT and Raytheon Visions Systems. We are excited to be partnering with RVS to develop, fabricate, and test infrared detectors grown on silicon wafers under this new award.

Universities and Foundations

UC DAVIS

University of Hawaii Institute for Astronomy

University of Rochester

NYSTAR

Gordon and Betty Moore Foundation

National Research Laboratories

Marshall Space Flight Center

NSF

NASA

LSST

MIT Lincoln Laboratory

Office of Science U.S. Department of Energy

National Optical Astronomy Observatory

CSIC

SLAC

JPL

Spitzer Space Telescope

Space Telescope Science Institute

nhsc

Sandia National Laboratories

Berkeley Lab

Industry

Teledyne Scientific & Imaging, LLC A Teledyne Technologies Company

Infotonics technology center inc

BAE Systems

Thermo Scientific

Kodak

Raytheon

Ball

ase Optics

ITT Engineered for life

Communications

Detector Virtual Workshop

In Fall of 2011, the Center for Detectors established the Detector Virtual Workshop (DVW). The DVW is dedicated to the advancement of UV/O/IR detectors with applications in astronomy and other fields, *e.g.*, biomedical imaging, solar energy, and photonics. The objectives of the workshop are to enable future national capabilities by disseminating knowledge, increase interdisciplinary opportunities, enhance interactions between academia, industry, and government, and provide student and professional training opportunities.

DVW topics addressed during the past year included superconducting single photon detectors, high time resolution astrophysics, EMCCDs, future space missions, next-generation detectors materials, UV/optical/infrared detectors, and discussions of non-astronomy applications. The series hosted 12 speakers in the academic year 2011-2012, and an additional talk in the summer of 2012. All talks were streamed for real-time viewing and archived for later retrieval. A number of the speakers are from universities, while others are employed at U.S. national laboratories or in industry. Professor Zoran Ninkov states, “I have used the recorded talks as the basis of class assignments for both undergraduate and graduate students. It was a pleasure and honor to have such high-level world-class researchers agree to be part of this RIT series. I hope this sort of activity continues in the future.”

The following pages feature each of the talks given this year in the DVW. The presentation file and archived video from each talk can be found in a dedicated section of the CfD’s website. DVW attendance generally ranged between 10-20 people in the in-person audience and a similar number in the virtual audience. Hits on the DVW web site generally increased by a factor of two to three around the time of the talk and maintained a lower level of activity for retrieval of archived talks.

The period of performance was extended through a no-cost extension until June 30, 2013, in order to accommodate several additional talks in the series. These will be given in the coming academic year.

Robert Hadfield

Reader in Physics and Royal Society University Research Fellow, Heriot-Watt University, Edinburgh, United Kingdom

Infrared Superconducting Single-Photon Detectors

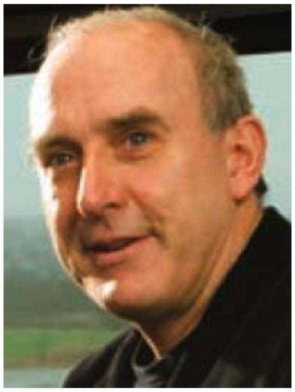
Abstract: Single-photon detectors are a key enabling technology for a host of applications at the frontiers of science, from imaging and ranging to quantum information processing. These advanced photon counting applications place exacting demands on detector performance, spurring the development of new detector technologies. A new class of single-photon detectors, based on a superconducting nanowire, holds particular promise for time-correlated single-photon counting at infrared wavelengths. These detectors offer wide spectral sensitivity (visible to mid-infrared) combined with low dark counts, short recovery times and exquisite timing resolution. These low temperature detectors can now be integrated into practical cryogen-free refrigerator systems. I will discuss the impact of these high-performance detectors in applications ranging from quantum cryptography to time-of-flight depth imaging. I will also give an outlook on future developments in this emerging photon-counting technology.

About the Speaker: Dr Robert Hadfield is an expert in infrared single-photon detectors based on superconducting materials. He received his PhD from the University of Cambridge, UK, in 2003 for work on nanoscale superconducting devices. He spent four years as a postdoctoral guest researcher at the US National Institute of Standards and Technology in Boulder, CO. Working together with Dr Sae Woo Nam, he implemented superconducting nanowire single-photon detectors into practical systems for use in quantum cryptography experiments over record distances. He joined Heriot-Watt University as a Royal Society University Research Fellow in 2007, and was promoted to Reader in Physics in 2009. His research team is pursing the development of next generation superconducting detectors and their implementation in new photon–counting applications. He has published over 40 peer-reviewed papers, 11 as first author, including a major topical review for Nature Photonics.

Andy Shearer

Director, Centre for Astronomy, School of Physics, NUI Galway, Galway Ireland

High Time Resolution Astrophysics in the ELT Era: Science Problems and Detector Requirements



Abstract: 30-40m telescopes will enable astronomical observations on sub-second, sub-millisecond and, in some cases, sub-microsecond time-scales. To date, these have been limited to a few of the brightest targets such as the Crab pulsar. In this talk, I will review the current state of optical HTRA science and its possibilities over the next 5 years. One of the challenges will be the requirement to move HTRA into the near infrared to match, for example, the spectral response of the European Extremely Large Telescope.

About the Speaker: Dr. Andy Shearer graduated from London University with a BSc in Astronomy in 1975. He subsequently obtained an MSc (1978) and PhD (1980) in Cosmic Ray Physics from Durham University. He worked as a post-doc in Bristol University and in industry before taking up a research position in the Experimental Physics department at University College Galway in 1991. In 1996, he was appointed as a lecturer in the Information Technology Department at the renamed National University of Ireland, Galway. In 2005, he founded the Irish Centre for High-End Computing (ICHEC), and was its first Director. His research interests cover high-time resolution astronomical observation, modeling astrophysical plasmas, and medical/astronomical image processing. He has a specific interest in optical observations of rotation-powered pulsars. His group is credited with the discovery of optical pulsations from two out of the five known optical pulsars. He is currently working on optical follow on studies of pulsars discovered by the Fermi Gamma-Ray Satellite. He is the Director of the Centre of Astronomy, NUI, Galway.

Karl Berggren

Associate Professor of Electrical Engineering, Department of Electrical Engineering and Computer Science, MIT

Superconducting Single-Photon Detectors

Abstract: Superconducting nanowire single-photon detectors are promising candidates for single-photon detection systems that require high efficiency, low noise, good timing accuracy, and sensitivity across a wide range of optical wavelengths. They may enable applications in quantum optics, laser radar, space communications, and integrated-circuit evaluation. However, these detectors also have interesting electrical, thermal, and optical properties at the nanoscale that influence their performance, and can be exploited to improve the device efficiency, particularly in the infrared. In this seminar, we will describe the device operation, what we know of the device physics, and describe how these devices can be used in applications. Examples will include a variant of a new device architecture that provides improved infrared sensitivity and readout signal to noise ratio, as well as a nano-antenna design that enhances the optical absorptance of the device.

About the Speaker: Dr. Karl K. Berggren is an Associate Professor of Electrical Engineering in MIT's Department of Electrical Engineering and Computer Science, and is the Director of the NanoStructures Laboratory, Associate Director of the Microsystems Technology Laboratory, and a member of the Research Laboratory of Electronics. From 1996 to 2003, Dr. Berggren was a member of the MIT Lincoln Laboratory technical staff, performing research on nanofabrication methods applied to superconductive classical and quantum (i.e. quantum computing) electronics. Since joining the faculty at MIT, Professor Berggren's research interests have centered on the application of new nanofabrication technology to superconducting single-photon detectors. He has expanded these detectors to include the capacity for photon-number resolution, and integrated the devices by using nano-optical techniques. His research includes the physics, electronics, optics, and fabrication of these devices, and includes work on applications of the devices to both quantum and classical communications.

