Wired Watershed

Fiber-optics bring new precision to ecosystem sensing

By Lee Sherman

Advanced fiber-optic cable captures finely detailed data, revealing the complexities of forests and watersheds. (Photo: George Cedilnik)

High-tech science got a lift last summer from a curiously low-tech device: a potato launcher. Puzzling over the best way to string fiber-optic cable through dense, old-growth canopy, OSU scientists devised a "canon" with an air-compression gun and fishing line weighted by a starchy tuber. From a 100-foot research tower in Oregon's H.J. Andrews Experimental Forest, a research assistant spent an afternoon in June launching lengths of Swiss-made cable through towering boughs of Douglas fir and big-leaf maple.

"We needed a projectile with a mass sufficient to place the line, something that would not be hazardous and would not light the forest on fire," explains OSU researcher John Selker. "We tried everything — bows and arrows, slingshots. In the end, we were shooting organic, biodegradable potatoes around the forest."

Transformative Science

Selker, a professor in the Department of Biological and Ecological Engineering, is taking ecosystem sensing to new heights with an advanced generation of high-tech cable. Today's fiber optics use glass strands so pure that pulses of light zip along the line with little resistance. By detecting the tiny amount of light that scatters back from the source, scientists can measure the temperature of the glass. What that means for monitoring the infinite complexities of ecosystems such as watersheds and ancient forests is an exponential increase in precision, down to hundredths of a degree. Scientists can now take measurements more frequently (every three seconds) at closer increments (every meter) across longer distances (up to five or six miles), capturing spatial structure in three dimensions. The result is an infinitely more nuanced — and thus more accurate — depiction of the natural world.

"With fiber optics, we're getting about 10,000 times more data than we did with traditional sensors," says Selker, a hydrologist who studies stream dynamics. "We've added a whole bunch of zeroes to the precision of our measurements. This is transformative science. It's changing how we see the world."

Getting finer data about the temperature, relative humidity and evaporation of a stream will vastly improve resource management, Selker predicts. Indeed, warming is one of the greatest dangers threatening watersheds. That's because fish thrive in narrow spectra of water temperature. A few degrees warmer can mean less oxygen, more pathogens and greater stress on aquatic animals. Strategies for stream protection and restoration can be more effective if based on truer readings and better models.

But for its promise to be fully realized, the novel technology needs rigorous field testing. "There are a whole lot of practical problems to be overcome," Selker says. The sensors need to be carefully calibrated, for example, to correct for things like weld joints in the wires, "jitter" caused by stream flow and albedo (light reflection).

"The history of science is littered with great measurement techniques that fizzled because of poorly run experiments," says Selker. "We need to seed the science community with people who know how to do this."

So Selker, along with colleagues at the University of Nevada, the Delft University of Technology in the Netherlands and the U.S. Geological Survey recently led two international workshops to test and troubleshoot fiber optics and sensing instruments in real-life settings. The National Science Foundation's Consortium of Universities for the Advancement of Hydrologic Science funded the sessions, which were part training, part joint problem-solving — what Selker calls "proof of concept" studies.

Researchers lay cable at Blue Lake Reservoir in Oregon's Cascades for an experiment measuring relative humidity during an OSU-led summer workshop. (Photo: Lina DiGregorio)

Global Enterprise

In June, one of those workshops drew participants from five countries and 12 states to the 15,800-acre Andrews Forest in the western Cascades.

The nearly 40 industry-based engineers, university researchers, cable-manufacturer representatives and sensor makers hailed from Germany, Switzerland, The Netherlands, Spain, Quebec, and across the United States — a testament not only to the scientific promise of the new technology but also to its economic potential for cable and instrument manufacturers. In advance of the workshop, giant spools of fiber were flown in from Europe and Taiwan. A setback was narrowly averted when a FedEx driver, running late after losing his way on a logging road, pulled up just in time with his cargo — 360 pounds of high-resolution Swiss cable worth $100,000.

Some of the cable shipped in for the workshops is unique, custom-created just for eco-sensing.

"The cool thing is that we've got industrial participation from every major maker of these instruments — Agilent, Sensornet, Sensor-Tran," Selker says. "Then the cable producers — Brugg Cables out of Switzerland, AFL Telecommunications from North Carolina — sent their teams out here to learn how their cables behave in the ecosystem. Our rigorous requirements demand completely new solutions."

