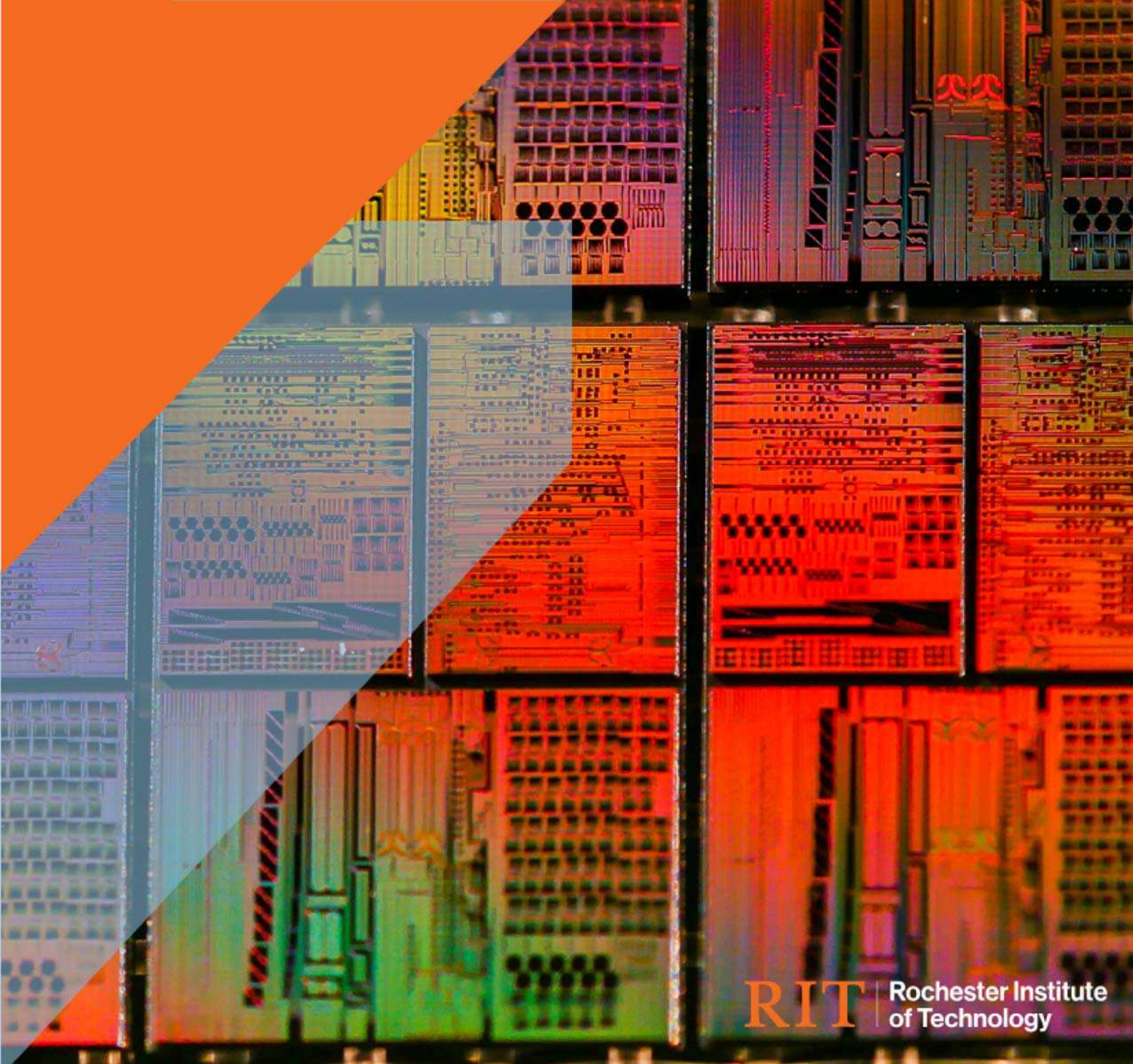
2019 Center for Detectors

Annual Report



RIT | Rochester Institute of Technology

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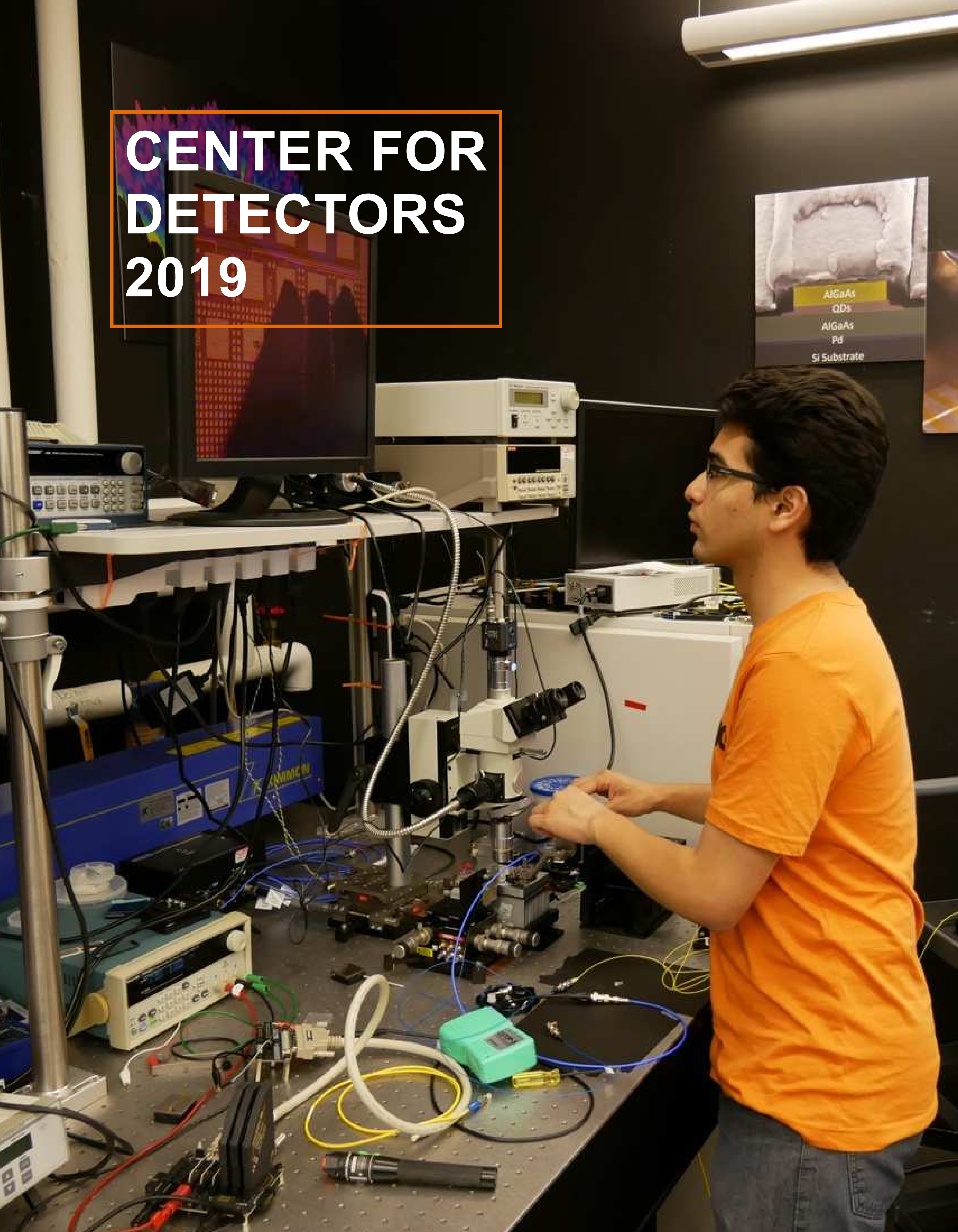
CENTER FOR DETECTORS 2019



Director's Comments

The Center for Detectors (CfD) grew more in physical size, membership, and publication productivity during the past year than any other since its establishment in 2010.

CfD faculty member Dr. Michael Zemcov expanded his facilities to house CIBER-2, a near-infrared rocket-borne instrument. In addition, he and collaborators won a grant in a very competitive process to proceed with the development of NASA's new mission, SPHEREx, set to launch in 2023. Zemcov's will help design the instrument and prepare the data pipeline for when the SPHEREx spacecraft begins making observations. Dr. Gregory Howland, a new RIT faculty member in the School of Physics and Astronomy, joined our team of researchers. His membership increases CfD lab space and scientific scope to include the innovative field of quantum optics and photonics.

In partnership with many external organizations, like Precision Optical Transceivers and AIM Photonics, we provided research experiences for the largest number of undergraduate students in one year to date. In 2019, CfD faculty advised 40 undergraduate students and 19 PhD students. Students joined as a part of senior projects, REUs (Research Experiences for Undergraduates), and co-ops where they worked on interdisciplinary teams tackling real world problems.

With increased research activity and the surge of student involvement, the CfD produced more publications than ever. We published 60 papers this past year, which is approximately 50% greater than in any other year.

Dr. Howland, Lab Engineer Dr. Valerie Fleischauer, and BS/MS student Justin Gallagher established a new collaboration with Gigajot Technology, Inc. This new activity focuses on the study of a quantum image sensor for low light level applications, and expands on our rich history of collaborating with startup companies.

Other highlights include the first Photonics for Quantum Workshop (PfQ), held in January 2019. PfQ welcomed over 200 participants to hear talks from pioneers in the advancement of photonics for quantum devices and engage in panels from industry and education. The RIT Future Photon Initiative, of which the CfD is a leading member, will hold PfQ2 in 2020.

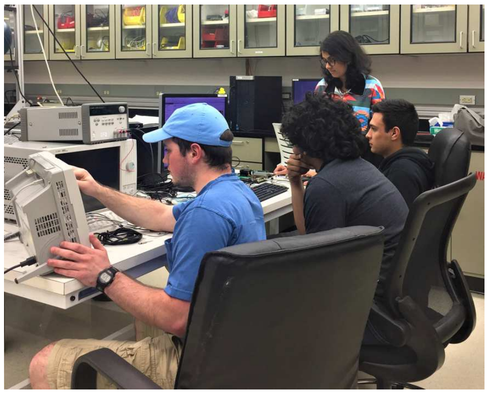
I know you will enjoy reading about the year's innovations in the Center for Detectors, and the team of students, faculty, and staff who made all of it possible.

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

Highlights

Collaborators

During this past year, CfD collaborated with Caltech on a number of projects, including the Tomographic Ionized-carbon Mapping Experiment (TIME). CfD also worked with Columbia University, AIM Photonics, and SUNY Polytechnic Institute to develop the Engineering Verification Test (EVT) Station for AIM Photonics. CfD continued long-term projects with organizations such as NASA, Harris, AFRL, Raytheon Vision Systems, and Thermo Fisher.



New Members

The CfD welcomed new Assistant Professor Dr. Greg Howland and new Lab Engineer, Valerie Fleischauer. Over the fiscal year of 2019, CfD added over 30 new student researchers at all levels of matriculation. See a full list of all new members in the Personnel section of this report.

Events

The CfD assisted the Future Photon Initiative (FPI) in organizing the Photonics for Quantum Workshop (PfQ) in January 2019. The PfQ Workshop featured 32 invited speakers, a panel on quantum integrated photonics, a panel on quantum careers and education, and a networking session for quantum employers and students. FPI and CfD will hold PfQ2 in 2020.

Community Outreach

CfD members volunteered their time to share their work with the Rochester community over this past year. Don Figer taught students at Park Road Elementary about big stars and the galaxy. Stefan Preble and Gregory Howland continued to work with the AIM Academy providing online courses to the Rochester community in silicon photonics.

Charter

About the Center for Detectors

The Center for Detectors (CfD) is an RIT academic research center established in 2010 in the College of Science. CfD designs, develops, and implements photon devices to enable scientific discoveries. CfD educates and trains students through research and development in detectors, instrumentation, observational astrophysics, nanostructures, silicon photonics, and wide-bandgap materials. Staff and student researchers investigate high impact engineering and development problems through external financial support from federal agencies, private foundations, national laboratories, and industry. CfD has nine labs on RIT's campus, including the Rochester Imaging Detector Lab, the predecessor to CfD.

Vision

The CfD vision is to be a global leader in the development of advanced photon detectors and their use in instrumentation applications spanning a variety of fields.

Mission

The CfD mission is to leverage multi-disciplinary and symbiotic relationships between students, staff, faculty, and external partners to improve the design and development of advanced photon detectors and associated technologies. CfD realizes this mission by developing and deploying detectors to enable space missions, exploiting detectors for quantum optics, developing material systems for detectors, and implementing detectors for integrated photonic chips.

Goals

- Create opportunities for faculty, students, and international leaders to advance the field of detectors and relevant areas of application
- Increase externally supported research
- Cultivate existing and new external collaborations
- Enhance collaborations with industry
- Develop single-photon detectors for quantum applications

Pilot local and national education programs in integrated photonics

Executive Summary

Research

The CfD had 28 active projects during the past year (19 ongoing and 9 new). New research grant funding totaled $1.9M.

Dr. Don Figer continued to develop infrared detectors that use HgCdTe material grown on silicon substrates. He and his team began work with Gigajot Technologies to characterize the Quanta Image Sensor. The device is a megapixel focal plane array that delivers photon counting capability at room temperature, and will thus be valuable for low light applications, such as astrophysics space-mission concepts.

Dr. Parsian Mohseni continued his development of low-cost and high-efficiency flexible light emitting diodes and photodetectors and explored answers to enabling cost-effective manufacturing of high-efficiency solar cells.

Dr. Zoran Ninkov continued research in imaging polarimetry, detector advancements, and micromirror development. His group further developed a method of coating detector arrays with nano materials for improved detector sensitivity in UV and blue light. The group continued developing their THz detector architecture and Digital Micromirror Devices for inspection and space applications.

Dr. Stefan Preble and his Integrated Photonics Group continued developing integrated photonics platforms. The group explored ways to implement quantum photonic circuits on a silicon chip. Dr. Preble and other CfD members continued to establish packaging design and test support for AIM Photonics. Dr. Preble and Dr. Gregory Howland provided education modules for integrated photonics design, manufacturing, packaging, and testing for the AIM Academy in collaboration with MIT.

Dr. Michael Zemcov and his student-based group developed a sub-orbital cosmic background experiment and an enabling cryogenic star tracker module. He also continued research to measure the cosmic background from the outer solar system using the New Horizons spacecraft. He won a new grant to develop the data analysis pipeline for SPHEREx, one of NASA's next mid-sized missions that will map the large-scale structure of galaxies in the Universe. Finally, Zemcov's team did systems analysis for a future NASA mission that will map star formation activity through the history of the Universe.

Dr. Jing Zhang and her PhD students developed high efficiency ultraviolet optoelectronics and solutions to key challenges in achieving high-efficiency single-mode GaN-based UV lasers.

Personnel

With the addition of Gregory Howland, CfD now has seven faculty research members, in addition to three Post Doctorial Researchers and five staff members. A record 40 undergraduate and 19 graduate students conducted research with CfD professors this year. The student researchers came from four different colleges and three REU programs. The majority of students (55%) were from the Kate Gleason College of Engineering, with 15% from the College of Science, 15% from the Golisano College of Computing and Information Sciences, 13% from REU programs, and 2% from the School of Film and Animation.

Student Vignettes

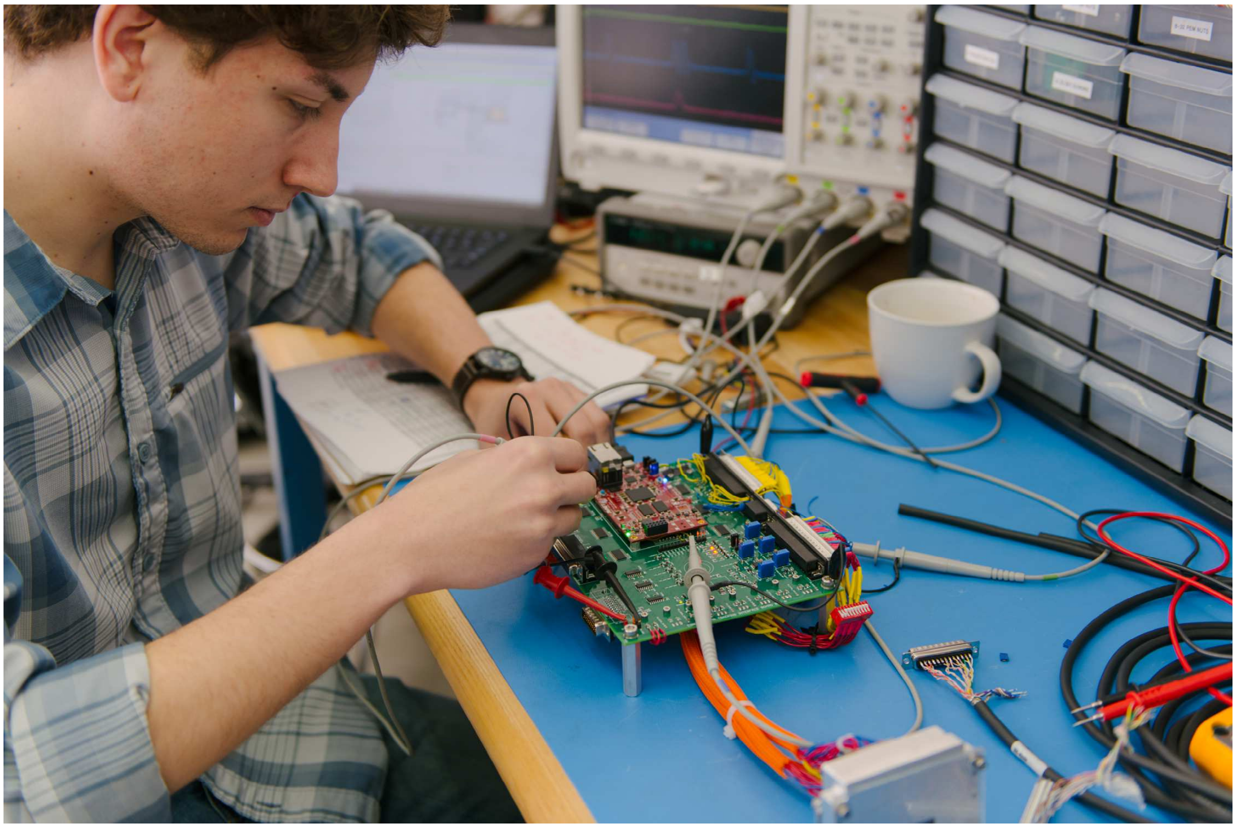
Student researchers in the CfD spend their time working on externally funded projects with guidance from their faculty advisors. In the Student Vignette section of this report, 17 of these students describe their contributions to projects over the past year.

Publications and News

CfD researchers published more articles than ever in the past year, publishing in journals such as, Nature Communications, the Astrophysical Journal, Astronomy and Astrophysics, and the Journal of Optics. CfD research caught the eye of both local and national media. Dr. Michael Zemcov received attention for his work on the newly-selected NASA mid-range explorer (MIDEX) mission, SPHEREx (the Spectro-Photometer for the History of the universe, Epoch of Reionization, and ices Explorer) that will map the large-scale structure of galaxies in the universe to shed light on the first instants of the universe.

Equipment and Facilities

This year, CfD added two research labs. New faculty member, Dr. Howland, acquired 700 square feet of lab space for a new quantum optics and photonics lab. Dr. Zemcov added the Suborbital Astrophysics Lab, a 345 square foot space to house CIBER-2 and CSTARS. The largest footprint of CfD is in Engineering Hall, with six laboratories and offices to accommodate approximately 20 people. Outside of Engineering Hall, the CfD has laboratories in the Chester F. Carlson Center for Imaging Science and Gosnell Hall.



Research

RESEARCH SUMMARIES

Research Projects

Studies of the Diffuse Optical Background with New Horizons

NASA
Michael Zemcov

The goal of this project is to measure the cosmic optical background (the sum of all emission from sources beyond the Milky Way at optical wavelengths) using images taken by the LORRI instrument on New Horizons. This allows for a comparison between this measurement and all expected sources of emission such as stars and galaxies, and potential identification of the source of any excess component of diffuse emission. Over the past year, we have narrowed down the available LORRI images (almost 7,000) using a variety of criteria including exposure time, presence of bright objects such as Pluto, and obfuscation due to reflected sunlight. The remaining 343 images have been astrometrically registered via their location on the sky, and masked in various ways, such as to exclude bright objects, cosmic rays, and saturated pixels. Many images have artifacts of optical ghosting due to illumination of LORRI's secondary mirror. Bright stars just beyond the LORRI field of view cause most of these ghosts (see Figure 1).

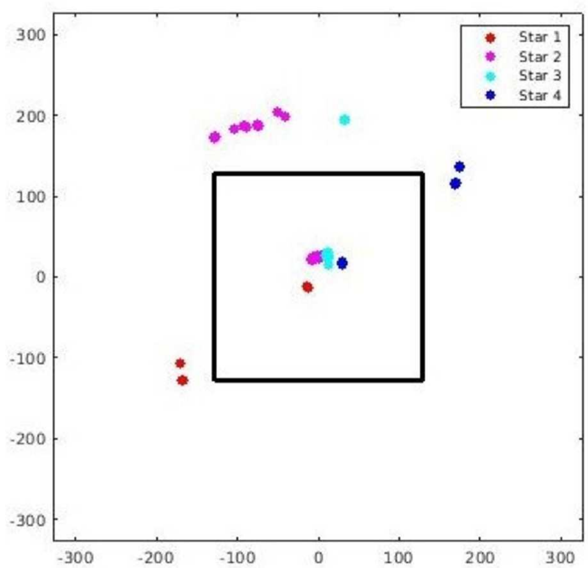


Figure 1. The black square represents the LORRI field of view. Points inside the square represent the location of ghosts in various LORRI images, while those outside the square represent the bright stars that caused them, with star/ghost pairs color coordinated.

This study has also allowed us to develop a method to automatically predict the locations of ghosts for further masking. Additionally, in January 2019, we used the WIYN 0.9-m telescope at the Kitt Peak National Observatory near Tucson, AZ to take companion images of selected LORRI fields, which will allow us to better estimate the residual faint starlight in those images. We plan to take additional images next January. We have also developed a stacking algorithm in order to determine the instrumental point spread function (PSF), used for image calibration, demonstrated in Figure 2. The algorithm takes cut-outs of all the stars in an image, up-samples them, and stacks them together on their original coordinates, generating a super-resolution image of the PSF. Future plans include ongoing analysis of the LORRI images, estimates of LORRI's pointing and dark current stability, and selection of data from New Horizons' other instruments MVIC and LEISA for similar study.

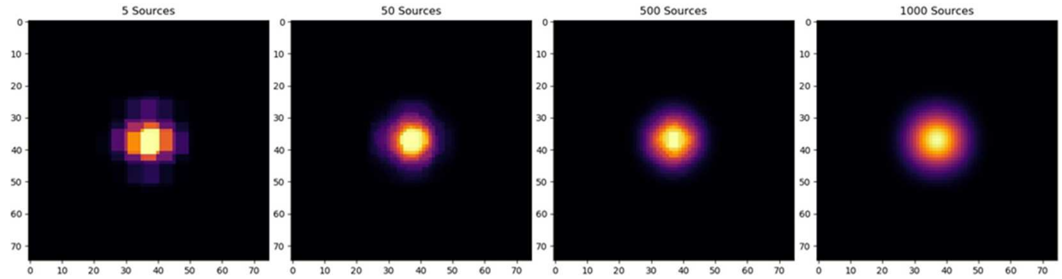


Figure 2. The snapshots illustrate how combining the mean of an increasing number of Gaussian source thumbnails improves the PSF via the stacking process. After combining sources, the PSF resembles that of the original point sources.

Quanta Image Sensor

Donald Figer

Single photon counting large-format detectors will be a key technology for the future NASA Astrophysics missions. The Quanta Image Sensor (QIS) is a candidate solution proposed in 2005 by Eric Fossum. The QIS is a megapixel focal plane array that delivers photon counting capability at room temperature. Figure 3 shows QIS detectors in a camera that we obtained from Gigajot Technology, Inc., the company that is commercializing the technology. The goal of the QIS at the Center for Detectors includes an extensive characterization program to assess the advantages that the QIS detector has over present devices, and to demonstrate its effectiveness in applications for future space-mission concepts. Current progress on the QIS includes the characterization of readout noise, conversion gain, and dark current. The QIS has also demonstrated parametric down-conversion imaging of photons through a non-linear BiBO crystal.

