Scientists design laser calibration system for next-gen gamma-ray telescope

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The HAWC Gamma-Ray Observatory, located in the mountains of Mexico, will detect some of the highest-energy gamma rays in the universe. Credit: Los Alamos National Lab photo

(Phys.org) —Super-high-energy galactic gamma rays have trillions of times more energy than visible light, and they disappear in the atmosphere before they hit the Earth's surface. So if you want to detect these mysterious phenomena, a regular telescope isn't much help.

To learn about the highest-energy gamma rays, scientists build elaborate observatories, and one of the most advanced is the new High-Altitude Water Cherenkov (HAWC) Gamma-Ray Observatory, high in the mountains about six hours from Mexico City. When it's completed, it will be the only facility in the world that can detect the highest-energy gamma rays, with energies of up to 100 TeV (trillion electron volts), or tens of trillions of times more energy than the light we see.

Petra Huentemeyer, an assistant professor of physics at Michigan Technological University, is part of that effort. Her team is designing the observatory's laser calibration system in cooperation with researchers from the University of New Mexico.

Scientists are interested in the highest-energy gamma rays because they hold clues to the nature of space and time. No one knows for sure where these rays come from. Perhaps they originated in the Big Bang, or they could be generated by some of the universe's showiest pyrotechnics: supernovae, huge explosions that occur when massive stars collapse to form neutron stars, quarks or black holes.

When one of these high-energy gamma rays approaches the Earth, it collides with molecules in the air, disintegrating and creating an air shower of other high-energy particles. It is these particles that the scientists actually track, using big tanks of water called Cherenkov detectors. When it's done, the HAWC Observatory will have 300 of these tanks, each 25 feet across and 16 feet high.

They are named after Pavel Alekseyevich Cherenkov, who discovered that light slows down while traveling through matter. It slows down so much that some particles can actually go faster than light. (In a vacuum, nothing travels faster than the speed of light.) These ultra-fast particles create a light cone and a shock wave, the photonic equivalent of a sonic boom.

When particles from gamma-ray air showers pour into the Cherenkov tanks at the HAWC Gamma-Ray Observatory, they will exceed light's speed limit in water and create light cones. Photomultipliers in the tank will convert some of that light to electricity—like a solar panel. That electricity triggers a laser, which travels through fiber optic cables to the HAWC computers and signals the presence of a gamma-ray-induced air shower.

When it goes on line in August, HAWC will be one of seven ground-based gamma-ray observatories in the world. It will not only lead the pack in detecting the highest-energy gamma rays; its extreme precision will also give better information on the origins of the gamma rays and their energy. "It's 15 times more sensitive than the Milagro Gamma-Ray Observatory at Los Alamos National Lab," said Huentemeyer.

Huentemeyer directs the HAWC team charged with calibrating the equipment and verifying that the data gathered are correct.

Calibration at the HAWC Observatory is critical, because the science depends on measurements that must be accurate to within of 10ths of billionths of a second. That precision is essential because the photomultipliers not only detect the presence of air showers. They also use the orientation of those air showers to figure out where the gamma rays come from.

"Think of the air showers like a pancake flying through space," said Huentemeyer. The "pancake" arrives at the Cherenkov detector and its array of photomultipliers at an angle.

That means that particles at the bottom edge of the pancake will trigger a photomultiplier first, and the particles at the top will be detected last. The time difference between the two strikes can be used to calculate the angle of the air shower, which can determine where in the sky the gamma ray appeared.

"We work on the timing of these hits to the photomultipliers, which are nanoseconds apart," Huentemeyer said. The electrical signals travel through 600 feet of fiber optic cable, and the team is responsible for making sure that everything is calibrated identically.

"A lot of work went into writing the software that allows this work to be remotely controlled," Huentemeyer said. "We also use software packages written for the Large Hadron Collider," the world's largest high-energy particle accelerator.

HAWC is just beginning its mission, so it hasn't detected evidence of the highest-energy gamma rays yet, since they are extremely rare. It has found lower-energy rays, and just to make sure its first detectors were working properly, the team snapped an image in one place it did not expect to find gamma rays: in the shadow of the moon.

When it's up and running, HAWC is set to pick up gamma rays traveling to Earth via the edge of the Milky Way galaxy.

"That's when things will really get interesting," Huentemeyer said.

Provided by Michigan Technological University