SPACE DAILY
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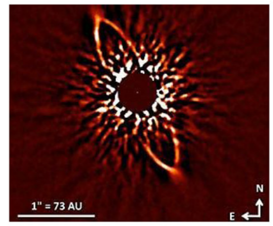
RIT Leads Development of Next-generation Infrared Detectors

by Staff Writers
Rochester NY (SPX) Jul 27, 2012



The National Science Foundation funding to develop the technology will carry Figer and his team to the second phase of the project and the design of a much bigger device on the scale of 4,000 by 4,000 pixels. An international consortium of organizations is needed to fund the fabrication of these larger detectors.

Cheaper, larger and better infrared detectors grown on silicon wafers could give more scientists access to infrared astronomy and further spur the hunt for exoplanets and the study of the universe's acceleration. Closer to home, the same technology could also advance remote sensing and medical imaging.

The National Science Foundation has awarded Rochester Institute of Technology $1.2 million to develop, fabricate and test a new family of detectors grown on silicon wafer substrates by Raytheon Visions Systems.

"If this is successful, the astronomy community will have a ready supply of affordable detectors that could be deployed on a wider range of facilities," says Don Figer, director of the Center for Detectors at RIT and lead scientist on the project.

"Right now infrared detectors are so expensive that there are only a few on the world's biggest telescopes-Keck, Gemini, the Very Large Telescope. Those are the only facilities that can afford them, and then they can only afford a few. They have big telescopes with big focal planes and tiny detectors in the middle."

Building and using advanced astronomical instrumentation is one of the strategic goals of the Center for Detectors, Figer says.

Advancing infrared detectors using silicon wafers will leverage the existing infrastructure built around the semiconductor industry and drive down the cost of building detectors.

Silicon wafers are commonly used for semiconductor circuits found at the heart of electronic devices. Their wide commercial application makes silicon wafers attractive for a number of reasons-they are produced in high volume, are readily available in large size and are inexpensive.

"The collaboration with RIT leverages over a decade of technologicaladvancements Raytheon has made in manufacturing large format MBE/Si focal planes," says Elizabeth Corrales, program manager at Raytheon Vision Systems.

"Infrared detectors with lower cost focal planes and improved performance will push the boundaries of infrared astronomy and continue Raytheon's 30-year service to the astronomy community."

Cost constraints limit the availability and scale of the current detector technology, which use small, scarcely produced Cadmium Zinc Telluride wafers.

"Today, a typical state-of-the-art device has 2,048 by 2,048 pixels at a cost around $350,000 to $500,000," Figer says. "Detectors on large telescopes can cost a significant fraction of the total instrument budget. Very large, affordable infrared arrays will be essential for making optimum use of the proposed 30-meter class ground-based telescopes of the future."

"The key to making larger-up to 14,000 by 14,000 pixels-and less expensive infrared detectors lies in using silicon wafer substrates, since large silicon wafers are common in the high-volume semiconductor industry and their coefficient of thermal expansion is well-matched to that of the silicon readout circuits," Figer says.

For the last 15 years, scientists have pursued the use of silicon substitutes in the quest for large infrared detectors. Until now, the crystal lattice mismatch between silicon and infrared materials has stymied advancement, causing defects that generate higher dark current, and thus higher noise, reduced quantum efficiency and increased image persistence.

Atoms in a silicon crystal are spaced closer together than those in infrared light-sensitive materials. When the infrared material is grown on the silicon, defects are generated. Photo-generated charge that represents the signal can get stuck and lost, or pop out of the lattice and show up as a phantom signal. The difference in atomic spacing can create the false signal.

Raytheon has developed the prototype detector technology using a method of depositing light-sensitive material onto silicon substrates while maintaining high vacuum throughout the many steps in the process. The material growth is done using a technique common to the semiconductor industry and known as molecular beam epitaxy.

"Raytheon has come up with an innovation to combine the silicon wafer with the mercury cadmium telluride light-sensitive layer in a way that eliminates all these bad effects," Figer says. "Our proposal is to do a fabrication run of parts based on this new technology and then evaluate the technology in the laboratory and on a telescope."

RIT and Raytheon will design and fabricate arrays of 1,024 by 1,024 pixels and 2,048 by 2,048 pixels and test them in the laboratories of the Center for Detector.

"Not only are silicon wafers much more affordable, but they can be made in much larger sizes because the wafers are now big," Figer says. "Instead of being a four-inch wafer, it can be 12 inches, for instance. We can make a 14,000-by-14,000-pixel detector. That has not been done. It could end up dominating the field in infrared detectors for the next 20 years."

Noise can obscure signals coming from the faint objects in the universe. Figer's team will measure the detector performance using a system based on one he designed for the Space Telescope Science Institute to measure the performance of detectors to be flown on the James Webb Telescope.

Figer will also develop a new light-tight detector housing to keep the detector optically and thermally isolated from everything around it. The box-within-a-box design is cooled to 60 Kelvin (-350 F) to reduce the glow, or blackbody radiation, emitted from warmer objects around the detector and prevent additional noise.

The National Science Foundation funding to develop the technology will carry Figer and his team to the second phase of the project and the design of a much bigger device on the scale of 4,000 by 4,000 pixels. An international consortium of organizations is needed to fund the fabrication of these larger detectors.

"I am going around the world talking to directors of observatories currently in existence and future observatories and asking them if they'd like to join a consortium of organizations, each of which contributes to, and benefits from, the development of the first run of 4K parts," he says. "This is the intermediate step before having a final product."

During the third and final phase of the program, Figer foresees RIT and Raytheon building an instrument for a large telescope. "One of the strategic goals for the Center for Detectors is to start a big astronomical instrumentation program at RIT," he says.

"There are only a handful of programs like that in the world. It's very competitive but it's also very fulfilling to both deploy the technology and use it for science in an astronomical instrument.

photonics.com

RIT, Raytheon to Develop Advanced IR Detectors

ROCHESTER, N.Y., Aug. 1, 2012 — The Rochester Institute of Technology was awarded a $1.2 million National Science Foundation award to develop, fabricate and test a new family of detectors grown on silicon wafer substrates by Raytheon Vision Systems of Waltham, Mass.

Cheaper, larger and better infrared detectors grown on silicon wafers could give more scientists access to infrared astronomy and further spur the hunt for exoplanets and the study of the universe's acceleration. Closer to home, the same technology could advance remote sensing and medical imaging.