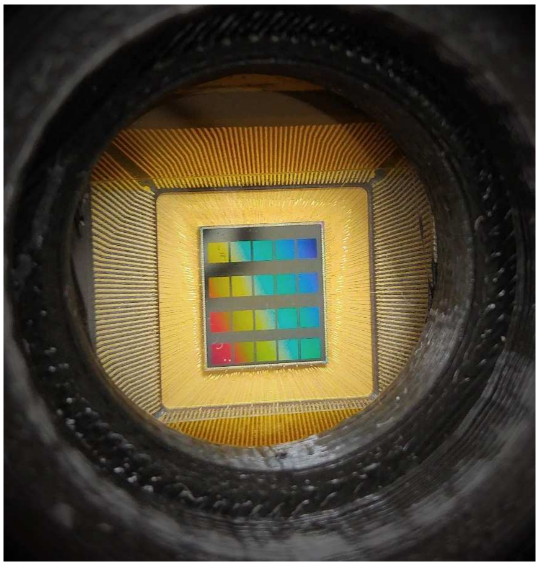


Figure 3. The image above shows twenty megapixel QIS arrays residing in the detector housing. Each detector has a side length of 1.1 μm. All twenty detectors fit within a square millimeter.

In the current paradigm, Charge-Coupled Devices (CCDs) and Complementary Metal-Oxide Semiconductors (CMOS) collect photons for a predetermined amount of time in a silicon “rainbucket.” In order to obtain photon-counting capabilities with current technology, CCDs and CMOS active pixel sensors require the use of cryogenics to reduce thermal noise and avalanche photo multipliers to increase the effective signal of a single photon. This results in expensive sensors that take up large amounts of space and additional equipment that can induce additional noise and lower quantum efficiency. With the QIS, a combination of sub-diffraction high-gain pixels with low well depths, low dark current, sub-electron readout noise, and correlated multiple sampling (CMS) on post capture enable photon counting capability. A final image is created post capture from multiple micro-frames that are taken in quick succession during an exposure.

Over the past year, we characterized the conversion gain and read noise of the QIS detector. We use conversion gain to convert the raw signal output of the detector into physical units such as number of electrons. Conversion gain of the QIS has been uniquely determined by illuminating the QIS in low-light and determining the location of peaks in signal that correspond to integer numbers of electrons (Figure 4).

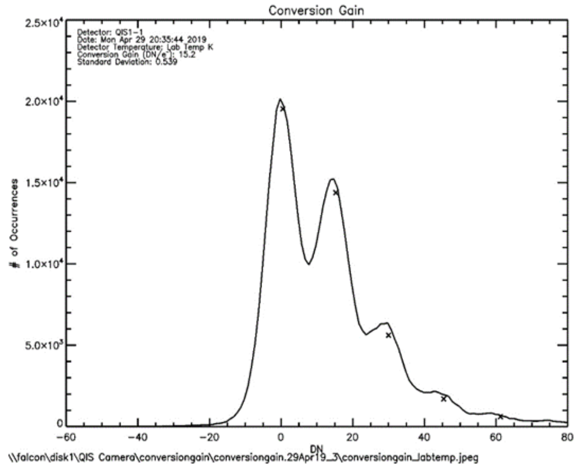


Figure 4. The graph shows the distribution of signal in the conversion gain analysis. The location of peaks corresponds to integer numbers of electrons detected as a signal. Location of peaks is determined from gaussian fitting and subtracting.

We also measured read noise, or the uncertainty in the voltage measurement of the detector output. We computed read noise as the standard deviation of pixel values for individual pixels in data sets containing many consecutive reads while keeping the detector in the dark.

Through a collaboration with CfD professor, Gregory Howland, we began using the QIS camera for quantum science and information experiments. In particular, we used the camera to image spontaneous parametric down-conversion (SPDC) of a 404 nm pump laser. In SPDC, the photons from a pump laser pass through a non-linear crystal, BiBO. Spontaneously, a photon down converts into a pair of photons with lower energy. In our optical bench, the QIS is able to detect the spatial correlation of photon-pairs by imaging the location of photon-pair generation within the BiBO crystal.

Integrated Quantum Photonics for Photon-Ion Entanglement

Air Force Research Laboratory
Stefan Preble

The primary objective of this project is the realization of an integrated photonics platform compatible with photon-ion entanglement. The platform will consist of photon sources and entangling circuits that interface with the visible/UV wavelengths of ion (such as Yb+, Ca+, Be+, Mg+, Sr+, Ba+, Zn+, Hg+ and Cd+) transitions. The challenge with realizing such a platform is that integrated photonic chips are relatively immature at visible wavelengths because of the traditional focus on telecom wavelength compatibility. We are developing a platform that operates at short wavelengths by using Aluminum Nitride (AlN), which is a large bandgap semiconductor that is transparent to the deep-UV (Figure 5). In parallel, we are leveraging our successes in quantum integrated photonics in telecom-compatible platforms, particularly silicon photonics. This will allow rapid validation of high performance photon sources, entanglement circuits, and quantum sensors. These circuits will then be transitioned to the new visible/UV platform, or interfaced with ions directly by using frequency conversion.

Figure 5. The image above shows UV light in an integrated photonic circuit.

New Infrared Detectors for Astrophysics

NSF/NASA
Donald Figer

This project aims to develop infrared detectors that use HgCdTe material grown on silicon substrates (MCT/Si). Traditionally, manufacturers use CdZnTe (CZT) substrates because they have the same lattice spacing as MCT, providing fewer possibilities for undesired energy states where atoms in the lattice do not meet. Unfortunately, CZT substrates are expensive and come in small sizes. Both factors increase the cost of MCT detectors. In contrast, Si wafers are widely available and in large sizes. MCT/Si technology will dramatically reduce the cost and size constraints imposed by CZT substrates for sensors for ground- and space-based astronomy missions.

Previous work on this project included targeted design changes to MCT/Si detectors that improved operation. The CfD tested multiple detector lots designed and fabricated by Raytheon Vision Systems (RVS). As an example of a successful design change, RVS excluded epoxy backfilling from the thinning process during detector substrate removal. This decreased interpixel capacitance, or undesired transfer of charge between pixels, caused by the epoxy filling.

Changes in the lot of detectors we received from RVS in late 2018 targeted improving dark current. Dark current measures signal when there is no illumination on the detector. As temperature increases, some lattice vibrations are larger than the bandgap energy of the detector material and cause an electronic transition to the conduction band resulting in a signal. We take many long exposures with no illumination to measure dark current. Figure 6 (left) is an example of a dark current histogram for F13, a detector from a previous lot. F13 has a large tail in the dark current histogram, and only about 65% of all pixels have a dark current below 0.6 e—/s. We hypothesized that mismatches in the lattice of the HgCdTe and Si substrate formed coupled dislocations, resulting in higher dark current.

The new detectors contained a thicker buffer layer to mitigate these lattice mismatches. Unfortunately, cracking in two of these detectors prevented their complete characterization. This mechanical failure during processing was likely an effect of the thicker buffer layer. RVS used a modified substrate-removal process for the third detector, F17 that addressed this issue. Figure 6 (right) shows the dark current histogram of F17. Compared with F13 in Figure 6 (left), the histogram tail in F17 is significantly smaller. Approximately 88% of all pixels have a dark current of 0.6 e—/s or lower. This shows that the change in buffer layer design improved dark current.

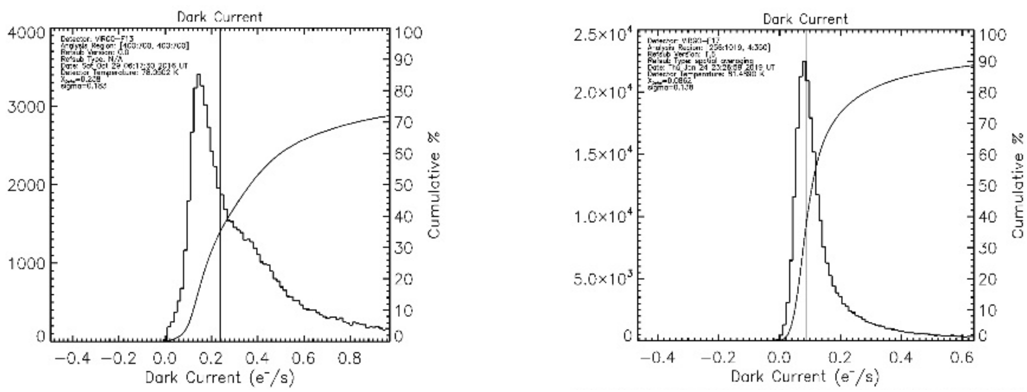


Figure 6. This figure shows the dark current histograms for detectors F13 (left) and F17 (right) at 80 K.

In F17, we also noticed an increase in the magnitude of the high dark current tail after the detector was exposed to air at room temperature before testing. This is easily removed by warming the detector to room temperature under vacuum in the dewar testing system, or by removing it and baking it in an oven.

These warming cycles recover the original dark current results by removing moisture from the detector surface. Warming does not influence the performance of detectors from previous lots that have inherently high dark current.

Previous work on this project identified persistence as another area of detector performance to improve. Also called latent charge or memory, persistence is the portion of the detector signal that is produced from photoelectron generating sources in previous images. In applications where illumination levels are low, like astronomy, persistence can add significant noise to images. We measure persistence by comparing the decay of signal in images after an illumination period to initial dark images. Figure 7 shows that persistence in F17 is wavelength dependent and decreases as a percentage of fluence during illumination. Previously characterized detectors, like V7, share these trends. Overall persistence in F17, however, is lower, reduced by approximately half at lower well capacities.

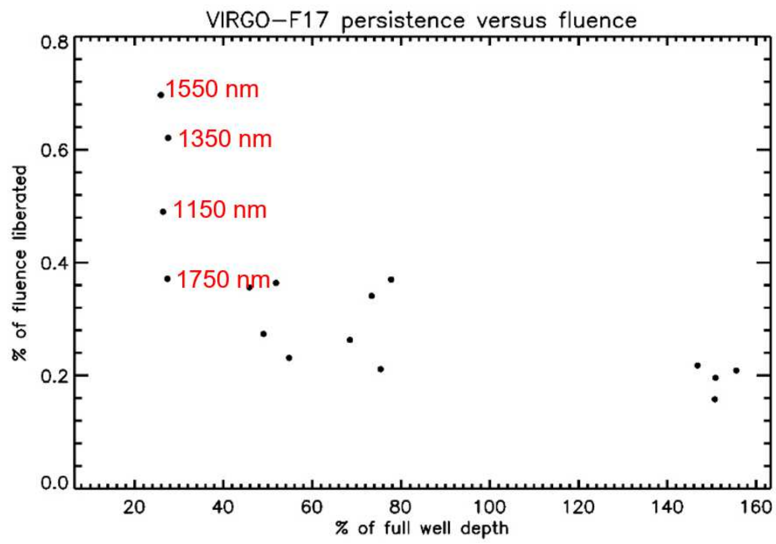


Figure 7. This figure shows the persistence vs fluence plot for F17 at 1150, 1350, 1550, and 1750 nm.

The decrease in dark current and persistence of F17 represents the success of design modifications by RVS in this detector lot. To complete the analysis of this detector, we will focus on understanding the origin of the observed increase in read noise with temperature. Once we have achieved this understanding, we will execute plans to test F17 for ground-based astronomy applications at a telescope.

Integrated Photonics Education at RIT

Empire State Development/Research Foundation of SUNY
Stefan Preble

The objective of this project is to support AIM Academy (the education arm of AIM Photonics) by providing education modules for integrated photonics design, manufacturing, packaging, and testing. This activity directly benefits the future workforce that will enable the silicon photonics economy.

The project structure educates students, workforce, veterans, and the community with short and degree courses (Figure 8), while also establishing an integrated photonics practice facility, and assessing workforce needs.

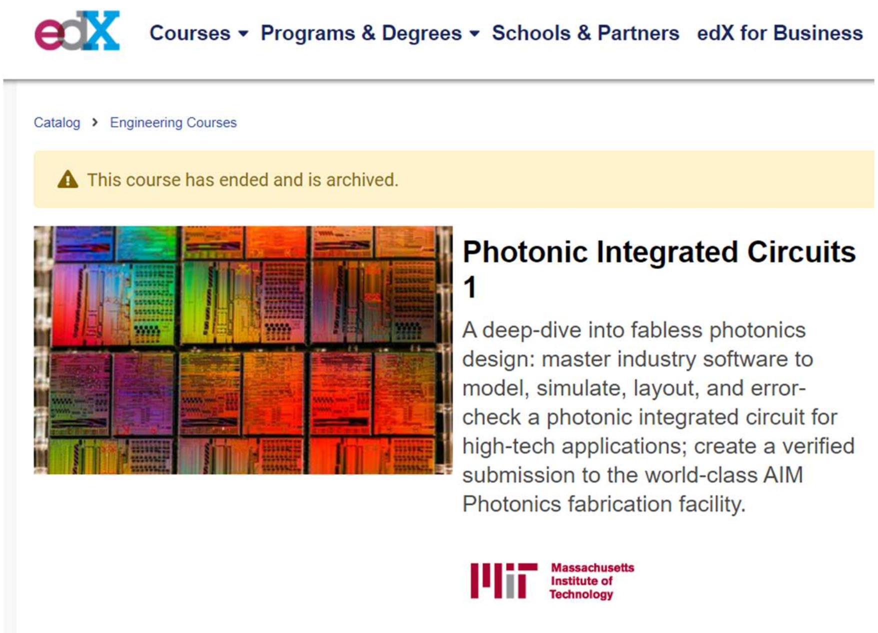


Figure 8. The photo above shows the edX course description, Photonic Integrated Circuits 1 that Professor Preble taught. The course had more than 1500 participants from academia and industry.

Understanding and Engineering Valence Band Structures of III-Nitride Semiconductors for High-Efficiency Ultraviolet Lasers and Emitters

Office of Naval Research
Jing Zhang

The purpose of this research is to develop solutions to key challenges in achieving high-efficiency single-mode GaN-based ultraviolet (UV) lasers with wavelength ranging from 220 nm up to 300 nm. Particularly, this research focuses on the fundamental physics understanding of the valence band structure of lll-Nitride wide bandgap gain active region, and develop promising solutions on nanostructured quantum wells and fabrication approach of large area GaN-based UV laser arrays. Those lasers would be a promising candidate for various naval applications in sensing and communication.

Quantum Optical Resonators: A Building Block for Quantum Computing and Sensing Systems

National Science Foundation
Stefan Preble

The overall goal of this project is to experimentally demonstrate the quantum optical response of ring resonators and use them as a robust building block for quantum information processing. We have shown that ring resonators operating in the quantum regime exhibit a resonant response that depends on the photon state. Unlike beam splitters, which operate with maximum fidelity with only one set of parameters, the unique passive feedback in ring resonators ensures high fidelity quantum interference over effectively an infinite device parameter space. The device's compact size and ability to be reconfigured dynamically with low energy requirements ensures that ring resonators are the ideal building block for realizing complex quantum optical circuits (Figure 9).

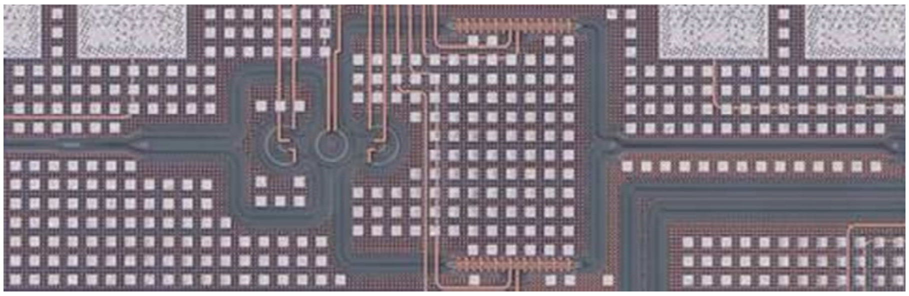


Figure 9. The photo above shows a quantum photonic circuit fabricated by AIM Photonics.

Quantum Silicon Photonics Measurement System

Air Force Office of Scientific Research (AFOSR)
Stefan Preble

The primary objective of this Defense University Research Instrumentation Program (DURIP) project is to demonstrate quantum photonic circuits on a silicon chip by using a quantum photonic measurement system with ultra-low noise and high efficiency. Quantum information science has shown that quantum effects can dramatically improve the performance of communication, computational and measurement systems. However, complex quantum systems have remained elusive due to the large number of resources (photon sources, circuits and detectors) that need to be tightly integrated. Preble is realizing breakthroughs by integrating quantum circuits on a silicon chip and developing scalable building blocks based on ring resonators, which dramatically reduce the footprint of the circuits and enable novel functionalities. The quantum measurement system, (Figure 10) consisting of a low-noise tunable laser and high efficiency single photon detectors, is a critical enabler of these quantum silicon photonic chips.

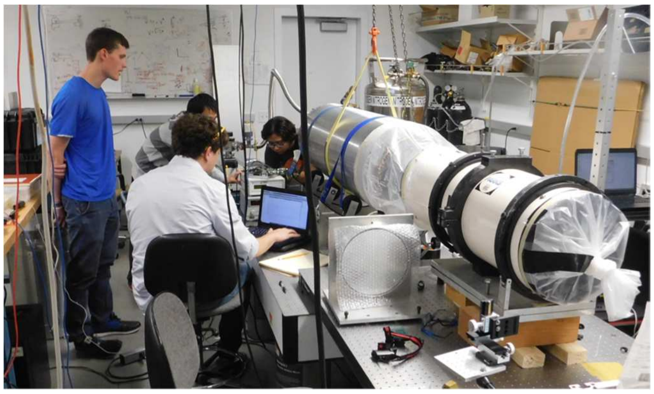
Figure 10. The Integrated Photonics Laboratory has a single photon detector system.

A Cryogenic Optical Camera for Attitude Control of Low-Temperature Sub-Orbital Payloads

NASA
Michael Zemcov

CCDs have been the dominant optical-wavelength detector architecture for high-end optical imaging applications for decades. However, CCDs are inoperable below 120 K due to electron freeze-out effects, prohibiting their use in space exploration applications requiring cryogenic temperatures. Megapixel CMOS devices are known to work at temperatures as low as 10 K, suggesting that imaging devices based on this technology would operate in cryogenic environments without requiring active heating. In this program, we take the first step to maturing this technology for flight applications in the cryogenic regime by developing and flying an attitude-sensing camera employing a low noise, high quantum efficiency cryogenic CMOS detector. By implementing an alternative imaging technology, we address NASA's major objective to "transform NASA missions and advance the Nation's capabilities by maturing crosscutting and innovative space technologies." This technology enables instruments ranging from actively cooled star trackers for sounding rockets to low-temperature deep space cameras.

The progress made by the undergraduate CSTARS (Cryogenic Star Tracking Attitude Regulation System) team has proven instrumental in the design of a second revision of the star tracker to support the Cosmic Infrared Background ExpeRiment (CIBER). The rocket skin of CIBER-1 underwent thermal contraction when exposed to the cryogenic temperatures, resulting in a noticeable drift in the measured data. CSTARS-2 will serve as a secondary star-tracking system on the CIBER-2 payload, located within the cryogenically cooled portion of the rocket. This will allow it to maintain the attitude of the rocket while the CIBER-2 detectors are capturing data. To support a higher resolution sCMOS detector operating at twice the frame rate, new focal plane and interfacing hardware was designed and tested. The new detector has proven fully functional at 80 K and the telemetry streams have been validated against NASA ground stations. In 2018, the CSTARS team installed CSTARS-2 into the CIBER-2 payload. CSTARS-2 underwent integration and environmental testing at Wallops Flight Facility in summer 2019 (Figure 11). Remaining work includes finalizing the star-tracking algorithm and analyzing the sensitivity of the detector at cryogenics temperature.



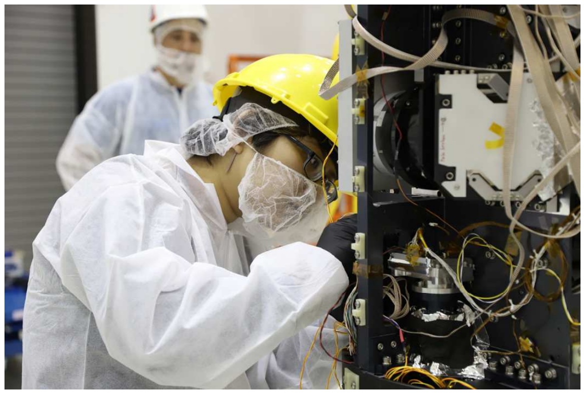


Figure 11. (left) CfD students monitor the CSTARS-2 detector as it captures images at a cryogenic temperature inside the CIBER-2 rocket skin at Caltech. (right) Chi Nguyen checks the CSTARS-2 mechanical components before the payload undergoes environmental testing at the Wallops Flight Facility.

Bifacial III-V Nanowire Array on Si Tandem Junctions Solar Cells

National Science Foundation
Parsian Katal Mohseni

Escalating trends in global energy consumption, mandates for increased national energy independence, and mounting alarm regarding anthropogenic climate change, all demand improved sustainable energy solutions. While the theoretical power generation potential of solar photovoltaics (PV) in the United States is greater than the combined potential of all other renewable resources, substantial market penetration of PV sand realization of grid-parity have been obstructed by high materials and manufacturing costs, as well as limitations in solar power conversion efficiencies (PCE). A pressing need exists for tandem solar cells utilizing two dissimilar materials (TDM) or more that are capable of PCE values beyond the ~30% Shockley-Queisser limit. In this program, we explore a transformative, bifacial solar cell design that employs arrays of TDM III-V compound semiconductor nanowires in tandem with a thinned, intermediate Si sub-cell. The use of epitaxial nanowire arrays overcomes the lattice matching criteria and enables direct III-V on Si monolithic integration. This design eliminates the need for high-cost wafers, growth of graded buffer layers, and anti-reflection coatings, while permitting ideal solar spectrum matching and capture of albedo radiation. The high risk-high payoff and exploratory research fits the NSF EAGER program, as it involves a radically unconventional approach with transformative potential to enable cost-effective manufacturing of high-efficiency TDM solar cells.

The technical approach of this EAGER project relies on selective-area heteroepitaxy of a GaAsP (1.75 eV) nanowire array on the top surface of a thinned Si (1.1 eV) sub-cell by metal-organic chemical vapor deposition. A bifacial, three dissimilar materials, tandem junction device is formed via monolithic integration of a backside InGaAs (0.5 eV) nanowire array. The vertical nanowires comprising the top- and back-surface arrays will contain radially-segmented p-i-n junctions and will be serially connected to the central Si sub-cell via epitaxial tunnel junctions. This design enables absorption of broadband incident solar energy as well as albedo radiation. Standard lattice-matching constraints are overcome via strain relaxation along nanowire free surfaces. Therefore, ideal spectral matching is realized without a need for graded buffer layers or dislocation mediation strategies. Use of vertical nanowire arrays with coaxial p-i-n junction geometries permits key advantages, including near-unity absorption of solar irradiance at normal and tilted incidence without the use of anti-reflection coatings, decoupling of photon absorption and carrier collection directions, and dramatic reduction of 95% in epitaxial volumes. Rigorous modeling of device parameters will be iteratively coupled with extensive materials characterization and property correlation experiments for optimization of III-V sub-cell structure on the single nanowire and ensemble array levels. The ultimate target of this work is demonstration of a functional bifacial, three dissimilar materials, nanowire-based tandem junction solar cell with one Sun power conversion efficiency of 30% or better.

AIM Photonics Test Assembly and Packaging Hub Planning

Air Force/Research foundation of SUNY
Stefan Preble

This project complements the planning, construction, and implementation of the Rochester, NY testing assembly and packaging (TAP) hub by coordinating process development with equipment installation and qualification. AIM Photonics has divided the hub stand-up into centrally funded operations activities (facilities, tool installation, baseline packaging etc.) and comprehensive process and platform development activities. The organization of the TAP hub project is along the following technical categories of Optical I/O, Testing, Metrology, and Reliability. We have set several tasks for specific Key Technology Manufacturing Areas (KTMA) - support, planning, documentation, and technology transfer. The hub will be equipped for 2.5 electronic/photonic packaging, attach and align tools for fibers and fiber/waveguide arrays, functional testing equipment, as well as a full line of metrology tools. The project emphasizes the most significant gaps in the manufacturing of Photonic Integrated Circuit (PIC)-enabled systems by enabling and ensuring access to standardized package designs, integrating the photonic, electronic, and physical designs, ensuring that metrology tools are available to test the physical integrity of the packages, and providing functional testing for digital, analog, and sensor-based photonic systems. (Figure 12Figure 12) The current activities are concentrating on establishing packaging design and test support for AIM Photonics members through the Rochester Hub, developing the tool qualification plans for optical I/O and testing, and planning release 0.5 of the AIM Photonics design guide.

