Annual Report

Center for Detectors 2021

Contents

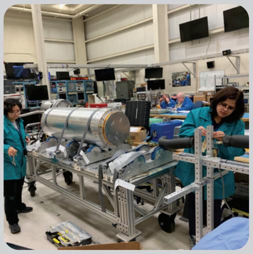
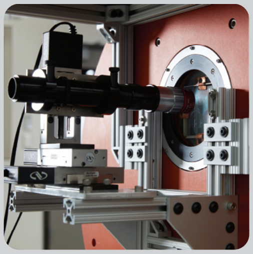
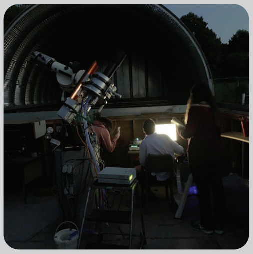
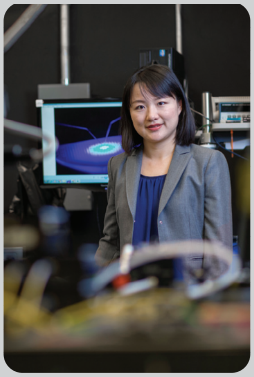
ANNUAL REPORT 2021

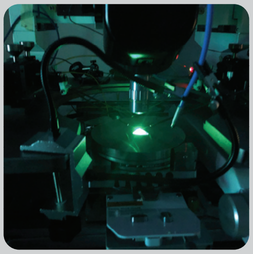
Center for Detectors

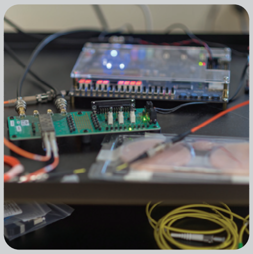
annual report 2021

Center for Detectors

director's comments
highlights
charter
executive summary





director’s comments

I wrote last year's director's comments from my home office, imagining that soon I would be back in the office and working directly in my lab like we did pre-covid. After a while, as most of us did, I realized I would be in my home office longer than anticipated. While I am thankful we built the Rochester Imaging Detector Lab to run remotely, my team and I, like many others, are anxious to be back in the lab regularly.

The Center for Detectors’ growing number of students and staff have flexible schedules split between home and on campus. Faculty created COVID-19 lab protocols to ensure labs had reduced capacity and proper spacing, allowing ongoing research to continue. Our students are still navigating through remote and in-person classes while completing experiments and taking data in less populated labs. The hallways seem quiet, but research work is humming along throughout CfD.

Dr. Michael Zemcov's CIBER-2 project, a near-infrared rocket-borne instrument, postponed flight at Las Cruses, NM due to the pandemic multiple times. In April, the team traveled to White Sands Missile Range to test the work they've done over nearly three years. Dr. Parsian Mohseni and fellow RIT professor Dr. Ke Du are developing a material system for covid sensing. Dr. Jing Zhang's graduate students work alone in the lab studying deep ultraviolet LEDs for multiple applications and quantum dots for single-photon emitters for quantum photonics.

With new challenges being in between home and our labs, CfD still had a productive year. We won $5.6M in new research funding, increasing our funding under management from $9.7M to 16.5M, and published 35 papers.

I encourage you to read all the details in this report and am interested in any feedback. Be safe.

Donald Figer

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

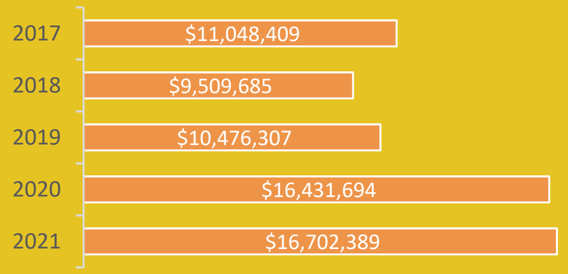
highlights

50+

students

37

active projects



external project totals per fiscal year

15+

featured news pieces

$5.6M

newly awarded funding

44

research publications

About

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, quantum optics and 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 organizations. CfD has nine labs on RIT's campus, including the Rochester Imaging Detector Lab, the predecessor to CfD.

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.

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.

Goals

- Create opportunities for faculty, students, and international leaders to advance the field of detectors and relevant areas of application
- Increase externally supported research at RIT
- Cultivate existing and new external collaborations with industry and academia
- Develop and use low noise large format detectors for Astrophysics
- Develop single-photon detectors for quantum applications
- Pilot local and national education programs in integrated photonics

Research

The CfD had 37 active projects during the past year (27 ongoing and 10 new), and won $5.6M in new research grant funding.

Dr. Don Figer continued to characterize the Quanta Image Sensor in collaboration with Dartmouth College. The device is a megapixel focal plane array that delivers photon counting capability at room temperature, and will be valuable for low light applications, such as astrophysics space-mission concepts. His NSF project developing infrared detectors that use HgCdTe material grown on silicon substrates is in its last year. The team is awaiting new detectors for characterization.

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 is at NSF serving as a program manager through the Intergovernmental Personnel Act program this year. His group continues research in imaging polarimetry, detector advancements, and micromirror development. His group further developed a method of coating detector arrays with nanomaterials for improved detector sensitivity in ultraviolet (UV) and blue light.

Dr. Stefan Preble and his Integrated Photonics Group are developing integrated photonics platforms, specifically implementing quantum photonic circuits on a silicon chip. Dr. Preble and other CfD members continued to establish packaging design and test support for AIM Photonics' Rochester facility. This includes education and workforce projects. Dr. Preble and Dr. Gregory Howland are developing a quantum optical semiconductor chip to demonstrate its application to efficient photonic entanglement, efficient logic gates such as Hadamard and CNOT, and quantum communication protocols through fiber optical channels for AdvR.

Dr. Michael Zemcov and his student-based group successfully launched the CIBER-2 sounding rocket payload at White Sands Missile Range in New Mexico. The payload is designed to probe the extragalactic background light. The newest version will identify the sources of the excess fluctuations by probing their spectral signatures from the optical to NIR. He also continued research to measure the cosmic background from the outer solar system using the New Horizons spacecraft, and continues 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.

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

CfD now has seven faculty research members, two Post-Doctoral Researchers, and five staff members. Our student researchers include 30 undergraduate and 21 graduate students. CfD students conduct research directly with CfD professors on externally funded projects. These students are mainly (58%) engineering students from the Kate Gleason College of Engineering. 39% of our students study in the College of Science, and 3% are from the Golisano College of Computing and Information Sciences.

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, nine of these students describe their contributions to projects over the past year.

Publications and News

CfD researchers published 44 articles in journals such as Journal of Applied Physics, the Astrophysical Journal, Astronomy and Astrophysics, Nanoscale Advances, and the IEE Photonics Journal. CfD research caught the eye of both local and national media. Dr. Zemcov and his team gained local and national recognition for their launch of the CIBER 2 payload.

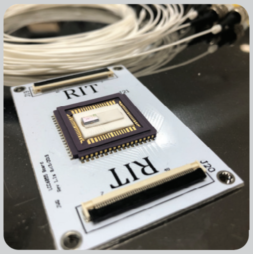
Equipment and Facilities

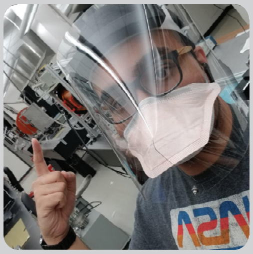
CfD made improvements to the two new research labs of Dr. Howland (Quantum Information) and Dr. Zemcov (Suborbital Astrophysics) allowing for student and faculty research to continue in new labs after quarantine. The largest footprint of CfD is in Engineering Hall, with six laboratories and offices to accommodate approximately 20 people. Outside of Engineering Hall, the CfD has laboratories in the Chester F. Carlson Center for Imaging Science and Gosnell Hall.

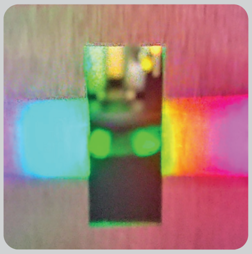
annual report 2021

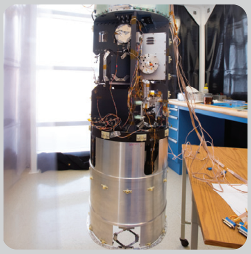
research

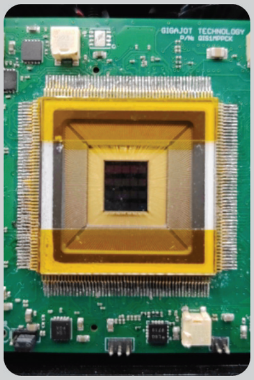
research
student vignettes
external
collaborators

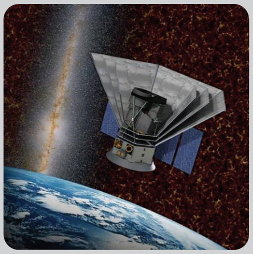


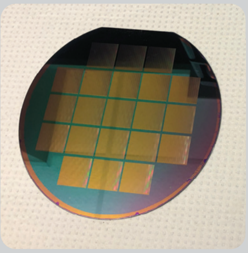












research

15 research areas

37 active research awards

10

newly funded grants

7 faculty members engaged in research

40 students actively participating in research

$16.7M

active funding

Studies of the Diffuse Optical Background with New Horizons

Michael Zemcov, NASA

The goal of this project is to measure the cosmic optical background (COB), which is the sum of all emission from sources beyond the Milky Way at optical wavelengths, using images taken by the Long-Range Reconnaissance Imager (LORRI) on New Horizons. This allows for a comparison between this measurement and all expected sources of emission such as galaxies, and potential identification of the source of any excess component of diffuse emission.

Over the past year, we have improved our subtraction of astrophysical foregrounds such as the diffuse galactic light (DGL), which is the contribution from dust in the Milky Way, and the integrated starlight (ISL), which is the contribution from faint, unresolved stars. We have improved our masking of bright stars and verified our estimate of the ISL with the Gaia DR2 catalog. We also corrected our images for known detector defects and developed a model for estimation of the contribution from diffuse optical ghosting due to off-axis bright sources (Figure 1).

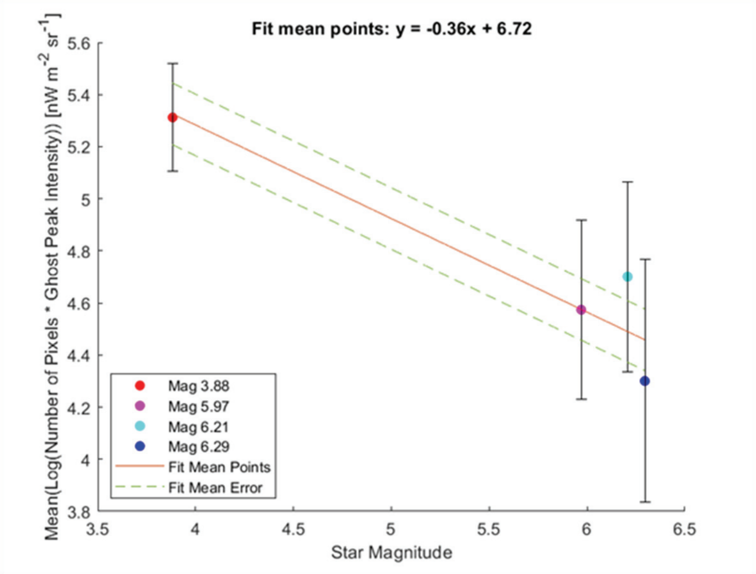


Figure 1. We predict the diffuse brightness caused by optical ghosting of off-axis bright stars by calculating the relationship between mean ghost intensity of measured ghosts and the magnitude of the star determined to cause each ghost. Each star is given a color-coded point, with black error bars indicating the standard deviation of all ghost intensities for that star. The orange line gives the linear fit between the points, with green dashed lines indicating the standard error on the fit.

Previously, we obtained companion images for select fields using the WIYN 0.9-m telescope at the Kitt Peak National Observatory to verify our estimate of the ISL. We compared source density in those images to that predicted by the TRILEGAL model (currently used for estimating the ISL) and the Gaia DR2 catalog, allowing us to determine that these images do not achieve sufficient depth to replace the TRILEGAL model for ISL estimation (Figure 2).

Future plans include an analysis of diffuse scattered light from all sources outside the LORRI field of view, data analysis pipeline validation, and a final analysis of all presently available LORRI data through 2020 including error assessment. This will provide a comprehensive measurement of the COB and an important point of comparison to previous measurements and current galaxy counts.

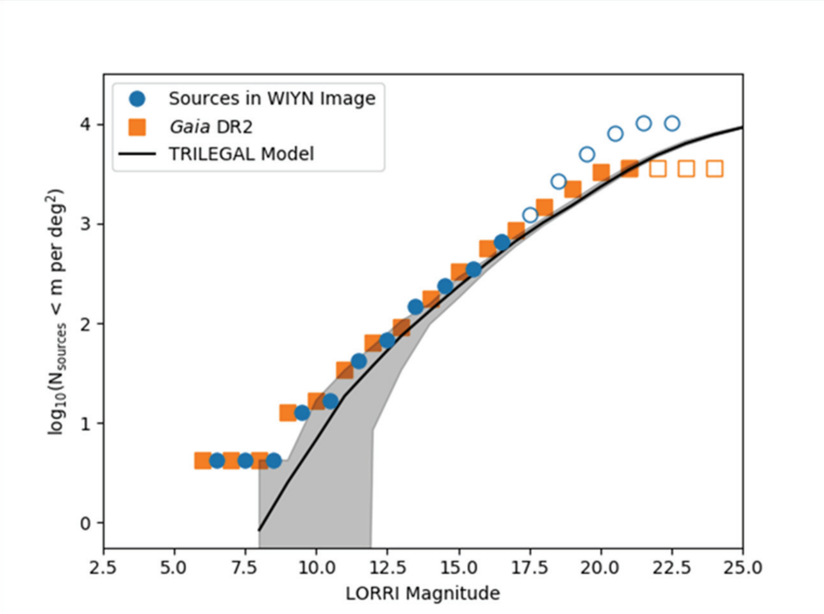


Figure 2. The graph shows a comparison of cumulative source density per magnitude bin for an example WIYN companion image of a LORRI field (blue), the mean of 10 TRILEGAL simulations of the same field (black), and Gaia DR2 sources (orange). WIYN marker bins are offset from Gaia marker bins by 0.5 mag for clarity. The open blue markers indicate the contribution from galaxies at mR > 16, and the open orange markers indicate the mG ~21 Gaia completion limit. The black shaded region gives the minimum and maximum cumulative source density of the 10 TRILEGAL simulations for each magnitude bin. The WIYN image does not achieve sufficient depth to replace TRILEGAL simulations as the primary method for calculating the contribution to the ISL from faint sources and has a large contribution from galaxies that would be challenging to remove.

A Single Photon Sensing and Photon Number Resolving Detector for NASA Missions

Donald Figer, NASA

Single photon counting large-format detectors will be a key technology for future NASA Astrophysics missions such as the LUVIOR and HabEx mission concepts. The goal of this project is to characterize and demonstrate single photon-sensing and photon-number resolving CMOS image sensors, developed by Dr. Eric Fossum (Dartmouth College) and his team of graduate students. Following the sensor characterization, we will irradiate one device to simulate damage from high-energy radiation in space while we demonstrate astronomical observations with another device at a telescope. In collaboration with Dartmouth, we will redesign the detector to achieve the science requirements of future NASA missions.

This project involves the work of numerous students, including one Dartmouth College graduate student, four RIT graduate students and seven RIT undergraduate students. The team fabricated the system hardware and electronics necessary to interface and control the QIS with our existing automated test suite (Figure 3). Now, the team is working to complete the Field Programmable Gate Array (FPGA) hardware program, which is responsible for generating system clocks and managing data transfer from the image sensor to a computer.

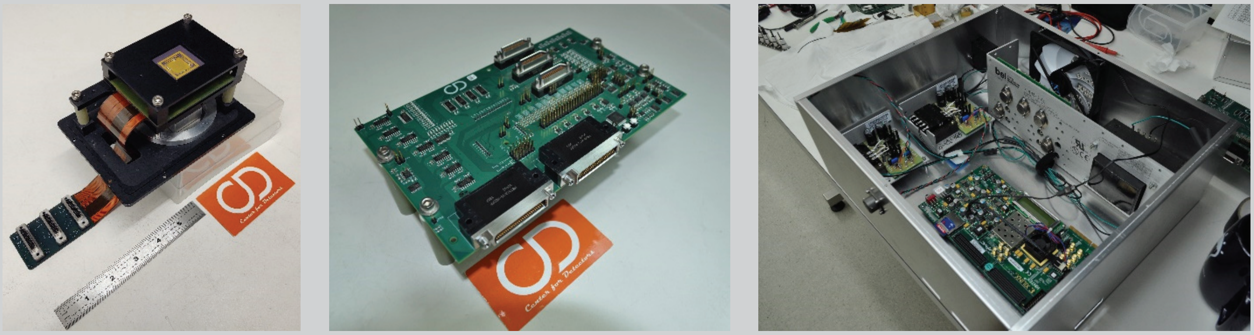


Figure 3. (left) The detector PCB is integrated within the detector PCB mount. (middle) The Cold Electronics Board (CEB) is mounted on g10 standoffs. The CEB contains a DAC, ADCs, current sources, and other components necessary to operate the QIS. (right) The assembled warm electronics box contains the FPGA, a custom PCB for LVDs communication, and low-noise linear power supplies that power the FPGA, and the CEB.

In addition to the development of our system electronics, we simulated the radiation space environment for an L2 orbit and computed the expected dark current increase of the QIS over an 11-year space mission. These results allow us to develop a radiation test program to demonstrate the radiation tolerance of the device (Figure 4). Finally, we began development of a new QIS for use in future NASA missions. By using the future NASA signature science cases found in the Large Ultraviolet Optical Infrared Surveyor (LUVOIR) final report, we derived the technical requirements and constraints on characterization metrics that a redesign sensor must achieve in order to complete the science.