"If this is successful, the astronomy community will have a ready supply of affordable detectors that could be deployed on a wider range of facilities," said Don Figer, director of the Center for Detectors at RIT and lead scientist on the project. "Right now infrared detectors are so expensive that there are only a few on the world's biggest telescopes — Keck, Gemini, the Very Large Telescope. Those are the only facilities that can afford them, and then they can only afford a few. They have big telescopes with big focal planes and tiny detectors in the middle."

A strategic goal for the Center for Detectors is building and using advanced astronomical instrumentation, Figer said.

Using silicon wafers to advance infrared detectors will leverage the existing infrastructure built around the semiconductor industry and drive down the cost of building detectors. Silicon wafers are commonly used for semiconductor circuits found at the core of electronic devices. Their wide commercial application makes silicon wafers attractive for a number of reasons — they are produced in high volume, are readily available in large sizes, and are inexpensive.

Cost constraints limit the availability and scale of current detector technology, which uses small, scarcely produced cadmium zinc telluride wafers.

For the past 15 years, researchers have pursued the use of silicon substitutes in the quest for large infrared detectors. Until recently, the crystal lattice mismatch between silicon and infrared materials has hindered advancements, causing defects that generate higher dark current noise, reduced quantum efficiency and increased image persistence.

When infrared light-sensitive materials are grown on silicon, defects are generated because their atoms are not as closely spaced together as atoms in a silicon crystal. Photogenerated charge representing the signal can get stuck and lost, or pop out of the lattice and show up as a phantom signal. The difference in atomic spacing can create the false signal.

Now scientists at Raytheon have developed a prototype detector that uses a method of depositing light-sensitive material onto silicon substrates while maintaining high vacuum throughout the many-step process. The material growth is completed using a molecular beam epitaxy technique.

"Raytheon has come up with an innovation to combine the silicon wafer with the mercury cadmium telluride light-sensitive layer in a way that eliminates all these bad effects," Figer said. "Our proposal is to do a fabrication run of parts based on this new technology and then evaluate the technology in the laboratory and on a telescope."

RIT and Raytheon will design and fabricate arrays of 1024 x 1024 pixels and 2048 x 2048 pixels and test them in the laboratories of the Center for Detectors.

"Not only are silicon wafers much more affordable, but they can be made in much larger sizes because the wafers are now big," Figer said. "Instead of being a four-inch wafer, it can be 12 inches, for instance. We can make a 14,000-by-14,000-pixel detector. That has not been done. It could end up dominating the field in infrared detectors for the next 20 years."

Figer's team will measure the detector's performance using a system based on one he designed for the Space Telescope Science Institute of Baltimore to measure the performance of detectors to be flown on the James Webb Telescope. He will also develop a new lighttight detector housing to keep the detector optically and thermally isolated from its surroundings. The box-within-a-box design is cooled to 60 Kelvin (-350 F) to reduce the blackbody radiation emitted from warmer objects around the detector and to prevent additional noise.

The NSF funding will carry Figer's team into the second phase of the project and the design of a larger, 4000 x 4000 pixel device. An international consortium of organizations is needed to fund the fabrication of these larger detectors.

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"One of the strategic goals for the Center for Detectors is to start a big astronomical instrumentation program at RIT," he said. "There are only a handful of programs like that in the world. It's very competitive, but it's also very fulfilling to both deploy the technology and use it for science in an astronomical instrument."

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Secret Spy Telescopes Made in Rochester

By: Caroline Tucker

June 5, 2012

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

The high-tech gadgets are currently being stored in the Rochester Tech Park in Gates.

The Rochester operations for ITT Exelis developed and built the telescopes in the late 1990's.

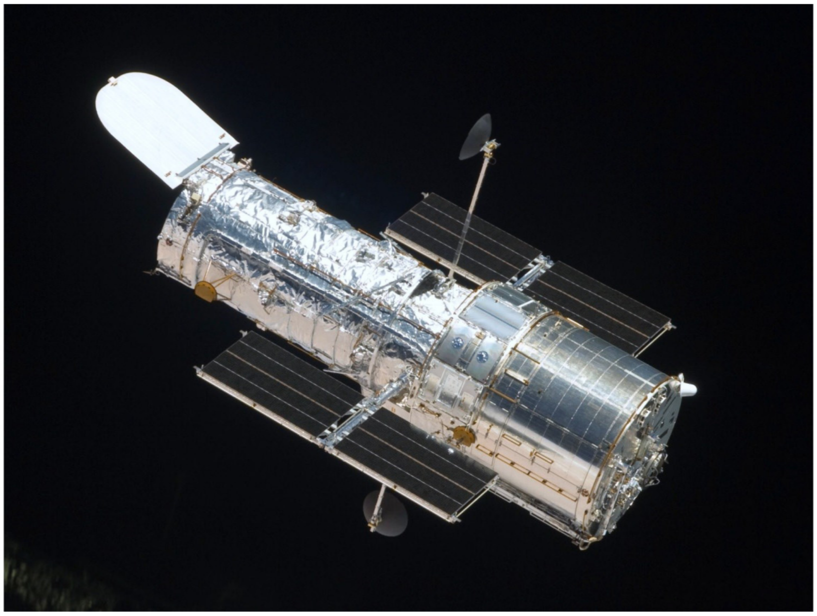
But the telescopes have never been used.

The National Reconnaissance Office, which operates the nations' spy satellites, is now offering the unused telescopes to NASA.

RIT's Director of the Center for Detectors says those telescopes will be fitted with cameras and highly-sensitive detectors to investigate more of the universe.

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

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



The company can't reveal what the telescopes look like but it's been reported that they are similar to the Hubble telescope.

ROCHESTER BUSINESS JOURNAL
RBJ

New center at RIT finds novel ways to use photo sensors

By NATE DOUGHERTY

For anyone who uses a cell phone camera, a type of digital feedback that causes graininess is inevitable. But researchers at a newly formed center at Rochester Institute of Technology are working on eliminating it, opening a realm of possibilities for astronomy, biomedicine and even national security.

Research opens paths in astronomy, national security

The Center for Detectors in RIT's College of Science works on projects that advance the science and technology of photon sensors through interdisciplinary

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RIT CENTER

Continued from page 1

research. Because of the nature of the projects, there is a good chance it will bring significant funding to RIT, Director Don Figer said.

Detectors, like those in cell phone cameras, are used for a range of activities such as detecting cancers or tracing airborne chemical agents in case of a terrorist attack.

