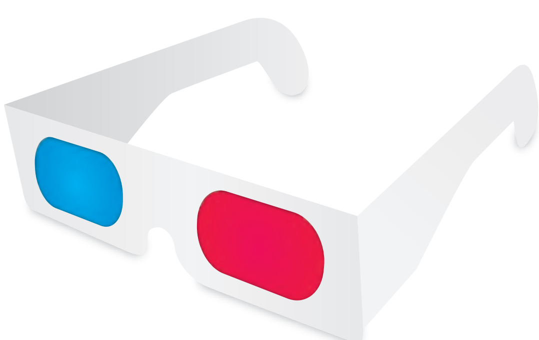
Illustration: Sandbox Studio

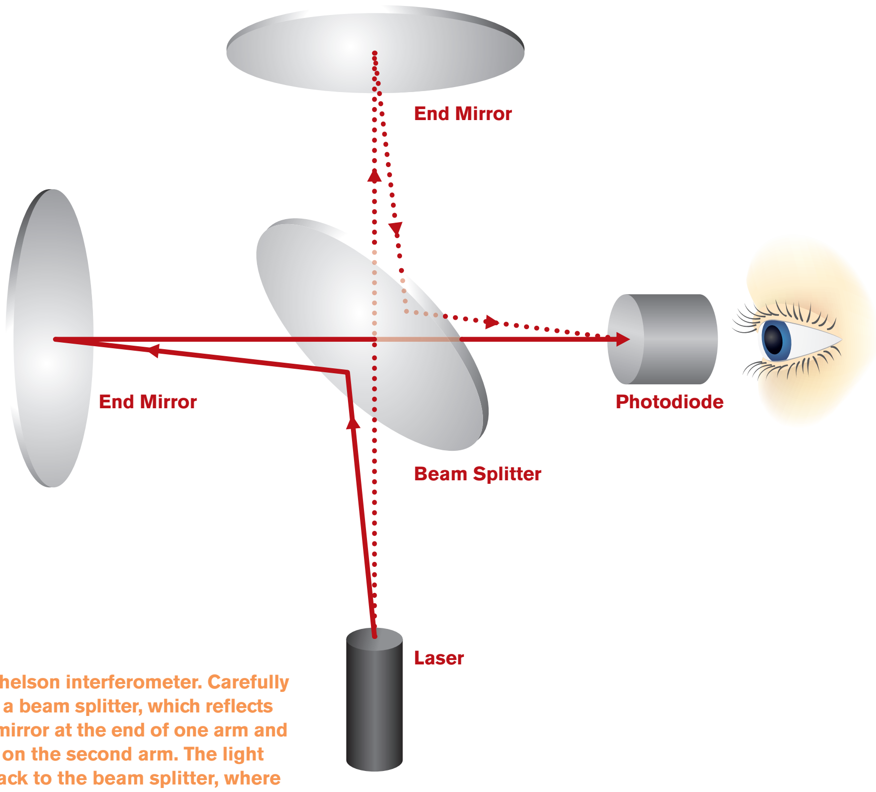
COULD YOUR LIFE BE A 3D MOVIE? A NEW FERMILAB EXPERIMENT AIMS TO PUT ON THE SPECIAL GLASSES AND FIND OUT. BY TONA KUNZ

Your three-dimensional reality may not exist. Instead, you and everything around you may exist as a hologram projected from a fundamental, underlying 2D reality.

True, you look three dimensional, but so does a spear coming at you from a 3D action flick. Being inside the hologram, rather than looking at it as you do a movie screen, could be disguising the hologram's existence. It's as if, once in the movie theater, you can't remove your 3D glasses to see what's real and what isn't.

Now a team of physicists based at Fermilab think they have devised a way to get a true view of the universe. Their experiment—the holometer—will use mostly off-the-shelf parts to make the world's most sensitive measurements of the travel times of laser beams. What they are looking for are tiny fluctuations in beam intensity caused by being in a hologram. The results could shatter our world view.





Sketch of a single simple Michelson interferometer. Carefully prepared laser light travels to a beam splitter, which reflects about half the light toward a mirror at the end of one arm and transmits the rest to a mirror on the second arm. The light from both mirrors bounces back to the beam splitter, where half is again reflected and half transmitted. A photodiode measures the total intensity of the combined light from the two arms, which provides an extremely sensitive measure of the position difference of the beam splitter in two directions.