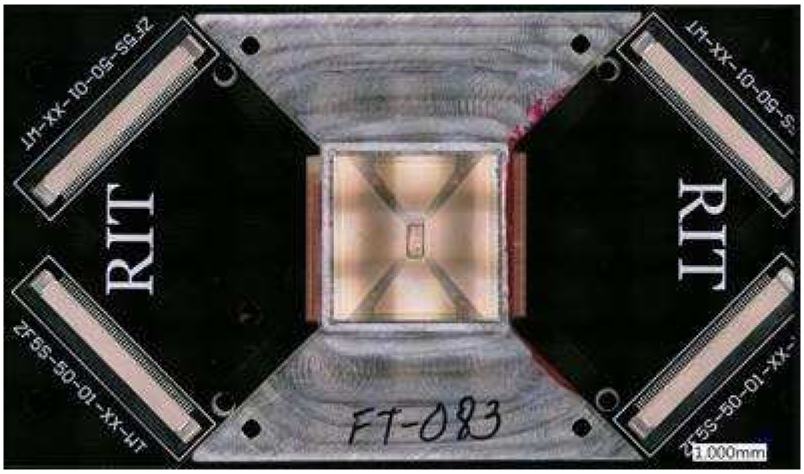


Figure 12. The photo above shows a packaged integrated photonic chip connected to printed circuit boards integrated into an RIT testbed.

Development of High Efficiency Ultraviolet Optoelectronics: Physics and Novel Device Concepts

National Science Foundation
Jing Zhang

III-nitride-based semiconductor (AlN, GaN, and InN) ultraviolet (UV) optoelectronics have great potential in replacing bulky mercury lamps and excimer lasers attributing to their compact size, lower operating voltage, excellent tunability, higher energy efficiency and longer lifetime. As a result, wide-bandgap AlGaN-based UV light-emitting diodes (LEDs) and laser diodes have attracted significant attentions recently as new UV light sources for various applications such as semiconductor photolithography, resin curing, water and air purification, sterilization, and biological/chemical sensing.

The objective of this project is to develop fundamental physics from the III-Nitride emitters and to propose novel materials and device concepts to address the issues from semiconductor UV LEDs, in order to achieve UV emitters with significantly improved efficiency covering 220 nm – 300 nm spectral regimes. The proposed research efforts will be divided into three major thrusts: Thrust 1: Development of delta quantum well (QW) UV LEDs covering ~240 nm – 250 nm; Thrust 2: Exploration of alternative UV active regions: III-Nitrides and beyond; and Thrust 3: Novel UV emitter device concepts.

Concept Study Report Preparation for SPHEREx MIDEX Phase A

NASA/Jet Propulsion Lab
Michael Zemcov

SPHEREx (the Spectro-Photometer for the History of the universe, Epoch of Reionization, and ices Explorer) is a proposed NASA mid-range explorer (MIDEX) mission that will perform an all-sky spectral survey in near-infrared bands. SPHEREx was selected for development in February 2019 and received significant press and community attention for being the next MIDEX mission. The instrument is designed to map the large-scale structure of galaxies in the universe to shed light on the first instants of the universe. SPHEREx (Figure 13) will also measure the light produced by stars and galaxies over time by using multiple wavelength bands and investigate how water and biogenic ices influence the formation of planetary systems by studying the abundance and composition of interstellar ices. RIT is responsible for the ongoing development of the data analysis pipeline, with plans for future publications on the analysis methods presently being developed. SPHEREx recently started Phase B, during which final mission trades are studied and preliminary designs are drawn up, and is currently funded for a full mission through to 2026.

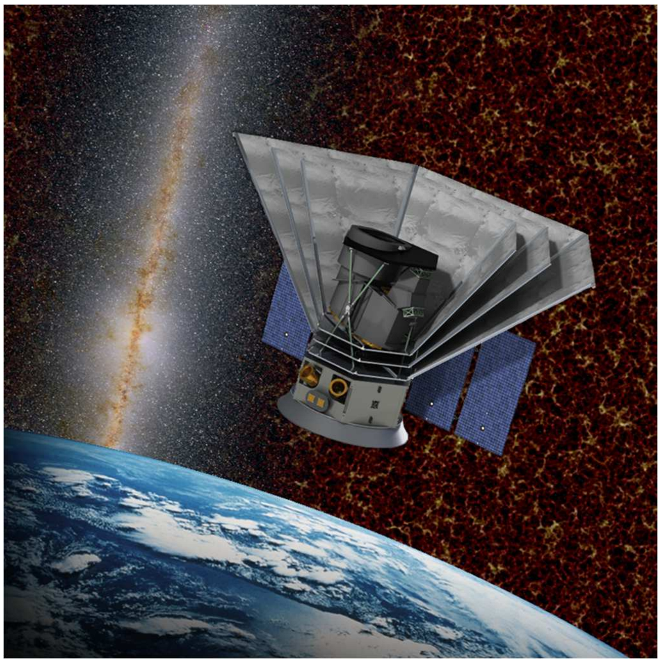


Figure 13. Above is an up to date graphic of SPHEREx.

Multi-Color Anisotropy Measurements of Cosmic Near-Infrared Extragalactic Background Light with CIBER-2

NASA/Caltech
Michael Zemcov

The Cosmic Infrared Background ExpeRiment (CIBER-2) is a near-infrared rocket-borne instrument designed to conduct comprehensive multi-band measurements of extragalactic background light anisotropy on arcsecond to degree angular scales. Recent measurements of the near-infrared extragalactic background light (EBL) anisotropy find excess spatial power above the level predicted by known galaxy populations at large angular scales. CIBER-2 is designed to make measurements of the EBL anisotropy with the sensitivity, spectral range, and spectral resolution required to disentangle the contributions to the EBL from various sources throughout cosmic history. CIBER-2 consists of a 28.5 cm Cassegrain telescope assembly, imaging optics, and cryogenics mounted aboard a sounding rocket. Two dichroic beam-splitters spectrally subdivide the incident radiation into three optical paths, which are further subdivided in two wavelength bands per path, for a total of six observational wavelength bands that span the optical to the near-infrared and produce six 1.2×2.4 degree images recorded by three 2048×2048

Figure 14. Chi Nguyen and her collaborators are lifting the experiment out of the rocket skin in the clean room at Wallops Flight Facility.

pixel HAWAII-2RG detector arrays. A small portion of each detector is also dedicated to absolute spectrophotometric imaging provided by a linear-variable filter. The instrument has several novel cryogenic mechanisms, a cryogenically-cooled pop-up baffle that extends during observations to provide radiative shielding and an electromagnetic cold shutter. A current model of the CIBER-2 payload can be seen in Figure 14. Over the past year, our local team has been contributing to the international collaboration by assisting with overall instrument design, including mechanical and electronic systems, assembling and characterizing the mechanical and optics elements at Caltech, integrating the payload and verifying the payload's communication with the rocket telemetry at Wallops Flight Facility, and flight planning activities. In addition, the RIT team is responsible for delivering the cryogenic star tracking camera system. The RIT installed the cryogenic star tracking system into CIBER-2 and the system is currently undergoing characterization with the payload.

Cosmic Dawn Intensity Mapper

NASA/University of California, Irvine
Michael Zemcov

The NASA Probe-Class Mission Concept Cosmic Dawn Intensity Mapper (CDIM), shown in Figure 15, will make pioneering observations of the Lyman-alpha, H-alpha and other spectral lines of interest throughout the history of the cosmos. Capable of spectro-imaging observations between 0.7 to 7 microns in the near-Infrared, CDIM will help move the astronomical community from broad-band astronomical imaging to low-resolution (R=300-400) 3D spectro-imaging of the universe to perform the science of the 2030s. In this program, we performed a mission concept study for NASA and the US astronomical community in preparation for the 2020 Astronomy Decadal Report. The RIT team lead by Dr. Michael Zemcov performed initial engineering and instrument design work in support of detailed science requirements derived by the science team. This work has led to a fully functional instrument sensitivity calculator, and a complete mission initial engineering study performed by an RIT Engineering MS student. The next phase of the concept is to see if probe-class astrophysics missions are recommended by the Astro2020 Decadal Survey.

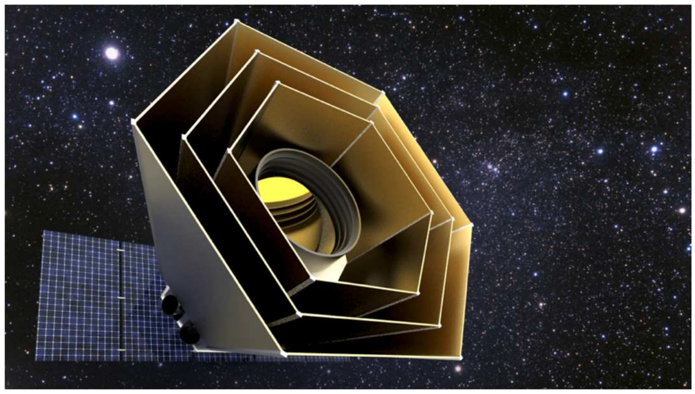


Figure 15. Shown above is a rendering of the Cosmic Dawn Intensity Mapper.

Selective Area Epitaxy of III-V Nanocrystals on Graphene and MoS_2 for Flexible Optoelectronics Application

RIT
Parsian Katal Mohseni

Atomically-thin, two-dimensional nanomaterials such as single-layer graphene (SLG) and monolayer molybdenum disulfide (MoS_2) have emerged as essential building blocks that can enable the development of a widely encompassing class of next-generation nanoelectronic devices. However, these monolayer materials have a critical drawback for applications in optoelectronic, in that they are either inherently incapable (*i.e.*, SLG) of, or are fundamentally inefficient (*i.e.*, MoS_2) in, absorbing and emitting light. The purpose of this work is to overcome this limitation through the monolithic integration of highly optically efficient 111-V semiconductor nanostructures with SLG and MoS_2 by selective area epitaxial (SAE) crystal growth. This effort aims to combine the characteristic benefits of monolayer materials and 111-V nanocrystals through the synthesis of novel types of hybrid nanostructures. The correlation of extensive structural and optical characterization experiments enables the optimization of SAE growth parameters, and subsequently enables the development of low-cost and high-efficiency flexible light emitting diodes and photodetectors.

Probing the History of Structure Formation through Intensity Mapping of the Near Infrared Extragalactic Background Light

NASA
Michael Zemcov

In 2017, the CfD was selected to receive a NASA Earth and Space Science Fellowship (NESSF), which supports a student's work on the instrument integration and data analysis of CIBER-2. NESSF support enables the student to participate fully in CIBER-2 and gain invaluable experience working on a suborbital project. This experience includes integrating and characterizing the rocket-home instrument at flight facilities; analyzing and interpreting observational data into science findings; and communicating progress to the CIBER-2 collaboration, NASA, and the public. In Figure 16, Chi Nguyen is shown characterizing the CIBER-2 telescope at Caltech over the summer of 2018. The fellowship has recently been renewed for a third year of funding.

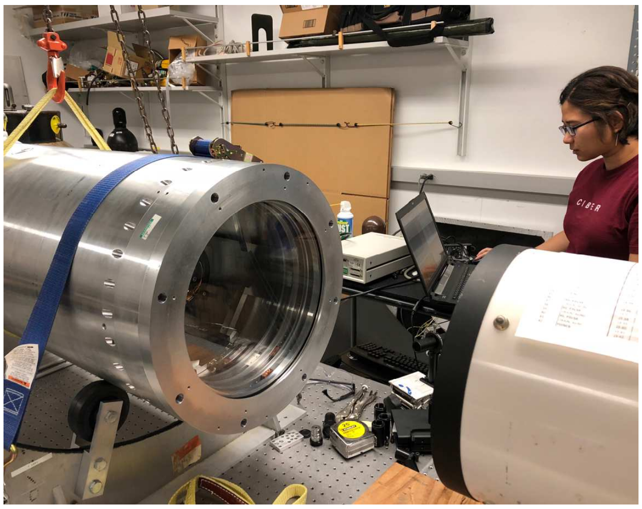


Figure 16. Chi Nguyen takes test images to characterize the CIBER-2 telescope as the payload is being cooled to 77 K.

The Development of Digital Micromirror Devices for use in Space

NASA
Zoran Ninkov

The Digital Micromirror Device (DMD), built by Texas Instruments, is the device used as the optical slit mask in the RITMOS Multi-Object Spectrometer. RITMOS records spectra of multiple stars within the field of view. The instrument has been improved, with newly written software and a new imaging camera. The 2010 Astronomy Decadal survey's leading suggestion for space instrumentation is a wide field IR Space Telescope which will require a multi-object spectrograph to accomplish its science goals. Other space-based missions requiring multi-object spectroscopy capability have been proposed, including for the ultraviolet (e.g. LUVOIR). There have been four key aspects of the performance of DMDs that have been questioned for use in a MOS for space. We have attempted to address each of these.

To assess the light scattering and reflectance properties of DMDs in a spectrograph configuration, an optical test set-up has been assembled. The test set-up is designed to simulate the performance of the DMD in a typical multi-object spectrograph (MOS) configuration. In a MOS, individual micromirrors are selected and turned to the on-state to reflect light to a spectrograph. All other micromirrors are turned to the off-state, away from the spectrograph. Light scattered from DMD mirrors in the off-state can contaminate the measured spectra.

For use in the infrared it is required that DMDs operate at cooled temperatures. The testing established that normal operation of these devices was able to be carried out to a temperature of near 77K. This was the limit of how cold the DMD could be cooled by the test configuration and did not reflect a failure of the DMD.

Radiation hardness of the DMD. Heavy ion and high energy proton testing of DMDs has been previously performed. Gamma radiation testing of DMDs was performed to determine the viability of the devices in the space radiation environment. Testing was performed at the NASA Goddard Space Flight Center's Radiation Effects Facility (Figure 17). The devices were found to tolerate the total-ionizing dose expected for a typical 4 year mission at an L2 orbit.

The DMDs are supplied by Texas Instruments with a protective borosilicate glass window. This glass limits the range of wavelengths that the device can be used for. We have developed a technique for removing these windows and repacking the devices with windows that are transmissive in the ultraviolet and infrared. Initially we have used magnesium fluoride and HEM Sapphire as the replacement window material. These devices have been successfully shake/shock/vibration tested at the NASA GSFC facility for verification of ability to survive a launch.

Figure 17. The picture shows (from left to right and top to bottom): Marty Carts (NASA), Lexi Irwin (PhD student), Kate Oram (PhD student), Zoran Ninkov (RIT), Tony Chapman (Thermo Scientific), Dmitry Vorobiev (CU/RIT), Eugene Gerashchenko (NASA) at the Gamma Testing facility at NASA Goddard Space Flight Center.

Developing THz Detector Technology for Inspection Applications

RIT
Zoran Ninkov

A silicon CMOS based array purposed for the terahertz regime has promising applications for many fields including security screening, manufacturing process monitoring, communications, and medicine. Current systems mainly consist of bulky technology, including large pulsed laser systems and are primarily laboratory-based setups. In this research, we chose a silicon CMOS based technology in order to eventually develop a compact, portable, practical imaging system. A large amount of recent research has been conducted regarding the detection of terahertz using silicon MOSFETs. The THz focal plane technology being tested is uncooled and employs direct overdamped, plasmonic detection with silicon CMOS MOSFETs that are each coupled to individual micro-antennae (Figure 18).

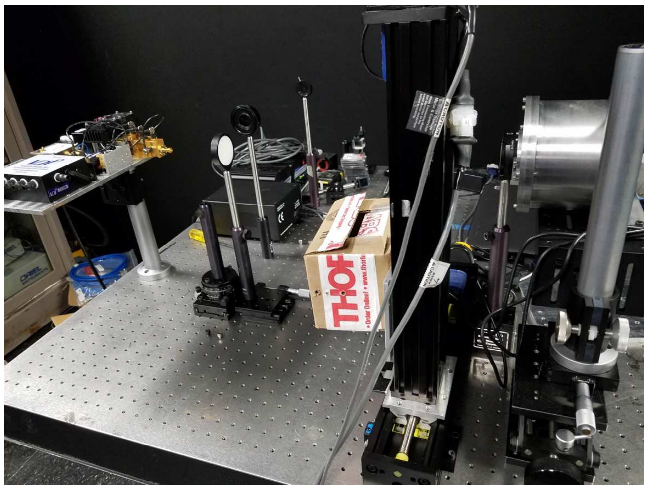


Figure 18. A photo of experimental THz scanner setup is shown above. The source is on the left, followed by the Teflon lens, and the test dewar enclosure on the right. The thor lab box, containing various targets, is mounted on XYZ and rotation stages for scanning.

The chip used in these experiments was custom designed and fabricated in a 0.35 µm silicon CMOS process using the MOSIS facility. On the chip is a test imaging array and fifteen test transistors. These 'test' transistors can be connected directly to outputs for characterization without clocking electronics. Our work has focused on characterizing the response from these five test transistors. Figure 19 shows a micrograph of the test chip with the test transistors located on the bottom edge.

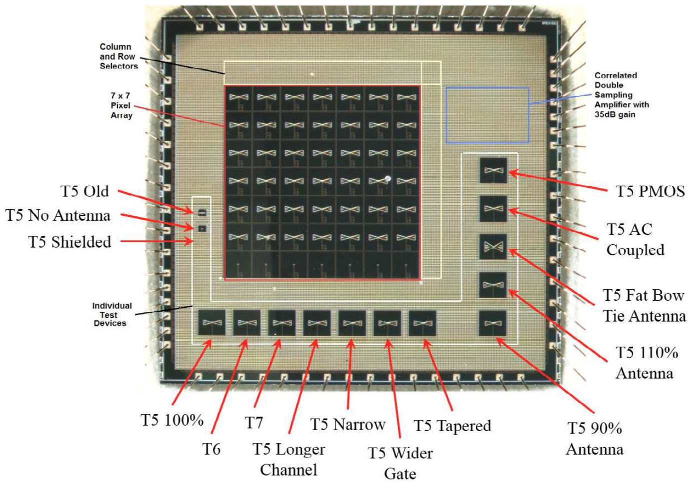


Figure 19. Above is a photo of the generation II MOSIS THz device. Fifteen test structures are along the edges.

The transistors were biased using SRS power supplies which connect to the test enclosure via low noise shielded twisted pair cables. The enclosure creates a Faraday cage around the fan-out board and test chip, and the connections are fed through the box with feed-through capacitors to reduce as much RF noise as possible. A removable high resistivity silicon window on the front of the enclosure precedes a high speed shutter which is controlled via digital I/O. The enclosure is mounted on XYZ and rotation stages for alignment purposes. A SRS 560 current preamplifier is commanded via a MATLAB serial interface for applying bias sweeps and relaying data. The radiation source is a 200 -300 GHz tunable source from Virginia Diodes

Development of Quantum Dot Coated Detector Arrays

NYSTAR/University of Rochester
Zoran Ninkov

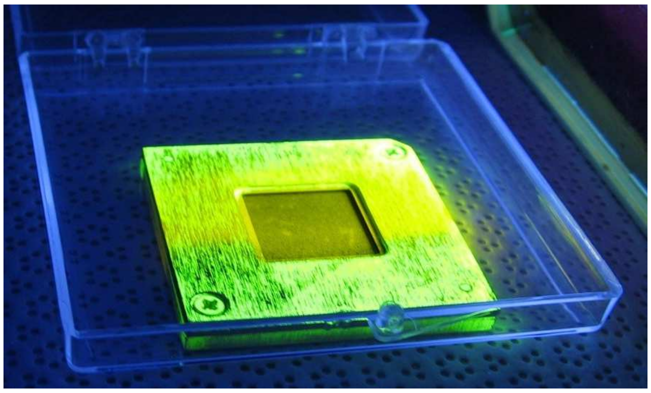


Figure 20. The yellow/green device above is a Quantum Dot coated detector in aluminum mask under UV illumination. The active area is 15 mm×15 mm.

There are many interesting things to see in the ultraviolet (UV). Lithography for integrated circuit production is exposed with 193 nm light with future, honey bees' view of flowers include the UV region, and analytical instruments use UV emissions to identify materials. 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 to visible light, which is more readily recorded by standard detector chips. We use an inkjet printer to deposit the quantum dots. This research has developed a method of coating detector arrays with nano materials and applied it to improve the ability of detectors to record UV and blue light (Figure 20).

Imaging Polarimetry

Zoran Ninkov

Imaging polarimeters utilizing the division-of-focal technique present unique challenges during the data reduction process. Because an image is formed directly on the polarizing optic, each pixel "sees" a different part of the scene; this problem is analogous to the challenges in color restoration that arise with the use of Bayer filters.

Although polarization is an inherent property of light, the vast majority of light sensors (including bolometers, semiconductor devices and photographic emulsions) are only able to measure the intensity of incident radiation. A polarimeter measures the polarization of the electromagnetic field by converting differences in polarization into differences in intensity. The microgrid polarizer array (MGPA) divides the focal plane into an array of superpixels. Each sub-pixel samples the electric field along a different direction, polarizing the light that passes through it and modulating the intensity according to the polarization of the light and the orientation of the polarizer. We are actively looking at techniques for hybridizing microgrid polarizer arrays to commercial CID, CCD and CMOS arrays.

We had the opportunity to deploy one of these polarization cameras to the CTIO 1 meter telescope in Chile, South America. Figure 21 shows an image of Jupiter obtained from that data, revealing the polarization signature.

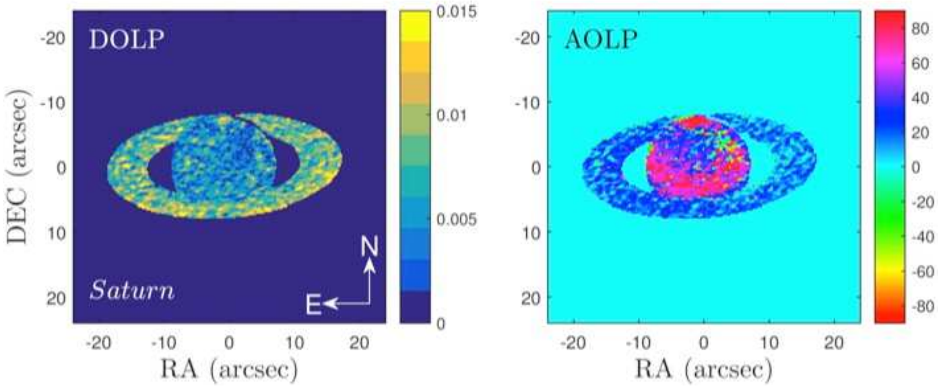


Figure 21. The figure shows two images of Jupiter in degree of linear polarization and angle of polarization.

Student Vignettes

Victoria Butler

Victoria Butler is a third-year PhD candidate in the Astrophysical Sciences and Technology program. She received her BS in Applied Physics with an Astronomy concentration at Rensselaer Polytechnic Institute (Troy, NY) in 2016.

Her current research focuses on the evolution of galaxies and galaxy clusters through the Epoch of Reionization and the Epoch of Peak Star Formation. She works on a millimeter-wave instrument designed to detect the ionized carbon and carbon monoxide reservoirs of high redshift galaxies that were evolving through these epochs.

A secondary science goal of the instrument is to measure the kinematic motions of the gas within clusters using the kinetic Sunyaev-Zel'dovich Effect (kSZE). This effect is caused by photons from the Cosmic Microwave Background (CMB) inverse Compton Scattering off the intra-cluster gas, causing a relative change in the intensity of the CMB. The change in this intensity can be used to calculate the peculiar motion of the cluster gas, and probe the gravitational potential of the cluster. This will lead to insights into the role of dark matter in the evolution of large-scale structure through cosmic history.

Her contribution to the project is the development of software that communicates with the bolometric instrument, operates the telescope and other connected devices, presents the live streaming data in graph form, and collates and saves that data into specially built file systems. Butler and a team from the University of Arizona deployed the instrument for an engineering run at the Arizona Radio Observatory (ARO) at Kitt Peak, Arizona, where it made test radio images of three planets pictured in Figure 22. Future work involves creating a data retrieval suite and inserting it into an analysis pipeline, which will reduce the raw data by removing atmospheric noise, among other tasks.

