Eye-opening optical research projects that could supercharge the Internet

By John Edwards

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Nikola Alic, a photonics research scientist at the University of California's Qualcomm Institute in San Diego, argues that optical research offers the best hope for helping the Internet accommodate the ever growing flow of multimedia services.

"All of today's information traffic in the backbone is transmitted over fiber-optic networks," he says. "A single optical fiber made of glass — more precisely, silica — offers more than 25 THz of bandwidth."

Alic leads one of several research teams worldwide that are independently investigating optical technologies that promise to make networks — and the Internet — faster and more efficient. "Extending reach and/or capacity of the fiber optic network is essential to accommodate growth," he says.

Killing crosstalk

Alic's photonics research team recently developed a method of increasing the maximum power at which optical signals can be sent through optical fibers, thereby also lengthening the maximum distance the signals can travel. The research also has the potential to boost the data transmission rates of the fiber-optic cables used by the Internet and many other types of networks.

Developing the new approach required the researchers to tackle a formidable technical roadblock: the fact that when moving beyond a threshold power level, adding extra power distorts the information carried in a fiber optic cable. "With fiber optics, after a certain point, the more power you add to the signal, the more distortion you get, in effect preventing a longer reach," Alic says. "Our approach removes this power limit, which in turn extends how far signals can travel in optical fiber without needing a repeater."

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The researchers addressed the power/distortion challenge by developing wideband "frequency combs" to ensure that the crosstalk signal distortions, created when bundled signal streams operating at different frequencies travel through an optical fiber, are predictable and reversible at the receiving end.

The frequency comb synchronizes the frequency variations of the different streams of optical information propagating through the optical fiber. Alic notes that the method compensates in advance for any crosstalk encountered by signals as they move along the cable. The frequency comb also ensures that any crosstalk created between the communication channels is completely reversible.

"In our experiments, we have pre-compensated the transmitted channels' waveforms, such that all of the nonlinear crosstalk in transmission gets cancelled and the channels are then received — even after thousands of kilometers — altogether free of nonlinear crosstalk," Alic says.

The technology effectively eliminates any need for electronic regenerators to be placed at strategic points along the optical cable run. Alic notes that eliminating the regenerators will make it far less expensive to install and maintain fiber-optic networks, since the devices represent the bulk of the cost of optical network deployment while also preventing the construction of a transparent optical network. "Eliminating periodic electronic regeneration will drastically change the economy of the network infrastructure, ultimately leading to cheaper and more efficient transmission of information," he says.

In lab experiments using three to five optical channels, the researchers were able to reliably decipher information that had traveled 12,000 kilometers through silica fiber optic cables using no regenerators. The frequency comb ensured that the network did not accumulate the random distortions that would make it impossible to reassemble the original content at the receiver. "Since the first demonstration, we have been able to double the reach in any fiber optic transmission system from its previously nonlinearity set limit," Alic says. "We are currently exploring the ultimate limits of the method."

Alic is confident that the same approach could be used in cables with far more communication channels. "Long haul and metro fiber optic transmission systems, both terrestrial and submarine," he says.

Research Scientist Nikola Alic in Calit2 Photonics Systems Laboratory
[Photo by Erik Jepsen/Calit2]

Building a better tunable filter

Wei Shi, an assistant professor at Université Laval in Québec, says the arrival of a speedier, more efficient Internet has been delayed by two key factors: excessive energy consumption and the stubbornly high cost of optical components. Aiming to overcome these roadblocks, Shi and his research team have developed a new type of tunable filter — a key component in high-capacity optical networks — with the aim of integrating the device onto a photonic chip.

Tunable filters play an important role in optical networks, isolating a specific communication channel from other channels. The devices also allow a network controller to select a precise frequency and bandwidth for each channel and then modify the settings on the fly.

The new filter's performance compares favorably to today's best tunable filters, yet is significantly smaller and less expensive, Shi says. The filter's tuning range, which dictates how rapidly the device can adjust to fluctuating data demands, is the widest ever demonstrated on a silicon chip, he adds. The device also offers a 670 GHz tuning span, far wider than the approximately 100-GHz span supported by other silicon-based filters. The researchers believe that future refinements will improve their device's tuning span even further, perhaps up to 1 THz. "The most exciting aspect is that these record-breaking results were achieved on the silicon photonic platform," Shi says.