"Depending on the application, you might be willing to try to make a better detector, and that's what we will do," Figer said. "For instance, if you're building a $5 billion space telescope, you might be willing to make a better detector than the $1 one in your phone.

"Those that go into space tend to cost $1 million a chip, and each one is like God's little creation, highly custom with exquisite performance."

The center occupies 5,000 square feet on campus and has 10 to 15 workers—including students—depending on the project, Figer said. He envisions the center growing to 50 people.

The work being done there has been an interdisciplinary effort, Figer said, and has included faculty and students from other universities and from different schools at RIT.

The E. Philip Saunders College of Business at RIT worked on a benchmarking study to examine how other centers operate and develop programs for students, and the RIT School of Design helped design the lab space and logo.

"We're kind of like a blank slate. We have beautiful space here in a very new building, but we don't have the kind of signage and posters and video displays," Figer said. "The School of Design knows how to take the mission of our organization and flow it down into different elements, a completely different realm of study I know nothing about."

The center formed from the Rochester Imaging Detector Laboratory, itself founded in 2006 as part of a faculty development grant from the New York State Foundation for Science, Technology and Innovation.

The laboratory has helped RIT become involved in some of the highest-profile projects in the field. Several projects were listed in the Astronomy Decadal Study, a report from the National Research Council that identifies the highest-priority research activities for astronomy and astrophysics in the next decade.

The center is expected to focus on discoveries that can fit with other optical systems, such as biophotonic imaging, which marries detectors with electronics and devices. This is used as a complement to X-ray technology, using optical light to look inside the human body.

Figer said the center could develop a biophotonics test bed with regional research hospitals, opening the possibility for commercial applications through local medical imaging companies.

"We want to have research in RIT's new Institute of Health Sciences and Technology that would leverage and take advantage of these cutting-edge detectors," Figer said. "In that case, the test bed would become a unique research tool for developing new medical instrumentation, a particularly fertile area for RIT's focus on innovative technology."

If successful, this would be the only biophotonic program in the world with that level of detectors, Figer said.

"Our detectors will represent a quantum leap in sensitivity and the ability to obtain data simultaneously from many more channels," he said. "Instead of having 16 pixels, for instance, we would have tens of thousands, or even millions, of pixels. You can imagine what kind of difference that would make."

Director Don Figer expects the center to gain funding from NASA, the National Science Foundation and the National Institutes of Health, among other agencies.

Funding opportunities

Under Figer, the laboratory had a track record of winning external research funding, bringing $7.5 million in total.

The funding came primarily from companies or government entities looking for the laboratory to do specific research projects, such as a partnership with the Massachusetts Institute of Technology Lincoln Laboratory to develop the zero read noise detector. That is funded through a $3 million grant from the Gordon and Betty Moore Foundation, set up by the co-founder of Intel Corp.

"The zero read noise detector is something that's never been done before," Figer said. "This detector would have a broad range of applications, particularly in cameras and spectrographs for a telescope 30 meters in diameter, larger than anything we have now. Using one of these detectors, the collective reading power of the telescope would be increased by four, which is better and cheaper than just building a bigger telescope."

Since its opening, the laboratory had been one of the best performers at the university in garnering money for sponsored research. Nearly half of its funding came from NASA, Figer said, including money for a project to help with autonomous landings on asteroids for which RIT ranked No. 1 out of 107 submissions, beating out MIT, Princeton University, Harvard University and NASA's own research centers.

The center has a bright outlook for continued funding, said David Bond, RIT's director for sponsored research services.

"I think they're well-positioned to continue growing because the nature of detectors falls squarely in the mission space of multiple federal agencies and some foundations," Bond said. "These are applications people haven't even thought of yet, and there really could be a lot of interesting science and basic research enabled by his work."

Figer said he expects the center to gain funding from NASA, the National Science Foundation and the National Institutes of Health, among other agencies. He is submitting a proposal for $50 million from NSF that would fund the center for 10 years.

Though that kind of grant is rare, Figer said he thinks the work being done at the center would justify it.

"The NSF has a program where they fund the kind of centers doing this work, but they can't fund too many," he said. "Since 1980 they've funded maybe 25. We want to use that to invent new kinds of detectors and also employ them in Upstate New York with big and small companies."

The NSF funding would allow the center to occupy its own building, Figer said, either in newly built space or in existing space at the university.

As the center completes projects, especially the zero read noise detector, it also will bring national attention to RIT, Bond said.

"That's a significant advance that would do a lot for the reputation of RIT," Bond said. "A cutting-edge discovery like that would make a strong statement about the research being done at RIT."

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Specific R&D

FPI will focus on four specific areas for research and development.

Integrated Photonics

Stefan Preble, director of the RIT Integrated Photonics Group, is leading work that integrates photons onto microchips, which will address the key computing, energy, communication, and sensing challenges of the future. Through the FPI, Preble believes revolutionary advances in photon science and technology can be made.

"The goal is to be able to process every photon. Light is made up of photons and it's very important you don't lose any of those. You want to get all the information you can from these photons. That's difficult to do at this point," Preble said.

A key theme will be the exploitation of the quantum properties of photons and matter to eliminate tradeoffs in speed, efficiency, and noise. "By moving to a quantum-limited regime in the laser, the waveguide, the detector, essentially you're able to have much higher performance than is possible in classical technology," Preble said. "As a result that shift helps us to answer those big questions."

Scaled Electronics

Bruce Smith, director of RIT's microsystems engineering doctoral program, leads this area, which focuses on microelectronics, "making devices very small, well beyond the wavelength of light itself. We're talking about building structures in electronic devices that approach the single nanometer scale.That requires huge challenges going beyond the traditional predictive scaling laws," Smith said.

Having the Initiative build partnerships with businesses, consortia, and other academic institutions is key. "More than ever, there are challenges that require thinking about nano-scale devices and process technology in nonconventional ways. Collaborating with groups that are involved with the latest advances is extremely important as we move to new opportunities to communicate with, connect to, and control the world around us." Smith said. "The current challenges aren't anything that can be resolved with one single discipline; the goal is to create opportunities to work together."

Photovoltaics

Seth Hubbard, director of RIT's NanoPower Research Laboratories, has overall responsibility for the energy area of the FPI. The United States and other countries have identified sustaining the energy supply as a high priority, according to Hubbard. His research focuses on photovoltaics, specifically improving the efficiency at which photovoltaics converts sunlight into electricity.

Hubbard, Preble, and Figer already have been collaborating for a number of years, and plans call for a multidisciplinary team of scientists and engineers to develop breakthroughs to advance the state of the art in device efficiency.