Going With the Flow

On Day Two of the five-day workshop, the group breaks up for three experiments: one to measure relative humidity at Blue Lake Reservoir, a second to compare cable types at Andrews experimental watershed 3, and the third to measure stream dynamics and air flow at watershed 1. As the morning mist dissolves, Selker leads a caravan of trucks and vans to the trailhead at watershed 1.

From there it's a short hike into the rainforest with spools of coiled cable, the researchers' hardhats of industrial yellow and red glaring against the organic greens of mosses and ferns. In the damp, dappled understory, the "stream team" unwinds the high-resolution cable — armored against the razor-sharp incisors of squirrels and muskrats by bright-blue plastic casing — and threads it through steel-eyed stakes driven into carpets of wood sorrel. Inside the blue casing, black and white strands of glass are twisted together to equalize the effect of sunlight absorption (black absorbs light, white reflects it).

Walkie-talkies link teammates wading downstream to those skirting steep ravines, their electronic bleip! bleip! bleip! shattering the silence of this place where Pacific giant salamanders can achieve 12 inches in length and some Douglas firs took root while Michelangelo painted the Sistine Chapel. The cable was installed on bedrock as well as on muddy banks to capture contrasts between groundwater and surface water temperatures. Readings will not only pinpoint groundwater upwellings but also detect how snowpack levels affect stream dynamics from year to year. Ultimately, these powerful tools will help scientists monitor watershed health in the face of global climate change.

Meanwhile, Adam Kennedy, a research assistant in the College of Forestry, leads the "air team" from high in the 100-foot tower. Taking aim with the potato launcher, he shoots lengths of cable this way and that over the treetops into the waiting arms of a professional tree climber posted aloft. The zigzag in the canopy will monitor the ebb and flow of the forest's active airshed.

"We're seeing explosive changes in the field of ecosystem sensing," Selker says. "It's a challenging, opportunity-filled moment."

Watch researchers deploy a fiber-optic network at the Andrews Forest, *oregonstate.edu/terra*

An international group of engineers, scientists and cable experts teams up in the H.J. Andrews Experimental Forest in June, stringing cable along a stream and, using a potato canon from a 100-foot tower, threading it through the old-growth canopy. (Photo: Lina DiGregorio)a

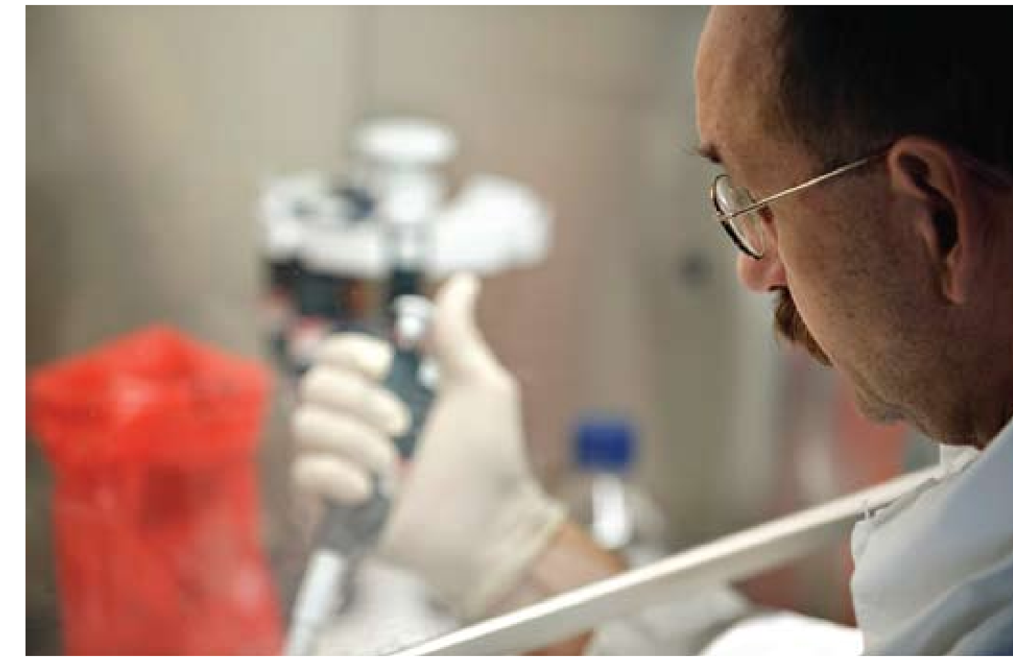
John Selker, a professor in the Department of Biological and Ecological Engineering, uses fiber-optics and other sensing and communication technologies to study watershed hydrology. He specializes in tracing contaminant transport, using light-emitting microbes to track groundwater movement and sampling water in the area known as the unsaturated zone (the area between the top of the ground and the water table).