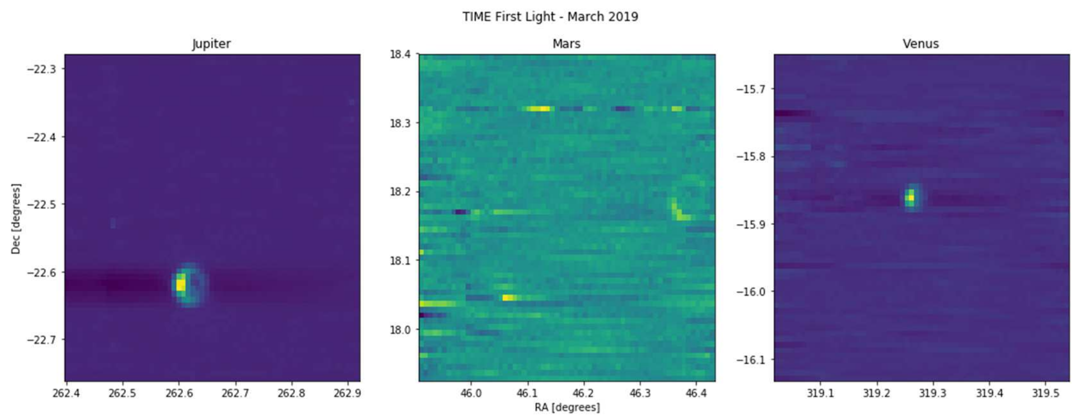


Figure 22. This photo shows the radio images taken by the bolometric instrument of three planets from the Arizona Radio Observatory at Kitt Peak. Victoria traveled to Arizona to help deploy the instrument and run tests.

Rhys D’Souza

Rhys D’Souza is a third-year student currently pursuing a Bachelor of Science in both Electrical Engineering: Computer Engineering Option, and Applied Mathematics.

At the Center for Detectors (CfD), Rhys works as a member of the Engineering Verification Test (EVT) team to design and perform tests related to a C Form-factor Pluggable (CFP) module that is part of the VCU108 FPGA (Figure 23, left). As part of his work, Rhys designed the Product Evaluation Kit (PEK) board (Figure 23, right) meant to interface with the CFP module as well as assist in writing the software that allows communication from the VCU108 to the PEK board. When connected to the CFP module, the PEK board allows for the transmission of data at speeds up to 25 Gb/s across four channels using laser drivers and photodiodes. The user can also perform certain functions on the PEK board via the on-board microcontroller.

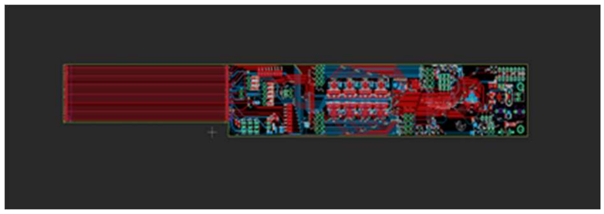


Figure 23. (left) Shown above is the CFP module on a VCU108. (right) D’Souza used Eagle to generate the PEK board design above.

Sidney Davis

Sidney Davis is a third-year undergraduate student pursuing both Bachelor and Master Degrees in Electrical Engineering: Robotics Option. His current research for CfD involves designing test equipment for high-speed optical transceivers as a member of the Engineering Verification Test (EVT) station. Sidney is also part of a team that is creating a user interface that allows a consumer to interact with a Photonic Integrated Circuit (PIC) on a Quad Small Form-Factor Pluggable (QSFP) module in a simple manner (Figure 24).

Figure 24. Above is the Xilinx VCU108 FPGA board that Davis used as the programmable system for communication between the user interface and peripheral QSFP modules.

His contribution includes designing the system that receives commands through UART communication from the user interface, interprets the command, and performs the desired test. Such tests include bit-error-rate tests, statistical eye diagram scans, sweep tests, and the analysis of multiple transmission rates on each individual transceiver line of a QSFP module.

Furthermore, the system can access data on the QSFP module through the I2C data line.

Michael Fanto

Michael Fanto is a graduate student member of FPI and CfD conducting research in integrated quantum photonics. He completed his BS degree in Physics from Utica College in 2002. His senior research project was on ultra-fast mode-locked fiber lasers, which gave him a tremendous experience with nonlinear interactions with materials.

After completing his BS degree, he accepted a position with the United States Air Force/Air Force Research Laboratory (AFRL) in Rome, NY as a research physicist (2002-present). While at AFRL, he has conducted research in a number of areas including fiber laser systems, optical modulators, laser radar, and quantum information science, including quantum computation.

In the summer of 2015, he was awarded an Air Force Development Opportunity package and accepted the admission to RIT to start his PhD in microsystems engineering in the integrated photonics group of Dr. Stefan Preble. He has been conducting research on photon pair sources utilizing the third order nonlinearity in silicon and the enhanced efficiency gained from a microring resonator. This research has broadened to include photon generation in the ultraviolet regime, beyond the typically generated infrared photons from silicon. To accomplish this task, one needs a larger bandgap material, and a candidate that can be fabricated into integrated waveguide circuits. The chosen material was aluminum nitride with a bandgap of 6.2 eV, allowing optical transparency well into the ultraviolet. The characterization and generation of photons with aluminum nitride has been the majority of his research conducted over the past years. Figure 25 shows UV photons fiber coupled into aluminum nitride waveguides and a microring resonator where other frequency photons are generated via nonlinear processes. Mike will present the results of this research at an international conference in Strasbourg, France later in 2019.

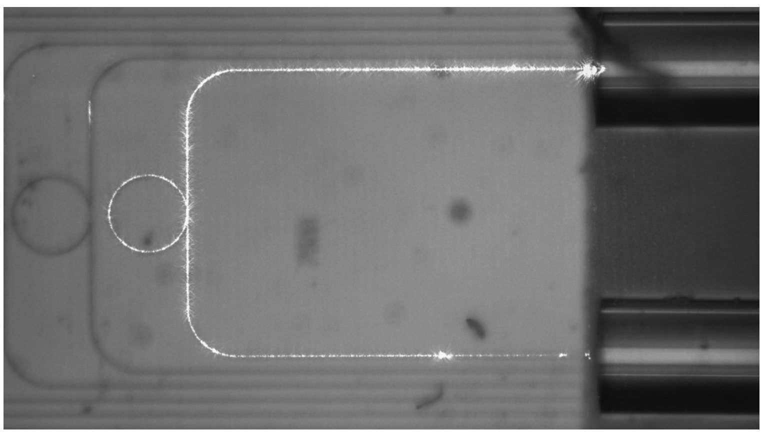


Figure 25. In the picture, you can see fiber coupling to the integrated aluminum nitride waveguides and microring resonators. A frequency doubled continuous wave Ti:Sapphire generating 369 nm is fiber coupled and that fiber is edge coupled to the aluminum nitride waveguide. A second fiber collects the residual pump light and any new frequencies generated via nonlinear processes in the integrated circuit at the output port to where it is sent various pieces of measurement equipment.

Justin Gallagher

Justin Gallagher is a fourth-year BS/MS student at RIT pursuing a Master of Science in Astrophysical Sciences and Technology in conjunction with a Bachelor of Science in Physics. Currently, Justin is a graduate researcher at CfD under the guidance of Dr. Donald F. Figer.

Within CfD, Justin's research primarily focuses on the Quanta Image Sensor (QIS), a next generation Complementary Metal Oxide Semiconductor (CMOS) active pixel sensor (Figure 26). Unlike conventional CMOS active pixel sensors, the QIS is able to attain sub-electron readout noise without the use of cryogenics and avalanche photomultipliers. This enables the QIS to have "Single-Photon resolving" capabilities, that is, the QIS is able to detect every photon that produces a photoelectron in the detector. Photon resolution allows the QIS to thrive in ultra-low-light applications where the average photon per pixel is less than one, such as astrophysical imaging, LIDAR imaging, neuromorphic computing, biophotonics, as well as bi-photon quantum entanglement experiments.

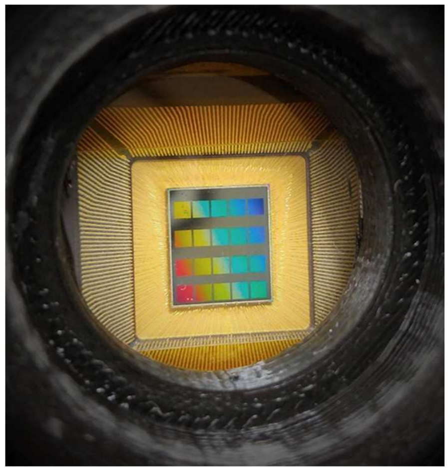


Figure 26. This picture shows twenty 1 Mpixel QIS arrays residing in the detector housing.

Justin's past research includes work on the evolution of high redshift galaxies and galaxy clusters. His work focused on the relationship between a galaxies' Star Formation Rate (SFR) and its local environment during the Epoch of Peak Star Formation. At low redshift, a strong relationship exists where galaxies in dense environments are hardly forming stars, and galaxies in voids are actively forming stars. Using data from the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS), Justin determined the SFR of a galaxy through use of the Spectral Energy Distribution (SED) fitting code Multi-wavelength Analysis of Galaxy Physical Properties (MAGPHYS), while the local environment was determined through Delaunay Triangulation and Voronoi Tessellation. Given an image of galaxies, Voronoi Tessellation can partition the image into Voronoi cells based on the distances between galaxies where the size of the cell is inversely related to the density of the environment, shown in Figure 27.

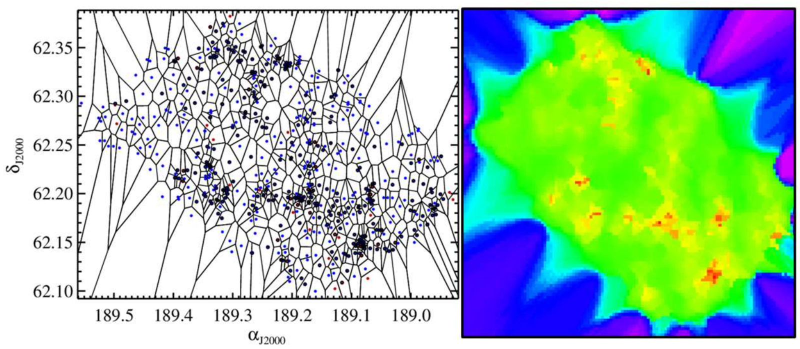


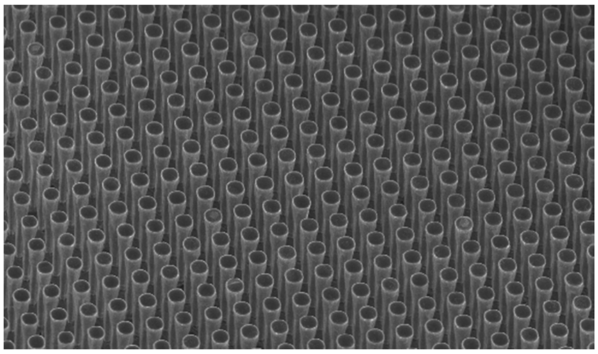
Figure 27. These pictures show a Voronoi Tessellation of the Hubble Space Telescope GOODS North Survey at a redshift slice ranging from z=1.0 to z=1.1 corresponding to a time when the universe was 40% its current age. Red regions denote a dense environment of galaxies. Green denotes an environment where the distance between the galaxies is large.

Matthew Hartensveld

Matthew Hartensveld is a graduate student in the Microsystems PhD program and a member of the Center for Detectors. He works with Dr. Jing Zhang in the Electrical and Microelectronic Engineering Department. Hartensveld has received his Bachelor's and Master's degrees from RIT in Microelectronic Engineering and Materials Science respectively.

For his Master's thesis Hartensveld developed etching techniques to create nanowire LEDs. Nanowire LEDs are poised to replace both OLED and LCD.

His current research led to novel display advancements for nanowire LEDs. This allows display technology to achieve a higher resolution with greater efficiency (Figure 28). Currently Hartensveld's focus is on developing full-scale display prototypes and integrating them with novel functionality.



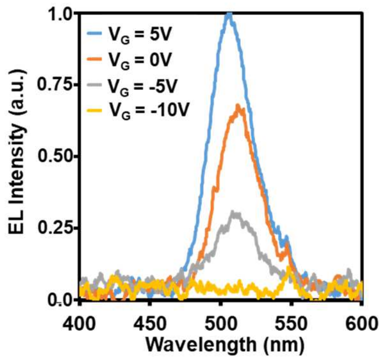


Figure 28. (left) The picture above is a Nanowire LED array for high-resolution displays. (right) This picture demonstrates an individual sub-pixel control.

Bryan Melanson

Bryan Melanson is a graduate student pursuing his PhD in the Microsystems Engineering Program. He completed his undergraduate degree in Materials Science and Engineering at the University of Washington in Seattle with a specialization in nanoscience and nanotechnology.

During the last two years of his undergraduate degree, Bryan worked as a research assistant at the Washington Nanofabrication Facility, an on-campus microelectronics and MEMS cleanroom user facility. While at the Washington Nanofabrication Facility, he assisted research engineers with the design and fabrication of MEMS accelerometers and micromirror arrays. Bryan has held internships at Intel and Modern Electron, a Seattle area startup designing solid-state heat to energy converters based on thermionic emission.

Bryan joined the Microsystems Engineering Program at RIT in August 2018 and works with Dr. Jing Zhang to develop and fabricate LEDs and other devices based on the AlGaN and InGaN materials systems. He is currently working on several projects, including the development of transparent current spreading layers using nanosphere lithography, deep-UV nanowire LEDs, and electrically pumped single photon emitters based on nanowire quantum dots. In the coming years Bryan will develop novel multiple quantum well structures to enhance the efficiency of UV-LEDs and grow them using the Molecular Beam Epitaxy (MBE) systems at Cornell University in Ithaca.

Mark Nash

Mark Nash is a researcher on the Engineering Verification Test (EVT) team in the CfD. He is a fourth-year BS/MS student in Computer Science. Prior to joining the CfD, he completed a co-op at Rheonix, a biomedical device company where he worked with software to control device functionality.

Within the CfD, along with other Computer Science students he is building a software application written in Python that interacts with various lab measurement instruments in order to remotely control and receive data from them (Figure 29). This will be able to efficiently test the validity of the outputs of a Photonic Integrated Circuit (PIC) without being in the lab. His contributions to the software have been writing drivers for many instruments and creating a command interpreter for a microprocessor using GNU Bison written in C. The microprocessor interacts with other printed circuit boards that read and output data from measurement instruments and photonic circuitry. An instrument setup is shown in Figure 29 (right). Upon the EVT project's completion, Precision Optical Transceivers will sell this test suite service to other companies for them to test their PICs.

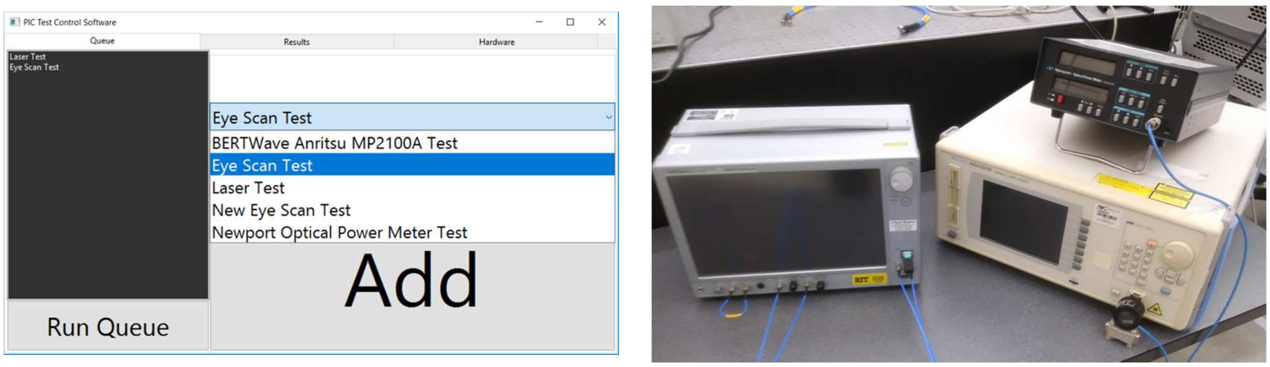


Figure 29. The left image shows the eye scan software that interacts with various measurement instruments, such as the set up shown on the right.

Chi Nguyen

Chi H. Nguyen is a graduate student in the Astrophysical Sciences and Technology (AST) PhD program and a member of the Center for Detectors. Her advisor is Dr. Michael Zemcov. Before coming to Rochester, she received a BS degree in Astronomy with a Math minor from the University of Arizona (Tucson, AZ).

For her senior thesis, Nguyen built a support structure with a robotic actuator for one of the mirrors in the South Pole Telescope Very Long Baseline Interferometry (SPT VLBI) project. The SPT VLBI is part of the Event Horizon Telescope, which uses a network of radio telescopes around the world to directly image supermassive black holes in nearby galaxies. Her instrument was implemented successfully in Antarctica in 2015. In addition to this research, Nguyen worked on various observational projects like studying the properties of exoplanet magnetic field using transit data.

Her PhD research focuses on understanding the Extragalactic Background Light (EBL). The EBL probes the history and origin of stellar emission, which allows astronomers to constrain models of star and galaxy formation. She is currently working on the Cosmic Infrared Background ExpeRiment 2 (CIBER-2) shown in Figure 30. CIBER-2 uses a small telescope launched on a Black Brant IX sounding rocket to map the fluctuations in the EBL intensity at near infrared wavelengths. Nguyen leads the mechanical design of many CIBER-2 sub-systems including the payload forward suspension and the radiation shield. In addition, she serves as the graduate mentor of project CSTARS, in which a group of RIT undergraduate students verifies the feasibility of flying a scientific CMOS detector on a sounding rocket at cryogenic temperature. The technology of CSTARS is currently being implemented into the CIBER-2 star tracker. After the construction of CIBER-2 is completed, she will develop a data analysis pipeline to extract EBL information from the flight data. As part of the integration process, she travels frequently to the California Institute of Technology (Pasadena, CA) to work directly with the payload. In 2017, she won a NASA Earth and Space Science Fellowship to support her work on CIBER-2.

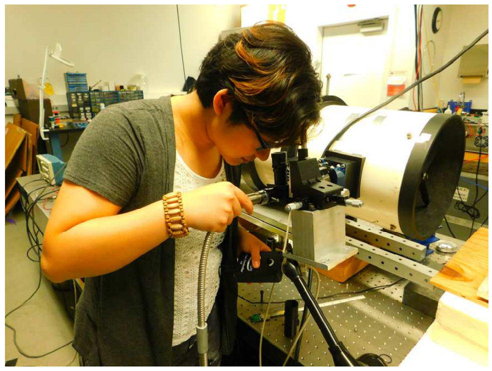


Figure 30. This picture shows Nguyen setting up the test stand for CIBER-2 optics characterization at Caltech.

Besides CIBER-2 and CSTARS, Nguyen is also involved with measuring the EBL intensity at visible wavelength using data from the LORRI camera onboard the New Horizons spacecraft. The early result of this project was published in Nature Communications in April 2017. Nguyen presented the New Horizons study at the 231st meeting of the American Astronomical Society in Washington D.C. in early 2018. Her poster presentation was met with positive feedback from the astronomy community and earned her a Chambliss Astronomy Achievement Student Award.

Kathleen Oram

Kathleen Oram is a graduate student in the Imaging Science PhD program in the Chester F. Carlson Center for Imaging Science at RIT. Her advisor is Dr. Zoran Ninkov. She received a BS degree in Physics from the University of Massachusetts Lowell in 2015. Her undergraduate research focused on the development and characterization of astronomical instrumentation for direct imaging of exoplanets and debris disks. Prior to coming to RIT, Kathleen was an optical engineer at L3 SSG (Willmington, MA) where she worked on the assembly, alignment, and testing of electro-optical payloads for space missions.

Kathleen's PhD research focuses on applications for digital micromirror devices (DMDs) in astronomy. DMDs are commercially available optical micro-electro-mechanical systems (MEMS) used for spatially modulating light. A DMD can be used as a programmable slit mask in a multi-object spectrometer to selectively capture the spectra of target sources. Several NASA missions plan to use DMDs for multi-object spectroscopy from both the ground and in space. In the past year, Kathleen has completed gamma radiation (total ionizing dose) testing on Extended Graphics Array (XGA) DMDs as part of a test campaign to qualify the devices for use in space. She presented the results of this testing with a talk at the 2019 SPIE Photonics West conference. She is also evaluating optical properties of DMDs including reflectance and contrast ratio. Her PhD research will also include developing a method to add integral field spectroscopy capabilities to existing DMD-based multi-object spectrometers using the Hadamard transform technique.

Gabrielle Picher

Gabrielle Picher is a fourth-year undergraduate student pursuing a BS/MS degree in Electrical Engineering.

She has been working as a Lab Assistant for her Engineering Co-Op, taking part in the Engineering Verification Test (EVT) Station, New Infrared Detectors, and Quantum Camera projects. On EVT, Gabrielle has worked on the PEK Evaluation Test Bed (PETB) by creating methods for testing QSFPs using Xilinx Vivado. Under the New Infrared Detectors for Astrophysics project, gathered data to characterize detectors sent by our collaborator, Raytheon Vision Systems. Additionally, she has helped with the upkeep of the dewar systems used to test these detectors. Finally, on the Quantum Image Sensor camera project, she has been working with a single photon camera in order to obtain data about its capabilities. This process involves developing experimental conditions for the capture of relevant data and developing methods for analyzing the data to achieve values such as dark current (e−/s). From helping program FPGAs, to taking apart DEWAR systems, to taking selfies with a single photon camera (Figure 31), she is continuing to make progress on each project.

Figure 31. The image above is a "quantum selfie" taken by the Quanta Image Sensor (QIS) camera.

Irfan Punekar

Irfan Punekar is a third-year undergraduate student pursuing a BS/MS Dual Degree in the Computer Engineering program.

He worked on the Engineering Verification Test (EVT) project through employment with Precision Optical Transceivers. Irfan spent most of his time designing a custom hardware framework from scratch using Xilinx Vivado and writing software in C to provide the necessary functionality. He focused primarily on the PEK Evaluation Test Bed (PETB) portion of the project, which uses a Field Programmable Gate Array (FPGA) (Figure 32) to test Quad Small Form Factor Pluggable (QSFP) Optical Transceivers and Photonic Integrated Circuits. The tests that can be run through the PETB include a Bit Error Rate Test (BERT), which generates a psudo-random sequence of bits, sends it through the transceiver, and compares it with the received sequence in order to find errors. This is used to test the quality of signal transmission through the system under test. His portion of the project was successfully completed and submitted in May 2019.

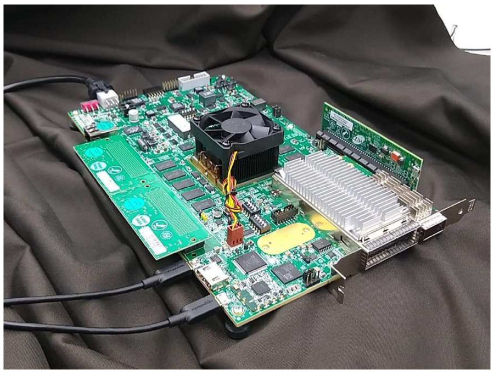


Figure 32. Shown above is the Xilinx FPGA used to create the PEK Evaluation Test Bed.

Katherine Seery

Katherine E. Seery is a graduate student in the Astrophysical Sciences and Technology (AST) PhD program and a member of the Center for Detectors. Her advisor is Dr. Zoran Ninkov. Before coming to Rochester, she received a BA degree in Physics and Mathematics with an Astronomy minor from Alfred University (Alfred, NY). She also received Alfred University's Natasha Goldowski Renner Prize in Physics. As an undergraduate student, Katherine completed summer internships on a variety of projects at NASA's Goddard Space Flight Center.

Since coming to RIT in 2014, she has also received her MS in Imaging Science. Katherine's PhD research focuses on developing a terahertz (THz), or sub-millimeter/millimeter waves, detector using Si-MOSFET CMOS devices and evaluating the devices for possible astrophysical applications. The devices are designed locally and fabricated using the MOSIS facility. The terahertz project is a collaboration between RIT, the University of Rochester, and Harris Corporation. Katherine has tested the individual pixels that have varied designs to characterize the devices and determine efficiency of designs so that they can be implemented into future large focal plane arrays for a variety of applications. She created a custom low noise setup to test the devices. The pixel characterization includes measuring the pixel-to-pixel frequency response, calculating responsivity, NEP, et cetera. In addition to pixel characterization, she has been fitting theoretical curves to the responses of the devices to attempt to better understand the underlying detection mechanism and optimize the devices. She has also tested a prototype 10x10 pixel array for imaging purposes and created a demonstration of an imaging system (Figure 33). The optimization of the single pixel designs would then be integrated into this chip in a future generation.

