Seismologists monitor ridgecrest aftershocks using novel fiber optic network

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A surface rupture shows ground movement following a pair of large earthquakes that struck near Ridgecrest, CA, on July 4 and 5, 2019. Credit: Ben Brooks, USGS; Public domain

Seismologists from Caltech are using fiber optic cables to monitor and record the aftershocks from the 2019 Ridgecrest earthquake sequence in greater detail than previously possible. Thousands of tiny aftershocks are occurring throughout the region each day, an unprecedented number of which will now be able to be tracked and studied.

The nascent technique involves shooting a beam of light down a "dark," or unused, fiber optic cable. When the beam hits tiny imperfections in the cable, a miniscule portion of the light is reflected back and recorded.

In this manner, each imperfection acts as a trackable waypoint along the fiber optic cable, which is typically buried several feet beneath the earth's surface. Seismic waves moving through the ground cause the cable to expand and contract minutely, which changes the travel time of light to and from these waypoints. By monitoring these changes, seismologists can observe the motion of seismic waves.

"These imperfections occur frequently enough that every few meters of fiber act like an individual seismometer. For the 50 kilometers of fiber optic cable in three different locations we've tapped into for the project, it's roughly akin to deploying over 6,000 seismometers in the area," says Zhongwen Zhan, assistant professor of geophysics, who is leading the effort.

The project was launched just days after the two large earthquakes struck the Ridgecrest area. Zhan called around, searching for unused fiber optic cable that would be long enough and close enough to the seismically active region to be useful. Eventually, the manager of the Inyokern Airport, Scott Seymour (who had also offered the use of the fiber network around the airport), connected Zhan with Michael Ort, the chief executive officer of the California Broadband Cooperative's Digital 395 project. The project aims to build a new 583-mile fiber network that mainly follows the U.S. Route 395, which runs north-south along the eastern side of the Sierra Nevada, passing near Ridgecrest.

Digital 395 has offered to let Zhan use three segments of its fiber optic cable: 10 kilometers from Ridgecrest to the west, and two sections both to the north and south of Olancha, near which there was intense seismic activity triggered by the M7.1 quake. "The July 4-5 earthquakes created a 50-kilometer-long rupture that has triggered aftershocks in separate regions that we'll be able to study," Zhan says. Meanwhile, the sensing instruments that Zhan connected to the fiber optic cable for the project were provided by manufacturers OptaSense and Silixa.

Zhan's team also deployed farther south at the Goldstone Deep Space Communications Complex, a NASA facility run by JPL. (JPL is managed by Caltech for NASA.) The site, which is close to Fort Irwin, hosts a dark fiber network that Zhan previously used to test the fiber optic seismic monitoring technology. "It's only about 70 kilometers from Ridgecrest, so this would be a good time go back," he says.

Immediately after the earthquake, the USGS also deployed temporary seismometers around Ridgecrest to monitor aftershocks. Zhan says his fiber optic system will complement rather than duplicate that effort. The temporary seismometers are able to cover a wider area but produce sparser readings, he says. They also tend to be battery operated and nonnetworked, meaning that the data they record will not be available until after their batteries run down and are retrieved, while a portion of the data from Zhan's fiber optic system will be available immediately.

Though the Ridgecrest seismic monitoring will be temporary, Zhan and his colleagues hope to establish similar systems permanently in key cities throughout Southern California. This work began with a pilot project in 2018 involving the Caltech Seismological Laboratory and the City of Pasadena to use a portion of the city's dark fiber to monitor temblors in the area.

"The combination of the Pasadena fiber array and the Ridgecrest deployments have provided two important science firsts: the Pasadena array is the first example of a permanent earthquake monitoring system using fiber optics, while the Ridgecrest deployments, also a first in earthquake monitoring, give us a glimpse of what we could see if we were able to continuously light up dark fiber throughout Southern California," says Michael Gurnis, John E. and Hazel S. Smits Professor of Geophysics and director of the Caltech Seismological Laboratory. "They allow us to observe and understand how seismic waves reverberate through our complex mountains and basins following a major temblor."

The information collected from the Ridgecrest fiber network will help seismologists learn more about how earthquake sequences decay and migrate through the earth, and will offer more details about how seismic waves move throughout the region around Ridgecrest.

Processing the large volume of data that the fiber optic system is gathering will take months, even using automated systems, says Zhan, who estimates that his team will receive on the order of 10 to 20 terabytes of data over the next few months.

"This will keep us busy for a while, but in the end, we'll have a clearer picture of how this sequence evolved than would otherwise be possible," Zhan says.

Provided by California Institute of Technology

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