While Hubbard has already developed collaborative relationships with a number of businesses over the years as a result of joint government funding, he believes the Future Photon Initiative will give the name recognition to be able to expand that.

Detectors

Two of the most exciting application areas for detectors are astrophysics and biophotonics, according to Figer, who oversees this area in his role as head of the Center for Detectors. The Center, which is one of the most well-funded astronomical detector programs in the world, is currently leading development programs for both single photon counting detectors and also large format infrared detectors. The FPI will leverage these developments for future astrophysics missions.

In the field of biophotonics, fast low- noise detectors are crucial for the develop- ment of next-generation biophotonic instruments. Ultimately, these instruments can help answer big questions such as how to extend the lives of breast cancer survivors and how to study brain hematomas in infants, Figer said. The Initiative plans to hire a principal investigator faculty member for this area.

AIM-ing up: Student-researchers help build the photonics ecosystem

Rochester is making an impact in photonics manufacturing, and RIT is playing a central role as a key partner in AIM Photonics, a national manufacturing initiative expected to stimulate economic development and global competitiveness.
Photonics is an intricate science about harnessing the power of light. RIT's numerous experts are contributing to photonic device manufacturing, industry assessment to improve workforce training and education, and device packaging and assembly solutions—all critical areas necessary for the growing photonics ecosystem.
RIT students are a big part of that system, creating photonics devices and solutions in classes and through research projects that will also become foundational materials to help train others for an industry expected to transform manufacturing.

"Photonics is the future," said Sanjna Lakshminarayanamurthy, a microelectronic engineering graduate student from India. "I do live in the present, but we need to have an eye for the future. I know I can contribute; I felt this work would bring out the best in me."

Lakshminarayanamurthy was one of 20 students taking Photonic Integrated Circuits, an upper-level course, delivered by Stefan Preble, associate professor of microsystems engineering in RIT's Kate Gleason College of Engineering, and several other faculty this past spring. Focused on learning the overall photonics manufacturing process, students designed a prototype photonics chip where laser light is precision-placed onto silicon.
"All the courses I took in microelectronics helped me in the clean room to work on this project. We tried different chemistries we had not used here before," she said. "Silicon photonics is just growing, and it can be compatible with the existing integrated circuit process."

Lakshminarayanamurthy helped define the preparation, etching steps and processing necessary to fabricate chips. Her project information will be integrated into the curriculum RIT is helping develop for AIM Academy, the educational arm of AIM Photonics. She will also use this knowledge in her new position as a process engineer at Global Foundries in Albany.
Once an optical fiber is aligned to a feature on silicon, the challenge becomes holding that fiber in place, protecting it during testing before packaging and assembly. Keyla Bastardo-Ramirez works closely with Martin Anslem, director of the Center for Electronics Manufacturing and Assembly, to produce solutions that ensure manufacturing processes are efficient, cost effective and sustainable. Her literature review on fiber attachment challenges, current solutions and those being developed is extensive. It also highlights the need to develop novel research programs that can eventually bridge the gap for adopting photonics integration technology in high volume production applications, she explained.
"When I started my master's degree in manufacturing and mechanical system integration, I already had experience working in manufacturing firms, not in the electronics industry, but I was already fascinated with manufacturing processes of any kind," said Bastardo-Ramirez, who is from Santo Domingo, Dominican Republic. "I would like to continue working on developing this technology in industry or in academia."
Industry will need students like Bastardo-Ramirez, who will be entering the photonics workforce once she graduates in December. Other workforce needs—from entry-level positions to research and development—are being assessed through the Photonics and Optics Workforce Education Research (POWER) group, founded by Ben Zwickl and Kelly Martin, both assistant professors in RIT's colleges of Science and Liberal Arts, respectively. POWER's research is on skills needed for photonics and optics; the group explores how academia and industry define, perceive, influence and value STEM workforce development.

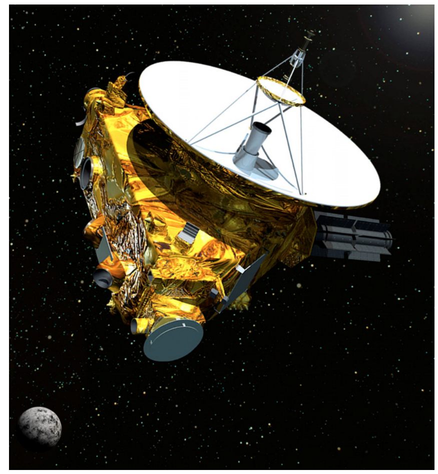
Alexandria Cervantes, an undergraduate on one of several projects within the research group, did in-depth interviews with managers and new hires from local companies as well as graduate research assistants at universities. Preliminary data revealed that supplementing current technical coursework with communications and interpersonal skills can benefit all students in STEM programs to better prepare them for success in their respective fields.
Cervantes' study was part of the Research Experiences for Undergraduates, where undergraduates from RIT and other national universities can apply for directed projects related to their degree programs and interests. Her work, titled, "Values and perception of communication in photonics and optics," and featured at this summer's Undergraduate Research Symposium, will become part of POWER's contribution to AIM's comprehensive workforce needs assessment studies.
Students are involved in many more projects related to photonics technology and education, and their work will reap dividends, not only for AIM Photonics, but for their own careers..

UNIVERSITY NEWS

RIT scientist measures brightness of the universe with NASA's New Horizons spacecraft Planetary mission offers up-close view of Cosmic Optical background.

April 11, 2017
by Susan Gawlowicz

Images taken by NASA's New Horizons mission on its way to Pluto, and now the Kuiper Belt, have given scientists an unexpected tool for measuring the brightness of all the galaxies in the universe, said a Rochester Institute of Technology researcher in a paper published this week in Nature Communications.



The New Horizons spacecraft flew by Pluto and is headed for the Kuiper Belt in the outer solar system. The space camera aboard New Horizons, in the artist's illustration above, could be used to re-measure the brightness of the cosmic optical background, said RIT scientist Michael Zemcov.

In the study, "Measurement of the Cosmic Optical Background using the Long Range Reconnaissance Imager on New Horizons," lead author Michael Zemcov used archival data from the instrument onboard New Horizons—the Long Range Reconnaissance Imager, or LORRI—to measure visible light from other galaxies. The light shining beyond the Milky Way is known as the cosmic optical background. Zemcov's findings give an upper limit to the amount of light in the cosmic optical background.