Alan Migdall

Fellow of the Joint Quantum Institute at the National Institute of Standards and Technology (NIST) and the University of Maryland

Metrology of and Metrology using Single Photon Detectors

Abstract: Given the tiny energies involved, the generation and detection of one photon at a time is an extraordinary feat. Even with this difficulty, the development of single-photon technology is rapidly advancing. Because this technology involves dealing directly with individual quantum states, it opens up many areas that push the conventional limits, and thus is a strong motivation for this development. One big driver has been the field of quantum information, which offers the potential of nothing less than revolutionizing our abilities to calculate here-to-fore intractable calculational problems, to test fundamental principles of nature, to provide communication where absolute security is based on fundamental physical principles, and to make measurements beyond what are fundamental limits in the classical world. With all this potential, it is no wonder there is such interest in improving single-photon devices. This talk will review single photon detector and source technology and some applications. One area of particular interest to NIST is their use in metrology. I will present techniques that use this technology for measurements that are not possible any other way and to, in turn, use the techniques made possible by these devices to characterize the devices themselves. This talk will also discuss their use in a fundamental test of nature.

About the Speaker: Alan Migdall is a Fellow of the Joint Quantum Institute at the National Institute of Standards and Technology (NIST) and the University of Maryland, where he works with non-classical light sources and detectors for use in absolute metrology, quantum information, and fundamental physics applications. He is also engaged in efforts aimed at advancing single-photon technologies for these applications. Migdall leads the Quantum Optics Group of the Quantum Measurement Division at NIST. He has organized a number of conferences and workshops on single-photon detector and source technology, as well as the applications and metrology of that technology. He founded the Single Photon Workshop, which debuted at NIST in Gaithersburg in 2003 and has continued biannually at metrology labs in the UK and Italy, NIST-Boulder, and Germany in 2011. He has recently co-authored a review of single-photon sources and detectors (Review of Scientific Instruments 82 071101[2011]).

Craig Mackay

Professor in Image Science in the Institute of Astronomy, University of Cambridge, United Kingdom

Electron Multiplying Charge Coupled Devices

Abstract: Almost as soon as CCDs were invented, astronomers dreamed of devices with negligible readout noise. Electron Multiplying CCDs (EMCCDs) offer this for the first time even at high read-out speeds, and have the potential to count individual photons. These devices have most of the highly-desirable characteristics of modern CCDs such as high quantum efficiency, excellent uniformity and freedom from defects. For many applications in astronomy, there remain significant advantages in using standard devices, but there are some applications which are beginning to be important where their characteristics offer the chance to design and build new classes of instruments. This talk will look at where these devices should or should not be used and then go on to describe what has to be done to get the very best out of them. There are significant differences between camera systems designed for general application and those which are optimized to give the very best ultralow signal performance in photon-counting mode. How the best performance is achieved and what needs to be done to maintain it will be described in this talk. Examples of the data obtained and scientific results achieved with photon-counting EMCCDs will be given.

About the Speaker: Craig Mackay has worked in the general area of scientific imaging systems for many years. He was a member of the Hubble Space Telescope Faint Object Camera team and worked for many years with CCD detectors. In 1985 he formed AstroCam Ltd that is now part of PerkinElmer Life Sciences. While in AstroCam, he developed automated DNA sequencers, protein electrophoresis systems, transmission electron microscope and X-ray imaging systems. He has been an innovator and leader in the development of ultra low light imaging systems, both in the visible and the infrared. He has been involved in developing Lucky Imaging systems for astronomy that allow diffraction limited imaging to be obtained from the ground for the first time without use of adaptive optics. Most recently, he has combined Lucky Imaging with low order adaptive optics to obtain the highest resolution images ever taken in the visible or the infrared either from ground or from space.

Bernard Rauscher

Astrophysicist, NASA Goddard Space Flight Center

Reducing the Read Noise of the James Webb Space Telescope Near Infrared Spectrograph Detector Subsystem

Abstract: We describe a Wiener optimal approach to using the reference output and reference pixels that are built into Teledyne's HAWAII-2RG detector arrays. In this way, we are reducing the total noise per ~1000 second 88 frame up-the-ramp dark integration from about 6.5 e- rms to roughly 5 e- rms. Using a principal components analysis formalism, we achieved these noise improvements without altering the hardware in any way. In addition to being lower, the noise is also cleaner with much less visible correlation. For example, the faint horizontal banding that is often seen in HAWAII-2RG images is almost completely removed. Preliminary testing suggests that the relative gains are even higher when using non flight grade components. We believe that these techniques are applicable to most HAWAII-2RG based instruments.

About the Speaker: Dr. Rauscher is a Civil Service experimental astrophysicist at NASA Goddard Space Flight Center (GSFC), where he is the James Webb Space Telescope (JWST) Detector Scientist, JWST Integrated Science Instruments Module (ISIM) Deputy Project Scientist, and Principal Investigator for the JWST Near Infrared Spectrograph Detector Subsystem. Dr. Rauscher has served as Principal Investigator for numerous suborbital projects developing and testing next-generation and photon-counting detectors for space and ground applications. He has over 20 years of experience, including hands-on testing of Teledyne HAWAII-4RG, HAWAII-2RG, HAWAII-1RG, HAWAII-1R, NICMOS-3, NICMOS-2, and 64×64 pixels Rockwell PANIC detectors, and Raytheon SB304, SB290, and ALADDIN detectors. His primary research interests are infrared astronomy instrumentation and the nature of Dark Matter and Dark Energy in the Universe.

Kieran O’Brien

Research Scientist in the Department of Physics, University of California Santa Barbara

Microwave Kinetic Inductance Detectors for Optical and Near-IR Astronomy

Abstract: In this talk, I will describe our ongoing work in the development of Microwave Kinetic Inductance Detectors (MKIDs) for optical and infrared astronomy. These super-conducting devices represent an important step towards the development of the 'ultimate detector'; one that can measure the position, energy and arrival time of a photon. I will describe the operating principles of the devices, their capabilities and their current status. I will describe ARCONS, the first MKID-based optical/IR instrument, and the results of our recent commissioning run at the Palomar observatory. Finally, I will discuss the future promise of the technology for a broad range of astrophysical programs ranging from large scale surveys to the characterization of transient sources discovered by current and future synoptic surveys.

About the Speaker: Dr. Kieran O'Brien gained his PhD from the University of St Andrews, UK in 2000. His thesis entitled 'X-ray and optical observations of X-ray Binaries' pioneered the technique of echo-tomography in X-ray Binaries. After a short post-doc at the University of Amsterdam, he joined ESO in 2002. He spent seven years as an Operations Staff Astronomer at the VLT in Chile. He was Instrument Scientist for the FORS spectrographs and deputy group leader of the Calibration group. During his time there, he furthered his interest in the development of high-speed instrumentation working with ULTRACAM and ULTRASPEC. He joined UCSB in 2009 and is a Research Scientist in the group of Professor Ben Mazin, working on the development of MKIDs for optical/IR astronomy. They recently commissioned the first optical/IR MKID camera at the Palomar 200-inch telescope. He continues to publish in the field of rapid correlated variability in X-ray binaries.

Mark Itzler

CEO & CTO at Princeton Lightwave Inc.

