IMAGING DETECTORS: Innovative CMOS circuitry helps detectors resist radiation damage

Scientists at Rochester Institute of Technology (RIT) and the University of Rochester (both Rochester, NY) have been awarded $9.5 million from the National Science Foundation (NSF) for a five-year project to develop radiation-hardened CMOS detectors. The researchers are working in collaboration with NASA scientists, to develop imaging detectors specifically for use in harsh extraterrestrial environments.

High-energy particles induce charge and damage electronics, making them critical to ensure reliability of devices in high-radiation environments. The project, led by University of Rochester's Simon Figer, aims to develop a new detector design that can withstand the harsher radiation environments than current technology can handle.

Figer's team has set out to develop a new detector design based on a patent of Rochester's Larry Melas that would allow detectors to hold up in cryogenic environments while simultaneously reducing readout noise to a level comparable to current CCD technology. The project aims to decrease radiation sensitivity by developing a marriage of beneficial qualities from CCD and CMOS detectors.

The researchers have developed a CMOS technology that will be tested at the Rochester Institute of Applied Technology Laboratory (RITL), and the device will be further tested at the NASA Marshall Space Flight Center in Huntsville, Alabama. The Rochester team members include Larry Melas, Melissa McGrath, and Melissa McGrath from NASA Marshall Space Flight Center.

The researchers achieve CCD-comparable read-out noise by using a path that restores charge to the charge-collection node. The team's innovation is to introduce an integration circuit that is not affected by radiation damage. While CMOS detectors offer a significant edge in operation at cryogenic temperatures relative to CCDs, they have a relatively high noise contribution.

The research team believes that the circuit's design will be critical to overcoming the high noise contribution of CMOS detectors. The design is expected to use a relatively high voltage for signaling, which can reduce noise and increase sensitivity. The team is also working on developing a path that restores charge to the charge-collection node, which can help reduce noise and increase sensitivity.

So far, the team has fabricated and measured performances on early prototype devices. They have fabricated, tested, and measured devices on the order of six to ten. More than a dozen of these devices are currently operational, and more than 30 are planned. The team plans to use these devices in future research.

The researchers believe that their work will help drive the development of new detection technologies for harsh environments, such as those found on Mars and other extraterrestrial bodies. The technology has the potential to revolutionize the way we detect radiation and could lead to new applications in fields such as medicine, national security, and space exploration.

The project is expected to have a significant impact on the development of new detection technologies for harsh environments, and could lead to new applications in fields such as medicine, national security, and space exploration.
Planetary 3-D Roadmaps

ROCHESTER, N.Y., May 16, 2008—A team of researchers at Rochester Institute of Technology (RIT) led by scientist Donald Figer, are developing an image detector that is out of this world. The new Lidar (light detection and ranging) imaging detector uses light, instead of radio waves, to measure distance and other features of celestial bodies.

In conjunction with MIT’s Lincoln Laboratory, RIT’s Imaging Detector Laboratory (RIDL) is creating the optical/ultraviolet imaging Lidar detector with the hope that it will provide 3-D location information for planetary surfaces. These “roadmaps” will provide robots, astronauts and engineers details about atmospheric composition, biohazards, wind speed and temperature. Information like this could help land future spacecraft and more effectively navigate roving cameras across a Martian or lunar terrain.

The Lidar imaging detector unit.

The device will consist of a 2-D continuous array of light sensing elements connected to high-speed circuits.

“The imaging Lidar detector could become a workhorse for a wide range of NASA missions,” says Figer, RIT professor and director of the RIDL. “It could support NASA’s planetary missions like Europa Geophysical Orbiter or a Mars High-resolution Spatial Mapper.”

Lidar works by measuring the time it takes for light to travel from a laser beam to an object and back into a light detector. The new detector can be used to measure distance, speed and rotation. It will provide high-spatial resolution topography as well as measurements of planetary atmospheric properties—pressure, temperature, chemical composition and ground-layer properties. The device can also be used to probe the environments of comets, asteroids and moons.

The team, consisting of Figer, Zoran Ninkov and Staff Baum from RIT and Brian Aull and Robert Reich from the Lincoln Laboratory, will apply Lidar techniques to design and fabricate a Geiger-Mode Avalanche Photodiode array detector. The device will consist of an array of sensors hybridized to a high-speed readout circuit to enable robust performance in space. The radiation-hard detector will capture high-resolution images and consume low amounts of power.