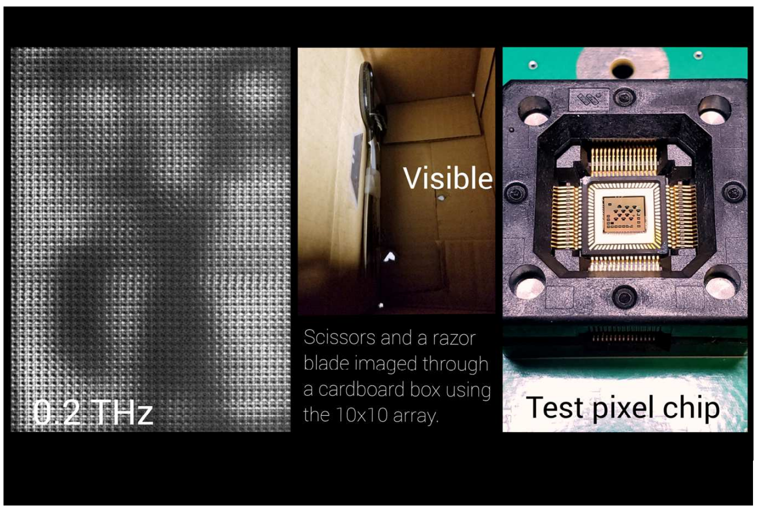


Figure 33. (left): A 0.2 THz mosaic image of the scissor and razor blade enclosed in a box as imaged by the 10x10 pixel array is shown. The pattern visible is due to variations of pixel response and will be accounted for using the power relation found from work with single pixel testing. (middle): You can see a visible image of the inside of the box. (right): Pictured here is a close up of one of the single pixel chips with varied designs.

Teresa Symons

Teresa Symons is a second-year graduate student pursuing her PhD in the Astrophysical Sciences and Technology program. She previously received her MS in Computational Physics and Astronomy from the University of Kansas and her BS in Space Physics from Embry-Riddle Aeronautical University. Over the past year, she has contributed to the point spread function (PSF) estimation component of the data analysis pipeline for the upcoming NASA medium explorer mission SPHEREx. She is also analyzing images taken by the New Horizons spacecraft to measure the cosmic optical background (COB), which is the faint background of light from all sources outside the Milky Way in optical wavelengths. Measuring the COB allows for a comparison with all expected sources of emission such as stars and galaxies, and potential identification of the source of any excess component of diffuse emission. In January of 2019, Teresa traveled to Kitt Peak National Observatory in Arizona to take companion images of New Horizons fields using the WIYN 0.9-meter telescope (Figure 34). She will use those images to better estimate the amount of residual starlight in the New Horizons images.

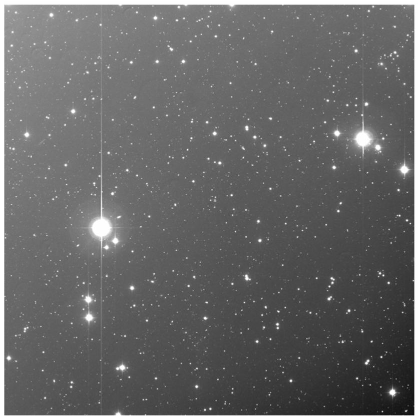


Figure 34. (left) Symons is standing in front of the building that houses the WIYN 0.9-meter telescope at Kitt Peak. (right) Symons used the WIYN 0.9-meter telescope to capture this companion image.

Adam Taylor

Adam Taylor is an undergraduate engineering student working toward completing a BS and MS in Electrical Engineering. Prior to working at CfD, he worked as a Hardware Test intern at Mastodon Design, and worked as a Digital Design intern at Texas Instruments immediately following his time at CfD.

While working at CfD, he was involved in the development of a photonics evaluation kit (PEK) for use in the validation of the engineering verification test (EVT) system. The PEK emulates a photonic integrated circuit (PIC) and is used to validate the interface between the EVT and any potential PIC under test. His contributions to the EVT project comprised of work on the quad small form-factor pluggable (QSFP) PEK. He wrote all of the initial code for the mixed signal processor (MSP) which sits at the heart of and controls the QSFP PEK. He was involved in the design process of the second version of that board. The microcontroller code will later be extended to the C form-factor pluggable (CFP) PEK. As the project proceeds, work will continue on the MSP code to fully control and integrate all of the hardware on the QSFP PEK in order to validate the EVT station interface for real photonic circuits.

Matthew van Niekerk

Matthew is a first-year PhD student pursuing his degree in Microsystems Engineering in the RIT Integrated Photonics Group with advisor Dr. Stefan Preble.

He received his BS degrees in Physics and Mathematics from Roberts Wesleyan College (Rochester, NY) in 2017.

His research has begun to focus on designing integrated photonic neural networks on-chip. The first chips recently arrived and his next step is to begin testing the different ideas.

The ultimate goal of the project is to assess different architectures and their suitability for neural network performance, implementing algorithms with high bandwidth and low power.

Additionally, he has been working with the CfD on packaging efforts to increase the throughput of the integrated photonic circuits (Figure 35). When not doing research, he spends time with his wife Shannon, and their dog Ernest.

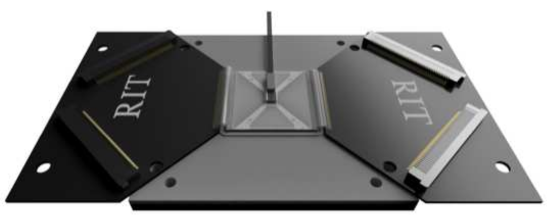


Figure 35. Shown above is a CAD rendered image of the prototype packaging solution currently in development, allowing for optical and electrical interconnects in a confined space. The PIC chip is bonded to an interposer (fabricated in the RIT SMFL) and then routed to two PCB boards; a fiber array provides the optical interconnect.

Isaac Witlin

During his senior year at RIT, Isaac Witlin worked as an Undergraduate Research Assistant for Dr. Michael Zemcov at the CfD. Isaac was hired to support the continued development of electrical systems for the CSTARS (Cryogenic Star Tracking Attitude Regulation System) experiments, shown in Figure 36 (right). These were devices meant to utilize sCMOS image technology to track the displacement of stars in the sky at cryogenic temperatures. His primary goal was to successfully develop and handshake CSTARS2 communication streams with the Black Brant XII sounding rocket Telemetry Encoder and Attitude Control System. In addition to accomplishing this, Isaac supported all the remaining electrical engineering tasks required for the CSTARS1 and CSTARS2 experiments, which included; validation of image data pipelines, creation of flight ready software, construction of specialized testing equipment, publications, and real time data analysis (Figure 36, left).

Isaac graduated with his BS in Electrical Engineering in spring 2019 and is moving on to become a Research and Development Engineer at the Pennsylvania State University's Applied Research Lab.

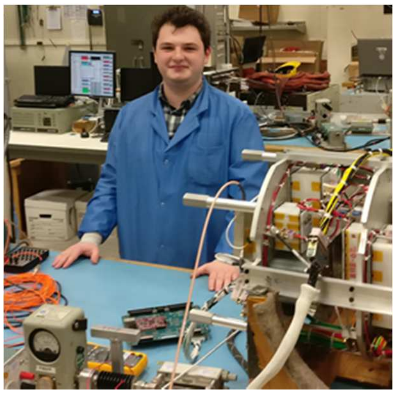


Figure 36. (left) Isaac Witlin sets up equipment at the Wallops Flight Facility in Wallops Island, VA. (right) Witlin used the CSTARS1 dolly to perform real time testing of flight ready software for CSTARS experiments.

External Funding

NSF, NASA, United States Air Force, and several other institutions provided CfD over $2.5M for projects this past fiscal year. Figure 37 illustrates the estimated funding provided to CfD per year since the inception of the Rochester Imaging Detector Laboratory (RIDL) in 2006, and continuing through the establishment of the CfD. The following pages show a breakdown of current grants and contracts.

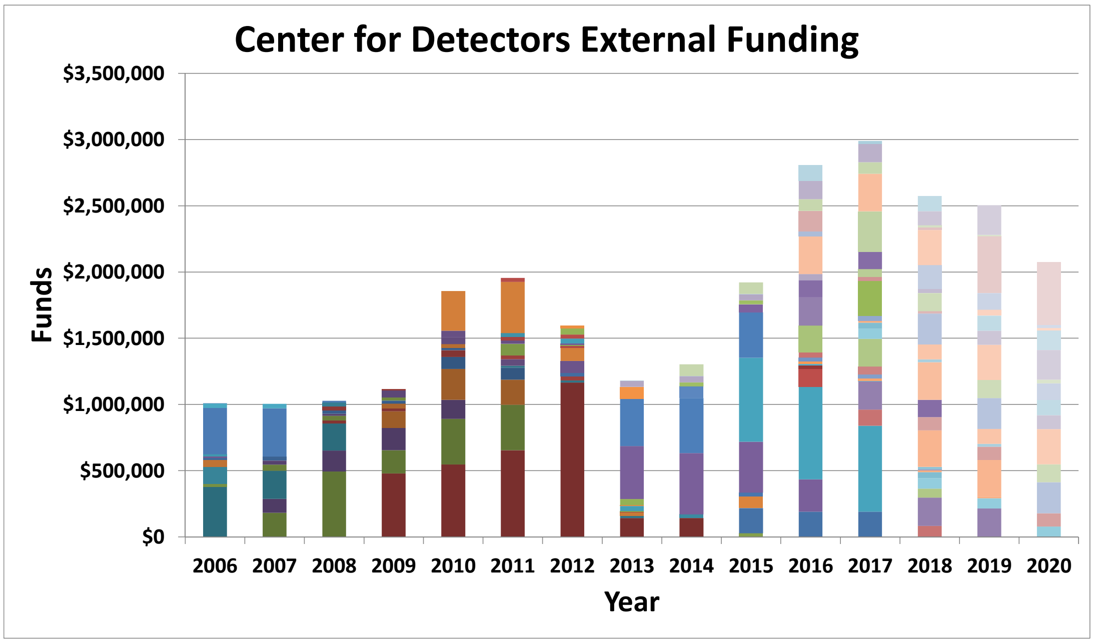


Figure 37. This chart shows historical and anticipated funding levels for CfD projects. Each color in the chart represents a unique research program and budget. Most projects have budgets that span multiple years. Federal agencies, national labs, and research foundations awarded CfD a total of $27M in research funding since the inception of the RIDL in 2006. NASA, NSF, United States Air Force, NYSTAR, and the Moore Foundation provided the most funding.

Grants and Contracts - New

Title	Funding Source	Dates	Amount
AIM Academy Photonic Integrated Circuit Design and Test Education Curricula	USAF/SUNYRF	1/1/2018-9/30/2019	$122,012
Air Force STTR Phase II AF16-AT01: Wafer-Level Electronic-Photonic Co-Packaging	USAF/Phase Sensitive Innovations Inc.	9/6/2018-8/31/2020	$250,257
Development of Quantum Dot Coated Detector Arrays	NYSDED/UR	7/1/2018-6/30/2019	$18,000
Development of Quantum Dot Coated Detector Arrays	ThemoFisher	7/1/2018-6/30/2019	$18,000
PIC: Hybrid Silicon Electronic-Photonic Integrated Neuromorphic Networks	NSF	9/1/2018-8/31/2021	$422,733
Precision - RIT Fiber Attach	Precision Optical Transceivers	1/15/2019-8/31/2019	$45,000

Title	Funding Source	Dates	Amount
Studies of the Diffuse Optical Background with New Horizons	NASA	9/4/2018-9/3/2021	$456,002
TAP Process Development 2019 (Rochester Hub)	USAF/SUNYRF	1/1/2019-12/31/2019	$1,635,999
Diagnosing, Addressing, and Forecasting CIB Contamination in Spectral Measurements of the Sunyaev Zel'dovich Effect	NASA	5/13/2019-5/12/2020	$445,481
		Total	$3,413,484

Grants and Contracts - Ongoing

Title	Funding Source	Dates	Amount
A Cryogenic Optical Camera for Attitude Control of Low-Temperature Sub-Orbital Payloads	NASA	5/9/2016-5/8/2019	$199,534
CAREER: Development of High Efficiency Ultraviolet Optoelectronics: Physics and Novel Device Concepts	NSF	3/15/2018-2/28/2023	$500,145
Collaborative Research: SOAR/SAM Multi Object Spectrograph (SAMOS)	NSF/JHU	9/1/2016-8/31/2019	$66,930
Concept Study Report Preparation for SPHEREx MIDEX Phase A	NASA/FFRDC-JPL	2/15/2018-9/30/2018	$33,035
Cosmic Dawn Intensity Mapper	NASA/UCI	4/17/2017-8/31/2018	$39,143
Developing the THz detector technology for inspection applications	HarrisRF/UR	7/1/2017-8/31/2018	$60,000
Development of Digital Micromirror Devices for Far-UV Applications	NASA	1/1/2018-12/31/2019	$536,981
DURIP - Equipment for Silicon Photonics Research	USAF	11/1/2017-10/31/2018	$178,236
EAGER: TDM solar cells: Bifacial III-V nanowire array on Si tandem junctions solar cells	NSF	5/1/2017-4/30/2020	$299,808
Future Leaders in Integrated Photonics (FLIP)	USAF/SUNYRF	1/1/2018-12/31/2018	$17,480
Integrated Quantum Photonics for Photon-Ion Entanglement	USAF	3/14/2016-9/30/2019	$1,100,000
Measuring the Pixel Response Function of Kepler CCDs to Improve the Kepler Database.	NASA	2/17/2016-2/16/2019	$246,920
Multi-Color Anisotropy Measurements of Cosmic Near-Infrared Extragalactic Background Light with CIBER-2	NASA/CALTECH	5/2/2016-5/1/2021	$186,536
Phase II: New Infrared Detectors for Astrophysics	NSF	9/15/2015-8/31/2019	$1,983,212

Title	Funding Source	Dates	Amount
Probing the History of Structure Formation through Intensity Mapping of the Near-Infrared Extragalactic Background Light	NASA	9/20/2017-9/19/2019	$80,880
Quantum optical resonators: a building block for quantum computing and sensing systems	NSF	8/1/2014-7/31/2018	$349,789
TAP Process Development 2017 (Rochester Hub)	USAF/SUNYRF	1/1/2017-3/31/2019	$262,573
TAP Process Development 2018 (Rochester Hub)	USAF/SUNYRF	1/1/2018-5/31/2019	$498,489
Understanding and Engineering Valence Band Structures of III-Nitride Semiconductors for High-Efficiency Ultraviolet Lasers and Emitters	ONR	6/1/2016-5/31/2020	$325,100
		Total	$6,765,257

Grants and Contracts - Completed within the Past Year

Title	Funding Source	Dates	Amount
Development of Quantum Dot Coated Detector Arrays	NYSDED/UR	7/1/2017-6/30/2018	$9,000
Development of Quantum Dot Coated Detector Arrays	ThemoFisher	7/1/2017-6/30/2018	$18,000
Developing the THz detector technology for inspection applications	NYSDED/UR	7/1/2017-6/30/2018	$30,000
The Development of Digital Micromirror Devices for use in Space	NASA	5/19/2014-5/18/2018	$565,275
Quantum Silicon Photonics Measurement System	USAF	9/15/2016-9/14/2017	$276,475
MRI: Acquisition of an Inductively Coupled Plasma ReactiveIon Etching System for Research and Education in Nanophotonics, Nanoelectronics and Nano Bio Devices	NSF	9/1/2016-8/31/2017	$305,000
OVPR (GWBC 2016) - Selective Area Epitaxy of III-V Nanocrystals on Graphene and MoS2 for Flexible Optoelectronics Application	RIT	5/1/2016-8/31/2017	$5,000
OVPR (GWBC 2016) - A Data Analysis Pipeline Simulator for a Millimeter-Wavelength Imaging Spectrometer	RIT	5/1/2016-8/31/2017	$5,000
Air Force STTR Phase 1 AF16-AT01: Wafer-Level Electronic-Photonic Co-Packaging	USAF/Phase Sensitive Innovations Inc.	11/15/2016-8/14/2017	$49,030
		Total	$1,262,780

Collaborating Partners

The CfD collaborates extensively with a broad range of organizations, including other academic institutions, government agencies, and industry leaders. Some examples are, Caltech, Cornell University, University of Rochester, NASA, NSF, Thermo Fisher Scientific, Raytheon Vision Systems, Gigajot Technology, and Precision Optical Transceivers.

Because of our collaborative approach, and the centrality of student involvement in all of our projects, CfD students benefit from exposure to a wide range of research and development environments. This is consistent with another major goal of the CfD to train students through deeply immersive work with authentic externally funded research that defines the cutting edge of what is possible. Some students have the opportunity to visit partner organizations for extended periods. This training and preparation in the CfD helps students launch their careers after graduation.

Universities			
University of Rochester	Columbia University	SUNY Polytechnic Institute	Caltech
Cornell University	University of Toronto	UCIrvine University of California	Dartmouth
Illinois University of Illinois at Urbana-Champaign	MIT	Johns Hopkins University	Leland Stanford Junior University 1891
University of California Santa Barbara	UB	University of Hawaii Institute for Astronomy	USRA
Laboratories, Federal Agencies, and Foundations			
NOAO	NASA	NSF	JPL
AFRL The Air Force Research Laboratory Lead | Discover | Develop | Deliver	Sandia National Laboratories	Department of Energy United States of America	Berkeley Lab
MIT Lincoln Laboratory	Gordon and Betty Moore Foundation	Office of Naval Research ONR Science & Technology	Space Telescope Science Institute
Industry			
Precision Optical Transceivers	Raytheon	AIM photonics	Thermo Scientific
Teledyne Scientific & Imaging, LLC A Teledyne Technologies Company	Toptica Photonics	gigajot Where every photon counts	ON Semiconductor
Ball	Harris	New York Photonics Rochester	Xanadu

Communication

Communication and Media

In the News

NSF Awards $1.2M to AIM Photonics' Partner Institutions

Published August 15, 2018
Photonics Media

The American Institute for Manufacturing Integrated Photonics (AIM Photonics), a public-private partnership headquartered in New York state to advance the nation's photonics manufacturing capabilities, has announced that three National Science Foundation (NSF)-funded grants totaling $1.2 million will enable collaborative photonics-centered R&D with the Rochester Institute of Technology (RIT), University of California, San Diego (UCSD), and University of Delaware (UD).

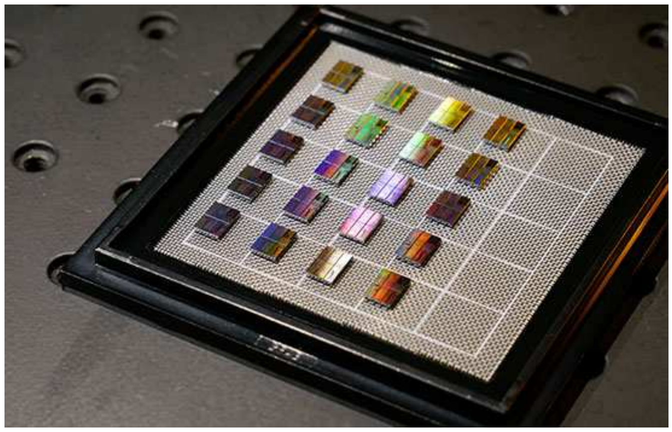


Figure 38. The image above shows photonic chips designed by Stefan Preble's Integrated Photonics Group and AIM Photonics partners.

"AIM Photonics is thrilled to work with leading academic institutions including RIT, UCSD, and UD on these three separate, NSF-funded projects to collaboratively enable photonics-focused devices and capabilities that can allow for the more efficient identification of materials, as well as enhanced processes for manufacturing complex photonic devices and next-generation computing capabilities," said Michael Liehr, CEO of AIM Photonics.

The NSF awarded RIT $423,000 as part of the research project titled "PIC: Hybrid Silicon Electronic-Photonic Integrated Neuromorphic Networks." The project will focus on realizing high-performance neural networks that will be integrated onto photonic chips for scalable and efficient architectures that, in tandem with integrated electronics, overcome challenges related to photonic memory and amplification. Applications include offering a hybrid, high-bandwidth computing approach in autonomous systems, information networks, cybersecurity, and robotics.

RIT will work with AIM Photonics to use its leading-edge PIC toolset, located at SUNY Polytechnic Institute in Albany, N.Y., and the AIM Photonics TAP facility in Rochester, N.Y. — the world's first 300-mm open access PIC test, assembly, and packaging (TAP) facility. The project will take place within RIT's Future Photon Initiative (FPI) and Center for Human-Aware AI (CHAI).

The NSF awarded UCSD $405,000 for research titled "PIC: Mobile in Situ Fourier Transform Spectrometer on a Chip," which will enable UCSD to rapidly prototype and test miniaturized and mobile platform-embedded optical spectrometers that will excel at chemical identification.

The initial design, fabrication, and validation of such a spectrometer on a Si chip have been recently reported in Nature Communications (9: 665 [2018]). This effort will continue and culminate with full-scale manufacturing runs at AIM Photonics' foundry at the Albany Nanotech Complex. The integrated chip-scale Fourier transform spectrometer is to be fully CMOS compatible for use in mobile phones and other mobile platforms, with potential impacts in areas ranging from environmental management, medicine, and security.

The NSF awarded UD $360,000 as part of the research project "PIC: Hybrid Integration of Electro-Optic and Semiconductor Photonic Devices and Circuits with the AIM Photonics Institute." The award will allow UD to work with AIM Photonics to leverage the initiative's expertise and state-of-the-art foundry for the development of new heterogeneous manufacturing processes for photonic devices, using new materials such as lithium niobate (LiNbO3), which can then be directly integrated with silicon CMOS systems for photonic devices and chip-scale systems.

The UD project aims to realize high-performance RF-photonic devices such as ultrahigh-frequency modulators (>100 GHz) that are used in data networks, high-efficiency chip-scale routers for advanced data centers, and high-power phased array antenna photonic feed networks that are compatible with older and next-generation wireless communications.

AIM Photonics features research, development, and commercialization nodes in Albany at SUNY Polytechnic Institute, and in Rochester, where state-of-the-art equipment and tools are being installed at AIM Photonics' TAP facility.

The initiative also includes an outreach and referral network with the University of Rochester; Rochester Institute of Technology; Columbia University; Massachusetts Institute of Technology; the University of California, Santa Barbara; the University of Arizona; and New York state community colleges. In total, AIM Photonics includes more than 100 signed members, partners, and additional interested collaborators.

RIT researchers help conduct experiment to study how the first stars and galaxies formed

Published April 23, 2019
By Luke Auburn, RIT University News

TIME aims to detect low-energy infrared waves from the material that formed the first stars

While many people flock to warm destinations for spring break, two Rochester Institute of Technology experimental cosmologists spent theirs 6,800 feet high on snow-covered Kitt Peak at the Arizona Radio Observatory. They were deploying an instrument to a 12-meter telescope for a project called the Tomographic Ionized-carbon Mapping Experiment (TIME), which aims to study the universe's first stars and galaxies.

The experiment uses a technique called intensity mapping to detect very low energy light waves from dust and gas in the early universe. The goal is to answer fundamental questions about the universe: how and when did the first stars and galaxies in the universe form? What were these first stars made out of? How much energy did they release?

"We have a good understanding of the properties of galaxies up to about 10 billion years ago," said Victoria Butler, an astrophysical sciences and technology Ph.D. student from Jefferson, Maine, who has been working on TIME for the past two years. "After that time, and for a narrow window in the history of the universe, they are much harder to see with other instruments. TIME is able to look at the gas and dust within these galaxies, allowing us to see what was fueling star formation, how much of it was there, where it was located, and how it transformed through that time period."

Butler has been working on implementing software designed to control the instrument under the guidance of Assistant Professor of Physics Michael Zemcov, who has been a TIME co-investigator since 2014. Parts of the instrument were designed and built at RIT's Center for Detectors by a group of senior RIT engineering students as part of their final project in collaboration with Ryan Kavanagh, a first-year physics student from Fairport, N.Y.

Figure 39. Michael Zemcov, left, and Victoria Butler, right, recently deployed an instrument at the Arizona Radio Observatory on Kitt Peak to help with the TIME experiment.

Butler spent 10 weeks on Kitt Peak testing to see how well TIME's detectors could see Mars, Venus and Jupiter during an engineering run. Since the planets are relatively bright, they make it easy to see how well focused the telescope and instrument optics are, whether or not they are centered within the image and which of the almost 2,000 detectors were able to see them. The detectors used by TIME are bolometers cooled to almost -460 degrees Fahrenheit. These extreme temperatures make the detectors more sensitive to small changes in energy caused by the collected photons.