"Determining how much light comes from all the galaxies beyond our own Milky Way galaxy has been a stubborn challenge in observational astrophysics," said Zemcov, assistant professor in RIT's School of Physics and Astronomy and member of RIT's Center for Detectors and Future Photon Initiative. Light from the cosmic optical background can reveal the number and location of stars, how galaxies work and give insights into the peculiar nature of exotic physical processes, such as light that may be produced when dark matter decays. Dark matter is the invisible substance thought to comprise 85 percent of matter in the universe.

"This result shows some of the promise of doing astronomy from the outer solar system," Zemcov said. "What we're seeing is that the optical background is completely consistent with the light from galaxies and we don't see a need for a lot of extra brightness; whereas previous measurements from near the Earth need a lot of extra brightness. The study is proof that this kind of measurement is possible from the outer solar system, and that LORRI is capable of doing it." Spacecraft in the outer solar system give scientists virtual front-row seats for observing the cosmic optical background. The faint light from distant galaxies is hard to see from the inner solar system because it is polluted by the brightness of sunlight reflected off interplanetary dust in the inner solar system. Cosmic dust is sooty bits of rock and small debris that moved, over time, from the outer solar system toward the sun. Scientists launching experiments on sounding rockets and satellites must account for the dust that makes the Earth's atmosphere many times brighter than the cosmic optical background.

NASA's New Horizons mission has been funded through 2021, and Zemcov is hopeful for the chance to use Long Range Reconnaissance Imager to re-measure the brightness of the cosmic optical background. "NASA sends missions to the outer solar system once a decade or so," Zemcov said. "What they send is typically going to planets and the instruments onboard are designed to look at them, not to do astrophysics. Measurements could be designed to optimize this technique while LORRI is still functioning."Zemcov's method harkens back to NASA's first long distance missions Pioneer 10 and 11 in 1972 and 1974. Light detectors on the instruments measured the brightness of objects outside the Milky Way and made the first direct benchmark of the cosmic optical background. "With a carefully designed survey, we should be able to produce a definitive measurement of the diffuse light in the local universe and a tight constraint on the light from galaxies in the optical wavebands," Zemcov said. Archived data from New Horizon's Long Range Reconnaissance Imager show "the power of LORRI for precise low-foreground measurements of the cosmic optical background," Zemcov wrote in the paper. Chi Nguyen, a Ph.D. student in RIT's astrophysical sciences and technology program, mined data sets from New Horizons' 2006 launch, Jupiter fly-by and cruise phase. She isolated four different spots on the sky between Jupiter and Uranus, captured in 2007, 2008 and 2010, that met their criteria: looking away from the solar system and looking out the galaxy. Poppy Immel, an undergraduate majoring in math and computer science, generated the data cuts and determined the photometric calibration of the instrument. Other co-authors include Asantha Cooray from University of California Irvine; Carey Lisee from Johns Hopkins University; and Andrew Poppe from UC Berkeley. Zemcov is affiliated with the Jet Propulsion Laboratory.

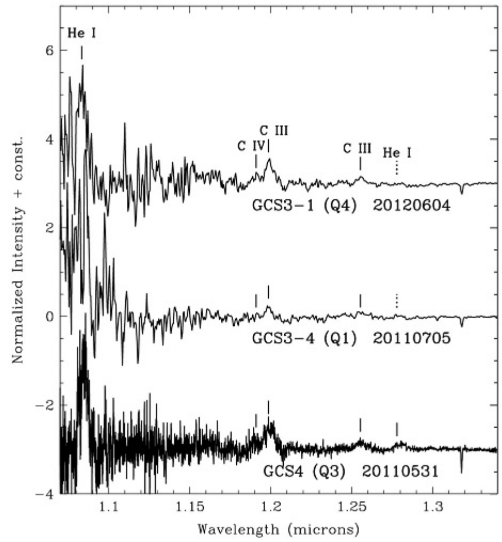
Center for Detectors

GEMINI OBSERVATORY

August 20, 2017

Most objects in the center of the Milky Way are so highly obscured from our view by intervening dust that, at wavelengths visible to the naked eye, only about one photon out of every trillion emitted by them toward the Earth actually reaches our planet. This makes it impossible to observe the copious visible light emitted by the Galactic center's stars, hot gas, the accretion disk encircling the supermassive black hole, and many other objects. The amount of obscuration decreases rapidly with increasing wavelength and thus most of our information about the Galactic center's resident objects and gas comes from infrared and radio observations.

For some Galactic center stars, those that are embedded in dust shells of their own making, the obscuration is even more extreme. Among these are five infrared-luminous objects known as the Infrared Quintuplet, located at the center of a cluster of hundreds of hot and massive stars, which has been given the name Quintuplet Cluster. The Quintuplet Cluster is only 30 parsecs (100 light years) distant from the central massive black hole at the very center of our galaxy.



J-band spectra of three of the five members of the Infrared Quintuplet showing emission lines of neutral helium and ionized carbon. The continuum radiation from the stars and their dust shells actually decrease rapidly from longer to shorter wavelengths and is barely detectable at the short wavelength edge of these spectra. In the figure the spectra have been "flattened" to more easily reveal the line emission. The increasing "noisiness" of the spectra toward their short wavelength edges demonstrates the increasing difficulty of detecting any light at all from these objects at those wavelengths.

The difficulty in observing these five stars is greater, not only due to the additional obscuration by their dust shells, but also because the shells are warmed by their central stars and emit bright infrared continuum radiation, diluting any infrared light from the stars themselves. The combination of these effects has made it very challenging, if not impossible, at any infrared wavelength to detect light from the interiors of the shells leaking through the dust "cocoons" and surviving the journey through the interstellar dust to our telescopes, or so it was thought. Thus, little has been learned about natures of these objects since they were discovered over a quarter century ago. The only clues were high-resolution infrared images which showed that the dust emission from two of the five resembled pinwheels. Previously this phenomenon had only been seen outside of the Galactic center, in a few objects identified as Wolf-Rayet colliding wind binaries, which are double star systems comprised of extremely luminous hot stars with massive winds.