The imaging component of the new detector will capture swaths of entire scenes where the laser beam travels. In contrast, today’s Lidar systems rely upon a single pixel design, limiting how much and how fast information can be captured.

“You would have to move your one pixel across a scene to build up an image,” says Figer. “That’s the state of the art Lidar right now. That’s what is flying on spacecraft now, looking down on Earth to get topographical information and on instruments flying around other planets.”

The Lidar imaging detector will be able to distinguish topographical details that differ in height by as little as one centimeter. This is an improvement in a technology that conflates objects less than one meter in relative height. The Lidar that is currently used could confuse a boulder for a pebble, an important detail when landing spacecraft.

“You can have your pixel correspond to a few feet by a few feet spatial resolution instead of kilometer by kilometer,” Figer says. “And now you can take Lidar pictures at fine resolutions and build up a map in hours instead of taking years at comparable resolution with a single image.”

The imaging Lidar detector will be tested at RIDL in environments that mimic aspects of planetary missions such as Europa, Titan and Mars. In conjunction with MIT’s Lincoln Laboratory, RIT’s Imaging Detector Laboratory (RIDL) is developing an image detector that is out of this world. The new Lidar (light detection and ranging) imaging detector uses light, instead of radio waves, to measure distance and other features of celestial bodies.

In addition to planetary mapping, Imaging Lidar detectors will have uses on Earth, such as remote sensing of the atmosphere for both climate studies and weather forecasting, topographical mapping, biohazard detection, autonomous vehicle navigation, battlefield friend or foe identification and missile tracking, to name a few.

RIT’s $547,000 Lidar program is funded by NASA, and includes a potential $589,000 phase for fabrication and testing.

For more information, visit www.rit.edu.
Detector Resists Radiation

ROCHESTER, N.Y., Aug. 15, 2007 – An imaging detector promises to revolutionize future NASA planetary missions with technology that could withstand the harsh radiation environments in space.

Scientists from Rochester Institute of Technology (RIT) and University of Rochester (UR) won $592,000 from the NASA Planetary Instrument Definition and Development Program to design, build and test a detector that should be resilient against radiation damage. The lightweight device will be smaller and consume less power than technology currently in use. The novel readout circuitry design will give the device a radiation tolerance not possible in standard optical detectors.

“All these benefits will lead to lower mission costs and greater scientific productivity,” said Donald Figer, director of the Rochester Imaging Detector Laboratory at RIT and lead scientist on the project, in an RIT press release. “But ultimately, radiation immunity is the focus.”

Figer’s team includes Zeljko Ignjatovic from UR, Zoran Ninkov from RIT, Melissa McGrath from NASA Marshall Space Flight Center and Shouleh Nikzad from NASA Jet Propulsion Laboratory.

“Our detector captures images directly in the digital domain at the pixel level rendering subsequent signal transmission less susceptible to cosmic radiation environment,” said Ignjatovic, assistant professor of electrical and computer engineering.

The new detector is based on a technology created by Ignjatovic and his colleagues at UR in which each pixel reads and converts its signal from analog to digital immediately upon capture. Standard optical detectors lack this capability. Instead, signals must travel along a line of sensors to reach a readout circuit. This wastes energy and leaves the signal vulnerable to radiation damage that degrades the circuit over time.

“Radiation-tolerant detectors are a critical need for NASA in the continued exploration of the solar system,” said McGrath, chief scientist in the Science and Mission Systems Office at NASA Marshall Space Flight Center.

Steff Baum, director of the Chester F. Carlson Center for Imaging Science at RIT, said, “In space astronomy and planetary missions, detectors are frequently the critical pacing item. By developing detectors with greatly reduced noise properties and greatly enhanced tolerance to radiation damage – the chief lifetime limiter of detectors in space – the collaboration should dramatically improve the reach in sensitivity and lifetime of the missions to explore and understand the nature of the planets with which we share our solar system.”

Testing the overall system will determine how the sensors hold up in cryogenic environments in which the detector is cooled to very low temperatures, simulating conditions in space. The device will be tested at RIT’s Rochester Imaging Detector Laboratory, a new facility to develop technologies for next-generation ground-based and space telescopes.

The imaging detector under development will boast a dynamic range and greatly shorter wavelength sensitivity. Figer said the detector could become a key technology for future planetary missions in the most severe radiation environments. The technology could figure heavily in missions under consideration for NASA’s Discovery, Mars Exploration and New Frontiers programs.

