A Sharp Focus on Sunlight
by Amber Khan

Deep in California’s Mojave Desert, thousands of mirrors line up perfectly across the dry, barren ground. They angle toward a massive central tower, as if worshipping the tall construct. The sun’s rays bounce off the mirrors onto the tower’s central receiver, exciting molten salt molecules in the core and heating them. Next, a generator switches on to create electricity, powering everything from boom boxes to blenders. Together they form one of many solar power plants installed in the area, which receives huge amounts of sunlight year-round.

Every year, the U.S. Department of Energy uses millions of acres and dollars to construct these colossal solar plants in sunny spots. But what if there were a cheaper way to gather sunlight into a tinier device—one that could sit on top of every roof to power an entire household?

Nobuhiko Kobayashi, an electrical engineer at UC Santa Cruz, is building such a device with his team of researchers. They are using flexible new materials and solar-inspired techniques to create a product that’s only about one foot wide, environmentally friendly, and affordable. “Our sun-to-fiber project is interesting because the question is simple,” Kobayashi says. “How much light can we squeeze into a tiny space?”

Today, only 0.25% of the country’s energy comes from sunlight. A big chunk of the rest comes from the nasty human habit of burning fuel. “The way we produce energy is to just burn everything,” Kobayashi says. “We get oil and burn it, we cut a tree and burn it. This burning is actually a very inefficient way to produce energy.” The goal of all this combustion is to obtain one thing humans rely on: heat. But most of this heat dissipates when we try to contain it. For example, car engines use just 30% of the potential heat that gasoline provides. The rest escapes into the atmosphere, which is both wasteful for our wallets and harmful for the environment. As oil prices soar and the environment deteriorates, efforts to extract energy from sunlight are steadily rising worldwide.

Harnessing the sun’s power for energy has its roots deep in Egyptian and Greek history. In the 3rd century BC, Archimedes reportedly used hundreds of metal shields to concentrate sunlight and set an enemy ship on fire. Shortly after, the Greeks invented the magnifying glass, which merchants sold to spark kindling.

Kobayashi’s sun-to-fiber project uses the same essential science as Archimedes’ shields and the magnifying glass. Metallic elements steer the sun’s light waves to focus on a point. When the temperature builds up high enough, a device harvests the heat for people to use as energy. To carry out their project, Kobayashi and his graduate student, Juan José Díaz León, created a unique set of metal materials—anti-reflective coating and a waveguide. Tango Systems, a thin-film development company in San Jose, and Antropy Inc. in Portola Valley work with the team to make the materials and fund the research.
Díaz León then assembles the sun-to-fiber invention at the team’s research laboratory in Mountain View, based at NASA Ames Research Center.

The device is an unremarkable black container, about the size of a Girl Scout Cookie box. But inside and outside of this box, the bizarre microscopic world of physics warps the sun’s light waves. On the surface, the team deposits a black anti-reflective coating using a metal-vapor technique called physical vapor deposition. A machine releases the vapor chemicals, which layer onto the surface like a fine mist of spray paint on a blank canvas. This metal oxide coating, called an anti-reflective coating, mostly contains aluminum, titanium, and oxygen, but it’s as black as ink and imperceptible to the eye. The coating helps most of the incoming sunlight to penetrate the layers; in contrast, solar cells keep in only a small fraction of the sun’s radiation.

Buried underneath the layers of anti-reflective coating is the bulk of Kobayashi’s novel product: the waveguide. It serves as an “optical coupler,” literally guiding waves of sunlight through a funnel-like structure to reach optical fibers at the far end. The anti-reflective coating’s special metal oxide structure keeps sunlight from escaping the waveguide, channeling the waves through the funnel.

The funnel only spans about the length of one adult hand. But when combined with the metal oxide film, the funnel’s shape pushes the collected sunlight waves into a narrow opening at its end. From there, the sharply focused light streams into optical fibers. “If we assume we’re not losing any sunlight in the process, it’s a very effective way to concentrate light to a point,” says Díaz León. Like a magnifying glass, this concentration of sunlight creates intense energy.

The bundles of fibers are made out of insulating material that directs the sun’s focused energy to a distant target—such as from a roof to the inside of a house. The fibers can connect directly to lighting fixtures, making it possible to power indoor lights with natural sunlight during the day. “We always turn on inside lights even when the sun is out, because of the way buildings are designed,” Kobayashi says. “This waveguide can run all the way through a house and save energy during the day.” In addition, the optical fibers can connect to energy storage units inside a home. So even when the sun isn’t shining outside, heat funneled by the waveguide would be available at night.

Combining the anti-reflective coating and the waveguide is a cheap and innovative way to channel vast amounts of sunlight to one point, Kobayashi says. This technology could even be more useful than solar cells, he thinks. “Solar cells only have an efficiency of about 25%,” he says. “We don’t have to burn anything in the process of using them, but to make them we have to burn a lot. They’re not as green as people like to think.” The solar panels that make up solar energy plants, such as the ones in the Mojave Desert, require tons of oil and metal to construct. For Kobayashi’s team, their sun-to-fiber application provides something novel: an inexpensive way to use solar energy without harming the environment and providing energy directly to residents.
But the team’s new technology does have its challenges. So far, the engineers have made and tested the different parts individually: the anti-reflective coating, waveguide, and the optical fibers. They have yet to combine all of the ingredients to make a final commercial product. When they complete the sun-to-fiber project, assuming all three parts cooperate with each other, other challenges may await. For example, the device must connect efficiently to an energy storage unit inside a house. This would give residents a way to make their own energy, providing a home with its personal helping of sunshine at night—once engineers address the hurdles of making that work.

For years, solar power has been a popular and idealized concept for engineers, politicians, and consumers. “There have been so many hypes out there,” Kobayashi admits. “We have to take these solar technologies one step at a time.” So out of the many promising solar-powered devices out there, what makes this one special? According to the scientists, the secret is in their materials. Also, their product provides energy at the residential level, rather than distributing it from a company miles away. “We have a system today that breaks down often and is expensive to fix,” says Kobayashi. “We pay a lot for PG&E, but it’s not a system that’s as strong as we like to think.”

Though obstacles lie ahead, the sun-to-fiber technology concept is promising. The different parts of the device offer a mix of applications elsewhere as well. For instance, the anti-reflective coating can be deposited on phone screens, making it possible to charge our cell phones with sunlight. “You can couple these techniques with all sorts of technology,” says Díaz León. “I’d say it’s only the beginning for sun-to-fiber.”

Amber Khan, an undergraduate majoring in molecular, cell, and developmental biology, wrote this story in spring 2014 for SCIC 160: Introduction to Science Writing.