Photon Counting with InGaAsP Single Photon Avalanche Diodes

Abstract: Single-photon detectors based on avalanche diode structures are frequently the preferred choice for photon counting applications in the short-wave infrared wavelength range from 0.9 – 1.7 µm requiring not only high performance, but also ease of implementation, scalability, and high reliability. Over the past decade, significant progress has been achieved for many properties of single photon avalanche diodes (SPADs) based on the InGaAsP materials system. There has been notable improvement in the fundamental tradeoff between photon detection efficiency and dark count rate, and high precision timing jitter has been demonstrated. One recent trend has been the focus on dramatically increasing the photon counting rates of these devices for communications applications, and enhanced counting rates have been realized through advances in hybrid back-end electronic circuitry. There has also been impressive scaling of these detectors to large format arrays to support applications such as 3-D LIDAR imaging, free space optical communications, and low light level sensing. New chip-level monolithic integration has also been implemented to achieve avalanche self-quenching, which promises high levels of SPAD performance and functionality with greatly simplified operational requirements. I will discuss the challenges inherent in further progress beyond these recent developments as well as the long-term prospects for the evolution of InGaAsP SPAD technology.

About the Speaker: Dr. Mark Itzler is currently CEO and CTO at Princeton Lightwave, Inc. For the past 15 years, he has engaged in the development and commercialization of InP-based photodetectors, with a focus on single photon avalanche diodes and on avalanche photodiodes for high-speed fiber optic receivers. Dr. Itzler is a past Chair of the IEEE LEOS Technical Committee on Photodetectors and Imaging; he is presently the Chair of the Advanced Photon Counting Techniques Conference held as part of the SPIE Defense, Security + Sensing Symposium. He is also an Associate Editor of Photonic Technology Letters. Dr. Itzler has authored about 70 technical papers and conference presentations, has been granted 12 patents, and is a Fellow of the IEEE. He recently co-authored a topical review on InGaAsP SPADs [J. Modern Optics 58, 174–200 (2011)].

Jim Beletic

Senior Director of Space & Astronomy at Teledyne Imaging Sensors

The Fantastical Discoveries of Astronomy made possible by the Wonderful Properties of II-VI Materials

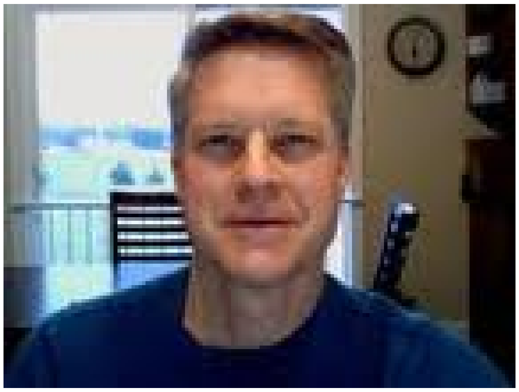
Abstract: The universe is an amazingly huge place. While humankind has directly explored Earth's sister planets with space probes, we don't have the means to venture beyond the solar system, and so almost all information about the universe comes from sensing light that happens our way. Astronomy is constantly striving to find better ways to sense the feeble amount of energy from distant stars and galaxies. This quest has led to a new generation of very large telescopes on the ground, and the deployment of the 2.4-meter Hubble telescope in space. Ground-based astronomy will soon begin construction on even more ambitious extremely large telescopes (ELTs), and the James Webb Space Telescope's 6.5-meter mirror will launch by the end of the decade. Possibly more important than the development of bigger telescopes is the rapid advancement in solid state detector technology. The detector revolution was led by silicon CCDs (IV material), but II-VI materials (HgCdTe) developed in the past two decades for sensing infrared light have made the most significant difference in astronomy. Infrared light is the only way to study a wide range of astronomical phenomena. This talk will present the cutting edge astronomy that is made possible by the wonderful properties of II-VI materials.

About the Speaker: Dr. Beletic is Senior Director of Space & Astronomy at Teledyne Imaging Sensors, a strategic business unit of Teledyne Scientific & Imaging, LLC. He has over 25 years of experience in astronomical instrumentation, with specialization in visible and infrared image sensor technologies. His career is a unique combination of international work experience that includes leadership positions at the world's foremost astronomical observatories and an industry leader in infrared sensors (Teledyne), and scientific positions at major research centers (Harvard University, MIT Lincoln Laboratory, Georgia Tech Research Institute). During his career, his teams have developed and delivered imaging sensors that are used at more than 30 of the most advanced telescopes on ground and in space. In recognition for his work in astronomy, an asteroid has been named after him. Fortunately, that asteroid has minimal chance of hitting the Earth.

Michael Krainak

Head of the Laser and Electro-Optics Branch at NASA-GSFC

Candidate detectors for space-qualified time-resolved photon counting



Abstract: Photon-counting detectors are required for numerous NASA future space-based applications including science instruments and free-space optical communication terminals. We discuss several photon-counting detector technologies that are under evaluation for possible deployment on the Ice, Cloud and Land Elevation Satellite-2 (ICESat2), Advance Topographic Laser Altimeter System (ATLAS), and other future NASA science instruments and free space laser communication terminals. Minimizing space-based resources (size, weight, power and cost) is an important goal for all NASA science missions. The sensitivity of the present analog detectors is limited. The receiver performance can be improved by one to two orders of magnitude by using single-photon-sensitive detectors. Photomultipliers and avalanche photodiodes are the primary candidates.

About the Speaker: Michael Krainak received his BS in electrical engineering from Catholic University and MS and PhD in Electrical Engineering from Johns Hopkins University. He started his career as a telephone switch office field engineer for AT&T Western Electric. He worked for ten years at the National Security Agency in signal processing, Fourier optics, and microelectronic circuit design. For twenty years he has worked at NASA Goddard Space Flight Center (GSFC) on inter-satellite laser communications, lidar, and laser transceiver technology development. Dr. Krainak is presently the Head of the Laser and Electro-Optics Branch at NASA-GSFC.

Sanjay Krishna

Professor, Department of Electrical and Computer Engineering University of New Mexico, Albuquerque, NM

The Infrared Retina: Ushering in the Fourth Generation of Infrared Detectors

Abstract: In this talk, I will try to look into the crystal ball to make predictions about the fourth generation of infrared detectors. Using the concept of a bio-inspired infrared retina, I will make a case for an enhanced functionality in the pixel. The key idea is to engineer the pixel such that it not only has the ability to sense multimodal data such as color, polarization, dynamic range and phase but also the intelligence to transmit a reduced data set to the central processing unit. I will use two material systems, which are emerging as promising infrared detector technologies, as prototypes to highlight this approach. These are InAs/InGaAs self-assembled quantum dots in well (DWELL) heterostructure, and InAs/(In,Ga)Sb strain layer superlattices (SLS) Detectors. Various approaches for realizing the infrared retina, such as plasmonic resonators, will be discussed. In addition to the applications of infrared imaging for defense application, I will highlight the role of infrared imaging in non-invasive medical diagnostics. In particular, I will highlight some work on using infrared imaging in the early detection of skin cancer.

About the Speaker: Sanjay Krishna is the Associate Director of the Center for High Technology Materials and a Professor in the Department of Electrical and Computer Engineering at the University of New Mexico. He received his MS from the Indian Institute of Technology (IIT), Madras, and an MS in Electrical Engineering in 1999 and PhD in Applied Physics in 2001 from the University of Michigan. He joined the University of New Mexico (UNM) as a tenure track faculty member in 2001. His present research interests include growth, fabrication, and characterization of nanoscale quantum dots and type_II InAs/InGaSb based SLS for mid infrared detectors. He has published more than 200 peer-reviewed journal articles (h-index=29), two book chapters, five patents, and has recently been elected as an SPIE Fellow.