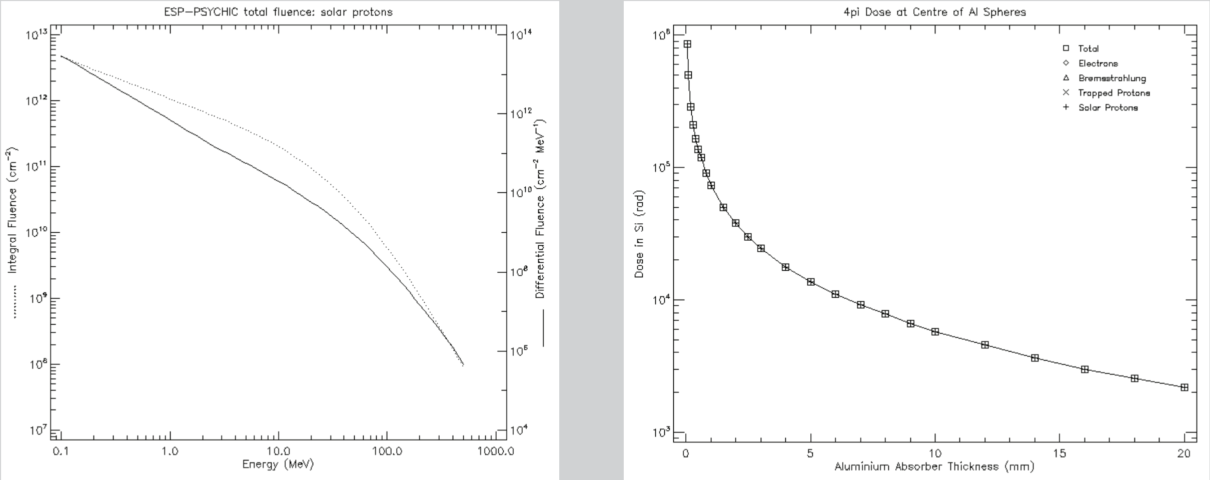


Figure 4. (left) The plot simulates solar proton fluence as a function of particle energy for 11-year mission at L2. (right) The graph shows simulated radiation dose at detector as a function of aluminum spherical shield thickness to approximate future telescope designs. The dose of other radiation sources (trapped protons, bremsstrahlung, and trapped electrons) is insignificant compared to the simulated dose for solar protons.

New Infrared Detectors for Astrophysics

Donald Figer, NSF/NASA

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 used in 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 an 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 5 (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 5 (right) shows the dark current histogram of F17. Compared with F13 in Figure 4 (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.

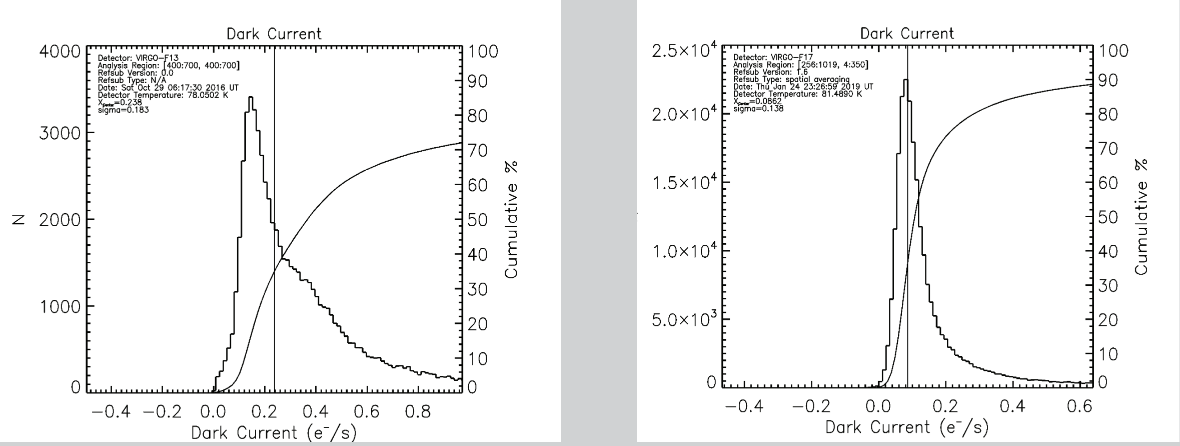


Figure 5. This figure shows the dark current histograms for detectors F13 (left) and F17 (right) at 80K.

In F17, we also noticed an increase in the magnitude of the high dark current tail to the detector after exposure 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 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 6 shows that persistence in F17 is wavelength dependent and decreases as a percentage of fluence during illumination. Previously characterized detectors, like F17, share these trends. Overall persistence in F17, however, is lower, reduced by approximately half at lower well capacities.

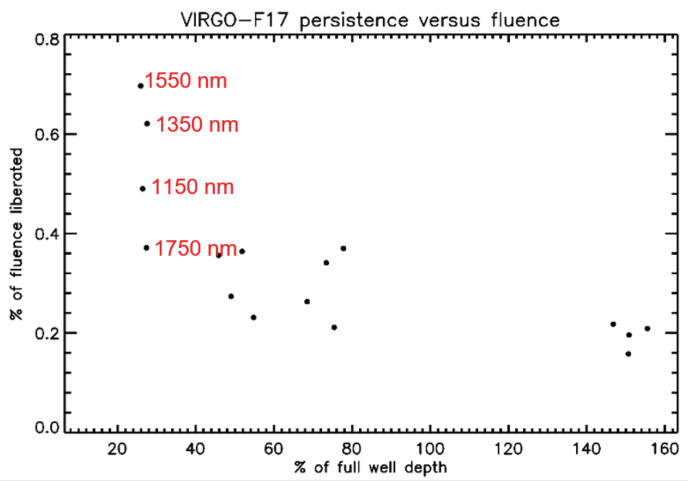


Figure 6. This figure shows the persistence vs fluence plot for F17 at 1150, 1350, 1550, and 1750 nm.

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.

Artificial Intelligence RF Photonic Signal Classifier

Stefan Preble, L3Harris Technologies

The objective of this project is to prove the feasibility of RF signal classification implemented using an integrated photonic neural network (Figure 7). The advantage of photonics is that it can realize wideband signal processing, at the speed of light, with minimal energy consumption. This project has made several technical advances: (1) Identified an approach for RF signal classification that uses photonics to simplify neural network classification. (2) Designed a linear optical neural network that is compact and achieves direct isomorphism between hardware and algorithm, enabling light speed neural processing. (3) Developed a new approach for realizing nonlinear photonic activation functions using optical-electronic-optical (O-E-O) transduction. Demonstrated proof-of-principal experimental operation and modeled cascadability.

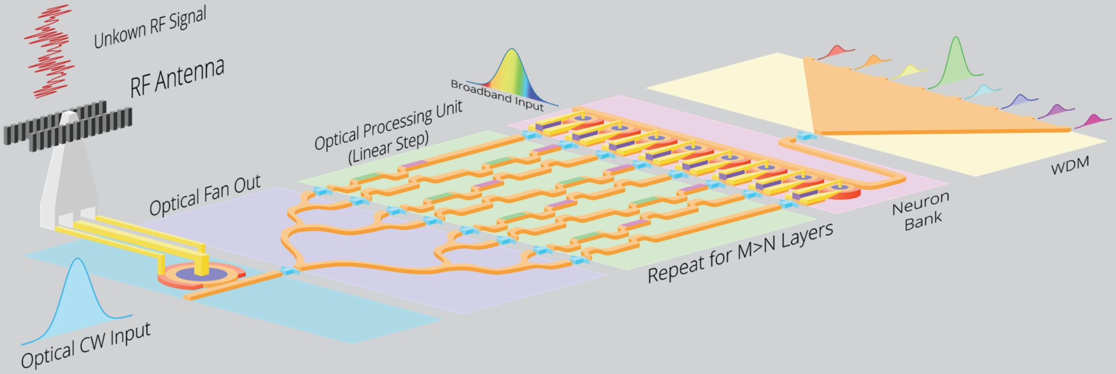


Figure 7. The figure shows the RF Photonic Neural Network Signal Processor.

Integrated Quantum Photonics for Photon-Ion Entanglement

Stefan Preble, Air Force Research Laboratory

The primary objective of this project is the realization of integrated quantum photonic platforms. We are developing platforms for UV-visible and separately for telecommunication wavelengths.

The UV-Vis platform uses AlN (Aluminum Nitride) waveguides, which is a large bandgap semiconductor that is transparent into the deep-UV. Consequently, it is ideal for interfacing with the visible/UV wavelengths of ion (such as Yb+, Ca+, Be+, Mg+, Sr+, Ba+, Zn+, Hg+ and Cd+) transitions. In this project, we have demonstrated the first high-Q ring resonators that operate at UV wavelengths.

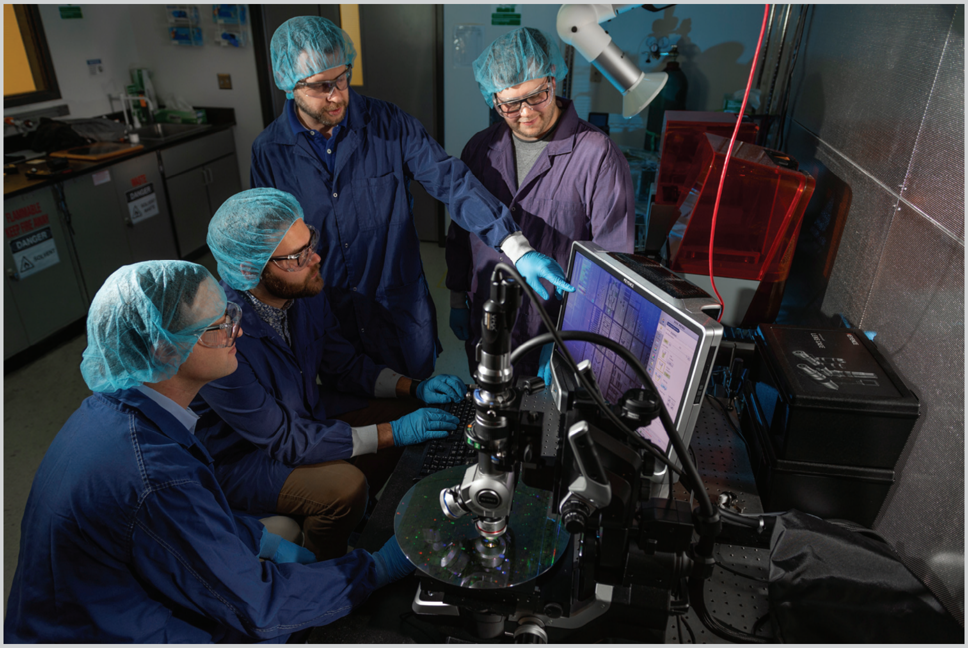


Figure 8. RIT researchers (From left to right, Stefan Preble, Matthew van Niekerk, Michael Fanto, and Gregory Howland) inspect the quantum photonics wafer under a microscope. Photo Credit: Elizabeth Lamark.

The telecommunication platform leverages the mass production of CMOS manufacturing to realize high quality, reproducible quantum photonic circuits in Silicon and Silicon Nitride. In collaboration with AFRL (Air Force Research Laboratory), RIT produced the Department of Defense's first-ever fully integrated 300mm diameter quantum photonics wafer (Figure 8). The wafer contains circuits for producing, entangling and manipulating quantum states of light. These are being used for quantum computing, communication and sensing applications. The wafer includes chip designs from both RIT and Air Force Research Laboratory, along with designs by collaborators at MIT, Purdue University, Oak Ridge National Laboratory, Army Research Lab.

Wideband Quantum Photonic Integrated Circuits for Highly Non-degenerate Photon Pair Entanglement

Stefan Preble, Air Force/AdvR, Inc.

The overall goal of this project is to develop and integrate Si photonics based wideband Quantum Photonic Integrated Circuits (Q-PICs) efficiently and robustly with highly nonlinear polarization entangled photon pair generating waveguides. The wideband Q-PICs can provide spectral filtering, timing compensation and low-loss routing to on-chip photonic gates for quantum processing. This project demonstrated the feasibility of maintaining robust, high efficiency coupling between an arrayed highly non-degenerate photon pair source and a hybrid Si/SiN Q-PIC. The key innovation in this effort is butt coupling a periodically poled Potassium Titanyl Phosphate (KTP) waveguide-based wavelength division Multiplexer (WDM) to the hybrid Q-PIC, which is fabricated with both Si and SiN waveguides for low loss transmission of the highly non-degenerate wavelengths (1550/810). High photon pair generation was demonstrated with high efficiency coupling to the Q-PIC (Figure 9).

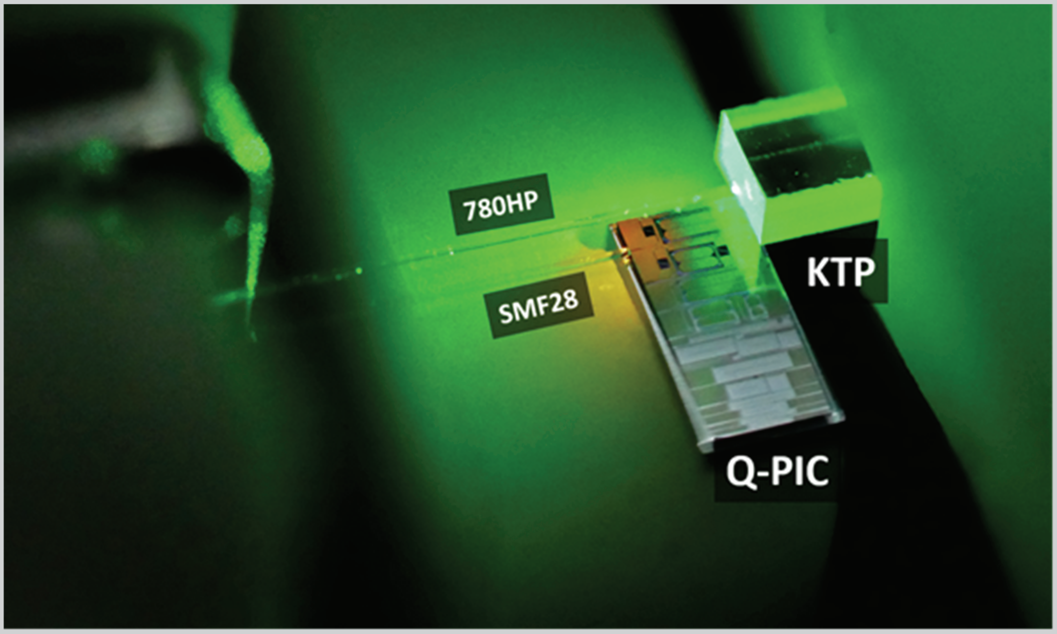


Figure 9. The green laser (532nm) pumps KTP and produces 810+1550nm photon pairs. The photons are separated by a WDM on the KTP chip. The 1550nm photons are coupled to a Q-PIC and then coupled into a SMF28 fiber; the 810nm photons are coupled directly out of the KTP into a 780HP single mode fiber.

RIT/L3Harris Quantum Information Collaboration

Stefan Preble, L3Harris Technologies

L3Harris has partnered with RIT on experiments and analysis focused on quantum information processing for communication, sensing, and computing. The exploratory partnership provides L3Harris access to FPI's laboratory space and researchers and students (Figure 10Figure 10 with the goal of identifying areas they can collaborate on in the future.

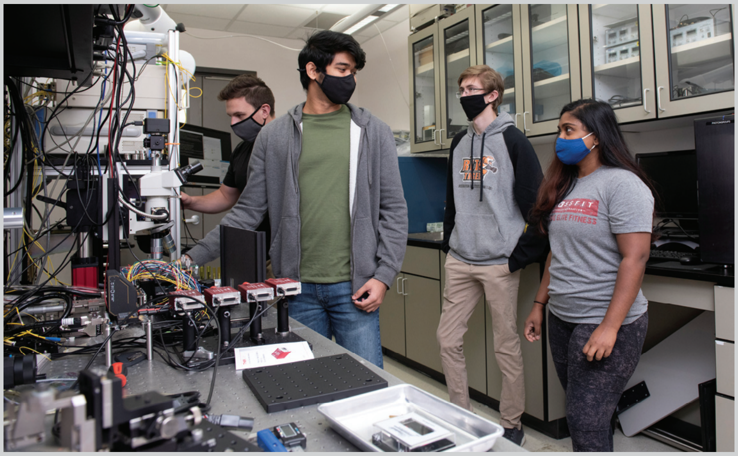


Figure 10. The collaboration between RIT and L3Harris engages students from RIT's graduate programs in physics and microsystems engineering. Photo Credit: A. Sue Weisler

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

Jing Zhang, Office of Naval Research

The objective of this project is to advance the fundamental understanding of the physics of GaN-based active regions in nitride heterostructures in order to enable high-efficiency electrically-injected UV lasers and emitters with wavelengths ranging from 220 nm to 300 nm at room temperature. Particularly, this research focuses on the fundamental understanding of the valence band structure of lll-Nitride wide bandgap gain active region, and develop promising solutions for nanostructured quantum wells and the 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.

SPHEREx: An All-Sky Spectral Survey, Phase B

Michael Zemcov, NASA/Jet Propulsion Lab

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. NASA selected SPHEREx for development in February 2019. SPHEREx is designed to map the large-scale structure of galaxies in the universe to shed light on the first instants of the universe, 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 that Zemcov's team is developing. We recently submitted a paper on advanced point spread function reconstruction techniques for the instrument (Figure 11). Over the past year, the SPHEREx team has remained busy executing the program's Phase B, during which final mission trades are studied and preliminary designs are drawn up. We expect a preliminary design review sometime in autumn 2020, after which we will begin the instrument build phase. SPHEREx is currently scheduled to launch in 2024 and is funded for a full mission through 2027.

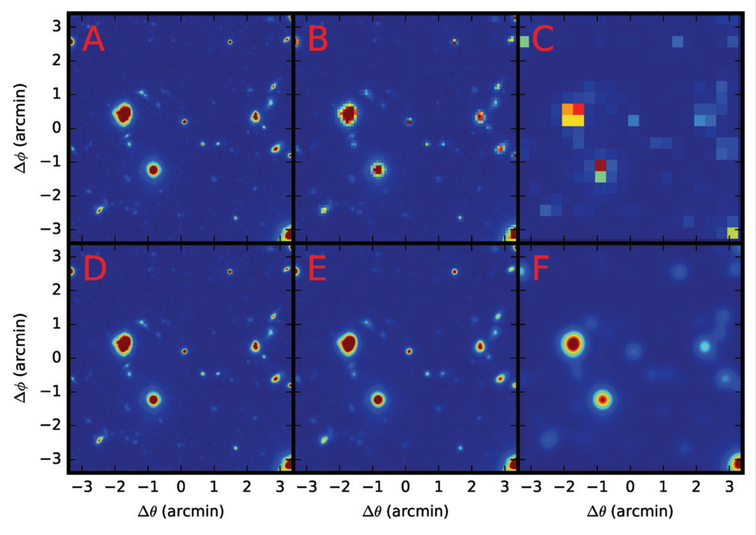


Figure 11. This figure shows examples of the relationship between pixelization and PSF. The top row shows the effect of changes in the pixel gridding of the input images, shown in Panel A, while the bottom row shows the effect of changing the width of the PSF. In Panel A, the pixelization is matched to the optical PSF, so that the FWHM~ 1 pixel. In this case, the spatial resolution of the telescope dominates the spatial resolution of the image. In Panel B, we show the case where θpix/FWHM~ 5 and the image spatial resolution is dominated by the pixel grid. Panel C shows the θpix/FWHM~ 20 case where the image spatial resolution is heavily gridding-dominated. The method described here takes advantage of the fact that the PSF is sampled in many different ways with respect to the pixel grid to allow reconstruction of the sub-pixel PSF shape. In the bottom row, we show examples of FWHMPSF/θpix = {2,5,20} in Panels D, E and F, respectively. In these cases, the sub-pixel PSF can be easily measured from point-like sources, and the method described here offers no improvement.

