UA makes mirrors for world's largest telescope

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An artist's rendering of what the Giant Magellan Telescope will look like once it begins science operations in Chile's Atacama Desert in 2020. (Image: GMTO)

(PhysOrg.com) -- The second of seven 27-foot diameter mirrors for the Giant Magellan Telescope was cast on Jan. 14 inside a rotating furnace at the UA's Steward Observatory Mirror Lab.

While Wildcat fans were cheering on the University of Arizona's men's basketball team on Jan. 14, a new chapter in our understanding of the universe was opening just across the street.

Underneath the football stadium, in the UA's Steward Observatory Mirror Lab, a red, round, humming furnace the size of a fairground carousel was spinning, while inside 21 tons of borosilicate glass heated to

1,170 degrees Celsius (2,140 F) slowly melted into a mold to create a honeycomb telescope mirror spanning almost 27 feet.

The mirror is one of seven that together will make the largest telescope ever built, the Giant Magellan Telescope, or GMT. Set to begin science operations in 2020 at the Las Campanas Observatory in northern Chile, the GMT will exploit the clear dark skies of the Atacama Desert where almost no water vapor in the atmosphere impedes the view into the night sky.

"Astronomical discovery has always been paced by the power of available telescopes and imaging technology," said Steward Observatory Director Peter Strittmatter. "The GMT allows another major step forward in both sensitivity and image sharpness. In fact the GMT will be able to acquire images 10 times sharper than the Hubble Space Telescope."

Like other mirrors produced by the mirror lab, the GMT mirrors are fabricated in a process called spin casting, thereby achieving the basic front surface in the shape of a paraboloid. A paraboloid is the shape taken on by water in a bucket when the bucket is spun around its axis; the water rises up the walls of the bucket while a depression forms in the center.

Except that in the case of the GMT, six mirrors will be arranged around a seventh in the center in a design called off-axis, thus serving as off-axis segments of one giant mirror. This design requires the shape of the outer mirrors to be asymmetric in profile; picture the spinning bucket of water again, but with the depression forming off to one side this time – a shape impossible to achieve in this hypothetical experiment.

Strittmatter said that fabricating a giant off-axis telescope mirror with those specifications was deemed as close to impossible when the mirror lab embarked on the project.

"This is mirror No. 2, so one could ask, ‘What's the big deal?' he said during a news conference on Saturday. "We had to demonstrate that one could actually make such off-axis mirror segments. That concern has been retired. We have succeeded and demonstrated we could fabricate GMT mirror No. 1."

"GMT No. 2 marks the beginning of the implementation of the whole project," Strittmatter added. "We are planning to move on to No. 3 soon. We have already ordered some of the materials. The project is moving along rather well."

"The novel technology developed at the UA's mirror lab is creating a whole new generation of large telescopes with unsurpassed image sharpness and light collecting power," said Wendy Freedman, who chairs the board of the Giant Magellan Telescope Organization, or GMTO.

"The two 6.5-meter mirrors made by the UA for the twin Magellan Telescopes at our Las Campanas Observatory site are performing superbly and led to our adoption of this technology for the GMT."

The UA's Steward Mirror Lab makes the world's only honeycomb mirrors in a process called spin casting inside this spinning furnace built in the 1980s. (Photo:

Patrick McArdle/UANews)

The GMT will allow astronomers to answer some of the most pressing questions about the cosmos including the detection, imaging, and characterization of planets orbiting other stars, the nature of dark matter and dark energy, the physics of black holes, and how stars and galaxies evolved during the earliest phases of the universe.

"We hope the GMT will allow us to detect the first generation of stars born after the Big Bang," said Matthew Colless, from the Australian Astronomical Observatory, one of two Australian partners of the GMTO.

Those very first stars formed while the universe was in its infancy, at a time when the only elements present were hydrogen and helium, and stars had yet to make all the heavier elements that would lead to planets and, ultimately, life.

At 360 square meters or about 3,900 square feet, the GMT's seven mirrors combine to form an area just a bit smaller than a basketball court.

"GMT's light-gathering ability is going to be equivalent to 2 billion people looking into the night sky," McCarthy said.