Jim Bangs

Raytheon Principal Engineering Fellow/ Principal Investigator Emerging Technology Advanced HgCdTe Programs

HgCdTe Infrared Imaging Focal Plane Arrays: Today's King of the Hill for Single and Dual Band Sensors

Abstract: For applications demanding focal plane arrays with the best possible infrared sensitivity in the visible through 14μm wavelength regimes, HgCdTe detectors have unsurpassed performance and technology and manufacturing maturity (TRL & MRL) and are likely to retain this leadership for at least the next 10 years. This talk will review infrared focal plane array figures of merit, detector technology considerations that factor into designing a detector array for a given application, state of the art performance capabilities of HgCdTe for single and dual band detector arrays and future directions for HgCdTe as well as other infrared imaging focal plane arrays.

About the Speaker: Jim Bangs has 25 years of experience at Raytheon Vision Systems (RVS) developing HgCdTe technology. Upon joining RVS in 1987 in the engineering rotation program, he spent 6 months running a HgCdTe Liquid Phase Epitaxial system, with subsequent rotations on projects developing HgCdTe JFETs and electronics design. The bulk of his career has been centered on HgCdTe detector development activities including development of high reliability detector architectures, the photo-voltaic HgCdTe detectors on MODIS-N (NASA's Terra & Aqua instruments), dual band, Large Format (developed high yield processes for fabricating European Southern Observatory's VISTA IR FPA), VLWIR, and MBE design and processes for fabricating detector arrays with HgCdTe on 6-inch Si wafers. From 2005 to 2010, he was the HgCdTe production line Technical Director that oversaw implementation of 6-inch HgCdTe automated fabrication processes into production. In 2009, Jim's Large Format IR&D team successfully developed the world's largest infrared focal plane array, a MWIR 4k×4k 20μm pitch HgCdTe/Si FPA. Since 2010, he has been primarily focused on the execution of challenging HgCdTe detector development programs. He is currently the Principal Investigator for AFRL's Surveillance Components Demonstration Program, and NVESD's High Definition Dual Band FPAs Development Program. Mr. Bangs obtained his MSEE with solid state emphasis from UCSB in 1987.

Hooman Mohseni

Director, Bio-inspired Sensors and Optoelectronics Lab (BISOL,) Northwestern University

Nano-injection Detectors and Imagers

Abstract: Traditional semiconductor photon detectors are based on layered heterostructures without a significant geometrical variation along lateral directions. In contrast, we have developed a detector that exploits the additional degrees of freedom offered by a three-dimensional geometry, and utilized a detection and amplification method that is inspired by the single-photon detection mechanism of the rod cells in the eye. In this talk, I present a review of the results we have achieved with our bio-inspired "Nano-injection" detector over the past six years. These include detailed explanation of the concept, evaluation of single-element devices to understand the physics of this device, and demonstration of the first nano-injection imaging arrays. In particular, I will explain the reasons for the unusually low noise of the device at a high internal gain, the sub-volt operation, and the source of extremely good timing jitter. The impact of this new detector on infrared imagers will also be presented. Specifically, I will present the superior signal-to-noise ratio of our first imagers, and the anticipated benefits to infrared imagers with very small pixel size and/or high frame rates.

About the Speaker: Hooman Mohseni joined Northwestern University in 2004. He is the director of the Bio-inspired Sensors and Optoelectronics Lab (BISOL), and Northwestern's Solid-state and Photonics Initiative. Prior to that he was at Sarnoff Corporation, where he led several government, domestic, and international research projects. He is a recipient of the National Science Foundation's CAREER Award in 2006, and the Young Faculty Award from Defense Advanced Project Agency (DARPA) in 2007. He was selected by NSF as a US delegates in the US-Japan Young Scientist Exchange Program on Nanotechnology in 2006, and the US-Korea Nano-manufacturing Exchange program in 2007. He has served as the Advisory Board, Program Chair and Co-chair in several major conferences including IEEE Photonics, SPIE Optics and Photonics, and SPIE Security and Defense. Dr. Mohseni has published over 110 peer-reviewed articles, and holds 13 issued US and International patents on novel optoelectronic devices and nanoprocessing. He has presented more than 42 invited and keynote talks at different commercial, government, and educational institutes. He is a Fellow of SPIE, and Senior Member of IEEE.

Other Speakers

In addition to the DVW, the Center has sponsored talks from several other invited speakers during the past academic year. Descriptions of these talks are included on the following pages.

Jon Morse

Associate Vice President for Research/Physical and Engineering Sciences, RPI

Frontiers in Astrophysics and the Federal Budget Landscape

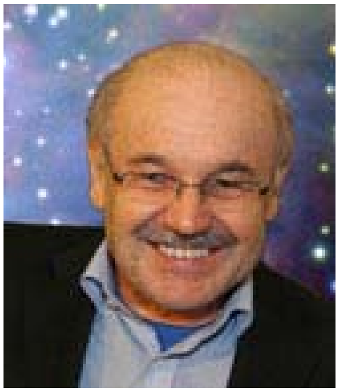
Abstract: Research in astronomy and astrophysics has produced a rich bounty of recent discoveries ranging from exploring the fundamental laws of nature, to the origins of stars and galaxies, to the search for Earth-like planets and life in the Universe. I discuss emerging opportunities in space astronomy and astrophysics, spurred by the deployment of powerful on-orbit capabilities during the past several years. I also review the federal budget process, the fiscal environment for federal funding in the physical sciences, and NASA's potential programmatic outlook in the context of the most recent decadal survey.

About the Speaker: Morse was Director of the Astrophysics Division at NASA Headquarters from 2007-2011, leading one of the world's largest space astrophysics programs. The $1.1 billion astrophysics portfolio includes over a dozen flight projects and grant programs for hundreds of researchers around the country. He has had overall management responsibility for major research missions with international scientific significance, such as the Hubble Space Telescope, Chandra X-ray Observatory, and the Spitzer Space Telescope. He has also overseen the successful launches of the Fermi Gamma-ray Space Telescope, Kepler observatory, Wide-field Infrared Survey Explorer (WISE), and Servicing Mission 4 to Hubble, to be followed soon by future observatories like the Stratospheric Observatory for Infrared Astronomy (SOFIA) and the Nuclear Spectroscopic Telescope Array (NuSTAR) Explorer mission. He became associate director of the internationally renowned Center for Astrophysics and Space Astronomy at the university in 2000. He earned his bachelor's degree in astronomy from Harvard University and his master's degree and doctorate in astrophysics from the University of North Carolina, Chapel Hill. He began his academic career as a postdoctoral research fellow at the Space Telescope Science Institute in Baltimore, MD.

Hans Zinnecker

SOFIA Science Mission Operations Deputy Director

First Results from SOFIA Early Science Observations



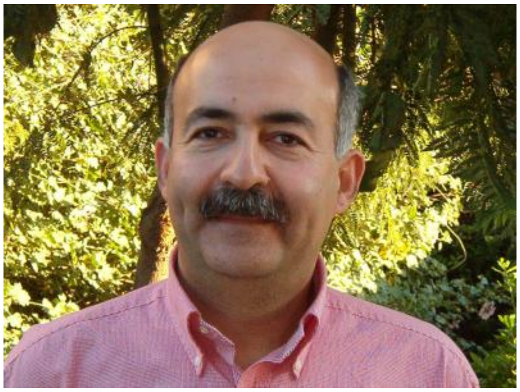
Abstract: We will describe the rationale, status, and potential of the Stratospheric Observatory for Infrared Astronomy (SOFIA), which has successfully started semi-regular observing flights in 2011. SOFIA is a Boeing 747-SP aircraft, modified to carry a 2.5m telescope capable of diffraction-limited observations at lambda>20microns. It flies at altitudes up to 45,000 feet, above more than 99% of the precipitable water vapor. With a projected lifetime of 20 years, it will outlive the Herschel satellite and will be the premier far-infrared platform for the next decade or two. First SOFIA science results include mid-IR (5-40mu) imaging of the Orion BNKL region and the galactic circumnuclear disk (with FORCAST, a camera from Cornell University; PI T. Herter), as well as Tera-Hertz spectroscopic maps of warm CO and the ionized carbon line at 158 microns in the M17SW star forming region (with GREAT, a high spectral resolution heterodyne spectrometer from MPIfR Bonn; PI R. Guesten). SOFIA is a joint project between NASA (80%) and the German DLR (20%). A new call for open time proposals will be issued in mid-Oct 2011.