Development of 400 nm GaN laser diode

Jing Zhang

Escalating trends in global energy consumption mandates like 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 and 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 contain radially segmented p-i-n junctions 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.

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

Jing Zhang, NSF

III-nitride-based semiconductor (AlN, GaN, and InN) ultraviolet (UV) optoelectronics have great potential in replacing bulky mercury lamps and excimer lasers due 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.

Measuring Reionization and the Growth of Molecular Gas with TIME

Michael Zemcov, NSF/Caltech

While waiting for the TIME instrument's second deployment, the team has focused on improving the quicklook data analysis infrastructure and simulated data pipeline. Work continued on an advanced biasing technique to quickly determine the state of almost 2000 TES bolometers, and then electrically bias them for optimal detection of sub-mm photons. This involved writing a script for determining the optimal bias during lab conditions, and then adjusting this bias for changes in loading due to atmosphere and astrophysical sources. Figure 12 shows the detection of the optimal bias regime denoted by the stars for each detector in a column. The incremental biasing technique is accomplished by choosing the most conservative bias and slowly stepping down until a maximum number of detectors can be reached. Biasing too low renders the detectors insensitive to on sky photons. This process is being automated for quick calibration of the instrument between science observations.

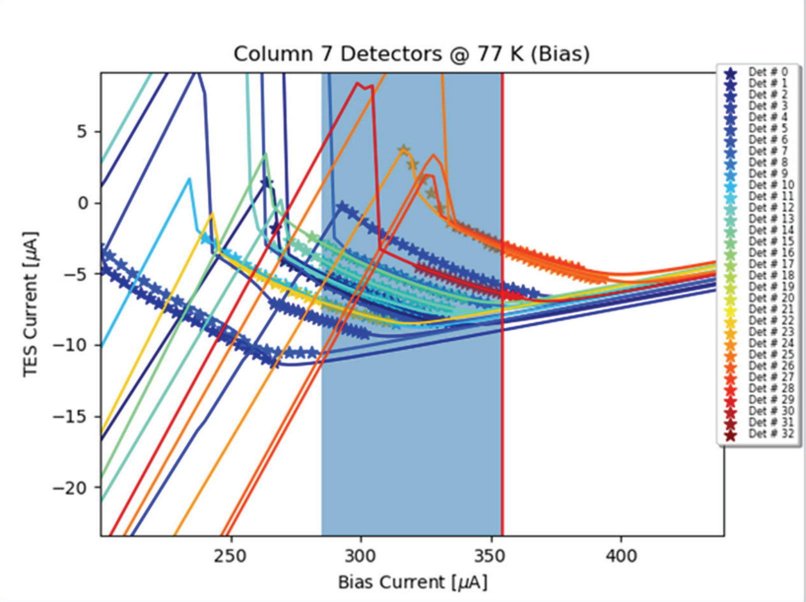


Figure 12. Each line in this graph represents an individual detector within the column for a specific lab temperature. The red line is the most conservative starting point at which to bias without shutting down the detectors. This is called the advanced detector biasing technique.

Updates were also made to the map making code which is responsible for converting raw detector timestreams into science output. To test the systematics and biases introduced into the data from the analysis pipeline, the team helped create simulated science data. TIME collaborators created artificial science sources, mimicking some of the planets observed in the last engineering run, and added atmospheric noise realizations. The team provided a simulated telescope scanning script which sampled this data in the appropriate sky configuration and output realistic detector timestreams (Figure 13). After these are run through the map making pipeline, the difference between the output maps and the input simulated sources should provide correctional factors used in the real analysis.

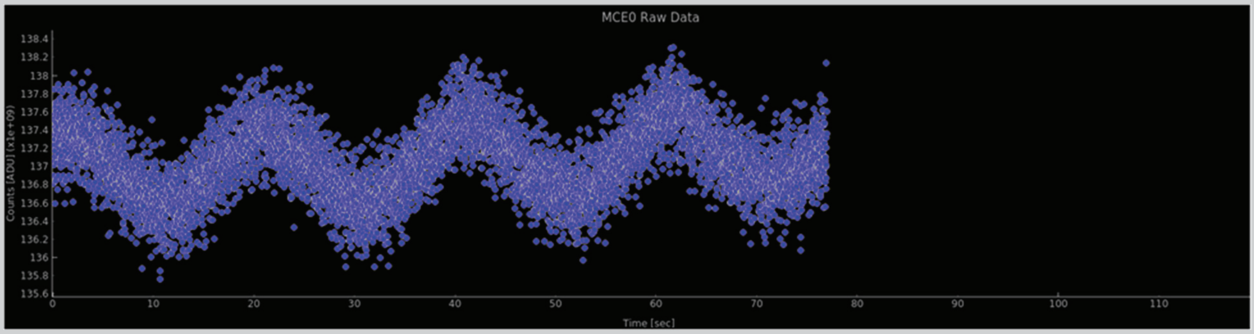


Figure 13. Above is a simulated detector timestream of 250 K blackbody source. This data includes frequency dependent noise from the atmosphere, and is made by artificially scanning back and forth across a 2D square of data. This data is visualized in the same GUI used for real TIME data acquisition at the telescope.

Diagnosing, Addressing, and Forecasting CIB Contamination in Spectral Measurements of the Sunyaev Zel'dovich Effect

Michael Zemcov, NASA

We have updated and improved our analysis of the ICM properties for the cluster RX J1347.5-1145. Significant improvements have been made to the simulated SPIRE map pipeline in order to reduce the error on the amplitude of the Sunyaev-Zeldovich effect. We have shifted to using an older empirical model for generating point sources in our images in order to better fit the high flux end of the map. Figure 14 shows the map histogram generated by both the Bethermin et al. 2012 and SIDES catalog, with the former clearly the better fit to the data.

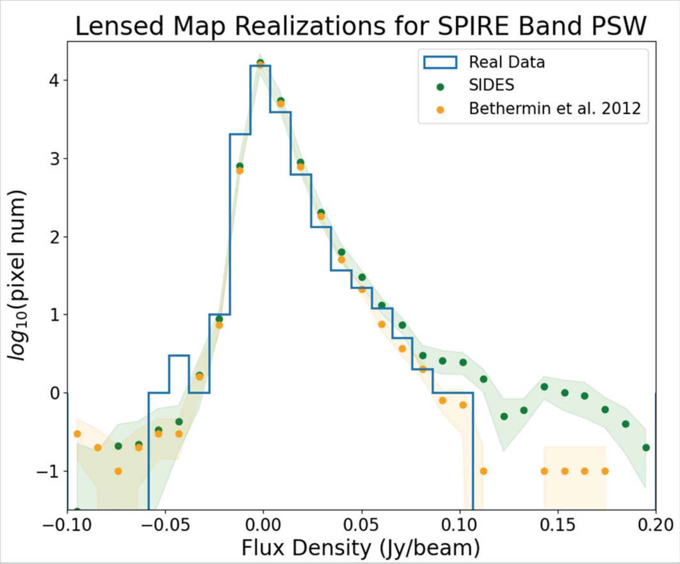


Figure 14. The figures show the identification and modeling of CIB point sources from SPIRE maps inside of PCAT. The challenge in this dataset is to prevent removing the extended emission from the SZ effect along with the flux from point sources. Ideally, the identified and removed point sources match the known source flux distribution from mock realizations of the same patch of sky.

In addition, we are also improving our simulations by mimicking the bright red sources seen in the real image. Figure 15 shows an example of the real SPIRE data, where 250, 350, and 500 micron bands were used to create a false color image. The central bright source in the image is one example of a source with an exceptionally red spectrum. Since objects like this are relatively rare in any single catalog realization, we used the point source cataloging software PCAT to identify the positions and fluxes of bright sources from the real map. We use the PCAT catalog to place these in exactly the same position in our simulated maps. This method allows us to characterize the uncertainty in our fit due to the unknown blend of point sources in the unresolved background. Each simulated realization will have a different distribution of these background sources, which in turn modifies our estimate of the SZ effect brightness in the image.

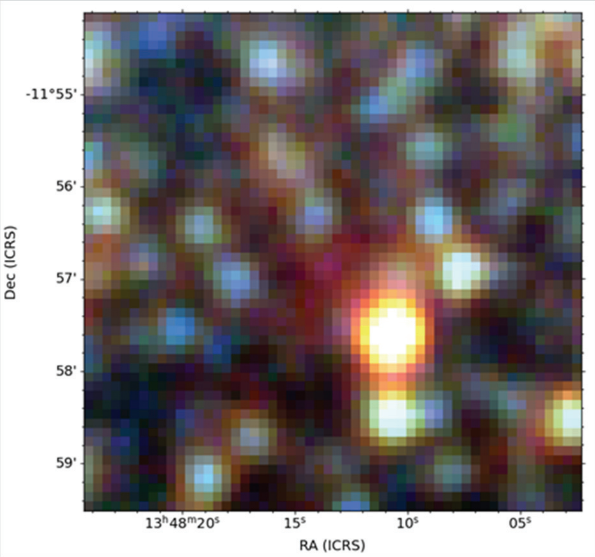


Figure 15. This schematic of the SPIRE data analysis pipeline was used to calculate the temperature of the gas in our cluster sample. PCAT is responsible for the middle three sections by modeling and removing CIB point sources, fitting templates for galactic dust, and the background flux offset. The residual contains the SZ effect, instrument noise, and confusion noise. The remaining signal is fit using an SZ template created by Bolocam; a ground based, bolometric SZ instrument.

Development of an On-Chip Integrated Spectrometer for Far-IR Astrophysics

Michael Zemcov, NASA /University of Illinois - Urbana Champaign

The primary objective is the production of an integrated on-chip spectrometer prototype operable at 150 micron wavelength. The spectrometer will be integrated with a kinetic inductance device (KID) detector array on the same chip, integrating the light dispersion and detection on a single Si wafer. We target a spectral resolution of R=I00, and plan to demonstrate at least 8 bands around the central wavelength. Spectral testing of the spectrometer prototype will be carried out using a compact Fourier Transform Spectrometer (FTS) that is being developed at RIT (Figure 16).

The FTS consists of a simple interferometer fed by a hot or cold thermal source, with path length difference adjusted using a linear actuator. The FTS is designed to be operated within a small cryostat to reduce stray radiation loading, and coupled either directly or via a small vacuum window to match that of the test bed. Varying the path length introduces a changing pattern of interference fringes at the detector under test, which will be analyzed to reconstruct the detector response as a function of frequency. The output of the FTS itself will be characterized using a laboratory bolometer system. Currently a warm version of the FTS system is being tested to aid in the development of software and integration of the final cold design. Once warm testing is finished we will modify this existing system for cryogenic operation.

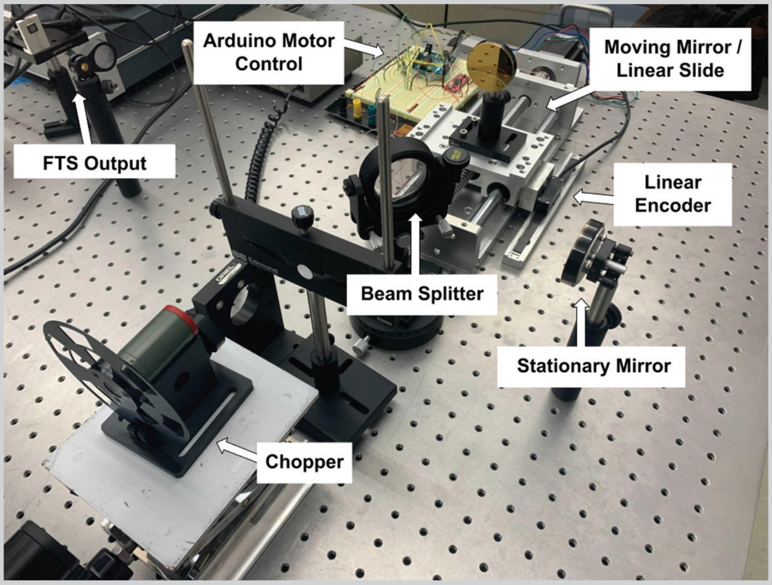


Figure 16. To allow for easier development of the software and techniques needed to create a cryogenic infrared FTS, we have developed an optical counterpart that mechanically operates very similarly. Using a red laser, we can visually focus the light traveling through the FTS. This technique allows for quick adjustments to the setup that would take much longer with an IR system. We are working on creating a spectrum of the laser in the same process as we would for the infrared using Python to collect positional information from a linear encoder and voltages from the output detector.

Development of Quantum Dot Coated Detector Arrays

Zoran Ninkov, NYSTAR/University of Rochester

There are many interesting things to see in the ultraviolet (UV). Lithography for integrated circuit production is exposed with 193 nm light with future, analytical instruments use UV emissions to identify materials, and honeybees' view of flowers include the UV region. Current silicon CMOS or CCD based detectors used in standard digital cameras do a poor job of recording UV images. Switching to exotic materials or polishing the detector until it is so thin that it is flexible and almost transparent may improve the ability to detect UV light. 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. Standard detector chips more readily record visible light. We use an inkjet printer to deposit the quantum dots. This research has developed a method of coating detector arrays with nanomaterials and applied it to improve the ability of detectors to record UV and blue light (Figure 17).

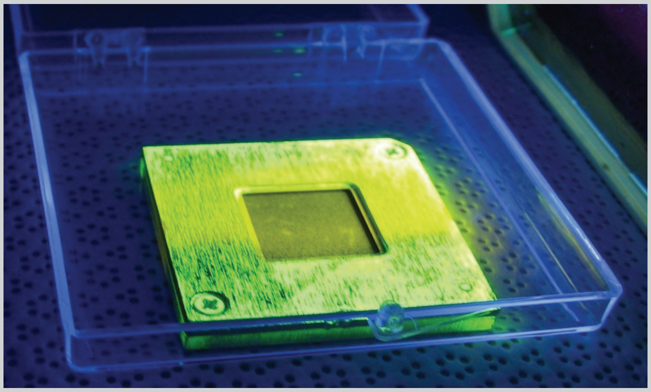


Figure 17. The yellow/green device above is a Quantum Dot coated detector in an aluminum mask under UV illumination. The active area is 15 mm×15 mm.

Analysis of The Optical Properties of Digital Micromirror Devices in The Ultraviolet Wavelength Regime

Zoran Ninkov, Space Telescope Science Institute

RIT proposes to support the efforts "The Space Telescope Ultraviolet Facility (The STUF)" project led by STScl PI Mario Gennaro. RIT will provide digital micromirror devices (DMDs) with standard protective windows replaced by ultraviolet transparent windows appropriate for studies of DMDs optical properties in the ultraviolet regime. Our proposal includes also a request to support a student from RIT for a two-year period.

MISE (The Mid-IR Sky Explorer)

Mike Zemcov

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 18 shows an image of Jupiter obtained from that data, revealing the polarization signature.

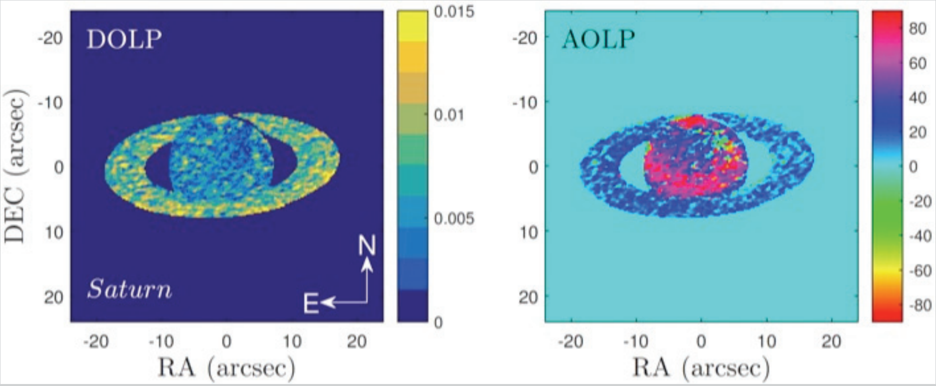


Figure 18. The figure shows two images of Jupiter in degree of linear polarization and angle of polarization.

Quantum Optical Semiconductor Chip and its Application to Quantum communication

Stefan Preble, Office of Naval Research/AdvR, Inc.

Develop a quantum optical semiconductor chip and demonstrate its application to efficient photonic entanglement, efficient logic gates such as Hadamard and CNOT, and quantum communication protocols through fiber optical channels.

On-Chip Quantum Photonic Sensors Using Entangled Photons and Squeezed States

Stefan Preble, Oak Ridge National Lab

As a part of this project, we have designed and tested new components that are more efficient and effective at manipulating the physical properties of light. These results have also demonstrated unique applications in quantum information science specifically for processing and sensing. We have also started laying out the design work for a different integrated photonics platform, aluminum nitride, which will be fabricated in a standard CMOS foundry.

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

Parsian Mohseni, NSF

Escalating trends in global energy consumption mandates like 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 and 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 contain radially segmented p-i-n junctions 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.

Serena Tramm

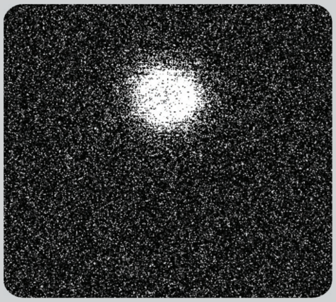
PhD Student Researcher, Astrophysical Sciences and Technology

Serena Tramm is a first-year graduate student pursuing her PhD in the Astrophysical Sciences and Technology program. She received her Bachelor of Science in Mechanical Engineering from Bucknell University in May 2020. For the past year, Serena has worked with Dr. Michael Zemcov and an international collaboration to develop a Fourier Transform Spectrometer (FTS) for far-infrared wavelengths. The FTS is being designed with the intent to one day calibrate instruments for detecting hypothesized dark matter particles outside the Earth's atmosphere. She has both developed and optimized the optical and thermal configurations. She designed the cryocooler housing as well as the layout of the spectrometer. The FTS is currently in the development phase with manufacturing to be completed by Fall 2021. Serena presented her work at the 237th American Astronomical Society Meeting in January 2021 and was awarded the Graduate Student Researcher Chambliss Astronomy Achievement Honorable Mention. Serena plans to continue to assist with the development of the FTS through the summer of 2021 while transitioning to her future role on the CIBER-2 project, also working with Dr. Zemcov.