The engineering run was a success despite challenges caused by snowstorms that caused officials to evacuate the mountain and downed powerlines. Zemcov, who joined Butler on Kitt Peak for a week in March, remarked how the mundane aspects of life can be the biggest obstacles to advanced science. "It's funny to think we're trying to detect photons from the other side of the universe and what is really limiting us is the bad weather, the fact people have to stay in cabins on top of the mountain, and getting power to the telescope," he said.

TIME is now returning to its lab back at Caltech where improved detectors are being developed for the first observation run in the winter of 2019. In the meantime, the researchers will analyze data collected from this run to determine noise properties of the instrument and telescope that would make it harder to see the science objects we are looking for.

Ask Astro: What is the maximum theoretical size of any star before it violates the laws of physics?

Published June 27, 2018
By James Boyton, Astronomy Magazine

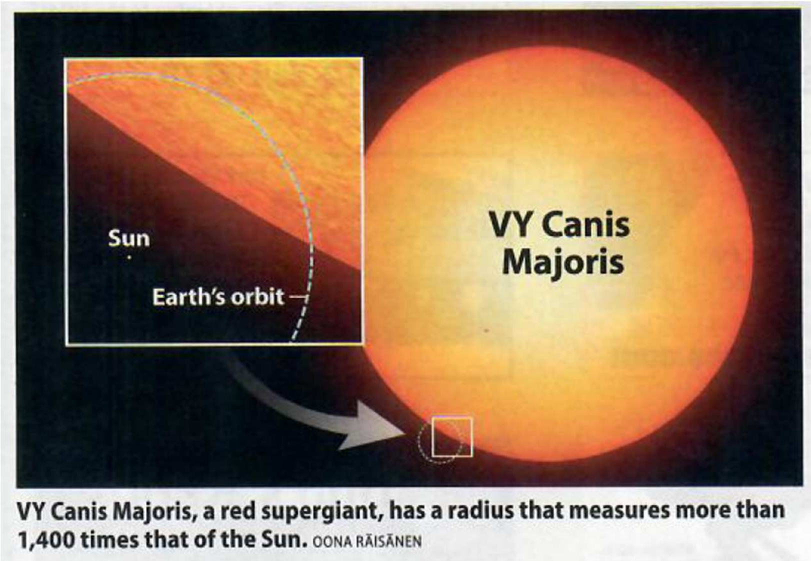


Figure 40. VY Canis Majoris, a red supergiant, has a radius that measures more than 1,400 times that of the Sun. Image: Oona Räisänen

The size of a star is a natural consequence of the balance between the inward pull of gravity and the outward pressure of radiation produced inside the star. When these two forces are balanced, the outer layers of the star are stable and said to be in hydrostatic equilibrium. In general, both the gravitational force and the energy generation rate are determined by the mass of a star. During most of their lives, stars burn hydrogen in their cores, and their structures are almost completely determined by their masses. Later in their lifetimes, energy is generated in a shell surrounding their cores, and the outer layers expand, such as in the red supergiant (for higher-mass stars) and red giant (for lower-mass stars) phases.

Although stars do not have surfaces, the most common definition for the outer boundary of a star is the photosphere, or the location where light leaves the star. The biggest stars are red supergiants, and the biggest has a radius that is approximately 1,800 times the radius of the Sun (432,300 miles [695,70 km]). The reason for this maximum observed size not well understood.

One might guess that a more massive star would grow to be bigger in its red supergiant phase, but more massive stars do not evolve through a red supergiant phase, and they consequently do not grow as large. Perhaps one could imagine a star with arbitrarily large mass and thus arbitrarily large size, but no stars have been found with masses beyond approximately 200 to 300 solar masses — even at that mass, they are smaller than the biggest red supergiants. One of the largest known stars is the red supergiant VY Canis Majoris, which would envelop Jupiter if it were placed at the Sun's location.

Donald Figer

Director of Center for Detectors and Professor of Imaging Science

Rochester Institute of Technology , Rochester, New York

RIT faculty part of NASA’s $242M SPHEREx mission

Published February 13, 2019
By Luke Auburn, RIT University News

Michael Zemcov on the team that will explore the origins of the universe, galaxies and water in planetary systems

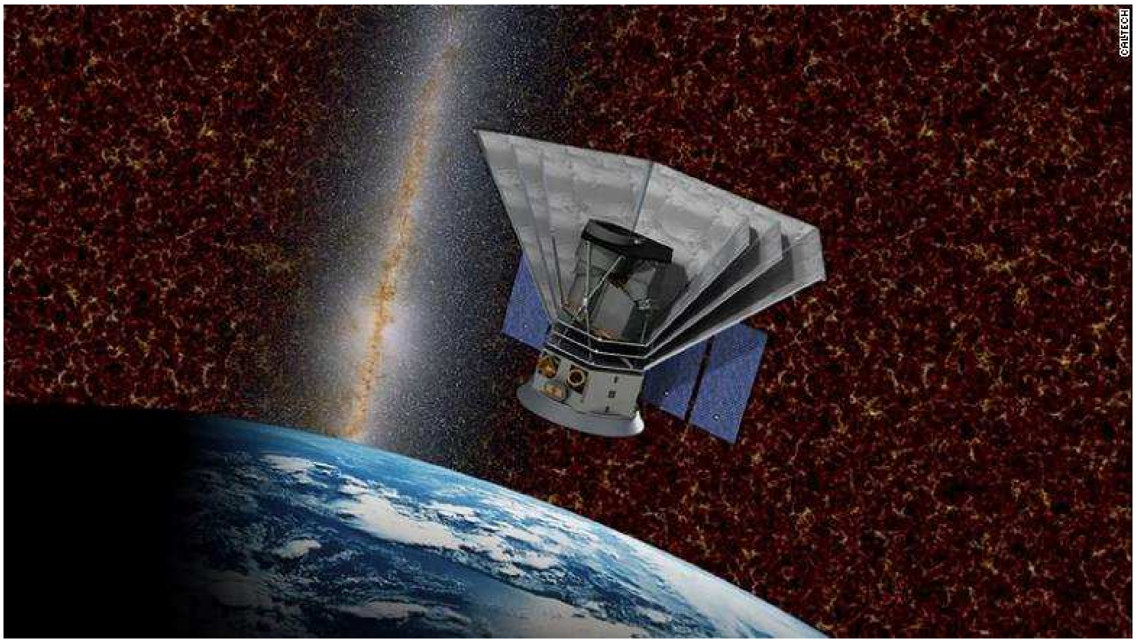


Figure 41. NASA’s Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx) mission is targeted to launch in 2023. SPHEREx will help astronomers understand both how our universe evolved and how common are the ingredients for life in our galaxy’s planetary systems. The image above is a recent graphic of SPHEREx.

A Rochester Institute of Technology professor is part of a small team of scientists contributing to NASA’s new mission to explore the origins of the universe by performing the first near-infrared all-sky spectral survey.

Assistant Professor Michael Zemcov is one of 19 co-investigators of the Spectro-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer (SPHEREx) mission, which received $242 million in funding from NASA today.

SPHEREx has three primary objectives. First, SPHEREx will map galaxies across much of the universe to study inflation, the rapid expansion thought to play a part in the universe’s creation. The mission also seeks to gain new insights into the origin and history of galaxy formation by measuring spatial fluctuations in the extragalactic background light. Third, SPHEREx aims to answer questions about the amount and evolution of key biogenic molecules such as water and carbon monoxide throughout all phases of star and planetary formation.

“I’m very excited by the opportunity to help explain if and how inflation happened, and to understand more about it,” said Zemcov. “There are hundreds of models for inflation right now and they all describe different scenarios that may have happened. Being able to constrain what actually happened would teach us new things about the fundamental physics of the early universe that we have no access to otherwise. For me that's really exciting because I don't see a better way to get at it right now. It's really unique."

Zemcov's primary role in the mission is to help design the instrument and prepare the data pipeline for when the SPHEREx spacecraft begins making observations. SPHEREx will produce a flood of data, so Zemcov will help make sure the data can be processed in a coherent and effective way. Zemcov developed familiarity with the hardware being used for SPHEREx while he was a postdoctoral researcher at Caltech working with principal investigator Professor James Bock. While he's excited about the mission's primary objectives, he thinks the data it will produce will be applied in ways we can't yet imagine.

"SPHEREx is so comprehensive," said Zemcov. "It's looking at the whole sky and very accurate in ways that are difficult to replicate from the ground. And it's a data set that everyone will use. We have these three detailed science cases we're very interested in, but we're going to make the data public as quickly as we can so that people can do whatever they want with it. We have had workshops devoted to people coming and saying what type of things they would do with such a data set, and for a lot of astrophysicists it will be transformational."

NASA Administrator Jim Bridenstine said, "I'm really excited about this new mission. Not only does it expand the United States' powerful fleet of space-based missions dedicated to uncovering the mysteries of the universe, it is a critical part of a balanced science program that includes missions of various sizes."

The SPHEREx spacecraft is expected to launch in 2023, and the SPHEREx team of scientists will now begin creating detailed designs for the spacecraft. Caltech and Jet Propulsion Laboratory will develop the SPHEREx payload. Caltech manages JPL for NASA. The spacecraft will be supplied by Ball Aerospace. The Korea Astronomy and Space Science Institute will contribute the non-flight cryogenic test chamber. The data will be made publicly available through IPAC. In addition to the Caltech/JPL and international scientists, the SPHEREx team includes scientists at institutions across the country, including UC Irvine, Ohio State University, the Harvard-Smithsonian Center for Astrophysics, Arizona State University, the University of Arizona, Rochester Institute of Technology, Argonne National Laboratory, and Johns Hopkins University.

For more information about the mission, go to https://www.nasa.gov/press-release/nasa-selects-new-mission-to-explore-origins-of-universe.

RIT contributes to success of photonics initiative

Published August 6, 2018
By Susan Gawlowicz, RIT University News

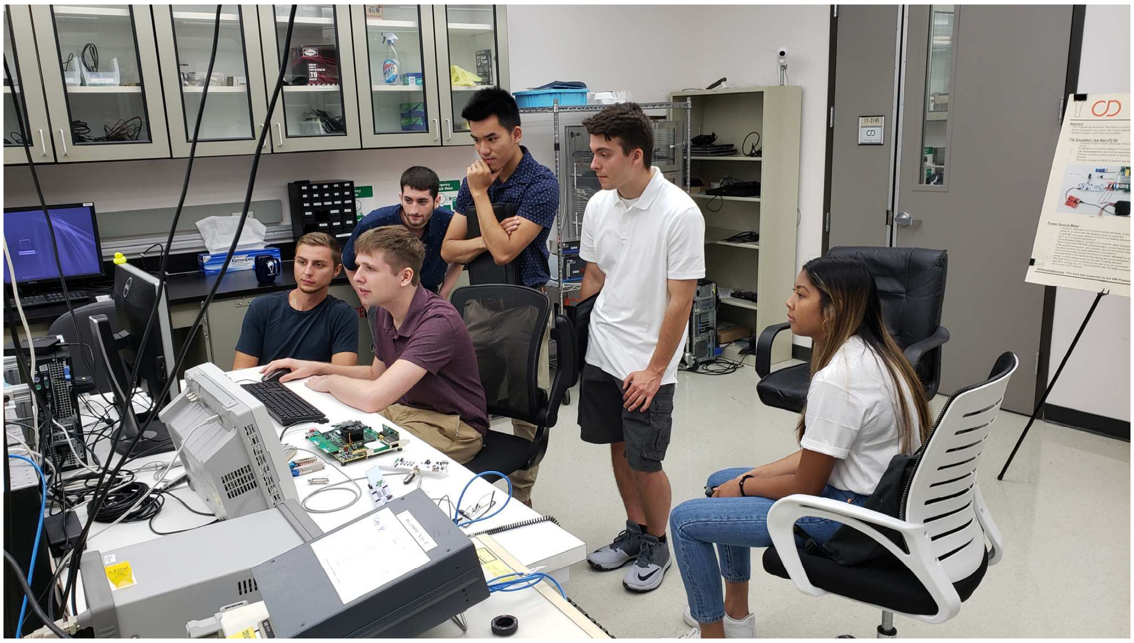


Figure 42. In the photo above, current CfD Co-op students show new students the software and hardware used in the Engineering Verification Test system project for AIM Photonics..

RIT's Future Photon Initiative is developing a system of quality-control protocols for a national photonics manufacturing hub located in Rochester.

The system will test and validate photonics devices produced at the American Institute for Manufacturing (AIM) Integrated Photonics facility. RIT, a Tier 1 Academic Member of AIM Photonics, is building software and hardware to interface with technology in development at Columbia University and at Precision Optical Transceivers Inc.

The Future Photon Initiative, an RIT signature research area led by Don Figer, will deliver the operational system to the AIM testing and packaging (TAP) facility in 2019.

Advanced photonics seeks to tap the speed and energy of photons, or light. The emerging technology could have wide-sweeping influence in potential markets including solar energy, biophotonics, high performance imaging, astrophysics, communications and electronics and computing. The industry's success is tied to developing scaled-up manufacturing processes that can mass produce functional photonic devices.

The AIM consortium is building the infrastructure and inventing the photonics products. It is building the photonics industry from the ground up.

"The tests don't exist yet. The devices don't exist yet. The software to design the devices doesn't exist," said Figer, whose team is developing the test station. "All these tools are in bits and pieces of the photonic ecosystem that we're building. It's the whole collaboration—AIM Photonics. One of the little pieces is the testing and verification."

Figer has experience designing tests for emerging technology. He tested imaging sensor technology for the James Webb Space Telescope and created the testing plan for infrared detectors on the Hubble Space Telescope. He is currently the co-chair of the detectors technology working group and a member of the High Definition Imager instrument team for NASA's future Large UV/Optical/IR Surveyor.

RIT has received multiple grants from AIM Photonics since 2015 for research projects in integrated photonics (circuit-sandwiches of new optical devices and traditional semi-conductors) and workforce education.

The majority of the funding supports research conducted by Stefan Preble, director of the RIT Integrated Photonics Group and professor of microsystems engineering in Kate Gleason College of Engineering. Preble coordinates AIM Photonics research projects at RIT.

Preble was instrumental in establishing a connection between RIT and Precision OT, a Rochester-based company that develops technology used in optical communication systems.

Precision OT's chief technology officer is Bryce Tennant '97 (electrical engineering), '04 (electrical engineering), a Ph.D. student researcher in microsystems engineering.

Precision OT is a member of the Future Photon Initiative's Industrial Partnership Program and occupies office space on the RIT campus for ease in collaboration. Equipment Precision OT purchased is used for research with RIT faculty and students.

"Precision's strategic partnership with the Future Photon Initiative has provided for a fruitful relationship between our company and the university," Tennant said. "Through the FPI we have been able to effectively build relationships with RIT, sponsor working projects with both faculty and students, and recruit new talent for our business."

Precision OT is working in tandem with Figer's research group to develop the integrated photonic reference design and programmable integrated circuits that will enhance the testing system's performance and efficiency.

"The Rochester TAP testing/verification project that Don's team is running at the Future Photon Initiative is a highly complex integrated system involving many intricate systems coordinating together to validate a multitude of integrated photonic devices," Tennant said. "The Future Photon Initiative's involvement with the software development and maintenance for the Rochester hub provides a critical component of the TAP's functionality."

About AIM Photonics

The American Institute for Manufacturing Integrated Photonics is part of the federal government's Manufacturing USA initiative. Created in July 2015, it is run by a consortium of 90 university, government and corporate partners, led by SUNY Polytechnic, RIT, University of Rochester and Massachusetts Institute of Technology.

A conversation on Photonics for Quantum

January 21, 2019
By Luke Auburn, RIT University News

Figure 43. Pictured above is Don Figer, Photonics for Quantum Workshop organizer and director of RIT's Future Photon Initiative, one of the university's signature research areas.

Recent advances in quantum science have leapfrogged existing capabilities in handling complex computational problems, providing communication security, and in enhancing navigation, imaging and other sensing technologies. Scientists and engineers from across the country will travel to RIT for the Photonics for Quantum Workshop Jan. 23-25 to discuss quantum technology development in five main applications—computing, communication, imaging, sensing and clocks.

Two of the conference's organizers, Don Figer, director of RIT's Future Photon Initiative, and Gregory Howland, a postdoctoral research fellow at RIT, answered questions about quantum science, photonics and where these two fields intersect.

Question: What is quantum physics in a nutshell?

Answer: Quantum physics is the field that seeks to understand the rules and effects of manipulating the smallest amount of energy at the subatomic level. Different rules govern matter at this scale, and scientists are attempting to harness the strange, unintuitive properties. Understanding quantum phenomena led to revolutionary technologies including semiconductor microelectronics, lasers, MRI machines, LEDs and CCD cameras. In the past few years, technical advances have triggered a new "Quantum 2.0" revolution that promises to change the world in a similar way.

Q: What is photonics?

A: Photonics describes the use of photons (light) in circuits, instead of using electrons, which are used in electronics. Light can carry energy—for example, for laser cutting and welding—or light can carry information—for example in the fiber optic networks that form the backbone of our telecommunications infrastructure. Many potential quantum 2.0 technologies are photon-based, including ultra-secure communication and networking, precision environmental sensing and ultra-low-light imaging. Quantum photonics leverages existing photonic technology and infrastructure, including lasers, optics, fiber-optics, integrated photonic circuits and advanced detectors.

Q: Why did you organize the Quantum for Photonics Workshop? What is the goal of the conference?

A: We organized the Quantum for Photonics Workshop in order to learn from others and share our ideas concerning the status, and potential, of photonics for quantum science and technology.

Q: How might quantum science and technology shape the future?

A: Quantum science and technologies are on the verge of enabling a variety of transformational technologies. Quantum clocks can remove reliance on GPS for navigation. Ultra-sensitive quantum cameras can see in the dark and around corners. Quantum sensors can monitor gas emissions for improved health and safety. Quantum-encrypted communications can be made unconditionally secure. Quantum simulators can model complex molecular interactions, leading to breakthroughs in medicine and energy. The ultimate goal is the Universal Quantum Computer, a device that can do some calculations intractable for today's computers. Quantum technologies will impact sectors including telecom, defense, medicine, information technology, finance and energy—many with near-term commercial prospects.

Q: What is the National Quantum Initiative Act?

A: The NQIA was a bipartisan act passed by Congress and signed by President Trump. It establishes a national strategic plan to coordinate the development of quantum technologies in the United States and provides $1.2 billion in funding for quantum technology research over five years. Similar large-scale initiatives and investments are underway in the United Kingdom, European Union and China. The NQIA will create new multidisciplinary research centers aimed at transitioning quantum technologies form laboratory experiment to deployable technologies. These centers and their partners will train the future quantum workforce

Q: What does it have to do with RIT?

A: Quantum technologies are transitioning from academic laboratories to applied technologies. RIT, with its expertise in advanced fabrication and packaging, strong multidisciplinary emphasis, and exceptional faculty and students, is well-positioned to help effect this change. There is also an increasing demand for programs and curricula to train a new quantum workforce. RIT has the resources and personnel to lead in this important area.

Handsworth grad examines inner workings of outer space with NASA project

Published May 22, 2019
By Jeremy Shepherd, North Shore News

Figure 44. (left) Michael Zemcov works on a four-stage, instrument-carrying rocket for NASA. Zemcov is currently working on an effort to map the cosmos in unprecedented detail.

Michael Zemcov is thinking about inflation and the pipeline – but his ruminations don't have a thing to do with money or oil.

In 2023, NASA is set to shine its high beams into the cosmos. The space agency's two-year, $242-million mission has a goal of surveying 300 million galaxies and drawing a map of the sky in 96 different colour bands, essentially bringing the world's biggest box of crayons to an indescribably awesome canvas. The mission is called the Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer, or SPHEREx.

But before we can see those Universal pictures in hi-def, streams of galactic data will flow back to Earth. And there, an enthusiastic Handsworth grad will be waiting.

For Zemcov, the fact finding mission began when he was a kid poring over accounts of Tang and the Milky Way in National Geographic.

"I was very interested in space as a little boy," he says.

As a student he was lazy and prone to daydreams, he recalls. Both his parents were microbiologists, which inspired his own form of youthful, scientific rebellion.

"I had this idea in my head that I would do anything that wasn't microbiology," he laughs.

Zemcov currently works as a professor at the Rochester Institute of Technology in New York. And while Handsworth is nearly 4,500 kilometres away, the school was an essential part of his journey.

As a teen Zemcov had an aptitude for science and math as well as an innate fascination with the mysteries of the universe.

"I really just followed things that were interesting and I asked questions I found interesting to pursue," he offers. While the material is complex, his rationale is disarmingly simple: "I can teach you physics but I can't teach you enthusiasm."

Mentored by UBC experimental cosmology professor Mark Halpern, Zemcov found a place for his passion in the riddles of the stars and the light between them.

"It's come out that the universe we live in is really weird," he says. "What is dark matter? Why is there so much of it?"

Fundamental physics offered ideas but not answers, Zemcov says. But SPHEREx might.

Every six months, the spacecraft will survey the entire sky. The technology is adapted from Earth satellites and Mars spacecraft but functionally it's a bit like training your cellphone camera on the scenery outside your car window. And instead of blurring or an extreme close-up of the careless photographer's thumb, the SPHEREx images can be marred by sensitivity to photons or less than uniform detectors.

"You kind of have to undo all that to get back and what the detector actually sees," Zemcov says.

The information from the spacecraft creates what Zemcov calls a "firehose of data."

In order to get scientific sense from that deluge, Zemcov is one of the planners of an information pipeline. There must be quality control at every step, he says, as well as assurance that an error can be detected at any of those steps.

"If you make a little mistake at the top of the pipeline, how does that propagate down through the whole thing?" he asks.

Once scientists can be sure that what's coming out of the pipeline is safe to consume, they're free to focus on inflation – the expansion of our universe in the "tiny fraction of a second" following the Big Bang.

The Big Bang is the best explanation for the reason the universe, like most shopping malls, looks the same in every direction.

"The problem is, we don't really have any direct proof," Zemcov says.

While we'll never have an eyewitness account, SPHEREx can build a three-dimensional map of the universe. We can see space when it was young and study the "little seeds of galaxies" before they took root.

In some ways, the project is like looking at the tag at the back of your shirt or figuring out why your car stopped squeaking when you brought it to the mechanic.

"What is the universe made of?" Zemcov asks. "Why did it do that?"

SPHEREx is an attempt to chronicle the odysseys of light and stars in the same way anthropologists study the movement of human beings. But it may also have ramifications on the future.

They'll be searching for water ice around young stars, Zemcov says.

"Where does water live when you have a young star that's forming planets?" he asks. "That's kind of an interesting question if we're going to search for life."

RIT hosts quantum workshop Jan. 23-25

Published December 7, 2018
By Susan Gawlowicz, RIT University News

An international conference on quantum science and technology is expected to draw hundreds of leaders in the field to Rochester Institute of Technology in January in response to a congressional imperative to accelerate quantum research.

The Photonics for Quantum Workshop will be held from 9 a.m. to 5 p.m. Jan. 23-25 in Ingle Auditorium in the Student Alumni Union on the RIT campus and will feature invited talks and poster presentations by scientists and engineers from the National Science Foundation, NASA, AIM Photonics, national laboratories, industry and academia. Topics will focus on quantum technology development in five main applications—computing, communication, imaging, sensing and clocks. Additional talks and a panel discussion will address the need for a quantum workforce pipeline that will create new job categories, such as “quantum engineer.”

Recent advances in quantum science have leapfrogged existing capabilities in handling complex computational problems, providing communication security, and in enhancing navigation, imaging and other sensing technologies.

“Quantum physics led to transformative technologies in the last century—transistors, microelectronics, LEDs, lasers, nuclear power, digital cameras and magnetic resonance imaging,” said Don Figer, conference organizer and director of RIT’s Future Photon Initiative, one of the university’s signature research areas. “The new Quantum 2.0 technologies can exploit fundamental properties of individual photons, trapped ions and superconducting circuits. The Photonics for Quantum workshop focuses on using photons in Quantum 2.0 technologies.”

The U.S. House of Representatives, in September, passed the $1.3 billion National Quantum Initiative Act to maintain U.S. scientific and technological leadership. Now before the Senate, the legislation would create a 10-year program to advance quantum development and technological applications and develop the quantum standards and measures for global use.

Quantum mechanics is a branch of physics that manipulates the smallest amount of energy at the subatomic level. Different rules govern matter at this scale, and scientists are using the strange, unintuitive properties created by quantum superposition and entanglement. Countries are racing to harness quantum capabilities, secure their networks and lead in emerging fields like artificial intelligence and synthetic biology.