About the Speaker: Hans Zinnecker, a well-known astrophysicist from Germany with a broad theoretical and observational background in the field of star formation, is the SOFIA Science Mission Operations Deputy Director. Zinnecker, a world-leading expert in young stars and their initial mass function, covers a vast spectrum in both high-mass and low-mass star formation, including binaries, disks, jets, and exoplanets. He has contributed to many topical international conferences and meetings, and served on many international committees (e.g. ESO, ESA, EC, IAU). He was the President of IAU Commission 26 on binary stars, and has been a member of several international astronomy prize selection panels. As SOFIA Mission Operations Deputy Director, Zinnecker co-directs SOFIA's overall scientific mission and is responsible for the Observatory's productivity. He also represents the German interests in both SOFIA's science and management, and is responsible for the US-based staff of the Deutsches SOFIA Institute. Amongst his various challenges is his hope to convert Herschel users to SOFIA users.

Bahram Mobasher

Professor of Physics and Observational Astronomy, University of California, Riverside

The Thirty Meter Telescope: Instruments and the Science Case



Abstract: In this talk, I will review current progress on the Thirty Meter Telescope (TMT) and the future plans. I will discuss the first light instruments designed for the TMT and their capabilities. In particular, I will talk about the Infra-Red Multi-object Spectrograph (IRMS), one of the three first-light instruments on the TMT, its potential compared to current facilities (i.e. the Keck), and how it could be developed using the same concepts as the current infrared spectrograph (MOSFIRE) on the Keck telescope. I will present a set of the outstanding scientific questions which need to be resolved by observations using the combination of the TMT and its state-of-the-art instruments.

About the Speaker: Bahram Mobasher is a Professor of Physics and Observational Astronomy at the University of California, Riverside.

In the News

Detector Virtual Workshop Speaker Series

In September 2011, RIT News released an article announcing the launch of the Detector Virtual Workshop speaker series. The piece introduced the RIT community to the goals of the Detector Virtual Workshop project, and highlighted the Center behind the award. As noted in the article, "the goal of the workshop series is to increase interdisciplinary opportunities, enhance interactions between academia, industry, and government, and provide students with professional networking opportunities." The article also featured Professor Robert Hadfield, of Heriot-Watt University in Edinburgh, Scotland, whose talk on "Infrared Superconducting Single Photon Detectors" was the inaugural talk in the series.

NASA Graduate Student Researchers Fellowship

In November of 2011, our own Christine Trombley, graduate student in RIT's astrophysical sciences and technology program in the College of Science, was featured in RIT's University News for her prestigious NASA fellowship.

November 10, 2011

> *Ms. Trombley worked in Goddard's Exoplanets and Stellar Astrophysics Laboratory, part of the Astrophysical Sciences Division. The research experience was the first part of Trombley's yearlong NASA Graduate Student Researchers fellow-ship, which is helping to fund her thesis work.*
>
> *"The Graduate Student Research fellowship is not just prestigious, but an opportunity to learn from experts in astrophysics," says Trombley, of Warren, Mich. "Directly interacting with experts in my field goes beyond keeping up with the literature. I can learn directly what people are not only currently working on but what science they plan to do in the near future."*
>
> *Massive stars—Trombley's main research interest—are up to 150 times larger than the sun, and "live fast and die young," she notes. Their crash-and-burn existence makes these stars difficult to find and observe.*
>
> *"The effects of such massive stars is extraordinary, despite their short lives," she says. "These stars enrich their local environments by exploding as supernovae, which changes the chemical composition of the material from which a new generation of stars will be born. The formation of these massive stars is not well under-stood, theoretically or observationally, making their discovery and characterization important."*
>
> *When Trombley returns to RIT for the winter quarter, she will rejoin the Center for Detectors, where she studies massive stars with her thesis advisor, Don Figer, director of the center.*
>
> *"This prestigious NASA fellowship allows Center for Detectors researcher Christine Trombley to push the limits beyond what is known about massive stars and their birthplaces," Figer says.*
>
> *After completing her research experience at Goddard Space Flight Center, Trombley will continue her thesis work, studying "massive star populations in stellar clusters, which are large aggregates of stars."*

"I am looking at the universality of the high mass initial mass function in stellar clusters, essentially whether or not massive stars form the same in different environments," she says.

Accounting for her Life

In late May 2012, our leading Executive Assistant, Adena Thomson, was featured in RIT's University News. The article describes Adena's trials and tribulations on the road to becoming the hardworking, successful student and professional she is today.

"I was a high school senior and poised to be valedictorian of my class when my parents suddenly uprooted our family to move out of state," Thomson recalls. "Six months and two more moves later, I decided to leave home. Academics have never been a problem for me, but stability and security have." Both RIT and the Center of Detectors seem to have provided Adena with the stability and security she has sought after for so long. She says, "At RIT, I've met peers who will be my friends for life, who share in both my struggles and accomplishments in spite of our diverse roots." Thomson is an MBA-Accounting major at RIT's Saunders College of Business. She tutors for the Accounting and Finance programs at RIT, as well as working for the CfD as a financial administrator and executive assistant.

As a professor within our institution describes her, Adena is a "rare gem," and we are extremely proud to have her as part of our team at the Center for Detectors at RIT.

NASA could soon get two former spy telescopes from right here in Rochester...

During June of 2012, the CfD was recognized on rochesterhomepage.net when Director Don Figer was quoted in a story about former spy telescopes.

June 5, 2012

NASA could soon get two former spy telescopes from right here in Rochester. The high-tech gadgets are currently being stored in the Rochester Tech Park in Gates. The Rochester operations for ITT Exelis developed and built the telescopes in the late 1990's. But the telescopes have never been used.

The company can't reveal what the telescopes look like but it's been reported that they are similar to the Hubble telescope. The National Reconnaissance Office, which operates the nations' spy satellites, is now offering the unused telescopes to NASA. RIT's Director of the Center for Detectors says those telescopes will be fitted with cameras and highly-sensitive detectors to investigate more of the universe.

"This is a huge gift for astronomy because these are exactly the kinds of telescopes we want to be using to answer the most fundamental questions in the universe and to also find another earth, exoplanets outside of our solar system those are the highest science priorities in astronomy," said Prof. Don Figer, Director of Center for Detectors at RIT.

Exelis says they were unable to even mention that they built these telescopes until this announcement was made.

RIT Leads Development of Next-Generation Infrared Detectors

In July of 2012, the Center for Detectors was featured in an RIT News release, *RIT Leads Development of Next-Generation Infrared Detectors*. The story was picked up by several other publications, including Photonics Online. The article describes the possibility of less expensive and more sophisticated infrared detectors, which would expand the astronomy and medical professions. It highlights the $1.2 million grant awarded to RIT by The National Science Foundation to "develop, fabricate and test a new family of detectors grown on silicon wafer substrates by Raytheon Visions Systems."

Center Director Donald Figer deems that building and utilizing advanced astronomical instrumentation is one of the strategic goals for the Center. "If this is successful, the astronomy community will have a ready supply of affordable detectors that could be deployed on a wider range of facilities. Right now infrared detectors are so expensive that there are only a few on the world's biggest telescopes—Keck, Gemini, the Very Large Telescope. Those are the only facilities that can afford them, and then they can only afford a few."