Several years ago, while using NIFS at Gemini North for an unrelated research program, Tom Geballe serendipitously discovered a very faint and broad emission line due to hot helium gas near 1.7 microns in the infrared spectrum of one of the Quintuplet stars. Prompted by this, a team consisting of him, Paco Najarro (Centro de Astrobiología, Spain), Don Figer (Rochester Institute of Technology), and Diego de la Fuente (Universidad Nacional Autónoma de México) successfully proposed to use NIFS and GNIRS to obtain sensitive spectra of all five members of the infrared Quintuplet, not only near 1.7 microns, but also down to wavelengths as short as 1.0 micron. Near the short end of that wavelength range, one photon in several thousand survives the journey first through the dust cocoon and then from the Galactic center to Earth. That fraction is much larger than the one in a trillion at visible wavelengths, but is still tiny. However, the contaminating emission from the warm dust shells is greatly reduced, increasing the contrast between any spectral features emitted from inside the dust shells and the continuum emission from the shells themselves. Thus, the team reasoned that with a large telescope, a sensitive spectrograph, and less dilution from the warm dust, they would be able to detect the faint light coming from within the cocoons.

The spectra, recently published in The Astrophysical Journal, reveal the presence of emission lines from four of the five members of the Quintuplet, and have allowed us to definitively identify the four as containing late-type, carbon-rich Wolf-Rayet stars, as was suspected based on the earlier imaging. These massive stars are only a few million years old, but have completely lost their outer hydrogen-rich layers and probably do not have much longer to exist before exploding violently as supernovae.

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RIT, FIT Camera Being Tested on ISS

ROCHESTER, N.Y. — Imaging technology advanced by researchers at the Rochester Institute of Technology (RIT) and the Florida Institute of Technology (FIT) is being tested on the International Space Station (ISS) and could someday be used on future space telescopes.

A new twist on the charge injection device (CID) camera, originally developed in 1972 by General Electric Co., fine-tunes the array of pixels for improved exposure control in low-light conditions. The enhanced technology could give scientists a new method for imaging planets around other stars and improve the search for habitable Earth-like planets.

Zoran Ninkov, professor at RIT's Chester F. Carlson Center for Imaging Science, and Daniel Batcheldor, head of physics and Space Sciences at FIT, designed the charge injection device camera to capture contrasts between light emitted by astronomical objects.

"CID arrays offer considerable promise in many applications due to the focal plane architecture that allows random pixel access and nondestructive readout," Ninkov said. "In addition to improving presently available devices, the development of next-generation imaging arrays promise considerable flexibility in read-out and on-chip processing for the future."

A SpaceX Falcon 9 rocket carried the charge injection device to the ISS in the cargo of supplies and science experiments in February. Astronauts have installed the camera on a platform outside the space station and will test the camera for six months.

"We expect to start seeing results by the end of April," Batcheldor said. "A complex test pattern will be sent from a successfully operated camera through the ISS systems and down to the ground. A successful demonstration of CIDs on the International Space Station will put this technology at the NASA Technology Readiness Level 8, which means it's ready to fly as a primary instrument on a future space telescope."

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Data Centers and Telecommunications

Integration and packaging of optical components such as laser sources, multiplexers, detectors and modulators into a single chip are ushering in a new era of communications to 100 Gbps and beyond.

Today's data centers deliver millions of services, processing terabytes of data per second around the world for billions of devices. Considering the volume, it's amazing that we ever have a signal. As the need for connectivity increases, data centers are under constant pressure to add more and more massive racks of servers and fiber optic interconnects, which takes money and time, energy and real estate.

The demand for large-scale cloud computing and ever-faster processing is growing so fast that network traffic in data centers is doubling every twelve months, according to Diane Bryant, vice president and general manager of data centers at Intel.[1] And copper wires struggle to transmit at data rates of 25 Gbps over a few meters, says Microsoft's general manager of hardware engineering, Kushagra Vaid. "As data rates start getting to 100 Gbps — and this will happen in the future — we are going to hit a brick wall," Vaid said.

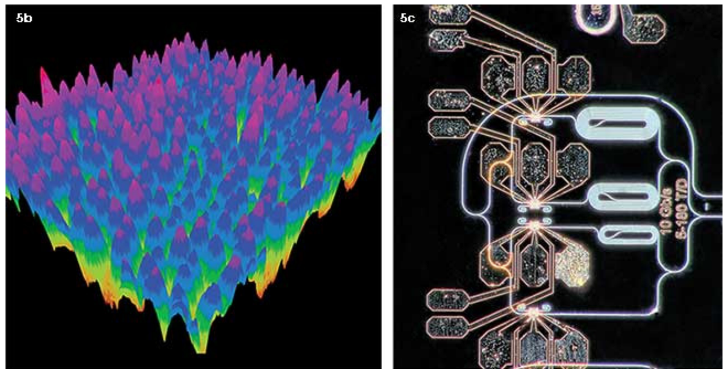

Figure 5b. *This false color 3D atomic force microscope image shows the height profile of the InAs QDs on Si (at left).* ***Figure 5c.*** *The Si PIC generates optical time-division multiplexing signals at 40 Gbps from 10 Gbps QD mode-locked lasers (right). The circuit splits the short pulses from the laser into four separate paths, each modulated by Si ring resonator electro-optic modulators, delayed and recombined at the higher data rate of 40 Gbps. Courtesy of K. Tian and Z. Wang, RIT and M. Fanto, RIT.*

PICture this

One of the steepest challenges to widespread adoption of PICs (photonic integrated circuit) is incorporating lasers into the chip. More than one material may emerge as a winner for use in hybrid lasers on PICs. Silicon itself doesn't lase, although adding a layer of a III-V material helps overcome that limitation; Intel added InP, for example. But III-V materials are inherently not compatible with conventional CMOS fabrication, leading to expensive work-arounds. Research is hot on the trail of graphene, a two-dimensional layered material that can emit, transmit and detect photons, but issues of CMOS scalability and performance are handicaps that will take time to overcome[4].

One lasing material showing great promise is quantum dots (QDs) (Figure 5). Recently, researchers at Rochester Institute of Technology (RIT, Rochester, N.Y.) demonstrated that indium arsenide (InAs) QD laser heterostructures can successfully be grown and transferred to Si substrates via a low-temperature palladium (Pd)-mediated wafer bonding process (Figure 5a, 5b). Associate professor of microsystems engineering Stefan Preble and colleagues at RIT, in collaboration with professor Wei Guo at the University of Massachusetts, Lowell, further demonstrated mode-locking of these lasers, which would enable stable optical pulse trains of short pulses (<10 ps) at high repetition rates for optical time-division multiplexing (OTDM), among other uses (Figure 5c)[5]. The group is looking at schemes to combine wavelength division multiplexing (WDM) with OTDM to get to data rates beyond 400 Gbps. The biggest hurdle with QDs is efficiency, but their temperature stability is making them hot prospects for next-generation PICs.