A HOLOGRAPHIC UNIVERSE

The idea of a holographic universe has floated around physics and cosmology communities for decades. Craig Hogan, director of Fermilab's Center for Particle Astrophysics, had long pondered how to test this odd but persistent theory. In 2007, when a British-German research team told him of a "mystery noise" in the data from its gravitational wave detector GEO600, Hogan recognized that a holographic universe might explain some of this noise and began thinking about how to design an experiment to clearly display the holographic effect.

Hogan used gravitational wave experiments, such as LIGO, as a model for the new experiment, now under construction at Fermilab. LIGO uses lasers to search for gravitational waves—energy flowing through the universe from giant, distant cataclysms, such as the collisions and mergers of black holes. For the holometer, Hogan's team shrank the machine and tuned the new experiment to look at a higher frequency where they would expect the universe to reveal its holographic nature.

Your everyday experience in a world that feels 3D may make you think that a holographic universe is pure science fiction. But human senses aren't always reliable: You feel as if you are standing still even though you, and the Earth, zoom around the sun at about 67,000 miles per hour.

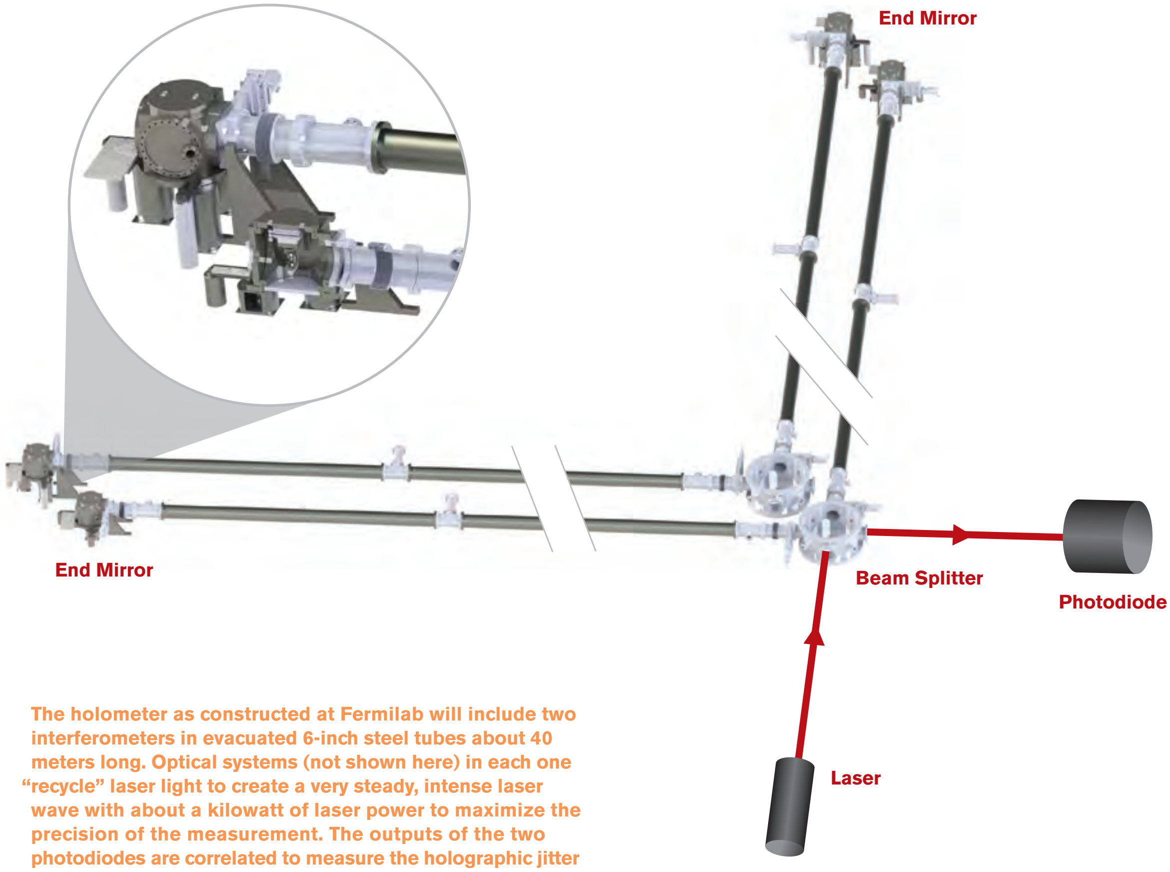
In a holographic universe, all the information describing a certain volume of space would reside on its 2D boundaries. A close look at the boundaries would reveal no detail smaller than individual packets of information, much like the dot-like pixels of a photograph that appear when you zoom in. But with increasing distance from the information source, the dots would appear to blend into one another to create a smooth picture and, eventually, a 3D image. Think of the universe as a Magic Eye poster, with myriad dots on a 2D surface that turn into a 3D picture if you look at it in just the right way.

