with electric bus trials in four U.S. cities. The transit trials featured a bus in Wenatchee, Wash., that slurped energy from a charging pad installed along its route at a rate of 200 kW. The bus was built by the Chinese company BYD at its facility in Lancaster, Calif. That's on par with some of the fastest DC chargers, enough to "keep the bus in 24/7 operation, without ever going back to the garage" to recharge, Daga says.

Daga points out that taxi or ride-hailing drivers are strongly inclined to avoid downtime–whether that means waiting in line for gasoline pumps or detouring for lengthy charges at depots. With an inductive system, "they won't lose a single minute of revenue time charging their vehicle."

The company claims its technology delivers 94 percent charging efficiency, which holds steady as scalable power climbs to 200 or even 350 kW. That's a winning contrast with DC fast chargers, whose efficiency drops sharply at higher power because of massive resistance and the resulting heat demands of liquid-cooled cables, which themselves create more energy losses.

"It's the perfect charging technology," said Morgan Lind, chief operating officer of Recharge Infra, owned by Infracapital and Fortum. Recharge Infra tabbed Momentum Dynamics after learning it could deliver 50 kW or more through a roughly 18-cm air gap between vehicle and pavement–a huge improvement over companies that promised no more than 11 kW.

Backers cite several additional benefits. With systems buried entirely underground, the plan eliminates chargers that compete for parking or sidewalk space; moving parts and vandalism or damage from the elements; and wired infrastructure, including unsightly towers for electric buses.

"It makes the experience of refueling invisible," Daga said. "We could get clean cities and clean streets at the same time."

Furthermore, says Daga, inductive systems will deliver a daisy chain of gains. With enough charging pads, they could keep vehicle batteries in a permanent "sweet spot" between 75 and 85 percent capacity, avoiding deep cycling, which kills batteries before their time. Largely freed from range concerns, EVs could carry smaller battery packs, trimming their daunting weight and cost, while further boosting energy efficiency.

For taxi fleets or passenger cars, Momentum Dynamics is developing software to track even the briefest charging events and bill customers automatically, similar to an automated tolling system. The company has also developed a Near Field Communication system, which would allow autonomous cars to align and connect with charging pads. Bidirectional charging could let cars contribute supplementary power to the grid.

Lind says the Jaguar taxis should start running their meters, and no-fuss chargers, by year's end. Lind called Norway–with only 5 million residents, but a determination to wean itself off of fossil-fueled vehicles–an ideal, if tiny, test bench.

"We are an extremely small country, but we see that we can be a guiding star to many other countries," says Lind. "The avalanche of EVs is coming, and there's no stopping it." –LAWRENCE ULRICH

A version of this article appears in our Cars That Think blog.

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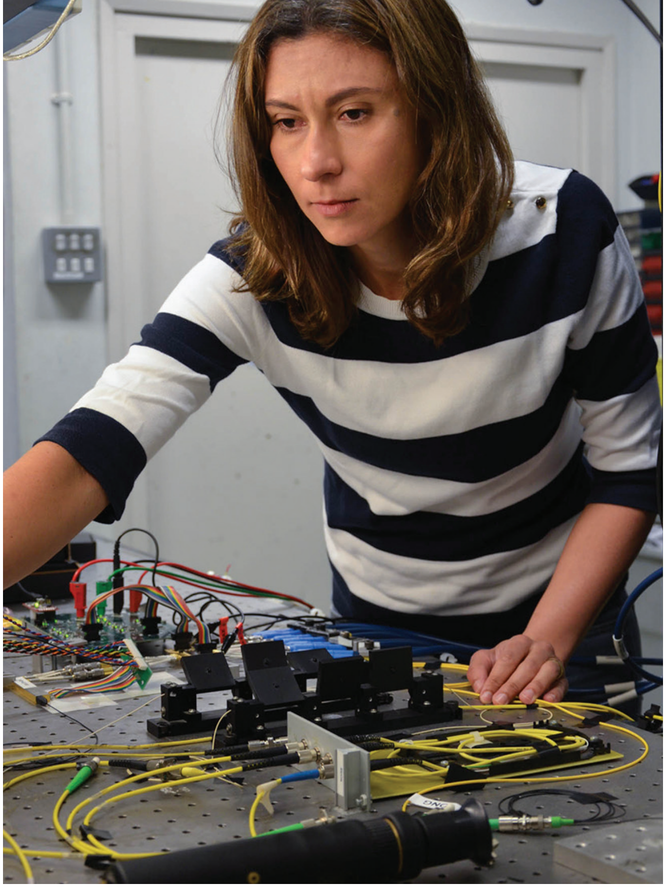
SAME OLD FIBERS, RECORD-BREAKING SPEEDS