"Quantum dots have recently been pulling ahead of quantum wells as a promising next-gen PIC solution," said Preble. "The QD is less susceptible to defects that destroy performance over time. And several promising approaches for direct growth of QDs on Si chips are emerging. But the yield and long-term reliability of QDs on silicon remains to be proven."

Other schemes beyond WDM and OTDM may someday be able to carry terabyte data rates on a single chip. Assistant professor of electrical engineering Liang Feng at the University at Buffalo, State University of New York, and colleagues recently demonstrated a tiny microring laser that emits photons in a radially polarized stream. The orbital angular momentum (OAM) of the photons creates a vortex shape that offers novel degrees of freedom and flexible control through on-demand topological charge and polarization states. The scheme may enable mode multiplexing over many orders (potentially an infinite number of orders) for tens of OAM channels[6,7,8] (Figure 6). The OAM laser might offer entirely new ways of implementing high-speed, secure optical signals in both classical and quantum regimes.

"Fifty years ago you couldn't have imagined what our everyday life would be like today," said Feng. "The power in our laptops is as great as the supercomputers that helped put astronauts on the moon. We certainly have a very long way to go, but all over the world people are trying to increase the laser energy emission in photonic circuits. In the next 50 years, it's exciting to imagine what we'll accomplish."

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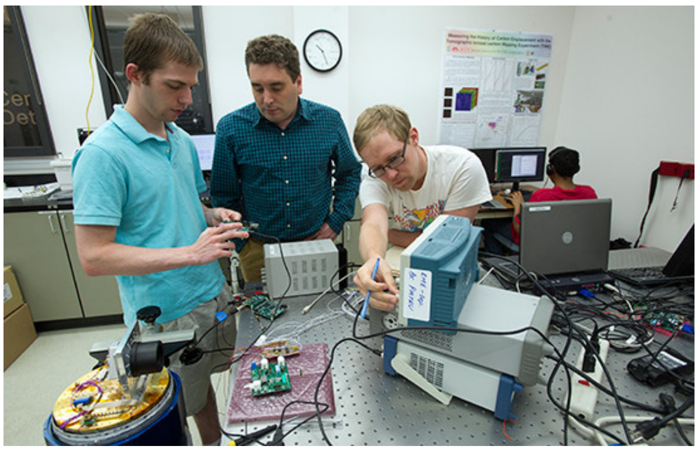
INFORM. INSPIRE. ENTERTAIN.

How does any ship, from watercraft to spacecraft, successfully navigate away from the sight of natural landmarks on the Earth's surface? **By using the stars.** A team of engineering undergraduates at the Rochester Institute of Technology (RIT) are reaching for those stars with a new research project for NASA: designing a "compass" for rockets using a new type of detector technology. What these engineers are working to design, build and eventually deploy is a star-tracking system for rocket navigation. Intended to fly on a NASA technology demonstration mission later in the year, the system combines telescope and camera components that will orient rocket payloads based on images of the visible star field.

Star-Tracking Navigation Systems with New Cryogenic Materials



Star-tracking systems have been used for satellite, rocket and other spacecraft navigation for quite some time.

What sets this project apart is revealed in its name: the Cryogenic Star Tracking Attitude Regulation System (CSTARS). The RIT students are experimenting with detectors made of metal-oxide semiconductors (CMOS), which show promise to operate well even at temperatures as cold as that of liquid nitrogen, minus 320 degrees Fahrenheit.

Being able to operate at super-low temperatures is important for space systems, as the cryogenic temperatures reduce dark current in the sensors and increase instrument sensitivity. The traditional technology used in astronomical imagine systems is often similar to that found in consumer electronics – charge-coupled detectors (CCDs) – which become inoperable at very cold temperatures.

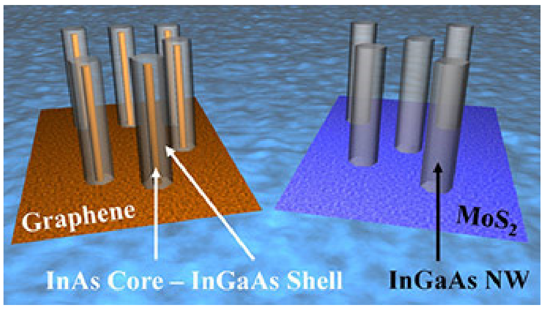
The prototype from RIT is a move toward developing fully cryogenic detectors that could improve the sensitivity of NASA's future deep-space cameras. The star tracker will fly as part of a technology demonstration payload on a suborbital sounding rocket launching from NASA's Wallops Flight Facility in December of this year.
"The aim is to control this sensor and make it work at cold temperatures," said Kevin Kruse, a fifth-year electrical engineering student and the team leader. "Then we'll launch it into space to take pictures. A future mission would involve us guiding the rocket using the images we take."

Engineering Undergrads Build Their Skills with NASA Projects
The project at RIT is funded with a $200,000 grant from NASA's Undergraduate Student Instrument Project (USIP) Flight Research Opportunity program, which provides research grants specifically to undergraduate-led teams. The program is geared to supporting the development of professional engineering skills in undergraduate engineering students. It also gives these students the valuable experience that comes from creating experiments directly relevant to NASA missions.

The students on the team hail from a range of engineering disciplines. Members include electrical, mechanical and computer engineering undergraduates. They are also working with team members from other departments at RIT, including physics, computational mathematics and business.
This type of interdisciplinary team environment enhances the experience and skills these students learn by creating an experience the same as how teams in future professional projects will operate. Between the high-level technical skills students develop through these kinds of programs, as well as the leadership and teamwork skills that come from collaborative projects, these engineers will have great experiences to bring with them into graduate school or their future career.

Solar Power for Everyone

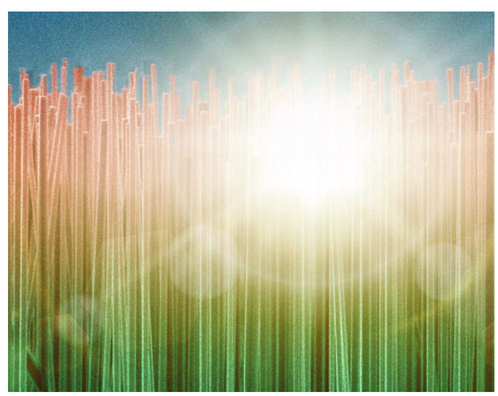
Researchers at the Rochester Institute of Technology (RIT) are taking an unconventional approach to improving efficiency and lowering the cost of solar cell technology in the ongoing quest for feasible ways to reduce the reliance on a complex electrical infrastructure.Parsian Mohseni, assistant professor in RIT's Kate Gleason College of Engineering, is co-principal investigator, leading a team conducting research using nanowire to capture more of the sun's energy instead of traditional film. He said that if trends go as expected, anyone with solar cells may be able to use them in their home while sending excess energy back to the grid. Consumers can also use the devices on-the-go, by taking them out of a backpack or attaching them to the roof of a car. "The idea is they can produce their own power wherever they are, whether at home or on the go," Mohseni said.