Student Exploration on Virtual Planetary Surfaces

Figure 22. The Planeterrainium in action.

This project has engaged a group of High School students to work with undergraduate students in developing explorations of virtual planetary surfaces. The project team devised the "3D Planeterrainium," which projects 3D red/cyan anaglyph images at the user's feet, allowing them to explore features of the surface of Mars (and other planets) as observed by NASA SMD missions. The Planeterrainium has been used to communicate science to K-12 audiences at such venues as the annual Imagine RIT festival on the RIT campus; AstroZone: Boston at the Boston Museum of Science; the USA Science and Engineering Festival (in Washington, DC); the Rochester Museum and Science Center; and the Wegmans LPGA Golf Tournament.

We proposed to work with a group of 15-20 high school students on the Rochester Institute of Technology campus to create explorations of planetary surface data that can be displayed in a digital immersive environment "as if you were really there." In this way, we would engage these high school students in planetary science topics, and involve them directly in using and exploring the vast array of SMD planetary data.

The high school students from the Rush-Henrietta school district collaborated with (initially) two RIT Software Engineering undergraduates to design and develop the "3D Planeterrainium" as an immersive tool to allow for the exploration of 3D data of planetary surfaces. The team felt that their tool better allowed users to appreciate the 3D planetary surfaces "at their feel" and gain a feeling of immersion with the scientific content.

The team found data primarily from the Mars Reconnaissance Orbiter HiRISE camera as the present best source of 3D data – but with the appreciation that future LIDAR imagers (the focus of the parent science proposal) would also produce data sets ideal for this system.

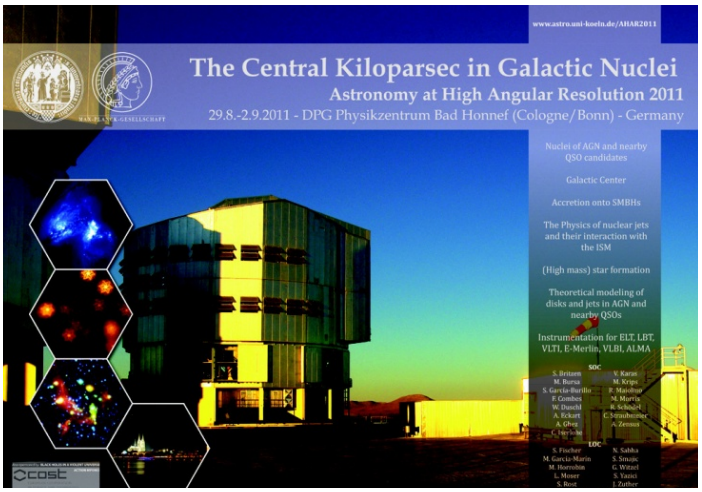
The system is powered by software using a "Google Mars" backbone, and is controlled by a hand held Nintendo WiiMote device. The choices of these systems were in order to maintain the low cost and friendly nature of the project, while using red/cyan anaglyph images allows for low cost projections systems and 3D glasses to replicate this concept very easily in classrooms or small science centers across the nation.

Invitations to Speak

Photonic Devices +Applications
SPIE Optics+Photonics
21 - 25 August 2011
San Diego Convention Center
San Diego, California United States

Optical Engineering +Applications
SPIE Optics+Photonics
21 - 25 August 2011
San Diego Convention Center
San Diego, California United States

CfD Director Don Figer presented an invited review talk on "Silicon single photon imaging detectors" and a contributed talk on "A photon-counting detector for exoplanet missions" at the Society of Photo-optical Instrumentation Engineers conference in August, 2011.



CfD Director Don Figer presented an invited talk on "Massive Star Formation in Nuclei of Galaxies" at The Central Kiloparsec in Galactic Nuclei conference in August, 2011.

NORTHWESTERN UNIVERSITY

CIERA
CENTER FOR INTERDISCIPLINARY EXPLORATION AND RESEARCH IN ASTROPHYSICS

Dr. Figer was invited to speak at Northwestern University's Astrophysics Seminar in Spring 2012. Figer presented a talk on "Single-photon Array Detectors."

CfD PhD student Christine Trombley gave a talk in the RIT Astrophysics Lunch Seminar Series in August 2011. Her talk was entitled "A Novel Approach to Simultaneous Spectral Subtyping in Stellar Clusters."

In November 2011, during her ten-week research experience at NASA GSFC, Trombley was asked to give a talk at the NASA/Goddard Exoplanet Club. She spoke on "A Novel Approach to Simultaneous Spectral Subtyping in Stellar Clusters."

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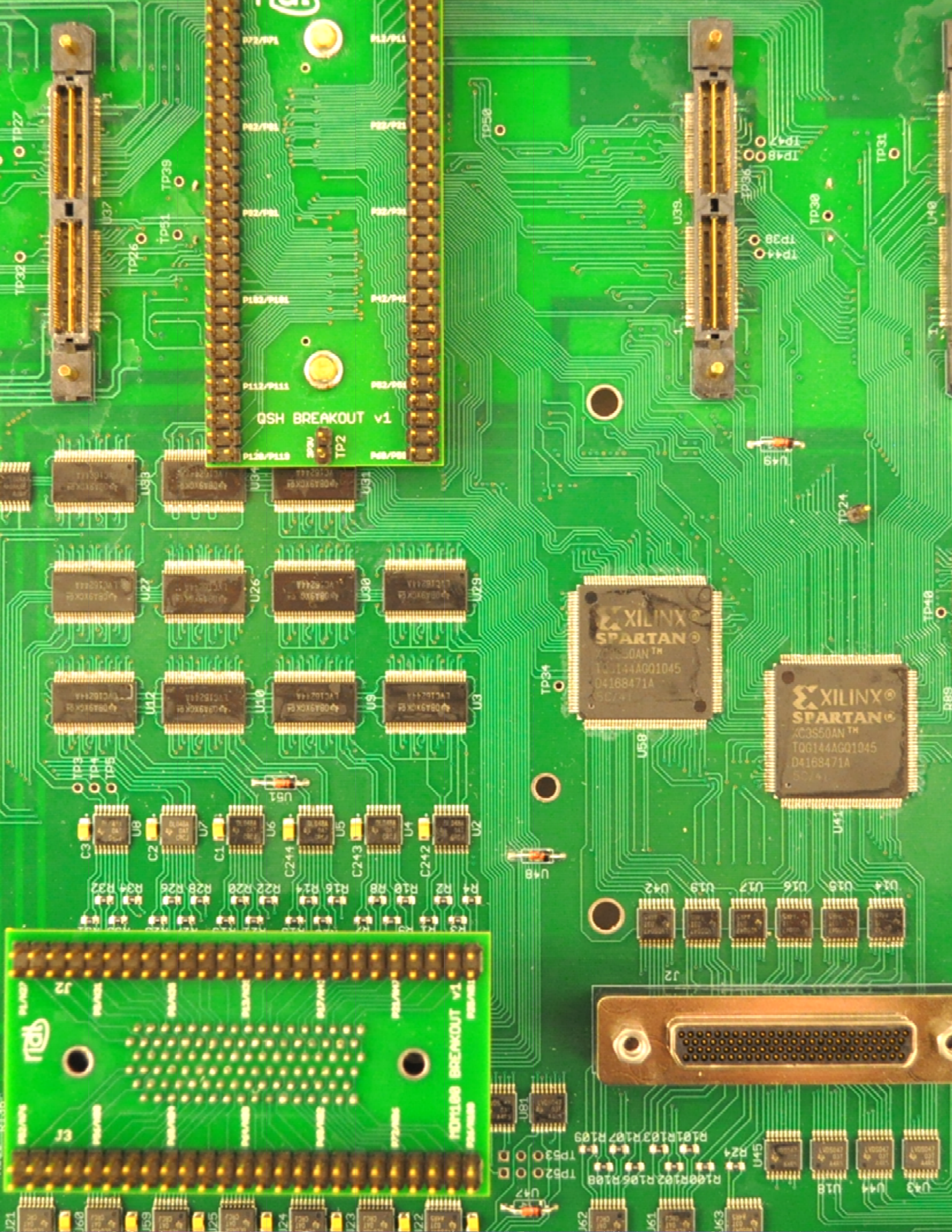
Organization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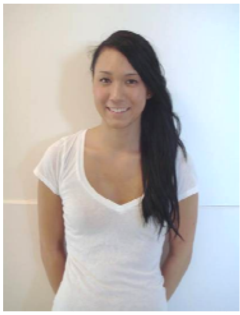