Equipment in the lab can carry 100 million Zoom videos

A team at the Optical Networks Group at University College London (UCL) has sent 178 terabits per second through a commercial single-mode optical fiber that has been on the market since 2007. It's a record for the standard single-mode fiber widely used in today's networks, and twice the data rate of any system now in use. The key to their success was transmitting it across a spectral range of 16.8 terahertz, more than double the broadest range now in commercial use.

The goal is to expand the capacity of today's installed fiber network to serve the relentless demand for more bandwidth for Zoom meetings, streaming video, and cloud computing. Digging holes in the ground to lay new fiber-optic cables can cost over US $600,000 a kilometer in metropolitan areas, so upgrading transmission using fibers already in the ground in combination with new optical transmitters, amplifiers, and receivers could save serious money. But it will require a new generation of optoelectronic technology.

A new generation of fibers that has been in development for the past few years promises higher capacity by carrying signals on multiple paths through single fibers. Called spatial division multiplexing, the idea has been demonstrated in fibers with multiple cores, multiple modes through individual cores, or combining multiple modes



DOUBLE THE DATA: New transmitters, amplifiers, and receivers could dramatically increase the capacity of networks without digging up existing optical fibers.

UNIVERSITY COLLEGE LONDON

in multiple fibers. But the technology is immature and would require the expensive laying of new fibers. Boosting capacity of fibers already in the ground would be faster and cheaper. Moreover, many installed fibers remain dark, carrying no traffic, or transmitting on only a few of the roughly 100 available wavelengths, making them a hot commodity for data networks.

"The fundamental issue is how much bandwidth we can get" through installed fibers, says Lidia Galdino, a UCL lecturer who leads a team including engineers from equipment maker Xtera and Japanese telecom firm KDDI. For a baseline, they tested Corning's SMF-28 ULL (ultra-low-loss) fiber, which has been on the market since 2007. With a pure silica core, its attenuation is specified at no more than 0.17 decibels per kilometer at the 1,550-nanometer minimum-loss wavelength—close to the theoretical limit. It can carry 100-gigabit-per-second signals more than a thousand kilometers through a series of amplifiers spaced every 125 km.

Generally, such long-haul fiber systems operate in the C band of wavelengths from 1,530 to 1,565 nm. A few also operate in the L band (1,565 to 1,625 nm), most notably the world's highest-capacity submarine cable, the 13,000-km Pacific Light Cable. That line has a nominal capacity of 24,000 Gb/s on each of six fiber pairs. For both bands, it uses well-developed erbium-doped fiber amplifiers, but that's about the limit of their spectral range.

To cover a broader spectral range, UCL added the largely unused 1,485- to 1,520-nm wavelengths in the S band. That required new amplifiers that use thulium to amplify those wavelengths. Because only two thulium amplifiers were available, they also added Raman-effect fiber amplifiers to balance gain across that band. In addition, they used inexpensive semiconductor optical amplifiers to boost signals reaching the receiver after passing through 40 km of fiber.

Another key to success is format. "We encoded the light in the best possible way," says Galdino: the geometric coding quadrature amplitude modulation (QAM) format, which takes advantage of differences in signal quality between bands. "Usually, commercial systems use 64 points, but we went to 1,024 [QAM levels]... an amazing achievement," for the best quality signals.

This experiment, reported in *IEEE Photonics Technology Letters*, is only the first in a planned series. The results are close to the Shannon limit on communication rates imposed by noise in the channel. The next step, says Galdino, will be buying more optical amplifiers so the group can extend transmission beyond 40 km.

Still, Galdino cautions, "This is fundamental research on the maximum capacity per channel." The goal of the UCL work is to find limits, rather than to design new equipment.

Industry will face the challenge of developing detectors, receivers, amplifiers, and high-quality lasers on new wavelengths, which it has already started. If it succeeds, a single-fiber pair will be able to carry enough video for all 50 million school-age children in the United States to be on two Zoom video channels at once. —JEFF HECHT

A version of this article appears in our Tech Talk blog.

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