The new tunable filter uses periodic nanostructures, approximately 10,000 times smaller than the width of a human hair, to separate different frequencies of light. Precise tuning is achieved with the assistance of micro-heaters, built into the silicon chip, that control the local temperature. The micro-heaters change the temperature of the nanostructures, enabling specific light frequencies to be separated.

The filter's wide tuning span allows it to handle a carrier signal with a large amount of data and to react dynamically to changes in network needs. The device is based on a compact, CMOS-compatible nanophotonic integrated platform, the same basic technology used to make integrated circuits. Since CMOS chip fabrication is already well optimized, chips containing the new filter could potentially be produced at a very low cost, Shi says.

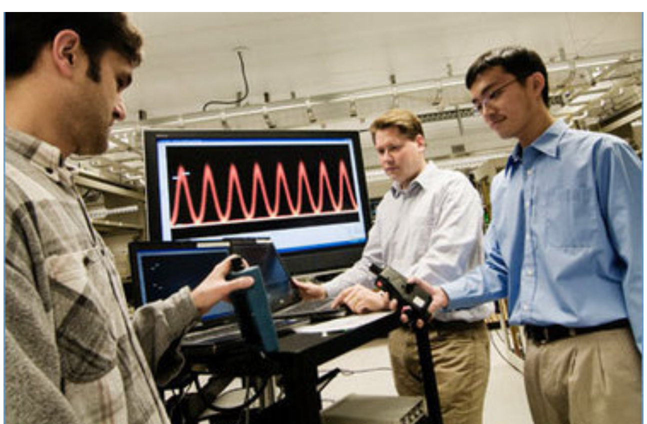
Higher capacity optical networks will impact users in a major way, Shi says, leading to an array of innovative services, such as videos that stream in 3D or 360 degrees and opening the door to far less expensive cloud data storage. “Think about the improvements to Internet services in the past 10 years,” Shi says. “We can now easily call each other with video, send large files almost instantly and generate the news feed of your 1,000 friends and subscriptions in milliseconds."

With their initial work completed, the researchers are now planning to integrate their tunable filter with other components on the same chip to enable chip-scale flexible optical networking. "This is only the beginning," Shi promises.

Eliminating the modulator bottleneck

Aiming to make optical networks function more efficiently and at a lower cost, a research team headed by Radan Slavik, a principal research fellow at the University of Southampton's Optoelectronics Research Centre (ORC), has developed a new type of modulator. The internal technology saves cost and space by enabling direct modulation of the laser currents used to generate highly advanced modulation format signals.

According to Slavik, the modulator offers a fresh approach to the generation of the spectrally-efficient advanced modulation format signals that are required by modern optical communication systems. Collaborating with engineers at Eblana Photonics, an Irish photonics component developer, the engineers developed an internal technology that could potentially replace the costly and power-inefficient external modulators that are currently used to generate modulation format signals. "The traditional modulator is really a bottleneck in many parts of the optical network," he says.



Research scientist Nikola Alic (at left) with colleagues in 2,000-sq-ft Calit2 photonics lab [Photo by Erik Jepsen/Calit2]

Slavik says that when he and his team began their work, the goal was to create a technology that would eliminate today's external electro-optic modulator. After approximately four years of work, they felt they had reached their target. "In our solution, the data are encoded directly into the lasers," Slavik says. "The laser's output intensity changes with the data streams — for binary encoding '0' would be laser off and '1' would be laser on."

A key obstacle the researchers encountered during their development work was a modulation chirp that emerged as the laser's power increased. "It changes the carrier frequency, which makes data encoding independently in the amplitude and phase impossible," Slavik says. The problem was solved with the help of a second laser. "We use an effect called optical injection locking, in which another laser is shined onto the laser that's directly-modulated with the data, which suppresses the chirp," Slavick says.

Lower cost and smaller size are the new technology's primary benefits, Slavick says. "As compared to the mainstream approach, it has a significantly smaller size, the potential for integration onto a single photonic chip and requires less power," he says. "It also has better linearity, which is important for advanced modulation formats."

The researchers are now working on the challenge of placing their new modulator onto a chip. "We just had the first chips manufactured and we need to test them now," Slavik says. "We need to optimize several components on the chip, but particularly for the lasers to achieve operation over large modulation speeds — 28G baud and beyond," he says.

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