In Development

Making Fiber Optics Work for Carbon Storage

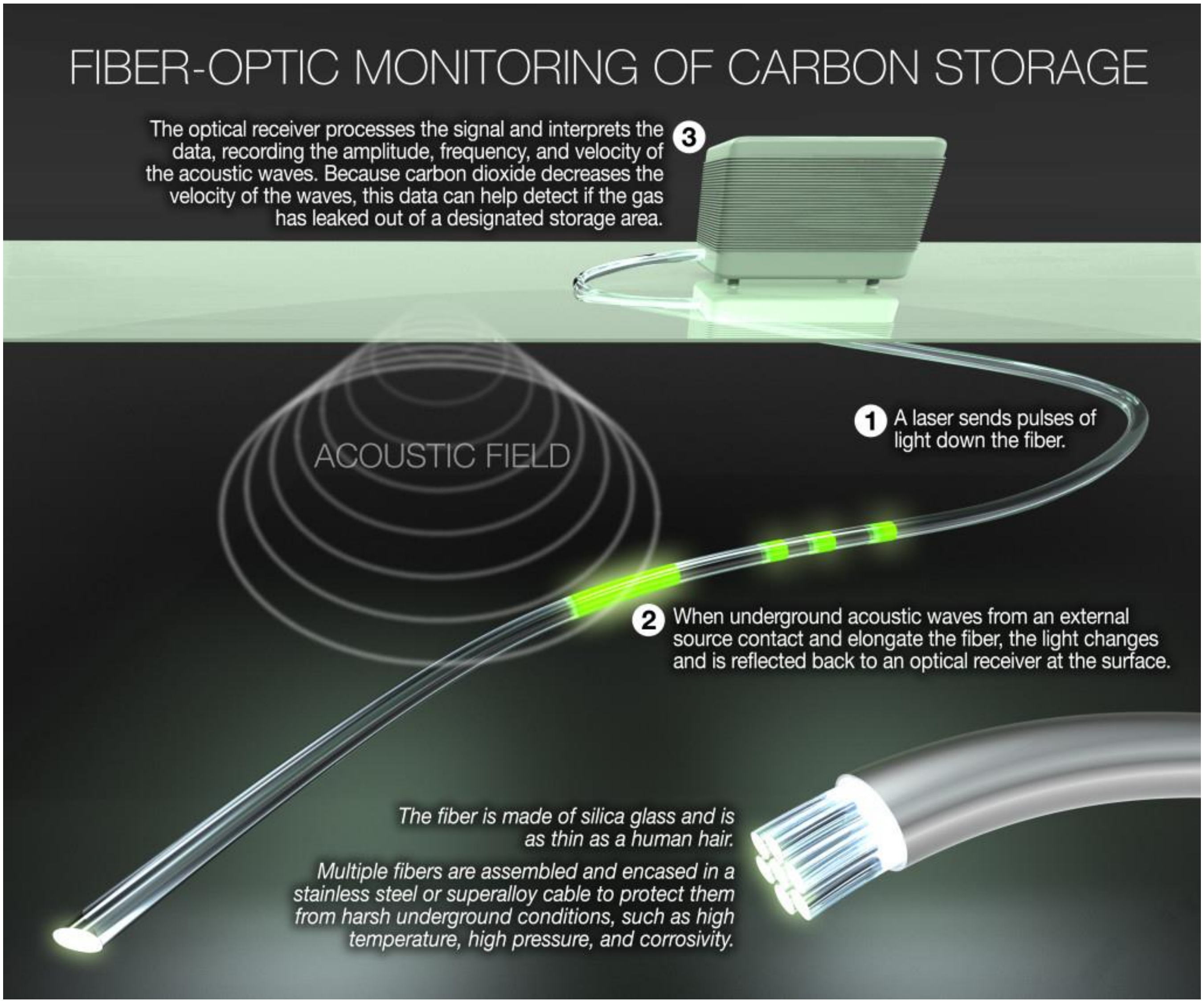
In Field Tests, Technology Demonstrates Potential for Cost-Effective, Accurate Monitoring of Underground Reservoirs

By Robert Ito

In Alabama field tests, EPRI has demonstrated the effective performance of fiber-optic arrays for monitoring carbon dioxide (CO_2) sequestration sites, creating an important application for this workhorse technology of the 1990s telecommunications boom. More field work is needed before commercialization.