In addition to RIT, the Photonics for Quantum Workshop is sponsored by ID Quantique, Princeton Instruments and TOPTICA Photonics Inc. To register, go to https://www.rit.edu/fpi/photonics-quantum-pfq-workshop.

Intersections: The RIT Podcast Ep. 18 How to Build a Career in Science

Published June 30, 2019
RIT University News

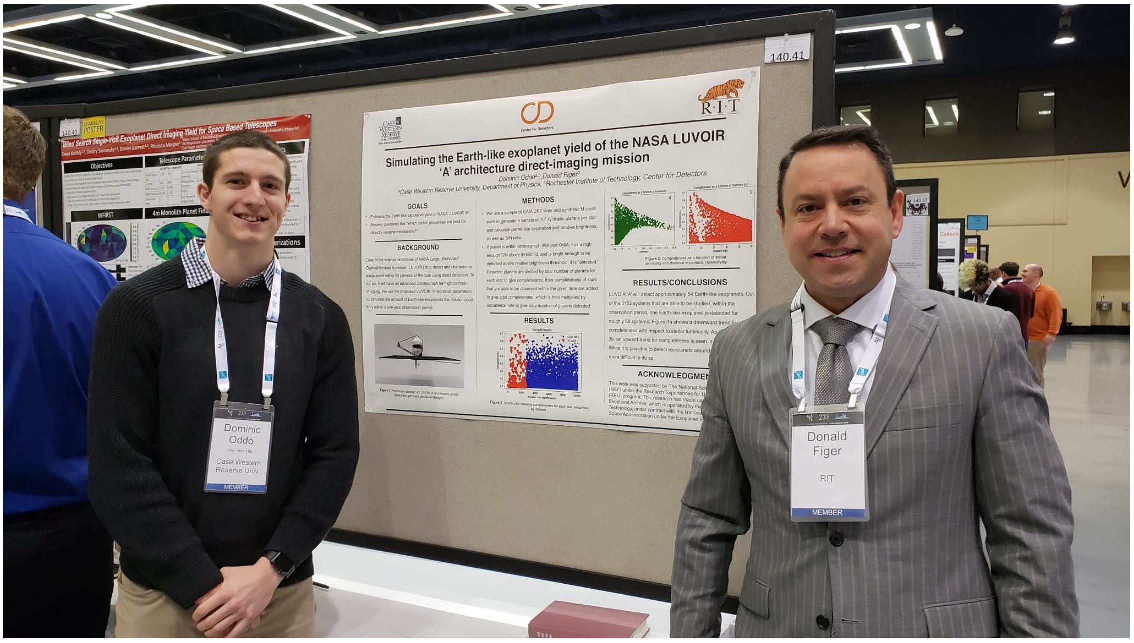


Figure 45. RIT professor Don Figer, right, and Case Western University Student, Dom pose in front of their poster "Simulating the earth-Like exoplanet yield of the NASA LUVOIR 'A' architecture directing imaging mission" at the American Astronomical Society (AAS) 223rd meeting.

In today's conversation, Don Figer, director of RIT's Center for Detectors, offers advice on how to build a career in science to Dom Oddo, a Case-Western Reserve student who participated at RIT recently in a National Science Foundation Research Experience for Undergraduates. Read the transcript of this podcast below

NARRATOR: Welcome to Intersections: The RIT Podcast. In today's conversation Don Figer, director of RIT's Center for Detectors offers advice on how to build a career in science to Dom Oddo, a Case Western Reserve student who recently participated at RIT in a National Science Foundation Research Experience for Undergraduates.

DON: How did you get connected with the REU?

DOM: So I had heard about the REU program just from people at college. And they told me that it was something that was pretty essential that you needed to do in order to gain experience to learn about what you want to do. So I looked up a list on the NSF website and I found RIT as one of them and so that's how I got in contact specifically here.

DON: I remember, of course, that we talked about it a little bit and you applied. We have several here; we have a lot of REUs.

DOM: We actually have seven REU groups.

DON: So you applied for a few of them and then you got accepted in one of them. Then we started the project. How would you explain the project that you're doing now? What is it? What are you trying to do?

DOM: I am trying to measure the amount of exoplanets that LUVOIR could detect with a simulation.

DON: And what's a LUVOIR?

DOM: LUVOIR is a future NASA mission. It stands for Large UV Optical InfraRed Surveyor and it is kind of like a successor to James Webb, which is a successor to Hubble in that it has very aggressive science goals, one of which is cosmology and larger structure, another being galaxy and galactic structure, and another is LUVOIR as a planet finder. So I want to study LUVOIR as a planet finder and look at how many Earth-like exoplanets it wants to detect.

DON: Is it going to launch before you retire? [laughs]

DOM: That's a good question, I'm not sure.

DON: So I ask that question because as you might've gathered by now these missions take a long time to plan.

DOM: Yeah.

DON: But I always found it interesting to be in on the early stages of the development of the mission because you can influence the structure, the architecture of the mission - what it's gonna do. You can also be granted special privileges to the data when the data comes, but you have to be working on the mission around the time that it launches. So it's just a question of how long you want to wait.

DOM: Yeah it is pretty interesting to be in on kind of like the ground floor of LUVOIR because when I tell people about LUVOIR they're like, "What is that?" They haven't heard of it yet. I wouldn't expect anyone to have heard of it yet because people barely know about James Webb, let alone LUVOIR, which is ten, twenty years down the line.

DON: So how would you describe the experience? Or to put it another way, how is it different or similar than what you might've expected before you got here?

DOM: When I came here and you told me I could pretty much do whatever I wanted to I was kind of baffled a little bit.

DON: Is it because you thought maybe you would be directed or guided into an existing channel of research? Which we could've done by the way. It was just more of a question of trying to figure out what would be most interesting for you.

DOM: Yeah. I did kind of think that when I got here, whichever professor I got, turned out to be you, would just say, "I'm working on this thing already, learn about it, study up." And then, you know, here's what I want you to try and do and you know take the summer to do it. But that isn't what you did here. You gave me a little bit more free range with my project, and I think that that really helped me to feel like it's my own project. I'm not just kind of like working on someone else's thing. Even though you already have done previous work on it, I still feel like I get to take ownership of my own project.

DON: Yeah so both of those experiences I think are worthwhile.

DOM: Sure, yeah absolutely.

DON: Where you're directed to do something and it's within the context of a research project where other people are doing different parts of it. So I think that's really interesting, too. And then this other approach is, I guess has a broader range of possibilities. And then you have more of the responsibility for figuring out what's interesting. There's going to come a time in your career when you will need the sort of intellectual maturity to figure out what's interesting and what's exciting for you. It's a really interesting thing to see in students because most students don't know how to do this because they never were trained to do it. All their lives they wake up in the morning, they get on the bus, they go to school, they're told what to do in the first period, the second period, all throughout the day. And then they go to extracurricular activities and they're told what to do, and how to hold the ball, and how to pass the ball, you know. But very rarely does someone ask them "Here, sit here for four hours and think about something interesting." And a lot of students, their minds would explode if someone asked them to do that because they would say "Well, where's the textbook? I gotta read the textbook. And where are the questions?"

DOM:"What do you want me to think about?"

DON: [Laughs] Yeah like, "Are these answers right? Is there an answer key?"

DOM: Yeah.

DON: But that doesn't make sense when you're trying to think of something that no one's ever thought about before. There's no textbook for that. You have to somehow learn to exercise your imagination so that it seizes on potentially interesting things. And then there's this issue of thinking about ripe questions, questions that are nearly answerable but haven't been answered yet. Sort of stepping on the edge or the border of what's known and what's not known. That's where the interesting stuff happens, that's where the interesting discoveries are. So this experience was more like me pushing you to struggle with the question of how to formulate the problem. And then how to pursue it. And then scrambling to go find research papers or experts, because that's the stuff that you're going to end up having to do as a real astronomer when you have your astronomer badge, right? [laughs] When they give you the badge and then you gotta go out and do some astronomy. Do you have plans to continue doing research for the rest of your undergraduate career?

DOM: I would definitely like to continue doing research. I can't say that I've nailed down any one thing that I wanna do yet. I mean like I've said before, exoplanets are really interesting to me in the context that they're alien worlds and they're really far away. And yet with the things that we've been doing, and especially trying to direct imaging them, they seem within our reach now, which is really cool. But no, I don't have anything lined up yet. You know if you would have me back like next summer I could come back here, and we could think about a different problem.

DON: Well other interesting possibilities are - so there's an art to this and some people do this really well. And that is to, you make connections, you make relationships and then you keep those, and then you expand.

DOM: Yeah.

DON: And you make new ones. And it's like this tree, right? You travel down all these different branches and at the end you have this big, thick, powerful tree. What's the mighty oak, is that what they call it?

DOM: Something like that, yeah.

DON: This big tree, right, and that's like your career. So next summer you could think about going to Space Telescope Science Institute for their summer program, and you could work with Chris Stark.

DOM: That would be nice.

DON: The assumption is that you're actually still interested in exoplanets.

DOM: Yeah.

DON: But if you're not, that's okay. They have so many different things at Space Telescope. And getting back to this tree and branch analogy, if you were to do that, work with Chris Stark, then you would still be in contact with me.

DOM: Mhm.

DON: That's where you're retaining relationships but then expanding further relationships. You don't cut the old relationships, you expand them. Then maybe, you know, the next year you go to - the CFA has a summer program, which is an amazing place because [clarifying] Center for Astrophysics, because you're there across the street from Harvard, and then MIT down the road, right? And then you make relationships with all those people, or some of them, right?

DOM: Yeah.

DON: And then eventually, when it comes time for you to pick an original area of research, for your PhD let's say, then all these people know you already, and then they consider you as a colleague, and then you can ask them for advice or you could ask them to collaborate on a project, right?

DOM: Yeah.

DON: So this is how to build a career, and this is the stuff that's not in the textbooks.

NARRATOR: Thanks for listening to Intersections: The RIT Podcast, a production of RIT Marketing and Communications.

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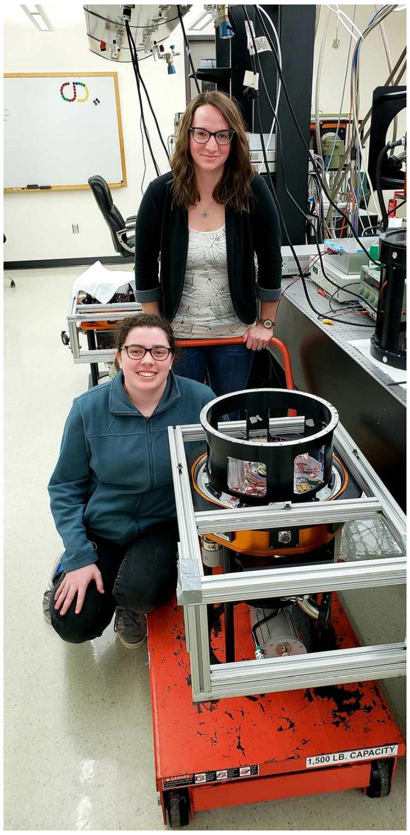

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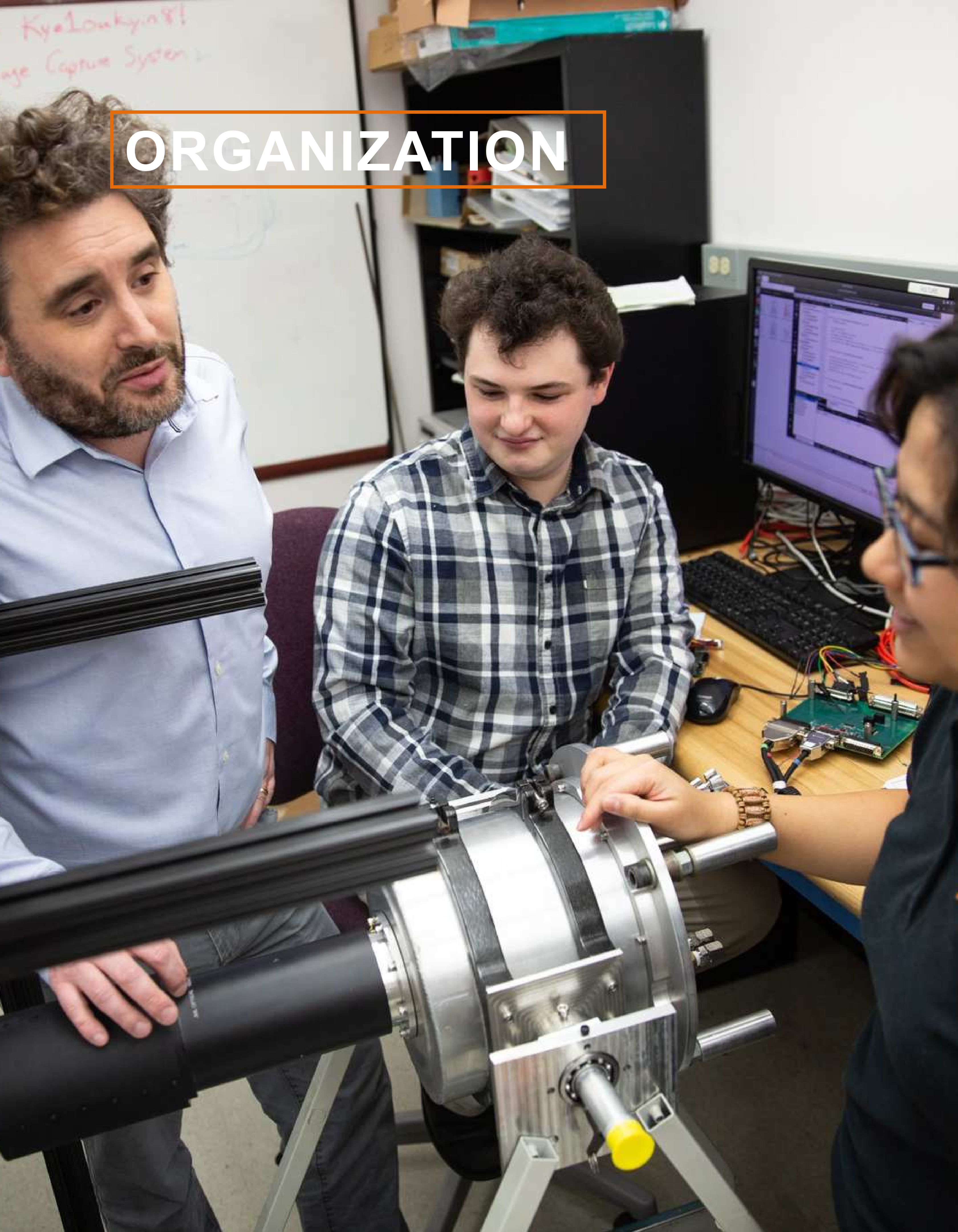

Personnel

Research Faculty

Don Figer

Director, Professor

Degrees: PhD Astronomy, 1995, University of California, Los Angeles; MS in Astronomy, 1992, University of Chicago; BA Physics, Math, Astronomy, 1989, Northwestern University

Dr. Figer is the Director of both the Center for Detectors and the Future Photon Initiative, as well as a Professor in the College of Science. Dr. Figer researches massive stars and develops advanced imaging detectors for cross-disciplinary applications. Other research interests of Dr. Figer are developing integrated sensor systems on a wafer and development of a single photon sensing and photon number resolving detector.

Projects led by Dr. Figer over the fiscal year are New Infrared Detectors for Astrophysics, the development of an Engineering Verification Test Station in support of AIM Photonics' Testing Assembly and Packaging (TAP) Hub, and identifying massive stars near the Galactic center.

Dr. Figer has received numerous awards for his work, including the NYSTAR Faculty Development Award, The NASA Space Act Award, and the AURA STScI Technology and Innovation Award.

Gregory Howland

Assistant Professor

Degrees: PhD Physics, 2014, University of Rochester; BA Physics, 2007, Oberlin College

Gregory Howland is an Assistant Professor in the College of Science at the Rochester Institute of Technology. Dr. Howland joined RIT as an Assistant Professor in 2019 after working in Stefan Preble's integrated photonics group as a Postdoctoral Associate.

His research focuses on high-dimensional quantum information science in photonic systems, with a current emphasis on quantum integrated photonic circuits.

Dr. Howland has played a major role in the CfD and FPI Quantum project proposals over the fiscal year.

His publications have appeared in Nature Communications, Physical Review X, Physical Review Letters, Physical Review A, Optics Express, and Applied Optics.

Parsian K. Mohseni

Assistant Professor

Degrees: PhD Engineering Physics, 2011, McMaster University, Canada; BEng. Engineering Physics, 2005, McMaster University, Canada

Dr. Mohseni is an Assistant Professor in the College of Engineering, and Head of the Epitaxially-Integrated Nanoscale Systems Laboratory. Dr. Mohseni's research interests are cross-disciplinary, spanning the fields of solid state physics, optoelectronics, materials characterization, nano-engineering, and physical chemistry. He is interested in novel, bottom-up and top-down methods for fabrication of III-V and Si nanostructures for applications including solar cells and photodetectors.

Dr. Mohseni's major research during the fiscal year involves exploration of a transformative, bifacial solar cell design that employs arrays of TDM III-V compound semiconductor nanowires in tandem with a thinned, intermediate Si sub-cell to enable cost-effective manufacturing of high-efficiency TDM solar cells.

Dr. Mohseni has received research awards from the Canadian Institute for Photonic Innovations and the Ontario Centres of Excellence, and won an NSF EAGER award.

Zoran Ninkov

Professor

Degrees: PhD, Astronomy, 1986, University of British Columbia; MSC Physical Chemistry, 1980, Monash University; BSC (1st class honors), Physics, 1977, University of Western Australia

Dr. Ninkov's research is focused on the development of novel two dimensional detector arrays for use in spaceborne and ground based astronomical imaging and spectroscopy, in particular polarization detectors and multi-mirror devices. Other research concentrations are the development of image processing techniques for optimal analysis of two dimensional imaging array detectors (InSb, NICMOS, CCD, CID and APS arrays) astronomical image data and the study of fundamental limitations of such devices.

Major projects led by Dr. Ninkov over the fiscal year are the development of quantum dot coated detector arrays sponsored by Thermo Fisher, and the development of digital micromirror devices for Far-UV applications through NASA.

Dr. Ninkov serves as the Associate Director at the C.E.K. Mees Observatory at the University of Rochester, a position he has held since 1995.

Stefan Preble

Professor

Degrees: PhD, Electrical & Computer Engineering, 2007, Cornell University; BS Electrical Engineering, 2002, Rochester Institute of Technology

Dr. Preble is Professor in the College of Engineering and the lead of the Lobozzo Photonics and Optical Characterization Lab. Dr. Preble's research concentrations are quantum computing, communication and sensing, photonics packaging, and integrated photonics education. His research focuses on novel silicon photonic devices with the goal of realizing high performance computing, communication, and sensing systems that leverage the high speed, bandwidth, and sensitivity of light.

Projects led by Dr. Preble during the fiscal year are integrated quantum photonics for photon-ion entanglement sponsored by the USAF, and the process development of the AIM Photonics' Testing Assembly and Packaging (TAP) Hub.

Dr. Preble has received numerous awards recognizing his work, including the 2019 RIT Trustee Scholarship Award, a DARPA (Defense Advanced Research Projects Agency) Young Faculty Award and an AFOSR (Air Force Office of Scientific Research) Young Investigator Award.

Michael Zemcov

Assistant Professor

Degrees: PhD Physics, Cardiff University, 2006, Cardiff, United Kingdom; BS Physics, 2003, University of British Columbia, Canada

Dr. Zemcov is an Assistant Professor in the College of Science and an experimental astrophysicist in the Future Photon Initiative and Center for Detectors. His scientific background and interests are centered on cosmological observations of the large-scale structure of the universe, and studies of fundamental physics. His expertise includes studies of the diffuse radiation in the cosmos, particularly the cosmic microwave and infrared background radiation, and the development of enabling technologies for ground-based, sub-orbital, orbital, and deep-space platforms.

Dr. Zemcov is a Principle or Senior Co-Investigator on several large programs, including the SPHEREx All-Sky Spectral Survey, the Cosmic Infrared Background Experiment, the Line Intensity Mapping Experiment, and the Tomographic Ionized-carbon Mapping Experiment.

Dr. Zemcov was awarded the NASA Achievement Award twice. He is Member of the American Astronomical Society and a fellow of the Royal Astronomical Society.

Jing Zhang

Assistant Professor

Degrees: PhD Electrical and Computer Engineering, 2013, Lehigh University; BS Electronic Science and Technology, 2009, Huazhong University of Science and Technology

Dr. Zhang is an Assistant Professor in the College of Engineering. Dr. Zhang's research areas use III-Nitride semiconductors for photonics and energy applications. Her research interests include the pursuit of novel materials for large thermoelectric figure of merit, semiconductor Ultraviolet Light Emitting Diodes (LEDs) and lasers, as well as III-Nitride solid state lighting devices.

Dr. Zhang's major project during the fiscal year is the development of solutions to key challenges in achieving high-efficiency single-mode GaN-based ultraviolet (UV) lasers with wavelength ranging from 220 nm up to 300 nm. This project focuses on the fundamental physics understanding of the valence band structure of lll-Nitride wide bandgap gain active region, and develop promising solutions on nanostructured quantum wells and fabrication approach of large area GaN-based UV laser arrays.

Dr. Zhang has published more than 30 refereed journal papers and 65 conference publications, including invited talks. Dr. Zhang won the NSF Career Award in 2018.

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Senior Systems Engineer, Precision Optical Transceivers
Degrees: BS Electrical Engineering, 1984, Rochester Institute of Technology

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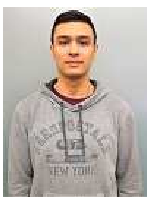

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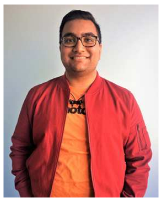

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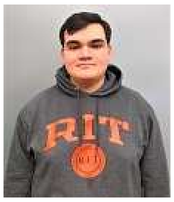

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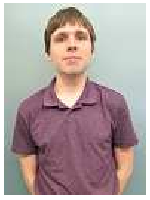

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Facilities and Equipment

The Center for Detectors (CfD) is located in Engineering Hall (Building 17) at the Rochester Institute of Technology. The CfD headquarters consists of approximately 7,000 square feet of office and research laboratory space. CfD lab space includes the Rochester Imaging Detector Laboratory (RIDL, see Figure 46), the Lobozzo Photonics and Optical Characterization Laboratory, the Integrated Photonics Laboratory, the Experimental Cosmology Laboratory, the Laboratory for Advanced Instrumentation Research (LAIR), the Quantum Imaging and Information Laboratory, the Suborbital Astrophysics Laboratory, and a semiconductor device optical property measurement laboratory.

Figure 46. The photo above shows the cryogenic dewars in the Rochester Imaging Detector Laboratory.

Facilities within CfD 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 computers. The equipment is capable of analyzing both analog and digital signals. 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.

Rochester Imaging Detector Lab

The RIDL detector testing systems use four cylindrical vacuum cryogenic dewars. Each individual system uses a cryocooler 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 temperature controllers to sense temperatures at 10 locations within the dewars and to control heaters 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 two Astronomical Research Camera controllers with 32 digitizing channels, a 1 MHz readout speed, and 16-bit readout capability. The readout systems also contain one Teledyne SIDECAR ASICs with 36 channels and readout speeds up to 5 MHz at 12-bits and 500 kHz at 16-bits, custom FPGA systems based on Altera and Xilinx parts, and a JMClarke Engineering controller with 16 readout channels and 16-bit readout designed specifically for Raytheon Vision System detectors. Figure 47 shows the electronics packages.

Figure 47 The three electronics packages used to test detectors are the Astronomical Research Camera Controller (left), JMClarke Engineering (middle), and the Teledyne SIDECAR ASIC (right).

The controllers drive signals through cable harnesses that interface with Detector Customization Circuits (DCCs) consisting 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 RIDL also has two large integrating spheres that provide uniform and calibrated illumination from the ultraviolet through the infrared. The dewars are stationed on large optical tables that have vibration-isolation legs (Figure 48).