Lazar Buntic

Graduate Student Researcher, Astrophysical Sciences and Technology

Lazar Buntic is a 2nd year graduate student in the AST department. He's spent the better part of the COVID lockdown figuring out how to redesign the Quanta Image Sensor (QIS) to fulfill the requirements of the upcoming LUVOIR space mission (Figure 19). He's currently preparing to take the QIS to the Mees Observatory to demonstrate the performance of the QIS. He is also preparing to perform radiation testing of the QIS at the Francis H. Burr Proton Therapy Center at Massachusetts General Hospital, to prove the radiation hardness of the QIS architecture for use in long-lived space missions. The QIS promises to be revolutionary for next generation space missions, and Lazar looks forward to seeing the effect that this technology will have on the development of science imagers in the future.



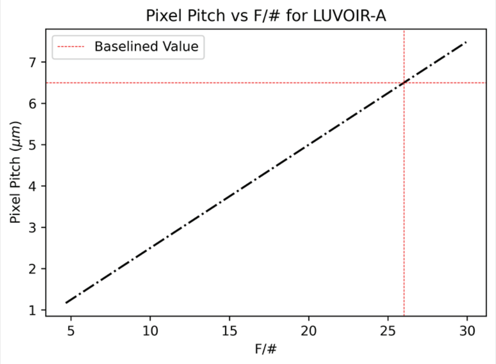


Figure 19. The graph above shows pixel pitch as a function of f-number for LUVOIR-A, assuming diffraction limited Nyquist sampling at 500 nm."

Victoria Butler

PhD Student Researcher, Astrophysical Sciences and Technology

Victoria Butler is a 5th year Ph.D candidate in the Astrophysical Sciences and Technology program, and on track to graduate in Spring 2022. She received her B.S. in Applied Physics with an Astronomy concentration at Rensselaer Polytechnic Institute (Troy, NY) in 2016.She is an experimental cosmologist studying the hot plasma in galaxy clusters at radio wavelengths. This intra-cluster medium (ICM) scatters photons from the Cosmic Microwave Background and is known as the Sunyaev-Zeldovich Effect (SZE). She uses archival data from the *Herschel*-SPIRE space telescope to study a flavor of this effect where the photons are scattered by electrons with relativistic energies. The rSZ effect can be used to estimate the temperature of the ICM and tells us something about the thermodynamic history of the cluster. She is performing an rSZ study on the galaxy cluster RXJ1347.5-1145 which is an exceptionally massive cool-core cluster with an X-ray temperature of roughly 16 keV. She helped create a custom analysis pipeline which fits an amplitude to the extended SZ emission using templates of the SZ shape from the Bolocam instrument. The amplitude from the three SPIRE bands is then fit with a spectrum using a maximum likelihood estimation technique which shows which ICM density and temperature produces the best fit spectrum. The results of her study should be published sometime 2021.

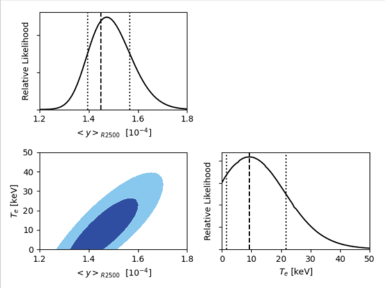


Figure 20. 2D confidence contours show the results of the Maximum Likelihood Estimation in the figures above. The 1D marginalized likelihoods are shown in the top and right figure for the y and T parameters respectively. The dashed line denotes the best fit value, while the dotted line is the 68% confidence interval.

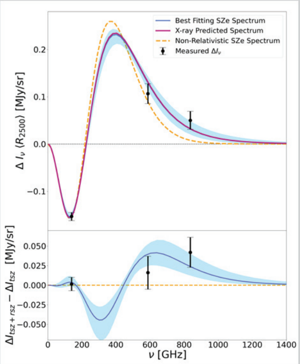


Figure 21. The generated spectrum for the best fitting y,T values is shown in blue in the graph above. The shaded region is the 1σ uncertainty on this spectrum for both top and bottom plot. Black points show the SZ amplitudes and uncertainties derived from the real SPIRE data.

Dale Mercado

Graduate Student Researcher, Astrophysical Sciences and Technology

Dale Mercado is a first year MS student in the Astrophysical Sciences and Technology program. He previously received his BS in Physics at RIT. This past year he has been working to develop an Infrared Fourier Transform Spectrometer (FTS) (Figure 22) for the calibration of future Infrared Detectors. Following the design of a Michelson-Morely interferometer this FTS is adapted with Infrared optics, and cryogenic conditions to reduce possible noise. This device will produce collimated IR light between the wavelengths of 50 - 500 μm with 1 μm resolution. In this research he has worked on developing automated control software written in python controlling an arduino and data collection from lab equipment, prototyping an optical FTS system for optical training and data processing calibrations, and is currently developing Anti-Reflection coatings techniques for the lenses required for the FTS in our labs. Current progress of this work was presented in a poster at the 237th American Astronomical Society Meeting in January 2021.

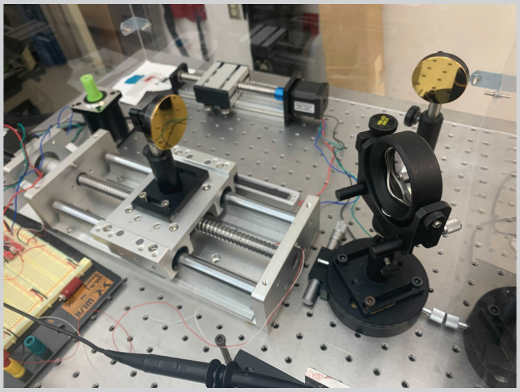


Figure 22. The current prototyped optical FTS (above) can determine the wavelengths of light traveling through in the system by changing the position of the mirror on the stage and observing the voltages from a detector.

Chi H. Nguyen

PhD Student Researcher, Astrophysical Sciences and Technology

Chi H. Nguyen is a recent alumna in the Astrophysical Sciences and Technology Ph.D program working with Dr. Michael Zemcov. Nguyen successfully defended in May 2021. Before coming to Rochester, she received a BS degree in Astronomy from the University of Arizona, Tucson. Nguyen's main research interests are the Extragalactic Background Light (EBL) and near-infrared instrumentation. The EBL probes the history and origin of stellar emission, and its fluctuations can be used to constrain models of star and galaxy formation. Her dissertation focuses on the Cosmic Infrared Background ExpeRiment 2 (CIBER-2) which comprises a small telescope and three HA-WAII-2RG detectors (0.5 - 2.0 micron) launched on a recoverable Black Brant IX sounding rocket. Nguyen led the characterization, integration, and launch campaign of CIBER-2. The first flight successfully concluded on June 7, 2021.Aside from CIBER-2 instrumentation, Nguyen also analyzed data from the last flight of CIBER-1. To extract the sky fluctuation signals from CIBER-1 data, she built and verified a model to account for the noise properties of its two near-infrared imagers. After graduation, Nguyen is heading to the California Institute of Technology to join the SPHEREx collaboration. At the same time, she is leading the analysis of CIBER-2 first flight.

Benjamin Dodds

Lab Assistant, Electrical Engineering

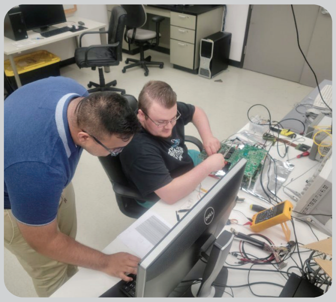
Ben Dodds is a fifth year pursuing both his Bachelor's and Master's degree in science in Electrical Engineering at RIT. He currently works on the NASA SAT Project, performing hardware verification and assembly (Figure 23). He also has helped created software to run on the Field Programmable Gate Array (FPGA) system for the Quanta Image Sensor (QIS) device.

Figure 23. Pictured above is the Warm Electronics Board Assembled for the SAT QIS Project.

Irfan Punekar

Graduate Researcher, Computer Engineering

Irfan Punekar is a fifth year student pursuing his Bachelors and Masters in Science in the Computer Engineering program. His current research is on the NASA SAT project, where he is working to develop a testing system for the Quanta Image Sensor (QIS), a single photon sensing and photon number resolving megapixel CMOS imager. The QIS is a 3D stacked CMOS Megapixel imager proposed, created, and developed by Eric Fossum, and is able to achieve photon number resolution at room temperature. Irfan specializes in field programmable gate array (FPGA) system design (Figure 24), embedded software design and implementation, and hardware / software systems integration.



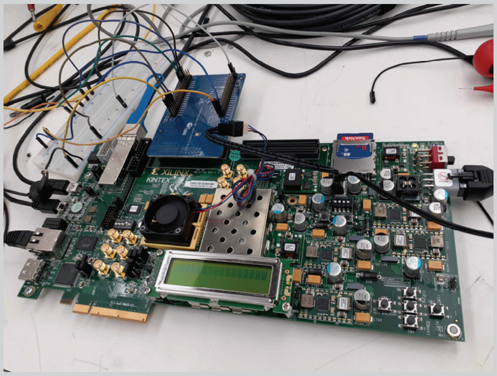
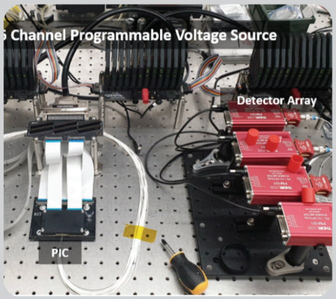


Figure 24. This FPGA evaluation kit forms the basis of the digital side of the data acquisition system for the single-photon detector project. Irfan designed the software for this system.

Vijay Soorya Shunmuga Sundaram

Graduate Research Assistant, Physics

Vijay S. S Sundaram is a second year Masters in Physics student. He is working with Dr. Stefan Preble and Dr. Greg Howland to investigate the feasibility of integrating a highly nonlinear, Periodically Poled Potassium Titanyl Phosphate (PPKTP) crystal with existing Silicon Photonic Integrated Circuits (Si-PIC) (Figure 25). This approach with enable the generation of highly nondegenerate visible-telecom photon pairs and provide a scalable system for their on-chip manipulation. Such a widely separated photon-pair source would form the key component of a quantum repeater circuit capable of transferring quantum states between distant quantum memories and processors, and for distributing entanglement over a series of such quantum nodes using already existing fiber-optic networks. Vijay successfully presented the results of this work at the CLEO 2021 Conference. He is also working on the testing and characterization of a photonic processor which would eventually be able to perform as a fully programmable, unitary matrix transformation function. This could then be used to realize a number of quantum logic gates and can be used for conducting quantum random walks or boson sampling experiments. Vijay will be joining the PhD in Microsystems Engineering program at RIT upon graduation.



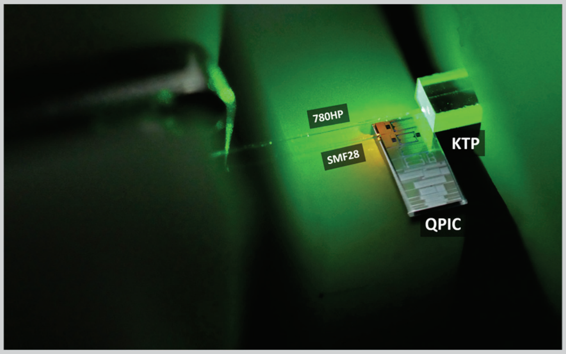


Figure 25. The PPKTP waveguide photon source above is pumped by a 532nm green laser, and producing a visible-telecom photon pair. The visible photon is coupled onto a 780HP fiber while the telecom photon is coupled to a silicon waveguide spiral on a Si-PIC chip.

Teresa Symons

PhD Student Researcher, Astrophysical Sciences and Technology

Teresa Symons is a fourth-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. During the past year, she published a paper titled “Superresolution reconstruction of severely undersampled point-spread functions using point-source stacking and deconvolution” in the Astrophysical Journal Supplement Series, presenting an algorithm for point spread function reconstruction she developed as part of the data analysis pipeline for the upcoming NASA medium explorer mission SPHEREx. She also analyzes images taken by the Long Range Reconnaissance Imager (LORRI) on NASA’s New Horizons spacecraft in order to measure the cosmic optical background (COB), which is the faint background of light in the universe from all sources outside the Milky Way at optical wavelengths (Figure 26). Measuring the COB allows for a comparison with all expected sources of emission such as galaxies, and potential identification of the source of any excess component of diffuse emission. Teresa presented a poster related to this work titled “Lessons learned from measuring the cosmic optical background with LORRI on New Horizons” at the 3rd Interstellar Probe Exploration Workshop, virtually hosted by the Johns Hopkins Applied Physics Laboratory.

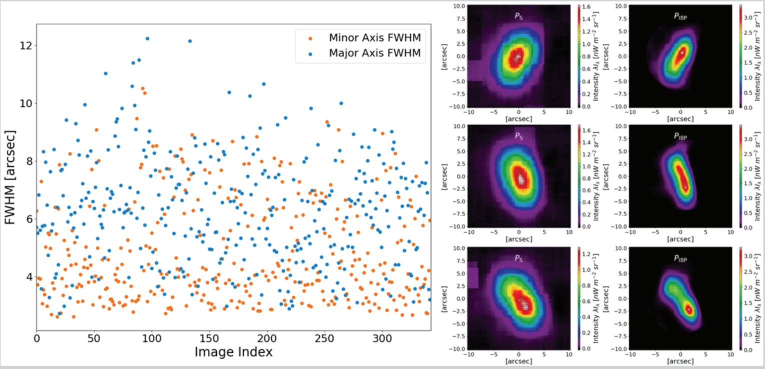


Figure 26. Estimation of LORRI's pointing stability. On the left is a comparison of measured major and minor axis full width half maximum (FWHM) for the reconstructed PSFs from a set of LORRI images. While FWHM varies, the lower limit is 2.6'', indicating a minimum pointing drift of ~1''. On the right are comparisons of P_S*, the stacked PSF, and* P_{IBP}*, the final reconstructed PSF, for several LORRI images.*

external funding

CfD projects are funded by a wide variety of sources, including federal agencies, industry, and private foundations. NSF, NASA, United States Air Force, and several other organizations awarded CfD $5.7M for projects this past fiscal year. Figure 27 illustrates the estimated funding expended by 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. The first table shows total funding amounts for newly awarded projects this year. The second table gives the total budgeted amount for ongoing grants within the fiscal year. The last table gives the total dollar amount for projects that ended in the past fiscal year.

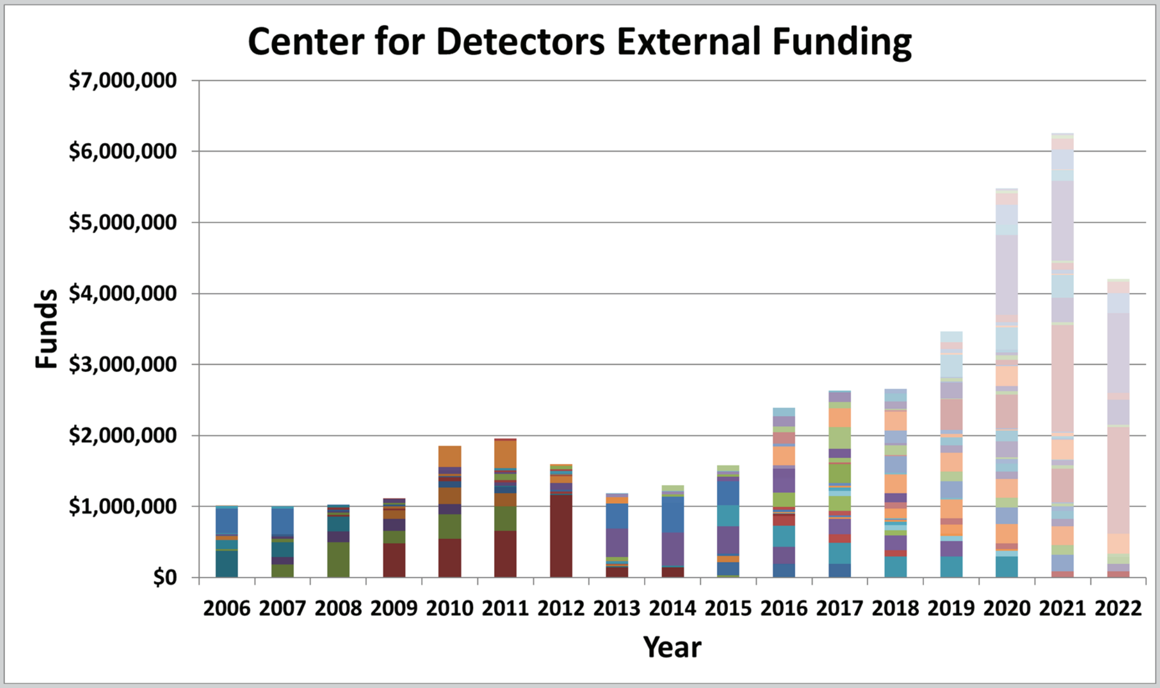


Figure 27. This chart shows historical and anticipated funding levels for CfD projects. Each color in the chart represents a unique research program and budget. Most projects have budgets that span multiple years. Federal agencies, national labs, and research foundations awarded CfD a total of $44M in 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
USAF/AdvR, Inc.	AFRL STTR Phase II: Wideband Quantum PICs (QPICs) for Conditioning, Routing and Gate Operations of Highly Non-degenerate Entangled Photons	3/17/2020 - 9/16/2022	$699,968
USAF/SUNYRF	AIM Academy Photonic Integrated Circuit ("PIC") Course Offerings (2019-2020)	2/15/2020 - 12/31/2020	$34,873
USAF/SUNYRF	AIM Academy Photonic Integrated Circuit 1 (PIC1) - Third Course Offering	3/1/2020 - 7/9/2020	$35,000

L3HT	Artificial Intelligence RF Photonic Signal Classifier	7/1/2020 - 6/30/2020	$49,888
Leonardo DRS	Development of 400 nm GaN laser diode	3/1/2020 - 2/28/2022	$75,837
NASA/UIUC	Development of an On-Chip Integrated Spectrometer for Far-IR Astrophysics	7/21/2020 - 7/20/2022	$127,358
NASA/UCI	MISE (The Mid-IR Sky Explorer)	6/25/2020 - 6/24/2020	$25,000
NYSESD/SUNYRF	NYS AIM Photonics Test, Assembly and Packaging (TAP) and Education & Workforce Development	5/1/2020 - 12/31/2023	$4,500,000
L3HT 3M Colibri System SpA TT Trading Co Ltd Creative Memories	RIT/L3Harris Quantum Information Collaboration	8/1/2020 - 6/30/2020	$65,625
L3HT	RIT/L3Harris Quantum Information Collaboration	8/1/2020 – 8/31/2020	$50,000
USAF	USAF - CRADA	4/12/2020 - 4/11/2026	$0
		Total	$5,663,549