Cost-effective, accurate monitoring of CO_2 flow, leakage, and distribution is needed to ensure safe, permanent storage in deep underground formations. Existing monitoring technology relies on an acoustic source—such as a heavy "thumper" truck that vibrates metal plates on the ground to send sound waves through the earth. The waves bounce off a reflective surface—for example, the bottom of a storage reservoir—and underground motion detectors called geophones measure the wave response, indicating the presence of CO_2. Geophones were first used by French soldiers during World War I to detect the presence of German tunnels. Today, geophones used for sophisticated time-lapse imaging of CO_2 plume positions must be set into place every time they are used to conduct underground surveys, which can result in inaccurate results if not placed in the same position every time. The devices are prone to mechanical failure, and their analog data transfer is slow.

Serving as both sensors and transmitters, fiber-optic cables can potentially provide more reliable data at a lower cost. Light pulses are sent down fibers and reflected back to the surface, with measurements made along the length of cables at any time. A data acquisition system gathers and interprets the sensor data. "With this approach, you can capture distributed data from 10,000 point-like measurements with 1-meter resolution along a 10,000-meter-long fiber-optic cable," said EPRI Principal Technical Leader Robert Trautz. "The spatial resolution on these fiber-optic arrays is about 10 times greater than standard geophones."



This graphic shows how fiber-optic monitoring of carbon storage works.

Unlike geophones, fiber-optic arrays can stay in the same place over a power plant's lifetime. They have no moving parts and are more durable. Cables are encased in protective materials such as stainless steel or Inconel (a nickel-based superalloy) to help them withstand the high temperatures, pressures, and salinity in deep underground environments. The arrays can transfer data at rates up to 16,000 samples per second.

With funding from the U.S. Department of Energy, EPRI has demonstrated how fiber-optic-based sensors can be used to identify dangerous, costly leaks and maximize CO_2 storage capacity—crucial to the successful implementation of carbon capture and storage technology. With continued testing, researchers believe that the commercial use of fiber-optic sensor arrays can revolutionize the emerging CO_2 storage industry.

Tests in Alabama

EPRI conducted initial tests at the Citronelle Oil Field in Alabama to compare the performance of geophones and fiber-optic arrays. Led by Trautz, researchers injected CO_2 into a storage reservoir 9,400 feet underground. Next, thumper trucks sent acoustic waves deep into the earth, and a crane raised and lowered a string of geophones to measure the reflected waves. Surveying the storage reservoir with this approach took about five days. Using a fiber-optic array, researchers completed the same survey in just one day. In addition to documenting the limitations of geophones—several were lost because of mechanical failure—researchers successfully used the fiber-optic sensors to create high-resolution seismic images of the storage reservoir.

The Citronelle tests comparing geophones and fiber-optic arrays will be completed in 2016. Researchers are looking for a site with a CO_2 injection well for further CO_2 flow and storage evaluations.

Temperature Sensing for CO_2 Storage

Because replacing water with CO_2 in deep underground wells and rock pores can change the thermal properties of these geological formations, temperature measurements can be used for monitoring CO_2 storage, distribution, and flow along a fiber-optic cable’s length. EPRI researchers are looking for a site host to test the *heat-pulse monitoring method*, which uses fiber-optic-based distributed temperature sensing technology coupled with copper heater elements to measure subtle changes in thermal properties related to CO_2 movement into and through rock.

“With further testing, I can see this technology becoming fully commercial in less than five years,” said Trautz.

Key EPRI Technical Experts

Robert Trautz