He added that the telescope's entire moving construction of 1,100 metric tons is designed to float on oil, with the mirrors floating on air cushions. This design creates a virtually frictionless mechanical structure that will have no limiting effect on the images.

As the furnace is spinning, technicians in the adjacent control room gather around a computer monitor to watch a time-lapse video recorded by a camera looking inside the oven and taking an image every 15 minutes.

First, chunks of glass are seen as they melt together like ice cubes in a drink. Soon, a pool of liquid glass is forming over an underlying honeycomb structure pre-assembled from a specialized heat-resistant material called alumina silica fiber board that looks a bit like Styrofoam. And then, rather suddenly, the surface drops, as the molten glass becomes liquid enough to run into the honeycomb scaffold, filling the space between the honeycomb mold structure.

Twenty-one tons of borosilicate glass chunks, melted at a temperature of 1,170 degrees Celsius (2,140 F), went into making the second mirror for the GMT. (Photo: Patrick McArdle/UANews)

The unique fabrication process resulting in a lightweight honeycomb glass structure is the key to the success of mirrors created at the UA's mirror lab. Not only are these mirrors so light they would float in water, but they are very stiff and quickly adjust to changes in nighttime air temperature, each resulting in sharper images.

Every mirror that came out of the mirror lab was cast in this furnace, which is the only one of its kind. The rotation ensures that the glass starts out close to the desired parabolic shape. Two hundred seventy heaters inside the furnace ensure the glass is heated evenly throughout, explained Kirk Kenagy, who helped build the giant rotating oven in 1984.

"If you wanted to make the world's largest pizza, this would be perfect," he said with a laugh.

Later that day, the engineers and technicians initiated the cool-down phase. Once the temperature drops below 1,000 degrees C, the glass starts to solidify.

"We cool the glass down fairly rapidly in the beginning," explained Randy Lutz, the mirror lab's mirror casting manager who has overseen the casting of eight mirrors. "This is to prevent the glass from forming crystals, which would make it more susceptible to breaking."

This so-called annealing phase marks the beginning of intense times for Lutz' team of five engineers and technicians, as they must be present around the clock during the entire cooling process of three months to make sure everything goes according to plan and be able to intervene at the drop of a hat if necessary.

Slow, steady rotation is necessary even after the glass has started to cool down to make sure the air flow inside the oven is even and cooling occurs at exactly the same rate throughout the mirror blank, explained Bruce Hille, the mirror lab's facility manager.

Although polishing the first GMT mirror into the desired asymmetric shape has taken almost seven years, the following mirrors are expected to be polished within 18 to 24 months each.

According to Dean Ketelsen, who has worked at the mirror lab for two decades, finishing the first GMT mirror has taken so long because the mirror lab team broke new ground in every respect. All the technology necessary to make it, polish it and test it had to be developed, and there was no room for mistakes.

GMT Project Director Patrick McCarthy said: "This second GMT casting is going forward now because the primary optics are on the critical path for the project and because the polishing of the first off-axis 8.4-meter GMT mirror is very close to completion, with an optical surface accuracy within about 25 nanometers, or about one-thousandth the thickness of a human hair."

According to mirror lab Director Roger Angel, the GMT mirrors have the smoothest surface of any telescope mirror, a prerequisite for observing planets around other stars, for example.

"If you have any roughness in the mirror surface, it scatters the starlight and you can't see the planet," he said.

The GMT is expected to serve as a highly versatile platform for astronomy for 50 years, keeping up with the scientific progress through modifications and addition of new instruments.

"We believe the GMT will be one of the defining instruments of how science will be done in the 21st century," McCarthy said. "With the name of our telescope, we tie ourselves to the great voyage of Magellan undertook in the early 1500s, recognizing for the first time how big the world is and discovering unknown lands."

"We like to think of GMT as the continuation of that journey, hoping to find out what the shape of the universe is and discover the things in it."

The mirror lab has already produced the world's four largest astronomical mirrors, each 8.4 meters in diameter. Two are in operation in the Large Binocular Telescope – currently the largest telescope in the world; one is for the Large Synoptic Survey Telescope; and the fourth is the first off-axis mirror for GMT. The mirror lab also has produced five 6.5-meter mirrors, two of which are in the twin Magellan telescopes at Las Campanas Observatory in Chile.

Provided by University of Arizona