Funding for his research has come from numerous agencies, including the National Science Foundation, U.S. Geological Survey, Consortium of Universities for the Advancement of Hydrologic Sciences, state and federal departments of agriculture, U.S. Environmental Protection Agency and U.S. Department of Energy.

Targeting an Old Foe

Creating options in the new war on tuberculosis

Luiz Bermudez lab shfot (photo: Karl Maasdam)



M. tuberculosis is a tenacious germ. Armored in a thick, waxy wall impervious to water, the bacterium can lie dormant in the lungs for decades, waiting for a weakness in its human host. When airborne on a cough or a laugh, it can infect a new victim in a simple breath of air. With a flip of a gene, it can dodge healing drugs by mobilizing legions of mutant clones.

Once considered a disease of the past (the last of Oregon's sanitariums were closed in the 1970s), TB is making a comeback. Around the world, more than 8 million people are infected yearly, and 2 million die. Piggybacking on the epidemic of HIV/AIDS, the opportunistic TB pathogen is more dangerous than ever. Some 12,000 strains, each bearing a distinct "genetic fingerprint," have turned up in hospitals, prisons, refugee camps and clinics.

In OSU's biohazard lab, thousands of these strains are undergoing experiments that could give the world its first new TB therapy in four decades. Luiz Bermudez, M.D., is leading an investigation into the anti-TB properties of a drug commonly used to treat malaria. The two-year project is funded by a nearly $1 million grant from the Bill and Melinda Gates Foundation, a major partner in a worldwide race to defeat M. tuberculosis.

Some strains have developed fierce resistance to the powerful drugs rifampin and isoniazid, the "backbone of modern anti-TB chemotherapy," explains Bermudez, a professor in the College of Veterinary Medicine. Until recently, scientists believed this potent cocktail had virtually wiped out the killer disease. But new drug-resistant strains have emerged. "Now it is very common for a healthy person to acquire drug-resistant bacteria directly," Bermudez warns. "In terms of public health, that is a nightmare."

The Centers for Disease Control (CDC) has designated some strains as "extensively drug resistant" (XDR) — that is, they survive just about anything doctors throw at them. In the U.S., 17 cases of XDR-TB have been reported.

With drug-resistant TB raging in hotspots such as Russia and Argentina, the Gates Foundation and others (including billionaire philanthropist George Soros, the World Health Organization and the World Bank) have mounted an aggressive 21st-century battle against the resurgent germ.

Of Germs and Genomes

Bermudez studies a family of infectious pathogens called mycobacteria, of which M. tuberculosis is one. Hansen's disease, or leprosy, is another. A third is M. avium, which attacks humans whose defenses are compromised by conditions such as HIV-AIDS.

When Bermudez and his colleagues — pharmacy professor Mark Zabriskie and several post-doctoral assistants — work with the rod-shaped microorganisms, they seal themselves into biohazard suits before entering OSU's Biosafety Level-3 laboratory. (Level 3 is designated by the CDC for airborne pathogens, including anthrax, West Nile virus, typhus and yellow fever.) The Gates-funded study focuses on Mefloquine, a drug that has proven extremely lethal to M. avium, both in test tubes and in animals. But there's a downside: Mefloquine causes neurological side-effects — from depression to paranoia — in 15 percent of patients.

In a recent breakthrough, Bermudez was able to isolate the most active compound in Mefloquine. It turned out to have a dual benefit. "The compound that is most effective against mycobacteria is the least toxic of the compounds," Bermudez says.

The agent has also proven effective against M. tuberculosis in test tubes. The researcher's goal now is to pinpoint the "essential target" on the DNA of resistant TB mutants. That is, he's looking for the key metabolic gene the germ needs to survive. Once he finds it, scientists can develop new drugs that attack TB in new ways. "Most antibiotics shut down bacteria by inhibiting protein synthesis," Bermudez says. "For Mefloquine, we don't yet know what the mechanism is. But it appears to do more than just inhibit the mycobacteria — it kills it."

In a world where everyone is only a plane ride from everyone else and M. tuberculosis can be transmitted in a cough, a sneeze, even a hymn sung with gusto in church, the stakes couldn't be higher.

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