"The holometer is designed to look for a particular kind of underlying blurriness in reality," says Hogan, a co-leader of the experiment.

There is no agreement among theorists for how the apparent 3D world emerges from an underlying 2D world, but an experiment such as the holometer could provide concrete evidence about how these worlds fit together.

The existence of the universe as a hologram, rather than as a 3D world, would signal a limit on the amount of information that the universe can contain, constraining it to two dimensions. And, because string theory can posit a number of different dimensions—up to 11 in some models—a limit on the amount of information available in the universe could affect physicists' understanding of certain string theory models.

"If the holographic theory is correct, there is a maximum bandwidth to reality," Hogan says. "That means it is possible in principle to learn everything about the physics of the universe."



The holometer as constructed at Fermilab will include two interferometers in evacuated 6-inch steel tubes about 40 meters long. Optical systems (not shown here) in each one "recycle" laser light to create a very steady, intense laser wave with about a kilowatt of laser power to maximize the precision of the measurement. The outputs of the two photodiodes are correlated to measure the holographic jitter of the spacetime the two machines share. The holometer will measure jitter as small as a few billionths of a billionth of a meter.

TESTING REALITY

The heart of the holometer is an instrument called an interferometer; two of them will operate simultaneously in the experiment. Each contains a pair of 40-meter-long tubes at right angles to each other. Physicists will test whether the universe is two or three dimensional by sending a laser beam into the corner where the tubes meet. There, a special half-silvered mirror (or "beam splitter") divides the light and sends half of it down each of the tubes. The light reflects back at the end of each tube and returns to the corner.

A measurement of the intensity of the combined (or "interfered") light allows an ultra-precise comparison of the position of the beam splitter mirror in the two spatial directions. If there is no holographic effect, the laser beams traveling through the tubes should stay in sync; the main fluctuations in the light's intensity are from quantum particles of the laser light itself. If the universe is holographic, an extra fluctuation in the detected light should appear due to the quantum nature of space-time. The holographic part of the fluctuation should be almost the same for two completely separate interferometers, as long as they are immediately adjacent and hence occupy nearly the same space-time. A fluctuation in the light would point to the holographic blurriness characteristic of a 2D universe.

Evidence for a 2D, holographic universe would be a first sign that quantum mechanics, which describes the behavior of all mass and energy, also applies to the behavior of space and time. It would also provide physicists with a way to incorporate gravity into quantum mechanics, a key step in testing the theory of the unification of forces. Answering the question "Do all of nature's forces become one?" is a central goal of 21st-century particle physics.

The disconnect between quantum mechanics and gravity is a stumbling block for physicists attempting to understand the nature of dark energy. Physicists believe that dark energy is responsible for pushing the universe apart, but the only evidence so far comes from large-scale cosmic observations. Because the holometer will probe the connection between mass-energy and space-time, it could help physicists better understand the physics of dark energy.

The holometer should start collecting data in 2012 and could show results in two days or two years, depending on the fine-tuning needed. Regardless of whether evidence of a holographic existence materializes, the experiment will develop laser technology for new dark matter experiments and help test potential background noise for the next generation of experiments searching for gravitational waves.

While Hogan, a theorist, is betting on a holographic universe, experimenters take a more down-to-earth stance. "Every other day I change my mind," says Fermilab scientist Chris Stoughton. "And how am I going to decide? Make the measurement."