Today's solar panels convert the sun's rays into electricity by exciting electrons in silicon cells using the photons of light from the sun. Silicon has remained the current conductive material of choice in most electronic devices because of its low cost, simple processing, and useful temperature range. But with the demand for more storage, better conductivity, lower prices, and higher power for new technologies such as photonics and higher speed transistors, researchers are looking to supplement silicon with other materials that can meet those needs.

Mohseni's team is building on work previously done that uses a combination of different types of materials, from Group Three and Five on the periodic table, and a different process for better conductive capabilities. But those materials are so expensive that they are used only in special applications, such as space technologies, and not for solar panels and other consumer products. Researchers began considering using these materials, a combination of metallic and non-metallic elements, around 1990. "It was a really novel approach then," Mohseni says. After some work, they realized they could get superior performance compared to any other existing solar cell technologies, but it remained too costly for everyday use. Mohseni's team began exploring ways to cut costs. One way is through the use of nanowires. The ultra-thin, grass-like vertical structures, they found, could be used as a replacement for the thin films made from silicon. The nanowires reduce the amount of material used in the devices and decreases costs by nearly 90 percent. When using film, Mohseni explained, the material has to be thick to capture more light, because when the light isn't absorbed, it will bounce or reflect off of the film. Nanowires act differently. If light bounces off one wire in an array, it can be captured by a nearby wire and re-absorbed.

"This effect of multiple scattering interactions increases the light-trapping capabilities of the nanowire array. Even though we are using 90 percent less material, we can absorb light better than a thin-film structure," he added. "It's a luxury that using nanowires provides for us."Mohseni was recently awarded about $300,000 for an Early Concepts Grant for Exploratory Research (EAGER) from the National Science Foundation. The award is designed to support exploratory early-stage work on untested but potentially transformative research ideas or approaches



The grant gives the team two years to advance the field. "During the two-year window, our goals are to realize high-quality nanowire growth on silicon. Our goals then continue on to characterize these materials to take advantage of them for solar cell applications," he says. "We want to characterize their structure, their optical properties, and their electrical properties, and learn how their composition or their spacing or their size modifies these properties. That's the materials exploration side of it." On the engineering side, the team will study "how to take advantage of these properties we've uncovered and make better solar cells. Then the last part is to fabricate solar cells that allow us to realize high efficiencies, all at a significantly lower cost than conventional technologies require," he noted. Mohseni hesitates to talk about a specific timetable because of so many factors beyond his control. "It's not a simple question to answer," he says. But he hopes it will be within the next decade that, "We are going to be independent of fossil fuels."

Center for Detectors

UNIVERSITY NEWS

RIT engineering faculty Jing Zhang awarded NSF grant for high-tech nanofabrication equipment
Plasma reactive ion etching system to be integrated into RIT's clean room and used for photonics and nanoelectronic device research and development

Jing Zhang, engineering faculty member at Rochester Institute of Technology, received a $305,000 grant from the National Science Foundation to acquire a new etching system for photonic, electronic and bio-device fabrication. The system strengthens RIT's fabrication capability in its Semiconductor & Microsystems Fabrication Laboratory to support new and existing multidisciplinary research in science and engineering, to enable educational curriculum development, and be used for workforce development and training activities led by RIT's engineering college.

The ICP-RIE system—an inductively coupled plasma reactive ion etching system—is equipment used to create specific structural patterns, or to expose different conductive layers, on the integrated circuits found in electronic devices, said Zhang.

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"If we want to fabricate a wafer into a device, we needed to have this type of etcher," said Zhang, the Kate Gleason Endowed Assistant Professor in the electrical and microelectronic engineering department in RIT's Kate Gleason College of Engineering. "There is no equipment like this close by so there was a huge need, and it will help with collaborations we have with other university and corporate researchers."

Traditional semiconductor research has focused on silicon-based materials. Zhang is working on compound semiconductors, and gallium nitride is an emerging material being applied. Gallium nitride-based semiconductors are being integrated into optoelectronics, such as LEDs, to power electronics for smart grid applications and power management for electric vehicles, solar applications to harvest solar energy and transfer it into electrical energy. New research in ultraviolet wavelength sensors is an emerging area, she explained.

"The instrument is essential to enable research and education on III-Nitride-based light emitting diodes and lasers, and other semiconductor devices. We are studying every aspect of this material, from understanding the physics to the realization of novel devices. This equipment will help with that process," said Zhang, who has been at RIT since 2014 and is part of a growing and accomplished group of semiconductor materials and photonics device researchers at the university. She has expertise in the area of ultraviolet and visible light emitting diodes, also referred to as LEDs, and in developing semiconductors for optoelectronic and electronic devices.

Plasma reactive-ion etching systems incorporate several steps to the integrated circuit fabrication process. Reactive plasm, deposited onto the wafer, removes and refines excess material to "etch" or form patterns into the layers of the integrated circuit. These etched micro-nanostructures are the foundation for complex semiconductor devices. The ICP-RIE system provides dry etching capability for various material systems such as compound semiconductors, dielectric materials and metals with fast etching rate, well-controlled selectivity and uniformity.

With the emphasis on workforce development in the area of photonics, having the new equipment also provides a key educational opportunity for training. RIT's microelectronic engineering department provides short courses in semiconductor fabrication for area high school and community college teachers and for regional company employees looking to advance knowledge in this area.

In the past year, RIT also acquired a metal organic vapor-phase epitaxy system, also referred to as an MOVPE, which grows III-V single crystal materials. The state-of-the-art tool gives researchers the ability to build high-performance optical and electronic devices and will be a key learning and training resource. This capability was once an outsourced to research laboratory partners such as NASA. Today, the in-house functionality provided by this equipment, combined with the ICP-RIE system, is available to RIT researchers as well as the regional Rochester photonics community, including partners in AIM Photonics, Zhang added.