Grants and Contracts - Ongoing

Title	Funding Source	Dates	Amount
NASA	A Single Photon Sensing and Photon Number Resolving Detector for NASA Missions	11/25/2019 - 11/24/2021	$945,229
NSF	Phase II: New Infrared Detectors for Astrophysics	9/15/2015 - 8/31/2022	$2,376,939
NSF	QLCI - CG: Quantum Photonic Institute	9/1/2019 - 8/31/2021	$149,214
NSF	EAGER: TDM solar cells: Bifacial III-V nanowire array on Si tandem junctions solar cells	5/1/2017 - 10/31/2020	$299,808
STScI	Analysis of the optical properties of digital micromirror devices in the ultraviolet wavelength regime	4/17/2020 - 12/31/2021	$142,007
NSF/JHU	Collaborative Research: SOAR/SAM Multi Object Spectrograph (SAMOS)	9/1/2016 - 8/31/2020	$71,036
NASA	Development of Digital Micromirror Devices for Far-UV Applications	1/1/2018 - 12/31/2021	$536,981
ThemFisher	Development of Quantum Dot Coated Detector Arrays	7/1/2019 - 6/30/2021	$48,000

NSF	Program Officer at NSF	1/21/2020 - 1/20/2022	$471,640
USAF/SUNYRF	AIM Academy Photonic Integrated Circuit Design and Test Education Curricula	1/1/2018 - 12/31/2020	$122,012
USAF/Phase Sensitive Innovations Inc.	Air Force STTR Phase II AF16-AT01: "Wafer-Level Electronic-Photonic Co-Packaging"	9/6/2018 - 10/30/2021	$250,257
USAF	Integrated Quantum Photonics for Photon-Ion Entanglement	3/14/2016 - 9/30/2021	$1,600,000
ONR/AdvR, Inc.	Navy SITR 2020.A - Topic N20A-T005 (Quantum Optical Semiconductor Chip and its Application to Quantum Communication)	5/4/2020 - 10/30/2020	$66,810
IC-USG/FFRDC-ORNL	On-chip quantum photonic sensors using entangled photons and squeezed states	10/1/2019 - 9/30/2021	$14,000
NSF	PIC: Hybrid Silicon Electronic Photonic Integrated Neuromorphic Networks	9/1/2018 - 8/31/2022	$523,053
USAF/AdvR, Inc.	Wideband Quantum Photonic Integrated Circuits for Highly Non-degenerate Photon Pair Entanglement	6/16/2020 - 11/16/2020	$72,260
NYSESD/SUNYRF	TAP Hub 2019 Development TAP Hub 2019 Development	1/1/2019 - 3/31/2021	$450,586
NASA	Diagnosing, Addressing, and Forecasting CIB Contamination in Spectral Measurements of the Sunyaev Zel'dovich Effect	5/13/2019 - 5/12/2022	$385,422
NSF/CALTECH	Measuring Reionization and the Growth of Molecular Gas with TIME	9/1/2019 - 8/31/2022	$192,389
NASA	Multi-Color Anisotropy Measurements of Cosmic Near-Infrared Extragalactic Background Light with CIBER-2	3/3/2020 - 3/2/2022	$844,110
NASA	Probing the History of Structure Formation through Intensity Mapping of the Near-Infrared Extragalactic Background Light	9/20/2017 - 9/19/2021	$122,697
NASA/CALTECH	SPHEREx: An All-Sky Spectral Survey, Phase B	5/20/2019 - 7/31/2021	$73,085
NASA	Studies of the Diffuse Optical Background with New Horizons	9/4/2018 - 9/3/2021	$456,000

NSF	CAREER: Development of High Efficiency Ultraviolet Optoelectronics: Physics and Novel Device Concepts	3/15/2018 - 2/28/2023	$500,145
ONR	Understanding and Engineering Valence Band Structures of III-Nitride Semiconductors for High-Efficiency Ultraviolet Lasers and Emitters	6/1/2016 - 11/30/2020	$325,100
		Total	$11,038,780

Grants and Contracts - Completed within the Past Year

Title	Funding Source	Dates	Amount
Development of Quantum Dot Coated Detector Arrays	NYSDED/UR	7/1/2019 - 6/30/2020	$9,000
Precision - RIT Fiber Attach	Precision Optical Transceivers	1/15/2019 - 8/31/2019	$45,000
Multi-Color Anisotropy Measurements of Cosmic Near-Infrared Extragalactic Background Light with CIBER2	NASA/CALTECH	5/2/2016 - 7/31/2019	$280,552
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
TAP Process Development 2018 (Rochester Hub)	USAF/SUNYRF	1/1/2018 - 12/31/2019	$498,489
AIM Academy Photonic Integrated Circuit Design and Test Education Curricula	USAF/SUNYRF	1/1/2018 - 4/1/2020	$122,012
TAP Hub 2019 Development TAP Hub 2019 Development	NYSESD/SUNYRF	1/1/2019 - 6/30/2020	$450,586
		Total	$1,730,739.00

collaborating partners

8

active projects with NASA

4

new projects funded with USAF

5.6

million dollars in new awards

10

new projects

collaborating partners

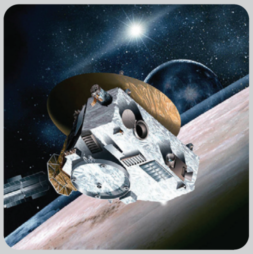
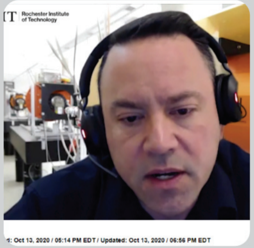
The CfD collaborates extensively with a broad range of organizations, including other academic institutions, government agencies, and industry leaders. Some examples are Caltech, Cornell University, University of Rochester, NASA, NSF, Thermo Fisher Scientific, Raytheon Vision Systems, Gigajot Technology, TOPTICA Photonics, and L3Harris.

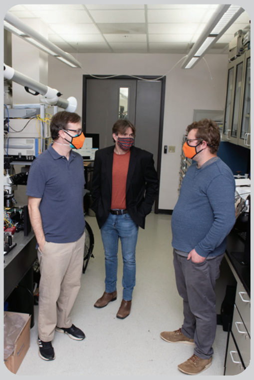
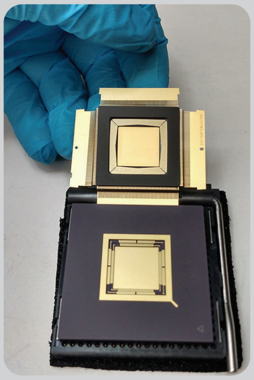
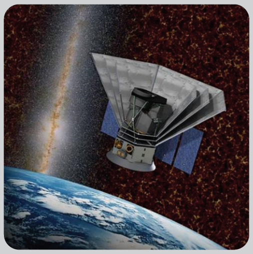
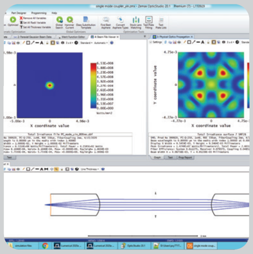
Because of our collaborative approach, and the centrality of student involvement in all of our projects, CfD students benefit from exposure to a wide range of research and development environments. This is consistent with a key objective of the CfD to train students through deeply immersive work with 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.

annual report 2021

communications

in the news
publications


communications

43

published articles

15

featured news pieces

3

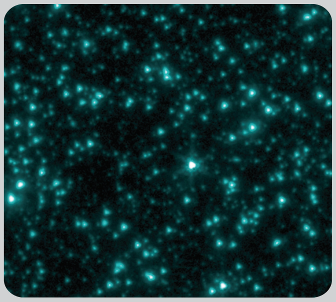
local broadcast news features

17

publishing organizations

Rocket Team to Discern if Our Star Count Should Go Way Up

NASA | June 7, 2021



UPDATE June 7, 2021: The Cosmic Infrared Background Experiment-2 or CIBER-2 was successfully launched on a NASA Black Brant IX sounding rocket at 2:25 a.m. EDT from the White Sands Missile Range in New Mexico. Preliminary indications show that the intended targets were viewed by the payload and good data was received. The payload flew to an apogee of about 193 miles before descending by parachute for recovery.

The universe contains a mind-boggling number of stars – but scientists' best estimates may be an undercount. A NASA-funded sounding rocket is launching with an improved instrument to look for evidence of extra stars that may have been missed in stellar head counts.

The Cosmic Infrared Background Experiment-2, or CIBER-2, mission is the latest in a series of sounding rocket launches that began in 2009. Led by Michael Zemcov, assistant professor of physics and astronomy at the Rochester Institute of Technology in New York, CIBER-2's launch window opens at the White Sands Missile Range in New Mexico on June 6, 2021.

If you've had the pleasure of seeing an open sky on a clear, dark night, you've probably been struck by the sheer number of stars. Perhaps you've even tried to count them up. (If not, a hint: There are somewhere around five thousand visible to the naked eye from Earth.) But the real wonder is that our speckled night sky represents only the tiniest sample of what's truly out there.

To get a rough estimate of the total number of stars in the universe, scientists have calculated the average number of stars in a galaxy – some estimates put it at about 100 million, though it could be 10 or more times higher – and multiplied it by the number of galaxies, taken to be about 2 trillion (also very tentative). That gets you one hundred quintillion stars (or 1 with 21 zeroes after it). That's more than 10 stars for every grain of sand on Earth (estimated at about seven and a half quintillion).

But even that astronomically high number may be an underestimate. That calculation assumes all, or at least most, stars are inside galaxies. Based on recent findings, that may not be quite true – and it's what the CIBER-2 mission is trying to figure out.

The CIBER-2 instrument, like the earlier CIBER instrument it's based on, will launch aboard a sounding rocket – a small suborbital rocket that carries scientific instruments on brief trips into space before falling back to Earth for recovery. Once above Earth's atmosphere, CIBER-2 will survey a patch of sky about 4 square degrees – for reference, the full Moon takes up about half a degree – that includes dozens of galaxy clusters. It won't count stars, but it will detect the diffuse, cosmos-filling glow known as the extragalactic background light.

"This background glow is the total light produced over cosmic history" said Jamie Bock, professor of physics at Caltech in Pasadena, California, and lead researcher for CIBER's first four flights. That background light spans a range of wavelengths, but CIBER-2 will focus on a small portion called the cosmic infrared background, or CIB. Much of the CIB is thought to come from M and K dwarfs, the most common star types in the universe, though that's not the only contributor. "Our method measures the total light, including from sources we haven't identified yet," Bock said.

When you can't count up individual stars in a galaxy, the CIB's brightness should give you a good estimate of how many M and K dwarfs there are. And if all those stars are inside the galaxy, that light should be brightest toward its center. In 2007, scientists used NASA's Spitzer Space Telescope to look at galaxy clusters and make this type of measurement.

But Spitzer observed more light than was expected from known galaxy populations – the fluctuations in brightness of the CIB hinted that they were missing something.

Bock and Zemcov – at the time a post-doctoral researcher but now the principal investigator for CIBER-2 – flew the first CIBER mission to check those results with a telescope better optimized for the task.

"So we did that measurement, and we came up with an answer that was uncomfortable," said Zemcov. "There were a lot more fluctuations than we were expecting – one explanation is there is more light coming from outside of galaxies than we had thought."

The extra light, they believe, may be from the glimmer of stray dwarf stars. These stars could have been flung out of their home galaxy when it merged with another, a process known as tidal stripping. Such far-flung stars are known to surround the Milky Way, though current counts suggest there's not nearly enough of them to produce the signal CIBER measured.

"More and more research suggests that there are a significant number of stars of this type outside of galaxies," Zemcov said.

But alternative hypotheses for this excess light have arisen. “We know some of that light comes from galaxies, and some the first stars ever to shine, even though they’re long gone now,” said Bock. Some light from our own galaxy could even pollute the measurements, though the CIBER team has done their best to filter it out. There are also more exotic possibilities, like direct-collapse black holes from the early universe – massive clouds of gas that collapsed into black holes without becoming stars first – whose ultraviolet light would have stretched across expanding space into the longer infrared wavelengths we see today. CIBER-2 was designed to help settle the matter by distinguishing these possibilities.

Light from extragalactic M and K dwarfs should spill over into visible range, so CIBER-2 was designed to observe an expanded range of wavelengths – from the near-infrared to green visible light – to see it if it’s there. CIBER-2 can also distinguish light from the first galaxies and stars or early direct-collapsing black holes: Both should have a characteristic portion of their total light missing, the part absorbed by the thick fog of intergalactic hydrogen in the early universe.

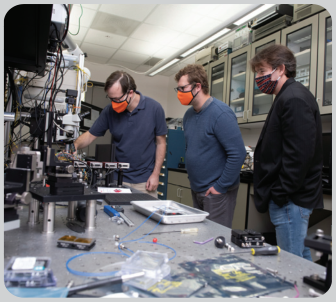
For now, all the possibilities remain on the table. But if our star count should indeed go up, CIBER-2’s results could soon tell us.

“There are hints that we are definitely not catching all the stuff in the universe. And the more people look, the more they see,” said Zemcov.

L3Harris becomes industry partner for RIT’s Future Photon Initiative

The partnership opens future opportunities for research in quantum information processing

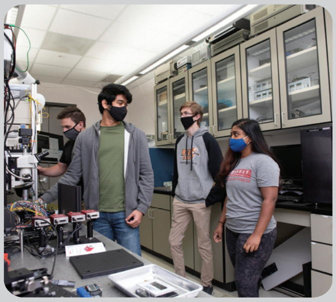
Luke Auburn | October 14, 2020



Rochester Institute of Technology’s Future Photon Initiative (FPI) and L3Harris have entered into a new industry partnership to develop quantum technologies. The partners will begin developing next steps for experiments and analysis focused on quantum information processing for communication, sensing, and computing.

The exploratory partnership provides L3Harris access to FPI’s laboratory space and researchers with the goal of identifying areas they can collaborate on in the future.

“Right now, we’re working to come up with what some of the potential projects might be,” said Professor Stefan Preble of RIT’s



Department of Microsystems Engineering, principal investigator of the grant. “This ties into our strengths nicely. The ultimate aim is to do experiments on quantum wafers and chips, which will allow us to integrate many things together.”

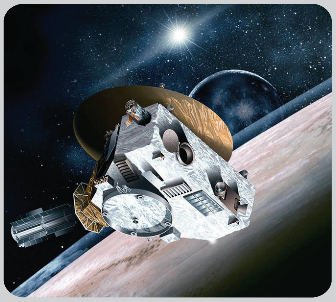
The initial grant provides RIT $50,000 in funding with the goal of pursuing bigger, focused projects. Co-PIs of the grant include Associate Professor Edwin Hach and Assistant Professor Gregory Howland from RIT’s School of Physics and Astronomy, plus the collaboration will engage students from RIT’s physics master’s program and microsystems engineering Ph.D. program.

“We have a strong quantum thrust at L3Harris and think quantum will help our current and future customers and open up opportunities,” said Tim Burt, a scientist from the Quantum Solutions Group at L3Harris. “While we have good scientists and engineers within L3Harris itself, there’s a very good thing that comes from working with academics in this field. We hope to be able to learn more deeply and where the edges are of this technology.”

To learn more about RIT’s work in quantum photonic technologies, visit the Future Photon Initiative website.

Scientists Discover Outer Space Isn't Pitch-Black After All

Nell Greenfieldboyce | November 18, 2020



Look up at the night sky and, if you're away from city lights, you'll see stars. The space between those bright points of light is, of course, filled with inky blackness.

Some astronomers have wondered about that all that dark space — about how dark it really is.

"Is space truly black?" says Tod Lauer, an astronomer with the National Science Foundation's National Optical-Infrared Astronomy Research Laboratory (NOIRLab) in Arizona. He says if you could look at the night sky without stars, galaxies and everything else known to give off visible light, "does the universe itself put out a glow?"

It's a tough question that astronomers have tried to answer for decades. Now, Lauer and other researchers with NASA's New Horizons space mission say they've finally been able to do it, using a spacecraft that's traveling far beyond the dwarf planet Pluto. The

group has posted its work online, and it will soon appear in The Astrophysical Journal.

New Horizons was originally designed to explore Pluto, but after whizzing past the dwarf planet in 2015, the intrepid spacecraft just kept going. It's now more than 4 billion miles from home — nearly 50 times farther away from the sun than the Earth is.

That's important because it means the spacecraft is far from major sources of light contamination that make it impossible to detect any tiny light signal from the universe itself. Around Earth and the inner solar system, for example, space is filled with dust particles that get lit up by the sun, creating a diffuse glow over the entire sky. But that dust isn't a problem out where New Horizons is. Plus, out there, the sunlight is much weaker.

To try to detect the faint glow of the universe, researchers went through images taken by the spacecraft's simple telescope and camera and looked for ones that were incredibly boring.

"The images were all of what you just simply call blank sky. There's a sprinkling of faint stars, there's a sprinkling of faint galaxies, but it looks random," Lauer says. "What you want is a place that doesn't have many bright stars in the images or bright stars even outside the field that can scatter light back into the camera."

Then they processed these images to remove all known sources of visible light. Once they'd subtracted out the light from stars, plus scattered light from the Milky Way and any stray light that might be a result of camera quirks, they were left with light coming in from beyond our own galaxy.

They then went a step further still, subtracting out light that they could attribute to all the galaxies thought to be out there. And it turns out, once that was done, there was still plenty of unexplained light.

In fact, the amount of light coming from mysterious sources was about equal to all the light coming in from the known galaxies, says Marc Postman, an astronomer with the Space Telescope Science Institute in Baltimore. So maybe there are unrecognized galaxies out there, he says, "or some other source of light that we don't yet know what it is."

The new findings are sure to get astronomers talking.

"They're saying that there's as much light outside of galaxies as there is inside of galaxies, which is a pretty tough pill to swallow, frankly," notes Michael Zemcov, an astrophysicist at Rochester Institute of Technology, who was not part of the research team.

A few years ago, Zemcov and some colleagues analyzed New Horizons data in a similar way. Using fewer images, they made a less precise measurement, but it was still compatible with the current results.

He says for 400 years, astronomers have been studying visible light and the sky in a serious way and yet somehow apparently "missed half the light in the universe."

"It's very difficult to turn around and say to the astronomical community, like, 'Hey, guys, we're missing half of the stuff out there,' " Zemcov says. Still, he buys the results: "I think the work is really solid."

So where does the light come from? Perhaps, he says, there are far more small, faint dwarf galaxies and other faint regions on the outskirts of galaxies that instruments such as the Hubble Space Telescope can't detect and so scientists just aren't aware of them. Or maybe there's more dust out there interfering with the measurements than scientists expected.

Or perhaps there's a more exotic explanation — some unknown phenomenon out in the universe that creates visible light. It's even possible it's something associated with dark matter, a mysterious form of matter that exerts a gravitational pull on visible matter but has never been seen directly.

"As a person who studies the universe, I really want to know what the universe is made of and what are all the components of the universe," Postman says. "We would like to think that the components that give off light are something that we can really get a good sense of and understand why there is that much light."