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Charter

About the CfD

The Center for Detectors designs, develops, and implements new advanced sensor technologies through collaboration with academic researchers, industry engineers, government scientists, and students. The CfD enables scientific discovery, national security, better living, and commercial innovation through the design and development of advanced photon detectors and associated technology in a broad array of applications such as astrophysics, biomedical imaging, Earth system science, and inter-planetary travel.

Vision and Mission

Our Vision is to be a global leader in realizing and deploying ideal detectors and associated systems. Our Mission is to enable scientific discovery, national security, better living, and commercial innovation through the design and development of advanced photon detectors and associated technology by leveraging collaborations with students, scientists, engineers, and business partners, at academic, industrial, and national research institutions.

Goals

- Develop and implement detector technologies that enable breakthroughs in science, defense, and better living.
- Train the next generation of U.S. scientists and engineers in team-based, interdisciplinary, world-class research.
- Create opportunities for faculty, students, and international leaders to advance the field of detectors and its relevant application areas.
- Grow externally-supported research.
- Increase economic activity for local, regional, and national companies.

Focus Areas

The Center applies its technologies to many different scientific areas including Astrophysics, Biomedical Imaging, Defense, Earth Systems Science, Energy, Homeland Security, and Quantum Information. These focus areas are mainly what brings together the great variety of individuals from diverse areas of expertise.

Astrophysics – A zero read noise detector will enable the discovery of Earth-like planets around nearby stars, life on other planets, the nature of dark energy and dark matter, and the origins of stars and galaxies.

Biomedical Imaging – The Biophotonic Experiment Sensor Testbed will enable safe detection and monitoring of breast cancer and cognitive functioning with unprecedented sensitivity.

Defense – Space-based cameras will be equipped with the most sensitive detectors that provide rapid delivery of the most sensitive information.

Earth Systems Science – The Center's detectors will be exploited to address fundamental Earth system science questions, such as sensing of photosynthesis or the creation of atmospheric pollutants, detection of atmospheric or ocean temperature gradients, or the timely viewing of extreme events.

Energy – New high photon-efficiency solar cells will be developed to ensure sustainable energy generation for economic competitiveness and national security.

Homeland Security – Advanced imaging detectors will be able to reveal potential airborne biochemical hazards through high-resolution three-dimensional ranging, spectral discrimination, and motion pattern recognition.

Quantum Information – High-speed single photon receivers will be deployed to support future technologies in photonics, communication, quantum computing, and quantum cryptography.

Governance

The Center is supervised and operated by its founding Director, Dr. Donald Figer. A committee of experts, from RIT and elsewhere, advise the Director to ensure successful definition and execution of the Center's vision and goals. The committee meets once per year after the completion of the CfD Annual Report. Center members include academic researchers, industry engineers, government scientists, and university/college students.

Funding

Since its inception in 2006, the Center for Detectors and its precursor entity, the Rochester Imaging Detector Laboratory, have secured over $9.8 million in research funding. The largest contributions are the Moore Foundation and NASA. The Moore Foundation has invested $2.8 million, and NSF $1.2 million. In addition, NASA has contributed close to $5 million.

Capabilities, Equipment, and Facilities

The Center for Detectors is located in the IT Collaboratory (Building 17) at the Rochester Institute of Technology. It has 5000 square feet of space for offices and labs, including offices for 17 people, and three research laboratories: the Rochester Imaging Detector Laboratory (see Figure 23), the Quantum Dot Detector Laboratory, and the clean room laboratory. The laboratories contain special facilities and equipment dedicated to the development of detectors.

Figure 23. Lab area in the Rochester Imaging Detector Laboratory.

These facilities include a permanent clean room, ESD stations, vacuum pumping systems, optical benches, flow tables, light sources, UV-IR monochromators, thermal control systems, cryogenic motion control systems, power supplies, general lab electronics, and data reduction PCs. The equipment is capable of analyzing both analog and digital signals. Separate rooms in the CfD are devoted to electrical rework and laser experiments. In addition to these dedicated facilities, the CfD has access to facilities within the Semiconductor and Microsystems Fabrication Laboratory (SMFL) and other areas across the RIT campus.

The RIDL detector testing systems (see Figure 24) use cylindrical vacuum cryogenic dewars. Each individual system uses a cryo-cooler that has two cooling stages: one at ~60 K (10 W) and another at ~10 K (7 W). The cold temperatures yield lower detector dark current and read noise. The systems use Lakeshore Model 340 temperature controllers to sense temperatures at 10 locations within the dewars and control a heater in the detector thermal path. This thermal control system stabilizes the detector thermal block to 400 μK RMS over timescales greater than 24 hours. The detector readout systems include an Astronomical Research Camera controller having 32 digitizing channels with 1 MHz readout speed and 16-bit readout capability, two Teledyne SIDECAR ASICs having 36 channels and readout speeds up to 5 MHz at 12-bits and 500 kHz at 16-bits, and custom FPGA systems based on Altera and Xilinx parts. The controllers drive signals through cable harnesses that interface with Detector Customization Circuits (DCCs), which are designed in-house and consist of multi-layer cryogenic flex boards. The DCCs terminate in a single connecter, which then mates to the detector connector. Three-axis motorized stages provide automated lateral and piston target adjustment. Two of the dewars have a side-looking port that is useful for exposing detectors to high energy radiation beams. The lab also has a large integrating sphere that provides uniform and calibrated illumination from the ultraviolet to through the infrared, and it can be mounted to the dewars. The dewars are stationed on large optical tables that have vibration-isolation legs.

Figure 24. Detectors are evaluated in three custom dewar test systems.

The lab equipment also includes a Pico Quant laser for LIDAR system characterization and other testing that requires laser illumination. In addition, the lab has monochromators with light sources that are able to produce light ranging from the UV into the IR, with an approximate wavelength range of 250 nm – 2500 nm. NIST-traceable calibrated photodiodes (with a wavelength range of 300 nm – 1100 nm) provide for absolute flux measurements. RIDL also has a spot projector to characterize the inter-pixel response of the detectors, including optical and electrical crosstalk. Figure 25 shows a laser spot projection system on a 3D motorized stage that produces a small (~few microns) point source for measurements of intrapixel sensitivity.