It might someday be used to capture hyperspectral imaging from a platform orbiting the outer planets or their satellites. Cameras looking down on Europa could take a picture of every wavelength at every pixel.

“We could use that information to figure out if there are lakes of water on Europa or hydrocarbons on Titan,” Figer said. “We can figure out the composition of a surface without having to land on it, which we might want to do 10 years later. Then we would know where to land.”

For more information, visit ridl.cis.rit.edu

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Mystery Of Quintuplet Stars In Milky Way Solved

ScienceDaily (Aug. 18, 2006) -- For the first time, scientists have identified the cluster of quintuplet stars in the Milky Way's galactic center, next to the super massive black hole, as massive binary stars nearing the end of their life cycle, solving a mystery that had dogged astronomers for more than 15 years. The nature of the stars was not entirely clear until now. In a paper published in the Aug. 18 issue of Science, co-authors Peter Tuthill of the University of Sydney and Donald Figer of Rochester Institute of Technology show that the quintuplet cluster consists of young massive binary stars that produce large amounts of dust. Their data reveal that five bright red stars are nearing the end of their "faint" lives of approximately 5 million years. These quickly evolving stars burn fast and bright, but do younger than fainter, older stars, which live for billions of years.

The study captures the Quintuplet stars just before disintegrating in supernovae explosions. Using advanced imaging techniques on the world's largest telescope at the W.M. Keck Observatory in Hawaii, the scientists captured the stars at the highest attainable resolution for the instrument, far exceeding the capacity of the Hubble Space Telescope, which meared the cluster a decade ago. The extra-resolution reveals scientists a new glimpse of the dust plumes surrounding the stars and the swirling winds Tuthill likened to pinwheels when he identified the first one in 1999 elsewhere in the galaxy. "Only a few pinwheels are known in the galaxy," Figer says. "The point is, we've found five next to each other in the same cluster. No one has seen anything like this before."

According to Figer, the swirling dust in pinwheel stars is key to understanding the presence of the stars and points to the presence of pairs of stars. The geometry of the plume allows scientists to measure the properties of the binary stars, including the orbital period and distance. "The only way that pinwheels can form is if they have two stars, swirling around each other. The stars are so close that their winds collide, forming dust in a spiral shape, just like water sprayed from a garden hose of a swirling sprinkler," Figer says. "A single star wouldn't be able to produce the dust and wouldn't have the spiral pattern."

An earlier study by Figer in 1996 claimed the Quintuplet cluster consists of evolved massive stars that produce dust. Figer's research could not be confirmed until now with the use of the Keck telescope. "If you want to understand star formation, you have to understand if they are forming alone or if they have partners," Figer says. "The answer gives us a clue as to whether stars form alone or in companions."

Adapted from materials provided by Rochester Institute of Technology.

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In Other News...

Two Supermassive Stars Found In The Milky Way (Apr. 2, 2008) -- Two of the most massive stars ever discovered, 300,000 times the mass of the sun, have been located in the Galactic Bar of the Milky Way. The stars are located near the center of the galaxy and are traveling at speeds of 200 kilometers per second. The discovery was made using the Very Large Telescope (VLT) at the European Southern Observatory in Chile.

Monster Super Star Cluster Discovered In Milky Way (May 30, 2005) -- European astronomers, including a scientist from Cardiff University, discovered the largest known star cluster in the Milky Way. The super cluster, called the "Wizard" cluster, is made up of approximately 10,000 stars. The giant mass of the cluster is equal to the Sun and is located in the direction of the constellation Hercules.

Astronomers Find First Cases For Galactic Superbursts (Jul. 25, 1999) -- A giant, empty void in our own galaxy was caused by a cluster of massive young stars at its centre, says an astrophysicist professor at the University of Toronto. The discovery was made using the Chandra X-ray Observatory and the Hubble Space Telescope.

With Computers, Astronomers Show Predicted Present Day Distribution Of Star Cluster (Dec. 1, 2008) -- With the help of an enormous computer simulations, astronomers have now shown that the first generation of stars -- which have never been observed by scientists -- should be distributed evenly.

Astronomers Discover A River Of Stars Streaming Across The Northern Sky (Mar. 22, 2008) -- Astronomers have discovered a narrow stream of stars extending at least 45 degrees across the northern sky. The stream is about 78,000 light-years distant from Earth and forms a giant arc over the entire sky.