But to do that, Postman notes, it's really essential to understand first how much light there is that needs to be accounted for, and that's where a study such as this one can help.

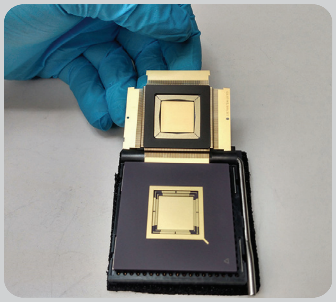
"It is a new measurement, with the capability that we have because we're in a unique place with a camera that can exploit that neat place," Lauer says.

Still, he adds, "Space is dark." Even after all this analysis, "It's still pretty dark."

RIT student Justin Gallagher helps lead NASA-funded project to build single photon detectors

Astrophysical sciences and technology student serves as project manager on nearly $1 million grant

Luke Auburn | August 5, 2020



An RIT student is on a mission to help build detectors that could identify individual photons from distant, inhabitable planets. Justin Gallagher, a fifth-year student from Rochester, N.Y., pursuing his BS in physics and MS in astrophysical sciences and technology, is serving as project manager for a nearly $1 million grant funded by NASA to create a single photon sensing and number resolving detector for NASA missions.

As project manager, Gallagher is responsible for keeping the project team on task and coordinating work between RIT and the project collaborators at Dartmouth. He is also tasked with designing the mechanical mounting for printed circuit boards, simulating the expected steady state temperature for those circuit boards and the detector, as well as performing cryogenic experiments to test parts for the preliminary design.

Keeping the project on schedule has been a challenge during the coronavirus pandemic. While Gallagher has remained in his hometown of Rochester and occasionally goes into the lab to maintain remote systems and helium compressors that cool experiments, much of the RIT project team is scattered across the country in places as far as Maine. But Don Figer, the principal investigator of the grant and director of RIT's Future Photon Initiative and the Center for Detectors, said that Gallagher has done an admirable job of keeping the project moving forward despite the conditions.

"It's difficult juggling work with lots of different people and taking responsibility for other people's work, but he has done a great job," said Figer. "When Justin came to me, he was already oriented to wanting to do practical things that would have an impact. He's the kind of student I think every single one of our students should be."

Gallagher initially came to Figer in search of a thesis advisor, but was hired by Figer to work for the Center of Detectors as well. Last summer Gallagher worked with Figer under the College of Science Emerson Summer Undergraduate Research Fellowship, which included a visit to a company in Pasadena, Calif. called Gigajot, which is developing image sensors to detect individual photons. All of this applied research experience as a student has Gallagher excited for a career in research and development, and he said he feels grateful for the opportunity to work on the project.

“This is an amazing opportunity for us students,” said Gallagher. “To be able to work on a full-fledged, funded project with deadlines during your college years, you feel like you’re making a real contribution. That kind of empowers you to be able to keep going. We presented results in the Single Photon Workshop last October in Milan, Italy, and here I am, a master’s student next to the actual experts in the field from different universities, government organizations, and companies around the world. That’s a big eye opener.”

Gallagher is set to graduate with his BS and MS degrees in August, but the Center for Detectors hired him as a lab engineer and he will continue to work on the project until its completion.

Team Members

An interdisciplinary team of RIT students is actively working on the project this summer. The students include:

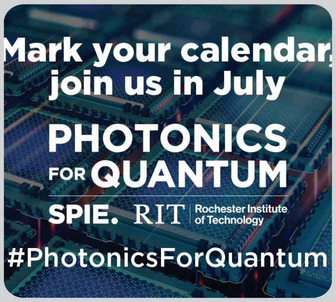
- Lazar Buntic, an astrophysical sciences and technology Ph.D. student from Belgrade, Serbia, who is responsible for modelling the radiation parameters for a future NASA mission to orbit at a point known as L2. Following this, he will design the radiation testing program.
- Jake Butler, a third-year computer engineering student from Cheshire, Conn. Butler is tasked with assisting in development of the field programmable gate arrays (FPGA) in the Qaunta Image Sensor (QIS) detector system and developing software.
- Justin Gallagher, a fifth-year student from Rochester pursuing his BS in physics and MS in astrophysical sciences and technology. Gallagher is the project manager and is also tasked with designing the mechanical mounting for printed circuit boards, simulating the expected steady state temperature for those circuit boards and the detector, as well as performing cryogenic experiments to test parts for the preliminary design.
- Scott Mann ’20 (electrical engineering) graduated in May and is currently working as a temporary employee. His job within the project is to design and fabricate the printed circuit boards for readout electronics that transmit information to and from the detector.
- Long Nguyen, a third-year electrical engineering student from Vietnam. Long simulates the readout electronics using the SPICE software and develops the readout electronic circuits. Long also is on a co-op with Sony Electronics.

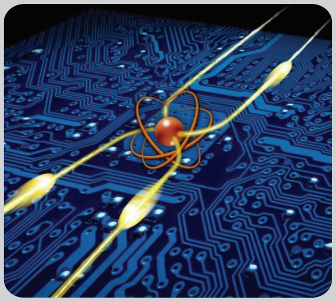
- Irfan Punekar, a fifth-year student from Manhattan pursuing his BS and MS degrees in computer engineering. He is working on developing the FPGA programming to create a test system for the QIS Detector.

RIT and SPIE partner on 2021 Photonics for Quantum event

Program focuses on how photonic devices impact quantum science, technology, and applications

Luke Auburn | June 2, 2021





SPIE, the international society for optics and photonics, and Rochester Institute of Technology will present the 2021 Photonics for Quantum Digital Forum July 16-20. Previously an RIT initiative, this year marks a new iteration of this event in the form of a partnership between RIT and SPIE.

The five-day event will include more than 20 speakers from across international industry and research as well as an interactive poster session. Discussions and presentations will focus on quantum topics spanning applications, experiments, quantum photonic integrated circuits, materials, integration between dissimilar material systems, devices, and concepts to support a national quantum foundry.

Invited speakers include Qunnect’s Noel Goddard; the US Air Force Research Laboratory’s Michael Fanto ’20 Ph.D. (microsystems engineering); Imperial College London’s Ian A. Walmsley; Eleni Diamanti of Sorbonne University’s Laboratoire d'Informatique de Paris 6; Laboratoire Matériaux et Phénomènes Quantiques’ Sara Ducci; the University of Birmingham’s Kai Bongs; and Anton Zeilinger of the University of Vienna and the Institute for Quantum Optics and Quantum Information of the Austrian Academy of sciences.

The Photonics for Quantum program sessions:

July 12: Networks and Communication

July 13: Computing and Simulation

July 14: Sensing and Imaging

July 15: Components

July 16: Special events and panels, including Women in Quantum (in conjunction with the SPIE Women in Optics program), global government initiatives and funding, and workforce and education

“RIT is thrilled to partner with SPIE to present this year’s Photonics for Quantum conference,” said Don Figer, director of RIT’s Future Photon Initiative. “For the past two years, this event has provided an important forum to discuss the latest breakthroughs in quantum science and technology, as well as how to unlock this growing field’s potential. We look forward to expanding the conference by accessing SPIE’s worldwide network.”

“We’re very excited to be partnering with RIT on this growing event,” said SPIE Director of Industry Development Stephen Anderson. “It’s a wonderful opportunity to help showcase the fast-emerging field of quantum technology and the exciting possibilities that exist in it for photonics. With its particular focus on scientific and academic content, covering both fundamental research and in-lab developments, Photonics for Quantum is a terrific complement to the industry-focused SPIE Quantum West and a great addition to the SPIE calendar.”

2021

1. Ahrens, Caitlin, Lisse, Carey, Zemcov, Michael, and Runyon, Kirby 2021, Spectral Science Priorities for an Infrared Spectrometer with Interstellar Probe, Bulletin of the American Astronomical Society, 53, 146
2. Baboli, Mohadeseh A., Abrand, Alireza, Burke, Robert A., Fedorenko, Anastasiia, Wilhelm, Thomas S., Polly, Stephen J., Dubey, Madan, Hubbard, Seth M., and Mohseni, Parsian K. 2021, Mixed-dimensional InAs nanowire on layered molybdenum disulfide heterostructures via selective-area van der Waals epitaxy, Nanoscale Advances, 3, 2802
3. Beasor, Emma R., Davies, Ben, Smith, Nathan, Gehrz, Robert D., Figer, Donald F. 2021, The Age of Westerland 1 Revisited, The Astrophysical Journal, 912, 16
4. Butler, V., Feder, R., Mantz, A., Mercado, D., Montana, A., Sayers, J., Vaughan, B., Zemcov, M., Zitrin, A. 2021, Determining Thermodynamic Properties of Cluster Gas Using Herschel-SPIRE, American Astronomical Society Meeting Abstracts, 53, 512.06
5. Cheng, Y., Arai, T., Bock, J. J., Chang, T., Cooray, A. R., Feder, R. M., Kim, M., Korngut, P. M., Lee, D., Liu, L., Matsumoto, T., Matsuura, S., Nguyen, C., Smidt, J., Tsumura, K., and Zemcov, M. 2021, Studying Near-Infrared Intra-Halo Light with CIBER Mission, American Astronomical Society Meeting Abstracts, 53, 411.05D
6. Cheng, Yun-Ting, Arai, Toshiaki, Bangale, Priyadarshini, Bock, James J., Chang, Tzu-Ching, Cooray, Asantha, Feder, Richard M., Korngut, Phillip M., Lee, Dae Hee, Liu, Lunjun, Matsumoto, Toshio, Matsuura, Shuji, Nguyen, Chi H., Sano, Kei, Tsumura, Kohji, and Zemcov, Michael 2021, Probing Intra-Halo Light with Galaxy Stacking in CIBER Images, arXiv e-prints, arXiv:2103.03882
7. Harman, Chester, Izenberg, Noam R., Stevenson, Kevin B., Zemcov, Michael, Lisse, Carey M., Arney, Giada, Redfield, Seth, Schwieterman, Edward, Rymer, Abigail, Poppe, Andrew, and Mandt, Kathleen E. 2021, Looking Back is Looking Forward: The Need for Retrospective Solar System Observations in Advance of Exoplanet Retrievals, Bulletin of the American Astronomical Society, 53, 126
8. Hartensveld, Matthew, Melanson, Bryan, Vangipuram, Thirupakuzi V, Seitz, Matthew, Zhang, Jing 2021, Realization of High-Efficiency Green InGaN Nanowire Light-Emitting Diodes using a Novel Dry-EtchHardmask Removal Process, EMC 2021
9. Howland, Gregory 2021, Efficiently quantifying entanglement in high-dimensional quantum photonic systems, Proc. SPIE 11699, Quantum Computing, Communication, and Simulation, 1169919
10. Korngut, Phillip, Kim, Min Gyu, Arai, Toshiaki, Bangale, Priyadarshini, Bock, James, Cooray, Asantha, Cheng, Yun Ting, Feder, Richard, Hristov, Viktor, Lanz, Alicia, Levenson, Louis, Matsumoto, Toshio, Matsuura, Shuji, Nguyen, Chi, Sano, Kei, Tsumura, Kohji, and Zemcov, Michael 2021, Measurements of the Zodiacal Light Absolute Intensity through Fraunhofer Absorption Line Spectroscopy with CIBER, arXiv e-prints, arXiv:2104.07104
11. Lisse, C. M., Zemcov, M. B., Poppe, A. R., Szalay, J. R., Draine, B. T., Horanyi, M., McNutt, R. L., Corcoros, A., Brandt, P. C., Paul, M. V., Sterken, V., Levasseur-Regourd, A. C., Lallement, R., Beichman, C. A., Postberg, F., Frisch, P. C., and Slavin, J. D. 2021, What Can an Interstellar Probe Mission at Large Heliocentric Distances Achieve with Remote Imaging and In Situ Dust Measurements?, Lunar and Planetary Science Conference, 2581

12. Lisse, Carey M., Zemcov, Michael, Mandt, Kathleen, Runyon, Kirby, Ahrens, Caitlin, Beichman, Chas, Bock, James, Brandt, Pontus, Cocoros, Alice, Draine, Bruce, Harman, Chester E., Horanyi, Mihaly, Izenberg, Noam, Lallement, Rosine, Levesseur-Regourd, Any-Chantal, McNutt, Ralph, Poppe, Andrew R., Paul, Michael, Sterken, Veerle, and Szalay, Jamey 2021, Instrumentation for Producing Groundbreaking Planetary & Astrophysical Science on an Interstellar Probe Mission, Bulletin of the American Astronomical Society, 53, 248
13. Melanson, Bryan, Liu, Cheng, Zhang, Jing 2021, Analysis of InGaN-Delta-InN Quantum Wells on InGaN Substrates for Red Light Emitting Diodes and Lasers, IEEE Photonics Journal, vol. 13, no. 1, pp. 1-10, Feb. 2021, Art no. 8200310, doi: 10.1109/JPHOT.2021.3053484.
14. Melanson, Bryan, Liu, Cheng, Zhang, Jing 2021, Demonstration of Flexible DUV Light Emitting Diodes through Formation of Nanowires with Inverse-Taper, CLEO
15. Mercado, D., Barry, P., Filippini, J., Nie, R., Patel, G., Shirokoff, E., Tramm, S., Trappe, N., and Zemcov, M. 2021, Design of a FIR Infrared Fourier Transform Spectrometer for the Calibration of On-Chip FIR Spectrometers, American Astronomical Society Meeting Abstracts, 53, 549.03
16. Mohadeseh A Baboli, Alireza Abrand, Robert A Burke, Anastasiia Fedorenko, Thomas S Wilhelm, Stephen J Polly, Madan Dubey, Seth M Hubbard, Parsian K Mohseni 2021, Mixed-dimensional InAs nanowire on layered molybdenum disulfide heterostructures via selective-area van der Waals epitaxy, Journal Nanoscale Advances Volume 3, Issue 10, Pages 2802-2811, Royal Society of Chemistry
17. Nguyen, C., and 30 colleagues 2021, Probing the Near-Infrared Extragalactic Background Light with the CIBER missions, American Astronomical Society Meeting Abstracts, 53, 410.06D
18. Parsian K. Mohseni et al. 2021, Mixed-dimensional InAs nanowire on layered molybdenum disulfi de heterostructures via selective-area van der Waals epitaxy Nanoscale Advances Volume 3 Number 10 21 May 2021 Pages 2669–2962
19. Poppe, Andrew, Szalay, J. R., Lisse, C. M., Horányi, M., Zemcov, M., Hsu, S., Pokorny, P., and Sterken, V. 2021, Dust Measurements from Interstellar Probe: Exploring the Zodiacal Cloud and the Interstellar Dust Environment, Bulletin of the American Astronomical Society, 53, 056
20. Pruessner, Marcel W., Kozak, Dmitry A., Tyndall, Nathan A., Rabinovich, William S., Deenadayalan, Venkatesh, Fanto, Michael, Preble, Stefan, Stievater, Todd H. 2021, Foundry-processed optomechanical photonic integrated circuits: publisher’s note, OSA Continuum 4, 1609-1609
21. Symons, Teresa, Zemcov, Michael, Bock, James, Cheng, Yun-Ting, Crill, Brendan, Hirata, Christopher, and Venuto, Stephanie 2021, Superresolution Reconstruction of Severely Undersampled Point-spread Functions Using Point-source Stacking and Deconvolution, The Astrophysical Journal Supplement Series, 252, 24
22. Tramm, S., Barry, P., Filippini, J., Mercado, D., Nie, R., Patel, G., Shirokoff, E., Trappe, N., and Zemcov, M. 2021, Development of an On-Chip Integrated Spectrometer for FIR Wavelengths, American Astronomical Society Meeting Abstracts, 53, 549.02
23. van Niekerk, Matthew, Jahani, Saman, Bickford, Justin, Cho, Pak, Anderson, Stephen, Leake, Gerald, Coleman, Daniel, Fanto, Michael L., Tison, Christopher C., Howland , Gregory A., Zubin, Jacob, Preble, Stefan F. 2021, Two-dimensional extreme skin depth engineering for CMOS photonics, J. Opt. Soc. Am. B 38, 1307-1316
24. Vaughan, B., Butler, V., Feder, R., Sayers, J., and Zemcov, M. 2021, Measuring the Sunyaev-Zeldovich effect with Herschel Fourier Transform Spectrometry., American Astronomical Society Meeting Abstracts, 53, 154.08

2020

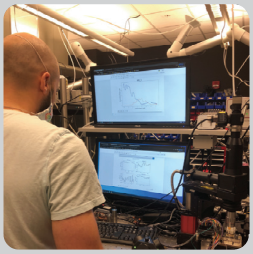
25. Crill, Brendan P., and 53 colleagues 2020, SPHEREx: NASA's near-infrared spectrophotometric all-sky survey, Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, 11443, 114430I
26. Deenadayalan, V., van Niekerk, M., Fanto, M., Preble, S. 2020, Silicon Photonic MEMS Phase Shifter Using Gradient Electric Force Actuation, in Frontiers in Optics / Laser Science, B. Lee, C. Mazzali, K. Corwin, and R. Jason Jones, eds., OSA Technical Digest (Optical Society of America, 2020), paper FW5D.3.
27. Figer, Donald F., Najarro, Francisco, Messineo, Maria, Clark, J. Simon, and Menten, Karl M. 2020, A New Candidate Luminous Blue Variable, The Astrophysical Journal, 901, L15
28. G. Chen et al., 2020, Photomixing THz Generation from Nitrogen-Ion–Implanted GaAs Metal-Semiconductor-Metal Diodes Enhanced by a Bragg Mirror, 2020 45th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), pp. 1-2, doi: 10.1109/IRMMW-THz46771.2020.9370390.
29. Harman, C. E., Izenberg, N., Stevenson, K., Zemcov, M. B., Lisse, C. M., Arney, G. N., Redfield, S., Schwieterman, E., Rymer, A. M., Poppe, A. R., and Mandt, K. 2020, The View From Out Here: the Solar System Planets as Exoplanet Analogs, AGU Fall Meeting Abstracts, 2020, SH017-0007
30. Hartensveld, Matthew, Melanson, Bryan, Vangipuram, Thirupakuzi V., Zhang, Jing 2020, 450 nm Gallium Nitride Alternating Current Light-Emitting Diode, IEEE Photonics Journal, vol. 12, no. 6, pp. 1-6, Dec. 2020, Art no. 8200906, doi: 10.1109/JPHOT.2020.3032382.
31. Hartensveld, Matthew, Melanson, Bryan, Zhang, Jing 2020, Ultraviolet Electrostatic Field Effect Light-Emitting Diode, IEEE Photonics Journal Volume 12 Issue 5 Pages 8200808
32. Lisse, C. M., Szalay, J., Poppe, A. R., Horanyi, M., Sterken, V. J., Beichman, C., Draine, B., Lallement, R., Levasseur-Regourd, A. C., Zemcov, M. B., McNutt, R. L., and Brandt, P. C. 2020, Interstellar Probe Measurements of Dust in Our Heliosphere, AGU Fall Meeting Abstracts, 2020, SH019-08
33. Lisse, Carey, Zemcov, Michael, Poppe, Andrew, Szalay, Jamey, Draine, Bruce, Horanyi, Mihaly, Sterken, Veele, Beichman, Chas, McNutt, Ralph, Corcoros, Alice, Brandt, Pontus, and Paul, Michael 2020, What Science Can an Interstellar Probe Mission at Large Heliocentric Distances Achieve With Remote Imaging and In Situ Dust Measurements?, European Planetary Science Congress, EPSC2020-845
34. Marzang, Vafa, Hosseini, Seyed Hossein, Rostami, Naghi, Alavi, Peyman, Mohseni, Parham, and Hashemzadeh, Seyed Majid 2020, A High Step-Up Nonisolated DC-DC Converter With Flexible Voltage Gain, IEEE Transactions on Power Electronics, 35, 10489
35. Messineo, Maria, Menten, Karl M., Figer, Donald F., and Clark, J. Simon 2020, Massive Stars in Molecular Clouds Rich in High-energy Sources: The Bridge of G332.809-0.132 and CS 78 in NGC 6334, The Astronomical Journal, 160, 65
36. Mohseni, Pedram and Charbon, Edoardo 2020, Introduction to the Special Issue on the 2020 IEEE International Solid-State Circuits Conference (ISSCC), IEEE Journal of Solid-State Circuits, 55, 2847
37. Oram, Kathleen and Ninkov, Zoran 2020, Digital micromirror device enabled integral field spectroscopy with the Hadamard transform technique, Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, 11446, 114462Y