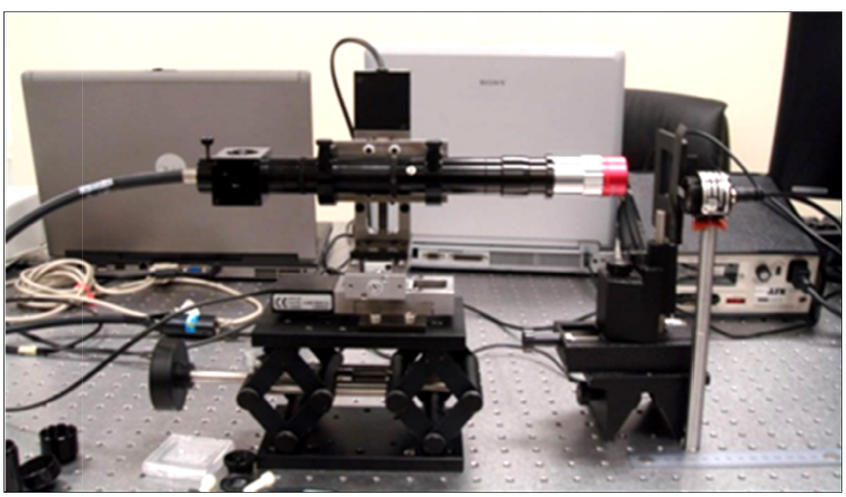

Figure 25. Laser spot projector with three axis motion control system.

The lab contains eight data reduction PCs, each with eight processors and up to 16 GB of memory for data acquisition, reduction, analysis and simulations, and 25 TB of data storage. Custom software runs an automated detector test suite of experiments. The test suite accommodates a wide variety of testing parameters through the use of parameter files. A complete test suite takes a few weeks to execute and produces ~0.5 TB of data. The data reduction computers reduce and analyze the data using custom automated code, producing publication-quality plots in near-real time as the data are taken.

CfD has the capability to design system components needed for detector testing using CAD programs, *e.g.* SolidWorks. This thermal finite element analysis software is also used to simulate thermal cooling of system components and detectors. Eagle and PCB Express are used to design layouts for readout circuits that interface with the detectors. System-based software tasks also include data processing with IDL, C and C++, HDL programming on Xilinx and Altera chips, as well as the SIDECAR ASIC.

CfD has a dedicated class 1000 cleanroom (by FED Standard 209E), located in the SMFL. The SMFL has 10,000 ft^2 of additional cleanroom space in class 1000, 100, and 10. Using the SMFL's resources, the Center can fabricate detectors with custom process flows, and has the freedom to use multiple process variations.

The Center's cleanroom and probe stations offer wafer-level testing, even during the fabrication process, allowing mid-process design changes (see Figure 26). The probe station accommodates electrical and circuit analysis of both wafers and packaged parts, including low current and radio frequency (RF) probing. Also available for CfD use are the Amray 1830 Scanning Electron Microscope (SEM; see Figure 27), used for high-magnification imaging of devices, and the WYKO white light interferometer, used for surface topography measurements. The SMFL also has other in-line fabrication metrology capabilities, including material layer thickness, refractive index, and wafer stress characterization tools.

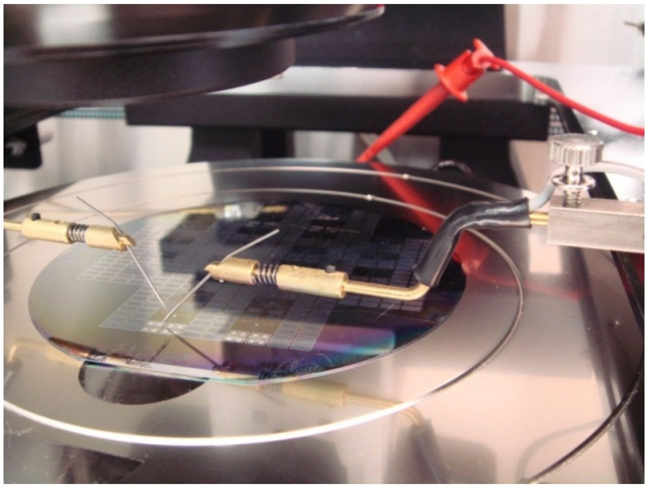

Figure 26. Device wafers are tested in the clean room lab probe station.

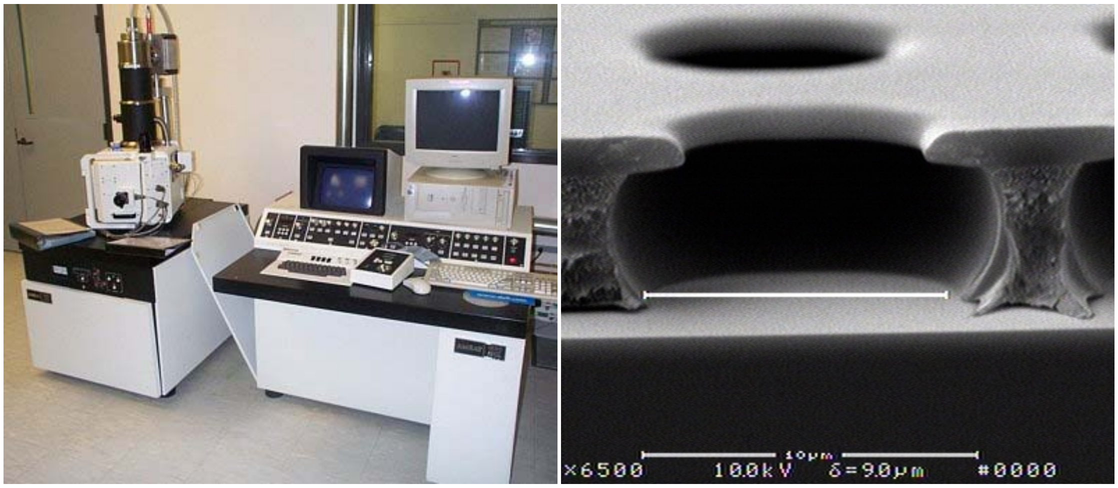

Figure 27. (left) The Amray 1830 Scanning Electron Microscope is used to image devices. (right) SEM image of device that has been prepared for indium bump deposition.

In addition to fabrication and testing capabilities, the Center for Detectors has access to sophisticated simulation software to predict the performance of devices, from fabrication processes to performance of a completed device. Silvaco Athena and Atlas are powerful software engines that simulate the effects of processing on device substrates and the electrical characteristics of a fabricated device. Athena simulations can describe all of the processes available in the RIT SMFL, building a physics-based model in 3D space of a device from initial substrate to completed device.

The Center for Detectors uses many other RIT facilities, *e.g.*, the Brinkman Lab, a state-of-the-art facility for precision machining, and the Center for Electronics Manufacturing and Assembly (CEMA), a facility for electronics packaging (see Figure 28).

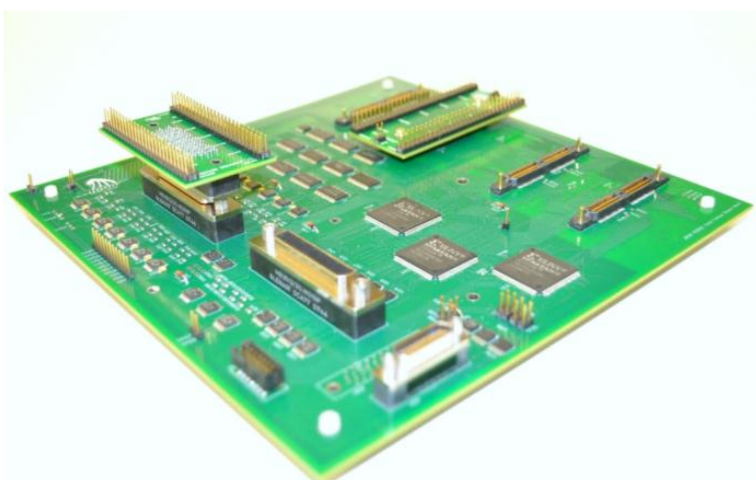

Figure 28. This image shows a cryogenic multi-layer circuit board designed in the CfD and populated in CEMA. All of the components on this board will be exposed to temperatures as low as 40 K, nanoTorr pressure levels, and high energy particle radiation.