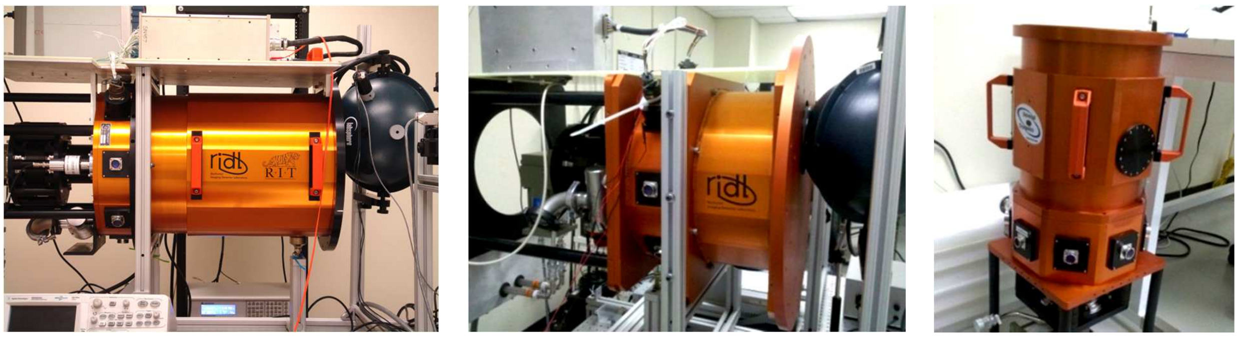


Figure 48. Detectors are evaluated in four custom dewar test systems. The fourth dewar (not pictured) is a duplicate of the one on the left.

The lab equipment also includes a PicoQuant laser for LIDAR system characterization and other testing that requires pulsed illumination. In addition, the lab has monochromators with light sources that are able to produce light ranging from the UV into the IR, with a wavelength range of 250 nm – 2500 nm. NIST-traceable calibrated photodiodes (with a wavelength range of 300 nm – 5000 nm) provide for absolute flux measurements. RIDL also has a spot projector to characterize the interpixel response of the detectors, including optical and electrical crosstalk. Figure 49 shows a laser spot projection system on a 3D motorized stage that produces a small (~few µm) point source for measurements of intrapixel sensitivity.

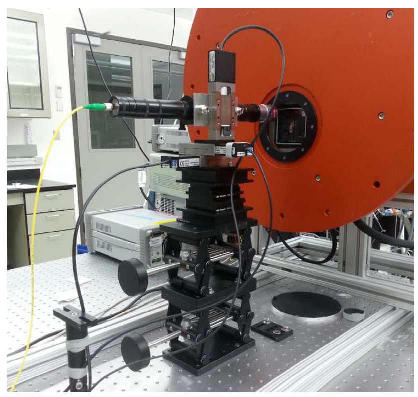


Figure 49. In the photo above, a laser spot projector with a three-axis motion control system projects a small spot of light within individual pixels of detectors in order to measure the response in all regions of a pixel.

RIDL has many data acquisition and reduction computers, each with eight to twenty-four threads and up to 32 GB of memory for data acquisition, reduction, analysis and simulations. A storage server with 10 Gbps optical network connection is the primary data reduction computer; it has 50 TB of mirrored storage space. Custom software runs an automated detector test suite of experiments. The test suite accommodates a wide variety of testing parameters using 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.

Lobozzo Photonics and Optical Characterization Lab

The RIT Integrated Photonics Group conducts research in the Lobozzo Photonics and Optical Characterization lab (Figure 50). Dr. Preble and his team develop high performance nanophotonic devices and systems using complementary metal–oxide–semiconductor compatible materials and processes. Their work enables unique performance and efficiency by leveraging the inherently high bandwidths and low power of photons with the intelligence of electronics. The Lobozzo lab includes a Ti:sapphire laser, optical parametric oscillator, atomic force microscope, ion mill, cryogenic optoelectronic probe station, and telecom test equipment. Other CfD faculty and students use the lab for terahertz measurements and time-resolved photoluminescence.

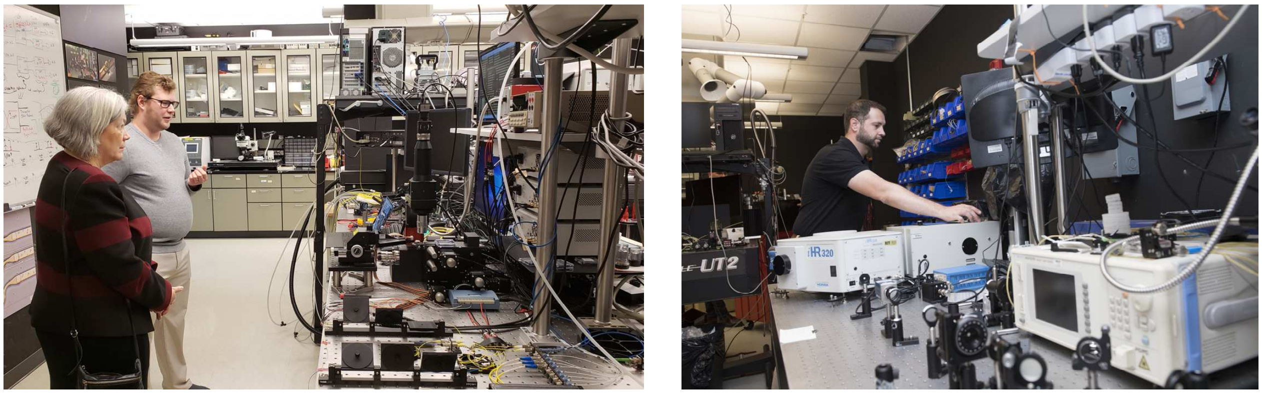


Figure 50. (left) Dr. Howland shows RIT Provost, Ellen Granberg the Photonics and Optical Characterization Lab. (left) Michael Fanto, one of Dr. Preble's PhD students works in the lab.

The Integrated Photonics Group added space for quantum integrated photonic experiments last year. Researchers use this lab to design and develop scalable quantum computing, communication and sensing circuits integrated on Silicon Photonic chips. These chips densely integrate photon sources, entanglement circuits and single photon detectors onto a phase stable platform. The Air Force Office of Scientific Research (AFOSR) provided funding through the Defense University Research Instrumentation Program for a Photon Spot single photon detector system (Figure 51, *right*) which has high detection efficiencies (>85%) and very low dark counts (<200Hz). The system has detectors for both short-wave infrared and UV wavelengths. The National Science Foundation, Air Force Research Laboratory, and the Gordon and Betty Moore Foundation fund the laboratories' research projects.

Figure 51. (left) The photo above shows the optical table used to run quantum integrated photonic experiments in the newly opened Integrated Photonics Lab. (right) This photo shows the Photon Spot single photon detector system funded by AFOSR.

CfD professor Dr. Jing Zhang leads a semiconductor device optical property measurement lab located within the Lobozzo laboratory. This lab contains a photoluminescence (PL) system, seen in Figure 52, including an iHR320 spectrometer, a Syncerity CCD Array detector, a liquid helium cyrostat and a 325 nm HeCd laser. There is LabSpec software capable of measuring semiconductor luminescence spectrum with wavelengths ranging from 325 nm – 800 nm. The liquid helium cyrostat enables the system to conduct measurements at temperatures as low as 4 K.

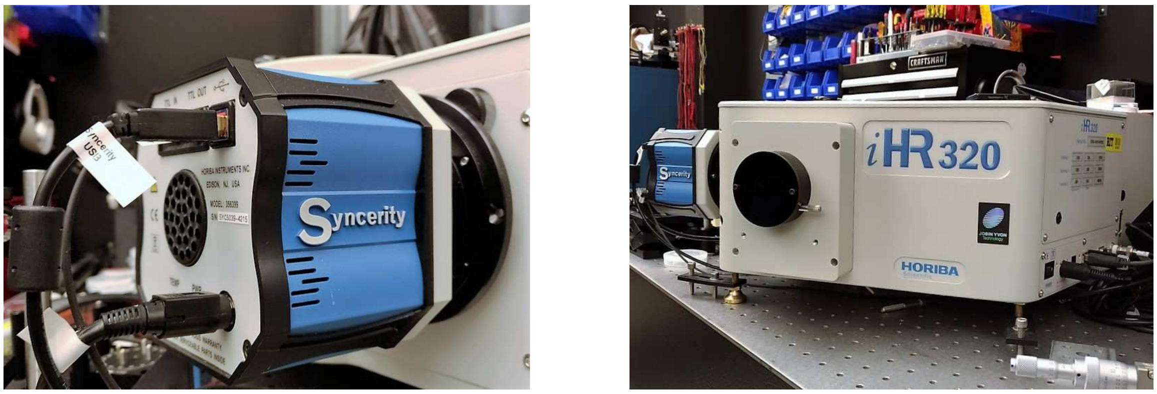


Figure 52. The Syncerity CCD Array detector (left) and the HR320 spectrometer (right) are part of the photoluminescence system.

The lab also includes an electroluminescence (EL) measurement setup (Figure 53) including a FLAME-S-UV-VIS-ES spectrometer (200 nm – 850 nm) and a rotatable stage that enables polarization-dependent and angle-dependent measurements.

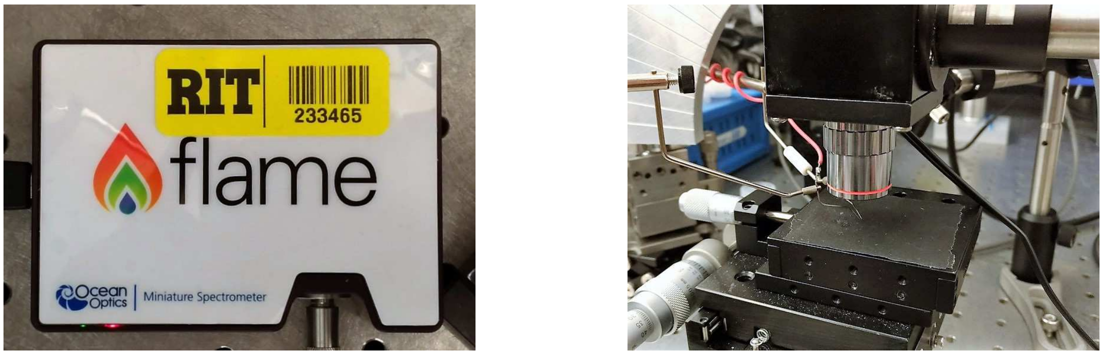


Figure 53. The electroluminescence measurement setup includes a rotating testing stage (right) and a FLAME 200 nm – 850 nm spectrometer (left).

Experimental Cosmology Lab

CfD professor Dr. Michael Zemcov directs the Experimental Cosmology Laboratory. This 375 square foot lab is capable of creating technologies for ground- and space-based applications in experimental astrophysics. The lab has equipment for fabricating and testing physical components and complementary software (Figure 54). Inside the lab are two Oerlikon Leybold Turbolab turbo-molecular pump systems, optical benches, lifting equipment, and tooling and component fabrication equipment. Multiple computers within the lab run algorithms for astrophysics simulations. The lab also includes a millimeter wave spectrometric readout system for transition edge superconducting bolometers, as well as two liquid helium cryostats and an electronic fabrication station. A new vibration test system and rapid-prototyping PCB mill add to the capabilities for cosmology instrumentation and testing in this lab.

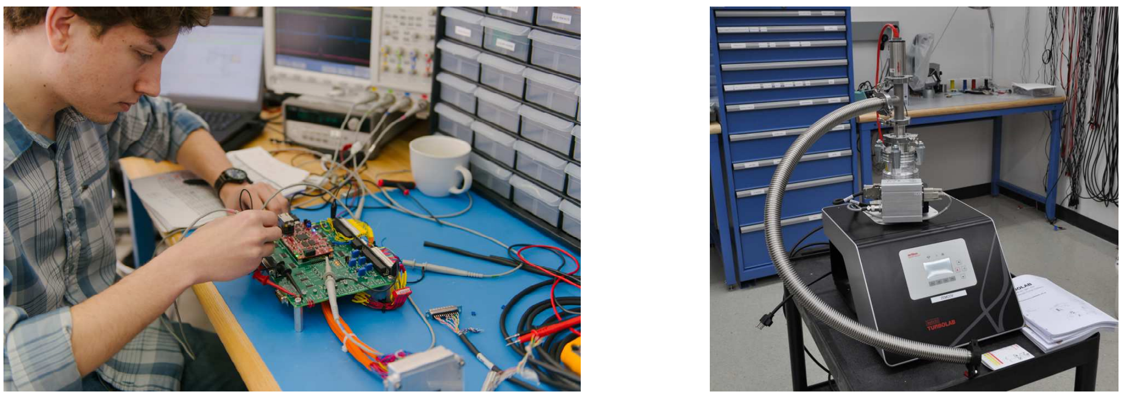
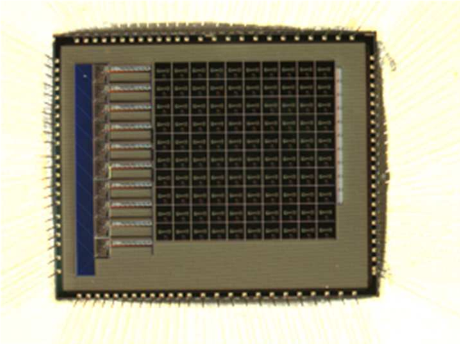


Figure 54. (left) Former CfD student, Ben Stewart is working with the FPGA-based control board, function generators, and oscilloscopes, used to develop CSTARS. (right) The picture shows one of the Oerlikon Leybold Turbolab turbo-molecular pumping stations in the lab.

Laboratory for Advanced Instrumentation Research

The Laboratory for Advanced Instrumentation Research (LAIR), led by CfD professor Dr. Zoran Ninkov, is in the Chester F. Carlson Center for Imaging Science, a short distance from the CfD Headquarters. The LAIR develops novel and innovative instruments for gathering data from a wide variety of physical phenomena and trains the next generation of instrument scientists who will occupy positions in government, industry, and academia. It includes hardware and software for developing terahertz (THz) imaging detectors using Si-MOSFET CMOS technology (Figure 55). Over the years, Dr. Ninkov and his team developed a wide variety of instruments at LAIR, including digital radiography systems, liquid crystal filter based imaging systems for airborne (UAV) mine detection, a speckle imaging camera for the

WIYN 3.6 meter telescope, a MEMS digital micromirror based multi-object spectrometer, and an X-ray imaging systems for laser fusion research. NASA, the NSF, NYSTAR and a variety of corporations such as Exelis, ITT, Kodak, Harris, Moxtek and ThermoFisher Scientific, have funded this research.



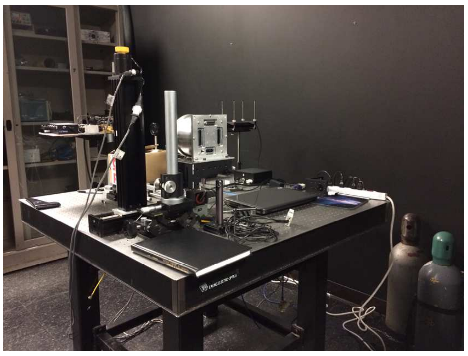


Figure 55. Student researchers in the LAIR developed a terahertz detector (left) and characterized it in the laboratory (right).

Epitaxially-Integrated Nanoscale Systems Lab

CfD professor Dr. Parsian Mohseni leads the Epitaxially-Integrated Nanoscale Systems Laboratory (EINSL). This lab, part of RIT's Nanopower Research Laboratory (NPRL), focuses on atomic-level semiconductor assembly and metalorganic chemical vapor deposition (MOCVD). The lab develops devices used for photovoltaics, optoelectronics, and nanoelectronics. Their research finds real-world applications in solar energy, solid-state lighting, and lasing. Current research areas in the EINSL include metal-assisted chemical etching of semiconductors using non-conventional catalysts, multi-junction III-V nanowire on silicon solar cells, and GaAsP/GaP nanowire white light LEDs.

Researchers in the EINSL have access to the wide range of capabilities provided by the NPRL, seen in Figure 56, which include a Perkin Elmer Lamda 900 UV-Vis-NIR optical spectrometer and a metal organic vapor phase epitaxy (MOVPE). NPRL also has multiple advanced microscopic imaging systems, including a Nikon Eclipse Digital Nomarski microscope, Hitachi S-900 High Resolution Near Field FE-SEM, and Zeiss Digital Microscopic Imaging System.

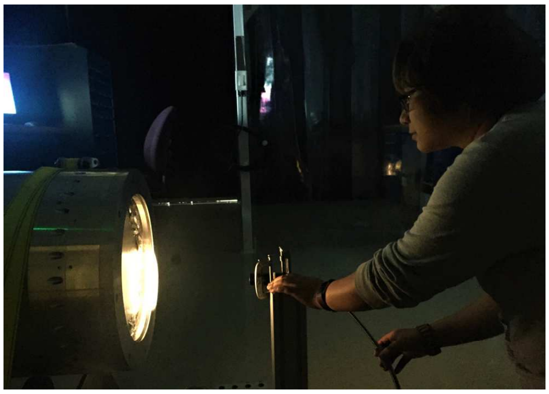
Figure 56. (left) PhD student Mohad Baboli loads a sample in the AIXTRON 3×2 Close Coupled Showerhead metal-organic chemical vapor deposition reactor, part of the MOVPE. (right) PhD student Alireza Abrand is processing samples in the fume hood.

Quantum Imaging and Information Lab

In the new Quantum Imaging and Information laboratory, Assistant Professor Gregory Howland studies how to create, manipulate, and detect quantum mechanical phenomena in the spatial degrees-of-freedom of quantum light. These “Quantum Images” encode large amounts of quantum information of single or entangled photons and serve as a platform for quantum sensing, quantum communication, and quantum computing. Specific research topics range from the applied – such as extreme low-light imaging – to the fundamental – such as quantifying large dimensional quantum entanglement. The 700 square foot laboratory will provide optical benches, laser sources, and single-photon detectors quantum-optical experiments using bulk, fiber, and integrated optics.

Suborbital Astrophysics Lab

The Suborbital Astrophysics Laboratory provides RIT with capabilities to design, integrate, and calibrate sounding rocket payloads for astrophysical science. It includes clean facilities to allow disassembly and assembly of rocket instruments, optical and electronic development and validation instruments, and cryogenic and vacuum capabilities. In this lab, Dr. Zemcov and his team are readying the CSTARS and CIBER-2 payloads for flight from White Sands Missile Range, NM (Figure 57).



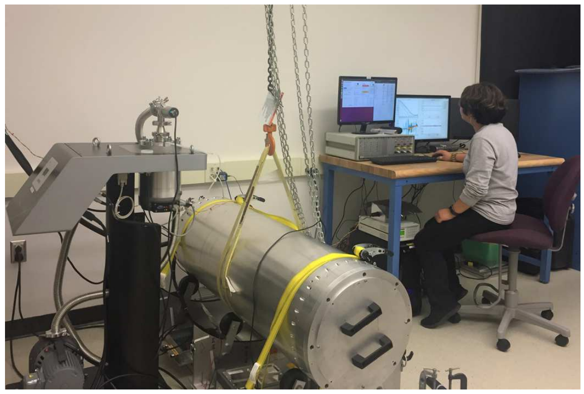


Figure 57. (left) In the picture above, Chi Nguyen measures light levels while characterizing the CIBER-2 payload. (right) Nguyen monitors the temperature for CIBER-2 during an experiment in the Suborbital Astrophysics Lab.

Semiconductor & Microsystems Fabrication Lab (SMFL)

CfD uses the SMFL, a 10,000 square foot cleanroom space in class 1000, 100, and 10. Using the SMFL’s resources, the Center can fabricate detectors with custom process flows and multiple process variations.

The Center’s flow bench and probe stations offer wafer-level testing, even during the fabrication process, allowing mid-process design changes (Figure 58). The probe station accommodates electrical and circuit analysis of both wafers and packaged parts, including low current and radio frequency (RF) probing.

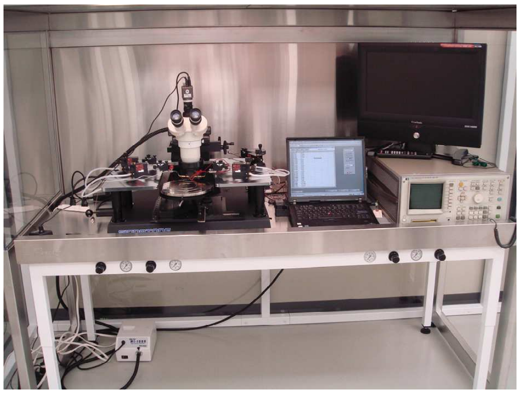


Figure 58. Shown above is the flow-bench lab probe station CfD researchers use to test device wafers.

The Amray 1830 Scanning Electron Microscope (SEM; see Figure 59), in the SMFL is used for high-magnification imaging of devices, and the WYKO white light interferometer is 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.

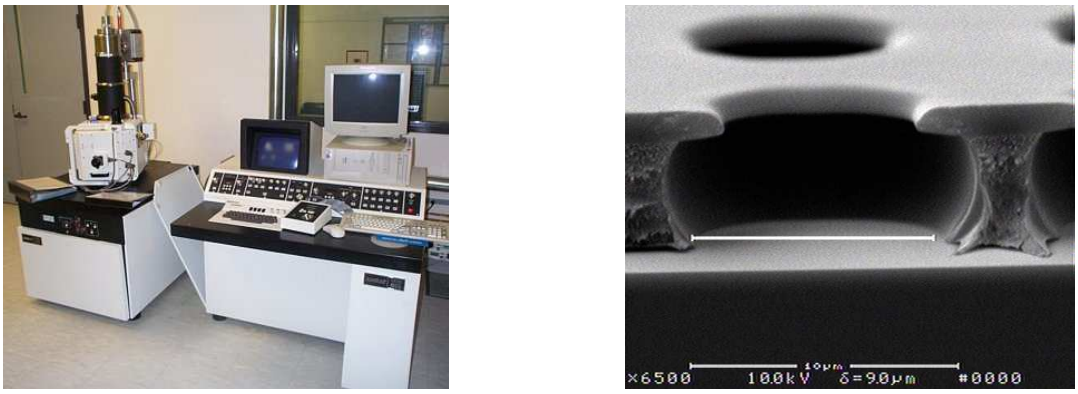


Figure 59. (left) CfD researchers use the Amray 1830 Scanning Electron Microscope to image devices. (right) The SEM image shows a sample prepared for indium bump deposition.

Figure 60 shows a customized setup consisting of two voltage power supplies, an oscilloscope, an LCD screen for viewing devices through the microscope probe station, and a custom circuit board for specific device diagnostics. The dedicated lab computer also runs a specially designed data acquisition program to collect and analyze data from prototype devices.

Figure 60. Former PhD student Kimberly Kolb conducts electrical experiments on one of the devices being characterized in the CfD.

The covered probe station ensures that no stray light enters the testing environment. These conditions provide the basis for valuable testing and data analysis. In the figure, the probe tip is in contact with a single test device via a metal pad with dimensions of only 70 µm by 70 µm (an area of 0.005 mm^2), seen in Figure 61.

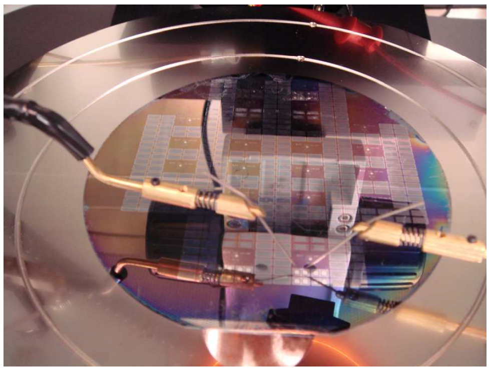


Figure 61. The image shows wafer testing using the probe station.

In addition to fabrication and testing capabilities, the CfD 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 SMFL, building a physics-based model in 3D space of a device from initial substrate to completed device.

Additional Labs

The CfD uses many other RIT facilities, including 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 (Figure 62).

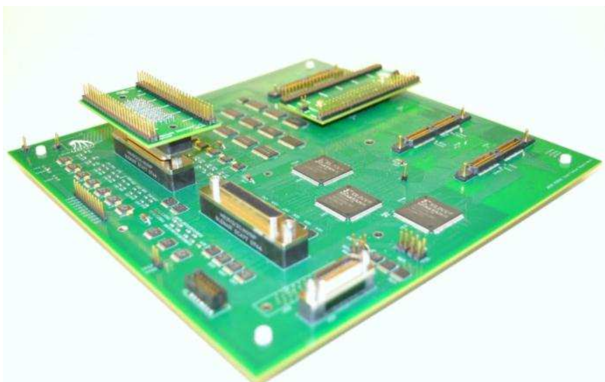


Figure 62. This image shows a cryogenic multi-layer circuit board designed in the CfD and populated in CEMA. All of the components on this board work at temperatures as low as 40 K, nanoTorr pressure levels, and in the presence of high energy particle radiation.

Center for Detectors

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