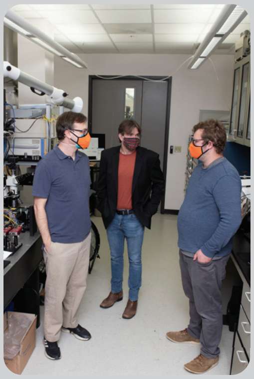
38. Oram, Kathleen, Ninkov, Zoran, Irwin, Alexis, Vorobiev, Dmitry, and Carts, Martin 2020, Total ionizing dose effects on digital micromirror devices, Journal of Astronomical Telescopes, Instruments, and Systems, 6, 045006
39. Sun, Guochao, and 25 colleagues 2020, Probing Cosmic Reionization and Molecular Gas Growth with TIME, arXiv e-prints, arXiv:2012.09160
40. Takimoto, Kohji, and 33 colleagues 2020, Pre-flight optical test and calibration for the Cosmic Infrared Background ExpeRiment 2 (CIBER-2), Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, 11443, 114435A
41. van Niekerk, M., Jahani, S., Bickford, J., Cho, P., Anderson, S., Leake, G., Coleman, D., Fanto, M., Tison, C., Howland, G., Jacob, Z., and Preble, S., 2020, Demonstration of Two-Dimensional Extreme Skin Depth Engineering in CMOS Photonics Foundry, in Frontiers in Optics / Laser Science, B. Lee, C. Mazzali, K. Corwin, and R. Jason Jones, eds., OSA Technical Digest (Optical Society of America, 2020), paper FTh1C.5
42. Vorobiev, Dmitry, Fleming, Brian, Oram, Kathleen V., Chafetz, Dana, Zimmer, Peter, Irwin, Alexis, Del Hoyo, Javier, Quijada, Manuel, and Ninkov, Zoran 2020, Far-UV multi-object spectroscopy with digital micromirror devices (DMDs), Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, 11444, 114446Y
43. Zemcov, M. B., Ahrens, C., Beichman, C., Brandt, P. C., Lisse, C. M., Mandt, K., McNutt, R. L., Poppe, A. R., and Runyon, K. 2020, A How-To Guide to Spectral-Imaging from Interstellar Probe, AGU Fall Meeting Abstracts, 2020, SH017-0017

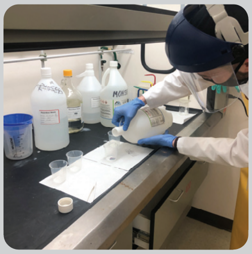
annual report 2021

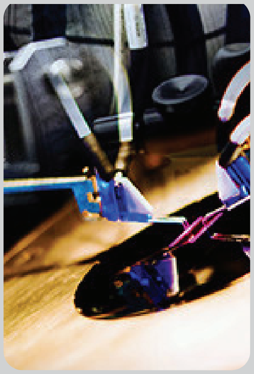
organization

personnel
facilities and equipment









9 specialized labs

3 colleges

27

graduate research students

16

undergraduate research students

Don Figer

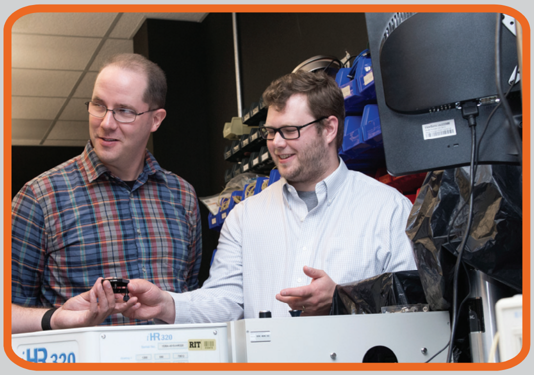
Director, Professor

PhD Astronomy, 1995, University of California, Los Angeles; MS 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, A Single Photon Sensing and Photon Number Resolving Detector for NASA Missions and New Infrared Detectors for Astrophysics.

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

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

Dr. Howland joined RIT as an assistant professor in the College of Science in 2019.

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

Dr. Howland is collaborating with L3Harris to investigate microring resonator (MRR) photonic integrated circuits (PICs) for quantum information processing by performing experimental demonstrations.

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

PhD Engineering Physics, 2011, McMaster University, Canada; BS Engineering Physics, 2005, McMaster University, Canada

Dr. Mohseni is an assistant professor in the College of Engineering. Dr. Mohseni's research interests are cross-disciplinary, spanning the fields of solid state physics, optoelectronics, materials characterization, nanoengineering, 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 is exploring a transformative bifacial solar cell design that employs arrays of TDM III-V compound semiconductor nanowires 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

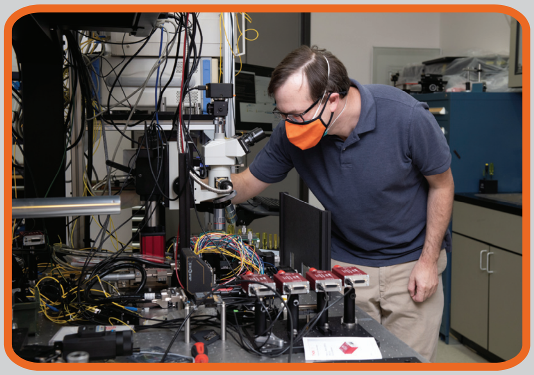
Professor

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.

Dr. Ninkov temporarily joined the NSF as a program manager through the Intergovernmental Personnel Act (IPA) program.

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

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 Integrated Photonics Group. 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.

Dr. Preble is researching photonic techniques with semiconductors and high-dimensional sensing for L3Harris. He continues to contribute to the 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

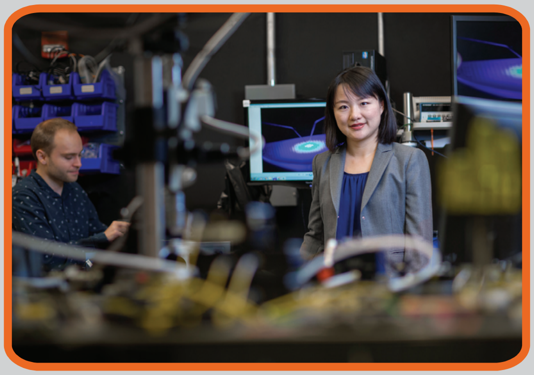
Assistant Professor

PhD Physics, 2006, Cardiff University; BS Physics, 2003, University of British Columbia

Dr. Zemcov is an assistant professor in the College of Science. His scientific background and interests are 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 and his collaborators successfully launched the CIBER-2 experiment in Summer 2021 at the White Sands Missile Range in New Mexico.

Dr. Zemcov received the NASA Achievement Award twice. He is a member of the American Astronomical Society and a fellow of the Royal Astronomical Society.



Jing Zhang

Assistant Professor

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 this fiscal year was collaborative research developing a high-efficiency 400 nm laser diode based on III-Nitride semiconductors. Collaborating with University of Wisconsin – Madison and Lehigh University. Her team is responsible for the design and modeling of III-Nitride quantum well (QW) active region for the 400 nm laser, fabrication process development of the laser diode, as well as materials/devices characterizations.

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.

staff

Priyadarshini Bangale

Postdoctoral Fellow

PhD Physics, 2019, Ludwig U. & Max-Planck Institute for Physics; MS Radio & Space Science, 2011, Clemens U. of Tech.; BS Elect. & Telecomm. Eng., 2001, Swami Ramanand Teerth Marathwada U.

Mario Ciminelli

Engineer

BS Mechanical Engineering, 1984; Rochester Institute of Technology

Justin Gallagher

Lab Engineer

BS/MS Astrophysical Sciences and Technology, 2020, Rochester Institute of Technology

Randy Kennard

Packaging Technician

AAS Mechanical Technology, 1995, Finger Lakes Community College

Thomas Palone

Reliability and Packaging Engineer

AAS Product and Machine Design, Alfred State

Robyn Rosechandler

Sr. Staff Assistant, Future Photon Initiative

BS Mass Communication, 2013, Black Hills State University

John Serafini

Postdoctoral Fellow

PhD Physics, 2016, University of Rochester; BS Biochemistry, 2008, University of Rochester

David Starling

Visiting Associate Professor (PennState – Hazleton)

PhD Physics, 2012, University of Rochester; MS Physics, 2008, University of Rochester; BS Physics and Mathematics, 2006, State University of New York at Fredonia

graduate students

Alireza Abrand

PhD Researcher

PhD Microsystems Engineering, Rochester Institute of Technology; MS Physics, 2014, Lund University, Sweden; BS Solid State Physics, 2010, University of Guilan, Iran

Chamithri Adikarige

MS Researcher

MS Physics, Rochester Institute of Technology; BS Physics and Astronomy, 2019, Washington State University

Lazar Buntic

PhD Researcher

PhD Astrophysical Sciences and Technology, Rochester Institute of Technology; BS Astrophysics, 2018, Penn State University

Victoria Butler

PhD Researcher

PhD Astrophysical Sciences and Technology, Rochester Institute of Technology; BS Applied Physics, 2016, Rensselaer Polytechnic Institute

Tessalie Caze-Cortes

Graduate Researcher

BS/MS Physics, 2021, Rochester Institute of Technology

Venkatesh Deenadayalan

PhD Researcher

PhD Microelectronic Engineering, Rochester Institute of Technology; MS Microelectronic Engineering; Rochester Institute of Technology; BS Electronics and Communication, 2015, SRM University, India

personnel

Matthew Hartensveld

PhD Researcher

PhD Microsystems Engineering, Rochester Institute of Technology; BS/MS Microelectronic Engineer/Material Science, 2018, Rochester Institute of Technology

Lexi Irwin

PhD Researcher

PhD Astrophysical Sciences and Technology, Rochester Institute of Technology; MS Imaging Science, 2020, Rochester Institute of Technology; BS Applied Physics, 2018, SUNY Geneseo

Reid Kovacs

Graduate Researcher

BS/MS Electrical Engineering, 2021, Rochester Institute of Technology

Evan Manfreda-Schulz

PhD Researcher

PhD Microsystems Engineering, Rochester Institute of Technology; BS Physics, 2020, Rochester Institute of Technology

Liza Matrecito

MS Researcher

MS Astrophysical Sciences and Technology, 2021, Rochester Institute of Technology; BS Physics and Astronomy, 2018, Northern Arizona University

Bryan Melanson

PhD Researcher

PhD Microsystems Engineering, Rochester Institute of Technology; BS Materials Science and Engineering, 2018, University of Washington

Dale Mercado

MS Researcher

MS Astrophysical Sciences and Technology, 2022, Rochester Institute of Technology; BS Physics, 2020, Rochester Institute of Technology

Chi Nguyen

PhD Researcher

PhD Astrophysical Sciences and Technology, Rochester Institute of Technology; BS Astronomy, 2015, University of Arizona

Kathleen Oram

PhD Researcher

PhD Imaging Science, Rochester Institute of Technology; BS Physics, 2015, University of Massachusetts Lowell

Mike Ortiz

Graduate Researcher

BS/MS Astrophysical Sciences and Technology, 2021, Rochester Institute of Technology

Irfan Punekar

Graduate Researcher

BS/MS Computer Engineering, 2021, Rochester Institute of Technology

Hector Rubio Rivera

PhD Researcher

PhD Microsystems Engineering, Rochester Institute of Technology; MS Microelectronics Engineering, 2020, Rochester Institute of Technology; BS Electronics Engineering, 2016, Universidad Autonoma de Baja California

Matthew Seitz

PhD Researcher

PhD Microsystems Engineering, 2023, Rochester Institute of Technology; MS Materials Science, 2020, Rochester Institute of Technology; BS Physics, 2017, University of Washington

Vijay Soorya Shunmuga Sundaram

MS Researcher

MS Physics, 2021, Rochester Institute of Technology; BTech Aerospace Engineering, 2018, Amrita Vishwa Vidyapeetham

Teresa Symons

PhD Researcher

PhD Astrophysical Sciences and Technology, Rochester Institute of Technology; MS Computational Physics and Astronomy, 2017, University of Kansas; BS Space Physics, 2014, Embry-Riddle Aeronautical University

Kyle Tezanos

MS Researcher

MS Materials Science & Engineering, 2021, Rochester Institute of Technology; BS Biochemistry, 2017, Rochester Institute of Technology

Serena Tramm

PhD Researcher

PhD Astrophysical Sciences and Technology, Rochester Institute of Technology; BS Mechanical Engineering, 2020, Bucknell University

Matthew van Niekerk

PhD Researcher

PhD Microsystems Engineering, Rochester Institute of Technology; BS Physics, Mathematics, 2017, Roberts Wesleyan College

Vijaygopal Thirupakuzi Vangipuram

Graduate Researcher

BS/MS Microelectronic Engineering, 2021, Rochester Institute of Technology

Jason Ziskind

Graduate Researcher

BS/MS Physics, 2022, Rochester Institute of Technology

Sami Znati

PhD Researcher

PhD Microsystems Engineering, 2024, Rochester Institute of Technology; PhD Oncology, 2020, UCL; BS Chemistry, 2014, Northeastern University

undergraduate students

Justin Baba

Capstone Researcher

BS Physics, 2021, Rochester Institute of Technology

Lucas Berens

Undergraduate Researcher

BS Physics, 2021, Rochester Institute of Technology

Gregory Bond

Lab Assistant

BS Chemical Engineering, 2021, Rochester Institute of Technology

Jake Butler

Co-Op Researcher

BS Computer Engineering 2023, Rochester Institute of Technology

Breonna Cosgrove

Executive Assistant

BFA Graphic Design, 2020, Rochester Institute of Technology

Benjamin Dodds

Lab Assistant

BS Electrical Engineering, 2022, Rochester Institute of Technology

personnel

Dulany Elliott

Undergraduate Researcher

BS Physics and Computer Science, 2023, Rochester Institute of Technology

Nash Flint

Undergraduate Researcher

BS Physics, 2021, Rochester Institute of Technology

Emily Greenberg

Undergraduate Researcher

BS Physics, 2022, Rochester Institute of Technology

Dennis Houlihan

Undergraduate Researcher

BS Physics, 2021, Rochester Institute of Technology

Jason Kaye

Co-op Mechanical Engineer

BS Mechanical Engineering Technology, 2023, Rochester Institute of Technology

Anthony Mazur

Undergraduate Researcher

BS Physics, 2022, Rochester Institute of Technology

Lily McKenna

Undergraduate Researcher

BS Physics, 2023, Rochester Institute of Technology

Long Nguyen

Undergraduate Researcher

BS Electrical Engineering, 2021, Rochester Institute of Technology

Tommy Nicholas

Undergraduate Researcher

BS Physics, 2023, Rochester Institute of Technology

Kayleigh Patterson

Executive Assistant

BS Physics, 2023, Rochester Institute of Technology

Nicholas Salazar

Executive Assistant

BS Management Information Systems, 2023, Rochester Institute of Technology

Emily Temple

Executive Assistant

BS Physics, 2023, Rochester Institute of Technology

Benjamin Vaughan

Undergraduate Researcher

BS Physics, 2021, Rochester Institute of Technology

Alex Zades

Undergraduate Researcher

BS Physics, 2022, Rochester Institute of Technology

Misty Zheng

Executive Assistant

BS, Applied Arts and Sciences, 2021, Rochester Institute of Technology

The Center for Detectors (CfD) headquarters, located in Engineering Hall (Building 17), consists of approximately 7, 000 square feet of office and research laboratory space. CfD lab space includes the Rochester Imaging Detector Laboratory (RIDL), the Lobozzo Photonics and Optical Characterization Laboratory, the Integrated Photonics Laboratory (Figure 28), the Experimental Cosmology Laboratory, the Laboratory for Advanced Instrumentation Research (LAIR), the Quantum Imaging and Information Laboratory (QIIL), the Suborbital Astrophysics Laboratory, and the Electrical and Optical Characterization Lab for LED devices.

Facilities within CfD include a permanent clean room, ESD stations, vacuum pumping systems, liquid and closed-cycle cryogenic dewars, optical benches, flow tables, light sources, UV-IR monochromators, thermal control systems, cryogenic motion control systems, single-photon detector systems, a cryogenic optoelectronic probe station, vibration testing stations, a suborbital rocket payload assembly area, power supplies, general lab electronics, and data reduction computers. 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.

Figure 28. Stefan Preble, Gregory Howland, and Edwin Hach inspect a photonic integrated chip under a microscope in the Integrated Photonics Lab.

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 colder 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 K 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 29 shows the electronics packages.

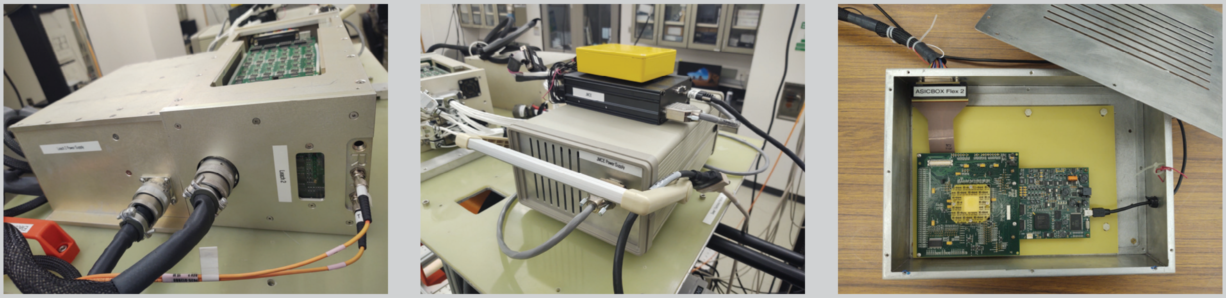


Figure 29. The Astronomical Research Camera Controller (left), the JMClarke Engineering (middle), and the Teledyne SIDECAR ASIC (right) are electronic data acquisition and control systems used by CfD to test detectors in RIDL.

