Optical Device Cancels Starlight So Astronomers Can See Distant Planets

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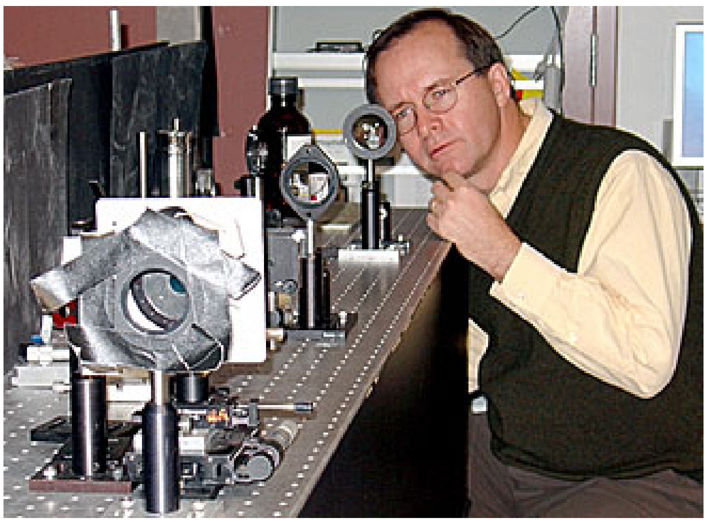


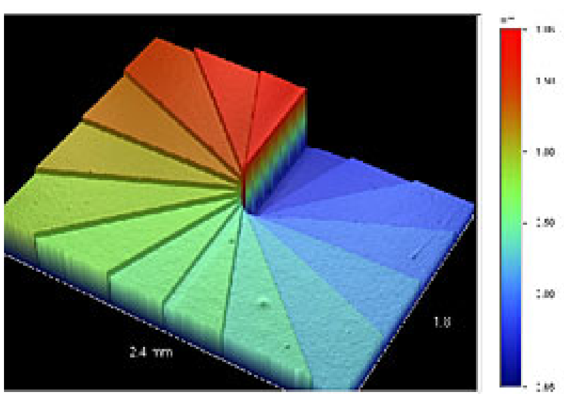
Grover Swartzlander, associate professor in UA's College of Optical Sciences, with a laboratory setup that checks an experimental optical vortex mask.

"Some people say that I study darkness, not optics," jokes Grover Swartzlander. But it's a kind of darkness that will allow astronomers to see the light. Swartzlander, an associate professor in The University of Arizona College of Optical Sciences, is developing devices that block out dazzling starlight, allowing astronomers to study planets in nearby solar systems.

The devices also may prove valuable to optical microscopy and be used to protect camera and imaging systems from glare.

The core of this technology is an "optical vortex mask" -- a thin, tiny, transparent glass chip that is etched with a series of steps in a pattern similar to a spiral staircase.

When light hits the mask dead on, it slows down more in the thicker layers than in thinner ones. Eventually, the light is split and phase shifted so some waves are 180 degrees out of phase with others. The light spins through the mask like wind in a hurricane. When it reaches the "eye" of this optical twister, light waves that are 180 degrees out of phase cancel one another, leaving a totally dark central core.



Measured surface profile of the helical vortex mask used in lab experiments. The pitch of the mask corresponds to two full waves of phase delay for green light. This false color image was obtained by Joanna Schmit (Veeco, Inc.) The mask was made by Eric Johnson of the University of Central Florida. (Graphic: Courtesy of Grover Swartzlander)

Swartzlander says this is like light following the threads of a bolt. The pitch of the optical "bolt" — the distance between two adjacent threads — is critical. "We're creating something special where the pitch should correspond to a change in the phase of one wavelength of light," he explained. "What we want is a mask that essentially cuts this plane, or sheet, of incoming light and curls it up into a continuous helical beam."

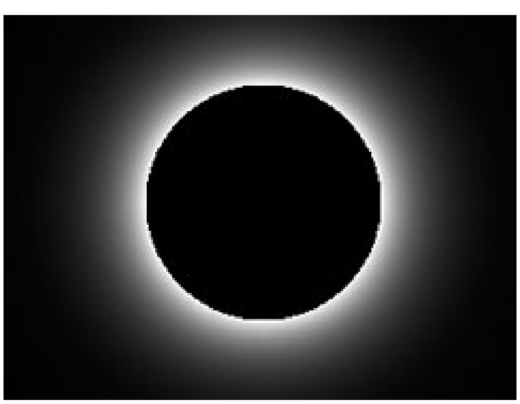
"What we've found recently is knock-your-socks-off amazing from a theoretical point of view," he added.

"Mathematically, it's beautiful."

Optical vortices are not a new idea, Swartzlander noted. But it wasn't until the mid 1990s that scientists were able to study the physics behind it. That's when advances in computer-generated holograms and high-precision lithography made such research possible.

Swartzlander and his graduate students, Gregory Foo and David Palacios, garnered media attention recently when "Optics Letters" published their article on how optical vortex masks might be used on powerful telescopes. The masks could be used to block starlight and allow astronomers to directly detect light from a 10-billion-times-dimmer planet orbiting the star.

This could be done with an "optical vortex coronagraph." In a traditional coronagraph, an opaque disk is used to block a star's light. But astronomers who are searching for faint planets near bright stars can't use the traditional coronagraph because glare from starlight diffracts around the disk obscuring light reflected from the planet.



Computed intensity of vortex coronagraph for a single color light source. The analytically derived distribution predicts there will be zero light across the central black disk. (Image courtesy of Grover Swartzlander, College of Optical Sciences)

"Any small amount of diffracted light from the star is still going to overwhelm the signal from the planet," Swartzlander explained. "But if the spiral of the vortex mask coincides exactly with the center of the star, the mask creates a black hole where there is no scattered light, and you'd see any planet off to the side."

The UA team, which also included Eric Christensen from UA's Lunar and Planetary Lab, demonstrated a prototype optical vortex coronagraph on Steward Observatory's 60-inch Mount Lemmon telescope two years ago. They couldn't search for planets outside our solar system because the 60-inch telescope isn't equipped with adaptive optics that corrects for atmospheric turbulence.

Instead, the team took pictures of Saturn and its rings to demonstrate how easily such a mask could be used with a telescope's existing camera system. A photo from the test is online at Swartzlander's website, www.u.arizona.edu/~grovers

Optical vortex coronagraphs could be valuable to future space telescopes, such as NASA's Terrestrial Planet Finder (TPF) and the European Space Agency's Darwin mission, Swartzlander noted. The TPF mission will use space-based telescopes to measure the size, temperature, and placement of planets as small as the Earth in the habitable areas of distant solar systems.

"We're applying for grants to make a better mask — to really ramp this thing up to get better quality optics, Swartzlander said. "We can demonstrate this now in the lab for laser beams, but we need a really good-quality mask to get closer to what's needed for a telescope."

The big challenge is developing a way to etch the mask to get "a big fat zero of light" at its core, he said.

Swartzlander and his graduate students are doing numerical simulations to determine the proper pitch for helical masks at the desired optical wavelengths. Swartzlander has filed a patent for a mask that covers more than one wavelength, or color of light.

The U.S. Army Research Office and State of Arizona Proposition 301 funds support this research.

Optical vortex masks also could be used in microscopy to enhance the contrast between biological tissues.

Source: University of Arizona, By Lori Stiles