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An imaging detector under development by a team of scientists from Rochester Institute of Technology and University of Rochester promises to revolutionize future NASA planetary missions with technology that could withstand the harsh radiation environments in space.

The team won $932,000 from the NASA Planetary Instrument Definition and Development Program to design, build and test a detector that should be resilient against radiation damage. The lightweight device will be smaller and consume less power than technology currently in use. The novel readout circuitry design will give the device a radiation tolerance not possible in standard optical detectors.

"All these benefits will lead to lower mission costs and greater scientific productivity," says Donald Figer, director of the Rochester Imaging Detector Laboratory at RIT and lead scientist on the project. "But, ultimately, radiation immunity is the focus."

Figer's team includes Zeljko Ignjatovic from UR, Zoran Ninkov from RIT, Melissa McGrath from NASA Marshall Space Flight Center, and Shouleh Nikzad from NASA Jet Propulsion Laboratory.

"Our detector captures images directly in the digital domain at the pixel level rendering subsequent signal transmission less susceptible to cosmic radiation environment," says Ignjatovic, assistant professor of electrical and computer engineering. "It makes use of the fact that only the original pixel signals are needed to produce an image, not the vast amount of multiplexed signals needed for standard readout circuits."

The new detector is based on a technology created by Ignjatovic and his colleagues at UR in which each pixel reads and converts its signal from analog to digital immediately upon capture. Standard optical detectors lack this capability. Instead, signals must travel along a line of sensors to reach a readout circuit. This wastes energy and leaves the signal vulnerable to radiation damage that degrades the circuit over time.

"Radiation tolerant detectors are a critical need for NASA in the continued exploration of the solar system," says McGrath, chief scientist in the Science and Mission Systems Office at NASA Marshall Space Flight Center.

"In space astronomy and planetary missions, detectors are frequently the critical pacing item," adds Stefi Baum, director of the Chester F. Carlson Center for Imaging Science at RIT. "This detector technology is a critical step in providing the improved capabilities that are required for future missions. The collaborative development of this technology promises to revolutionize future missions to explore and understand the nature of the planets with which we share our solar system."

Testing the overall system will determine how the sensors hold up in cryogenic environments where the detector is cooled to very low temperatures, mimicking conditions in space. The device will be tested at RIT in the Rochester Imaging Detector Laboratory, a new facility established to develop detector technologies for next-generation ground-based and space telescopes.

The new imaging detector under development will boast a dynamic range and greater short wavelength sensitivity. Figer believes the detector could become a key technology for future planetary missions in the most severe radiation environments. This detector technology could figure heavily in missions under consideration for NASA's Discovery, Mars Exploration and New Frontiers programs.

"We can figure out the composition of a surface without having to land on it, which we might want to do 10 years later. Then we would know where to land."
The discovery of dusty pinwheels around two stars in the Milky Way's Quintuplet cluster reveals each contains a pair of stars instead of just one. The finding puts to rest debate among astronomers over the nature of these dust-coooned stars.

A team led by Peter Tuthill, an astrophysicist at Australia's University of Sydney, investigated the cluster's brightest stars using the giant telescope at Keck Observatory in Hawaii. Quintuplet, named for its five prominent red stars, is one of our galaxy's most massive clusters. But its brightest stars have been hard to view in detail because they're quite distant — about 26,000 light-years away — and each is wrapped in a light-dimming shroud of dust. Quintuplet holds many Wolf-Rayet stars — a type thought to be the immediate precursors of supernovae.

"Only a few pinwheels are known in the galaxy," says team member Don Figer, an astronomer at the Rochester Institute of Technology in New York. "We've found five all next to each other in the same cluster."

The astronomers obtained cluster images with the greatest resolution yet, but they were unable to penetrate completely the stars' dusty shroud. Nevertheless, the new images allowed the team to see that the dust forms spirals. The geometry of the plume allows scientists to measure the properties of the binary stars, including orbital period and distance.

Tuthill and team member John Monnier of the University of Michigan at Ann Arbor had seen this before. In 1999, they identified dust pinwheels around two other Wolf-Rayet stars (WR 104 and WR 98a). The spiraling dust forms when a Wolf-Rayet star's violent outflow, called a stellar wind, collides with a similar outflow from an orbiting companion star. The interacting winds create the spiraling dust stream.

Quintuplet's stars show the same type of spiral, which tells researchers each is actually two or more stars and demonstrates that Quintuplet's most massive members are smaller than previously thought. The findings will appear in Friday's issue of the journal Science.