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 connector, 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 30).

Figure 30. Staff and students use the four custom dewar test systems to evaluate detectors in RIDL.

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 from the UV into the IR, corresponding to a wavelength range of 250 nm – 2500 nm. NIST-traceable calibrated photodiodes (with a wavelength range of 300 nm – 5000 nm) provide absolute flux measurements. RIDL also has a spot projector to characterize the interpixel response of the detectors, including optical and electrical crosstalk. Figure 31 shows a laser spot projection system on a 3D motorized stage that produces a small (~few µm) point source for measurements of intrapixel sensitivity.

RIDL has many data acquisition and reduction computers, each with 8 to 24 threads and up to 256 GB of memory for analysis, simulations, data acquisition, and reduction. A storage server with 10 Gbps optical network connection is the primary data reduction computer; it has 60 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 ~1 TB of data. The data reduction computers reduce and analyze the data using custom automated code, producing publication-quality plots in near-real time.

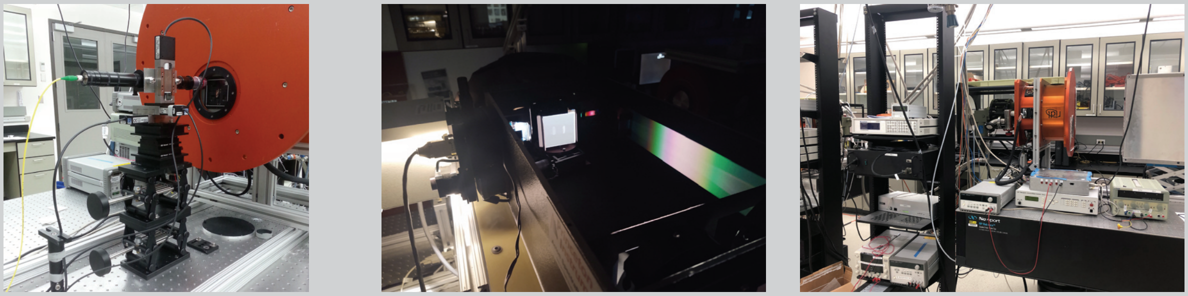


Figure 31. (left) A laser spot projector with a three-axis motion control system projects a small spot of light within individual pixels in order to measure the response in all regions of a pixel. (middle) A photo of a monochromator with light sources. (right) The control systems for the dewars including pressure, temperature and motor control.

Lobozzo Photonics and Optical Characterization Lab

The RIT Integrated Photonics Group conducts research in the Lobozzo Photonics and Optical Characterization lab (Figure 32). 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.

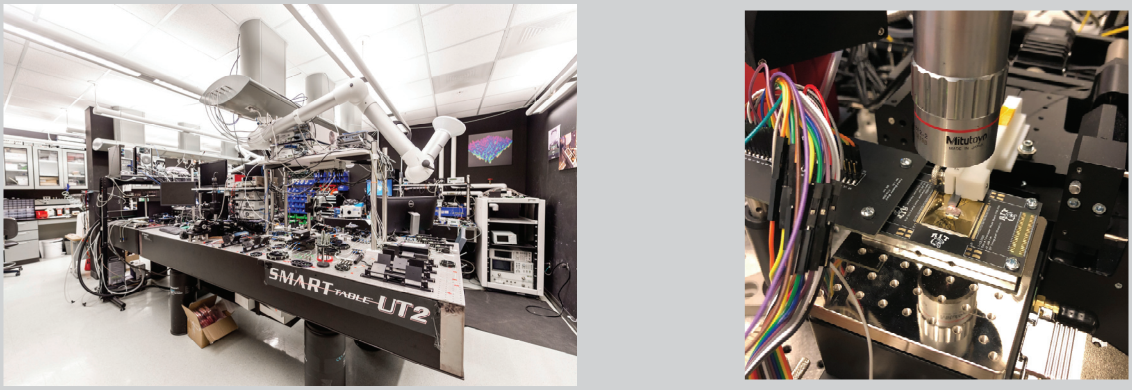


Figure 32. (left) The image show an overview of the Photonics and Optical Characterization Lab. (right) This photonic integrated circuit chip was specifically designed for quantum information processing.

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 33, including an iHR320 spectrometer, a Syncerity CCD Array detector, a liquid helium cryostat, 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.

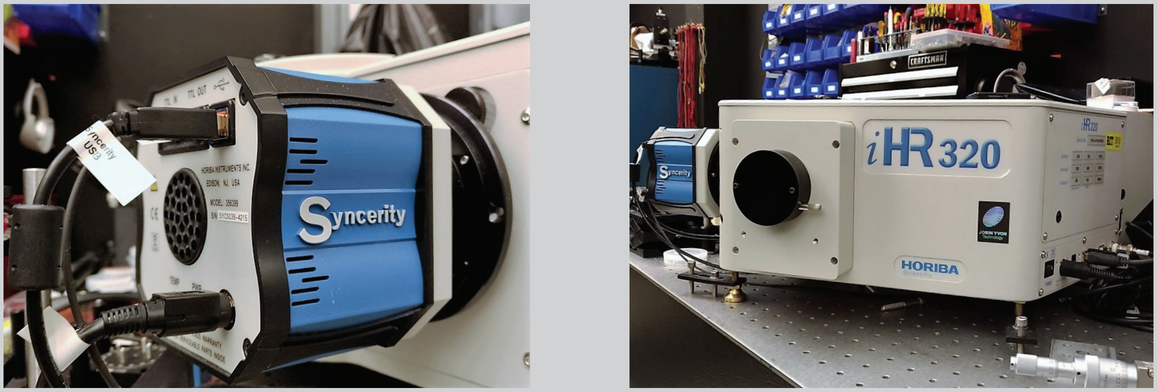


Figure 33. The Syncerity CCD Array detector (left) and the iHR320 spectrometer (right) are part of the photoluminescence system.

Integrated Photonics Lab

Researchers use the Integrated Photonics 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 34, *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 34. (left) The photo above shows the optical table used to run quantum integrated photonic experiments in the Integrated Photonics Lab. (right) The AFOSR funded this Photon Spot single-photon detector system for the Integrated Photonics Lab..

Experimental Cosmology Lab

This 375 square foot lab, led by Dr. Michael Zemocv, 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 35). 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 vibration test system and rapid-prototyping PCB mill adds to the capabilities for cosmology instrumentation and testing in this lab.

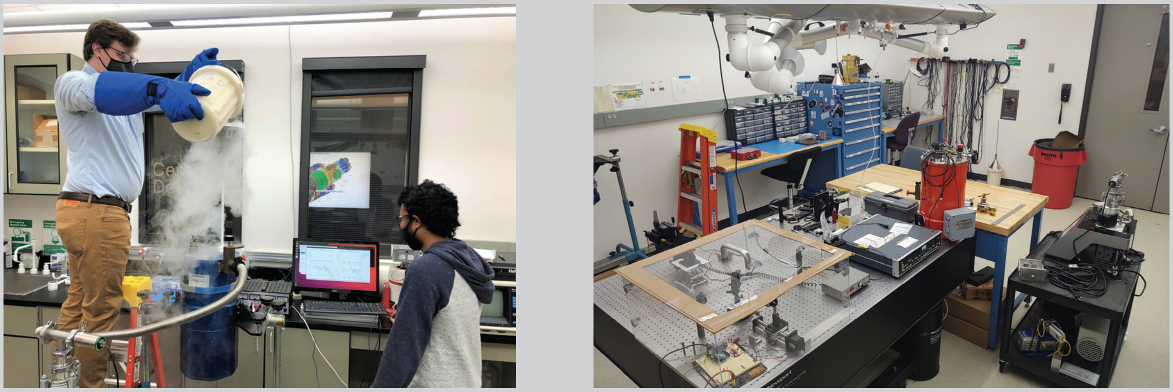


Figure 35. (left) CfD students, Dale and Gaurang, record data after pouring liquid nitrogen over the detector. (right) The picture shows an overview of the lab.

Suborbital Astrophysics Lab

The Suborbital Astrophysics Laboratory provides RIT with capabilities to design, integrate, and calibrate sounding rocket payloads for astrophysical sciences. It includes clean facilities to allow for disassembly and assembly of rocket instruments. It also contains optical and electronic development and validation instruments along cryogenic and vacuum capabilities. In this lab, Dr. Zemcov and his team prepared the CSTAR S and CIBER-2 payloads for flight at White Sands Missile Range, NM (Figure 36) which launched in spring 2021.

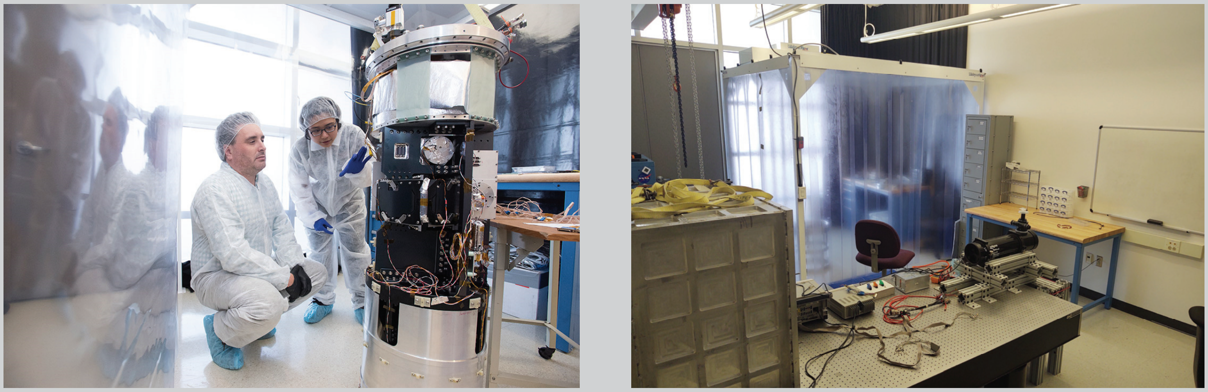


Figure 36. Michael Zemcov and Chi Nguyen inspect the CIBER-2 payload (left) in the clean room area of Suborbital Astrophysics Laboratory (right) before shipping it to NASA Wallops flight facility to test.

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 37). 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 unmanned aerial vehicle (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 system for laser fusion research. NASA, the NSF, NYSTAR and a variety of corporations, such as Exelis, ITT, Kodak, Harris, Moxtek, and Thermo Fisher Scientific, have funded this research.

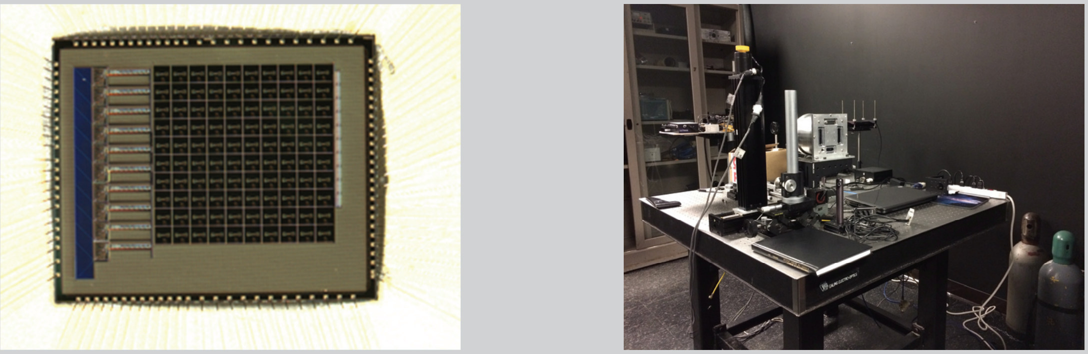


Figure 37. Student researchers in the LAIR developed a terahertz detector (left) and characterized it in the laboratory (right).

Epitaxially-Integrated Nanoscale Systems Lab

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. Dr. Mohseni's group is interested in exploring the fabrication of III-V semiconductor nanostructures using non-conventional metallic catalysts composed of carbon-nanotubes and graphene.

Researchers in the EINSL have access to the wide range of capabilities provided by the NPRL, seen in Figure 38, 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 38. (left) The photo shows an overview shot of the Epitaxially-Integrated Nanoscale Systems Laboratory. (right) Graduate student Kyle Tezanos 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 provides optical benches, laser sources, and single-photon detectors for quantum-optical experiments using bulk, fiber, and integrated optics. The labs optical benches provide a test bed to observe quantum entanglement and room to design a single pixel camera (Figure 39).

Figure 39. (left) Shown in the photo is an overview of the Quantum Imaging and Information laboratory. (right) Students and Faculty observed quantum entanglement in this testbed.

Electrical and Optical Characterization Lab for LED devices

The Electrical and Optical Characterization Lab for LED devices, used by Jing Zhang's research group, makes use of advanced tools and techniques to characterize fabricated devices. These devices include advanced LEDs for applications such as home lighting, display, and quantum computing. The lab includes equipment such as a semiconductor parameter analyzer, electrical probe station, an electroluminescence (EL) measurement setup (Figure 40), and a polarization-dependent setup. These tools help describe the power efficiency and optical pattern of the emitted light from these advanced LEDs.

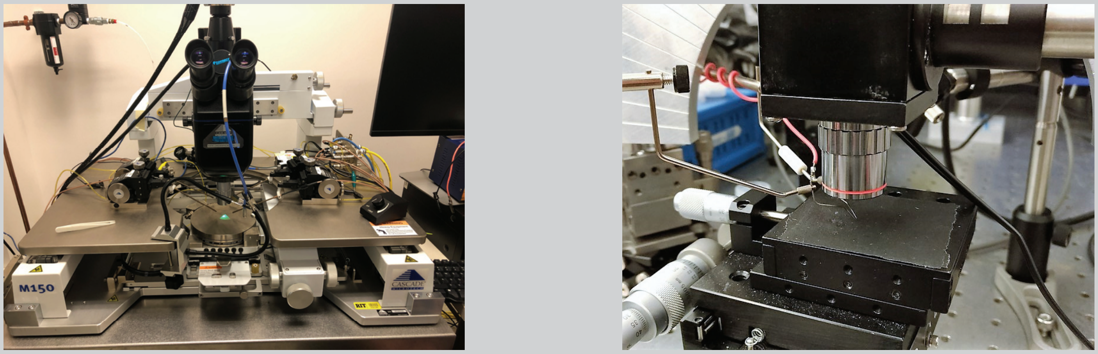


Figure 40. The electroluminescence measurement setup includes a rotating testing stage (right) and main probe station that tests wafers by dropping probes onto contact pads to light up the devices (left).

Semiconductor & Microsystems Fabrication Lab (SMFL)

The SMFL is equipped with micro-fabrication and metrology equipment to support research programs in photonic devices, nanomaterials, semiconductor materials and devices, nano-electronics, MEMS devices and sensors. These systems are utilized as part of RIT's role in AIM Photonics, to advance integrated photonics. Using the SMFL's resources, CfD can fabricate detectors with custom process flows and multiple process variations. The lab's flow bench and probe stations offer wafer-level testing, even during the fabrication process, allowing mid-process design changes (Figure 41). The probe station accommodates electrical and circuit analysis of both wafers and packaged parts, including low current and radio frequency (RF) probing.

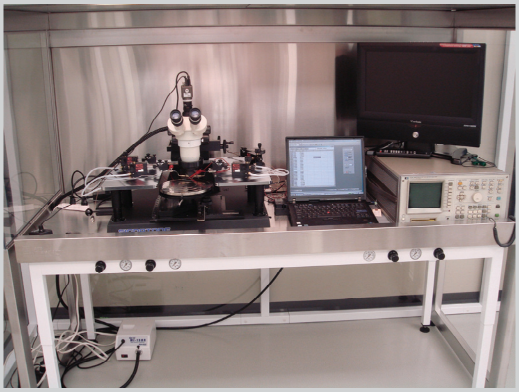


Figure 41. Shown above is the flow-bench lab probe station CfD researchers use to test device wafers.

CfD members use the metal organic vapor-phase epitaxy system (MOVPE) to grow III-V thin film crystals and nanostructures, and III-V lasers which Dr. Preble then integrates onto silicon photonic wafers (Figure 42.)

Figure 42. (left) Seth Hubbard tests a wafer load. (right) Karl Hirschman, Stefan Preble, and Seth Hubbard work in the SMFL developing and fabricating integrated circuits.

Figure 43 shows the TS Space Systems two-zone close match solar simulator testing photovoltaic solar cells under simulated sunlight conditions. The solar simulator is a dual source 18 kW system, custom built by TS Space Systems (Figure 43). The ultraviolet and visible (UV-VIS) portion of the spectrum are created using a 6 kW mercury halide arc lamp (also known as a hydrargyrum medium-arc iodide lamp, or HMI), while infrared (IR) was produced from a 12 kW quartz tungsten halogen (QTH) lamp. The output from these lamps were individually filtered to produce either AM0 or, with the insertion of an additional filter set, AM1.5G. The system was designed to produce a 300mm diameter beam. Additional characterization of nanomaterials electronic properties can be performed in the materials and device characterization space using the spectroradiometer, probe stations and IR cameras.

Figure 43. Parsian Mohseni is using the TS Space Systems two-zone close match solar simulator.

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 44).

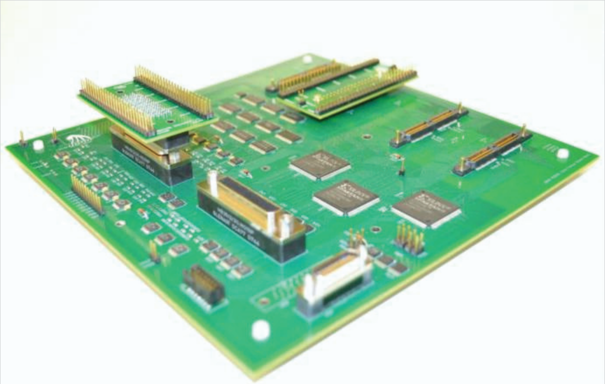


Figure 44. This image shows a cryogenic multi-layer circuit board designed in the CfD and populated in CEMA. All of the components on this board work at temperatures as low as 40 K, nanoTorr pressure levels, and in the presence of high energy particle radiation.

Center for Detectors

RIT | Rochester Institute of Technology