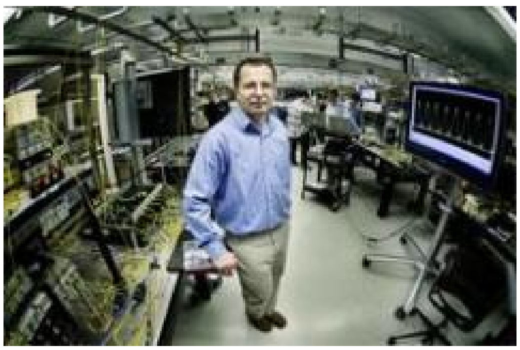
Engineers Closing the Gap Between High-Speed Data Transmission and Processing

January 27 2009



Jacobs School of Engineering professor Stojan Radic in the 2,000-square-foot Photonics Systems Lab in Atkinson Hall.

(PhysOrg.com) -- Electrical engineers at the University of California, San Diego have achieved world-record speeds for real-time signal processing in an effort to meet ambitious goals set by the Defense Advanced Research Projects Agency (DARPA) to develop the first Terabit-scale technology for optical processing. The technology could have widespread ramifications for networking, computing, defense and other industries.

UC San Diego electrical and computer engineering professor Stojan Radic and his team have demonstrated the first real-time sampling of a 320 Gigabits per second (Gb/s) channel, setting multiple records in the process. The results were outlined in papers delivered at the IEEE LEOS

Society for Photonics Winter Topical Meeting Jan. 12-14 in Innsbruck, Austria, at the Photonics West Conference this week in San Jose, Calif., and in recent submissions to *IEEE Photonics Technology Letters* and the *IEEE Journal of Lightwave Technology*.

Developed in the Photonics Systems Lab of the California Institute for Telecommunications and Information Technology (Calit2), the UC San Diego technology is part of an advanced program on parametric optical processing funded by DARPA. The program was envisioned and managed by Dr. Henryk Temkin of DARPA's Microsystems Technology Office.

"For the first time we have been able to process signals as fast as 320 Gb/s by making more than eight copies of the signal and simultaneously sampling all the copies - thereby allowing us to do real-time processing," said Radic, a professor in UCSD's Jacobs School of Engineering. The aggregate speed was a record, as were the number of copies simultaneously sampled. The demonstration also registered a five-fold improvement in a published optical delay demonstration.

"Calit2 has a strong interest in very fast optical processing in order to bridge the gap between transmission and real-time processing speeds," said Calit2 Director Larry Smarr. "The future of the Internet - especially for data-intensive collaborative science - is predicated on finding ways to process data on the fly, even at the highest transmission rates. The techniques invented by Professor Radic and his team are a major step forward to realizing this vision."

"The goal of the four-year project is to reach one Terabit per second processing with a single technology platform," said Radic. "A little over one year into the project, we have achieved one-third of that speed, which is about an order-of-magnitude faster than the advanced commercial optical transport at 40 Gb/s."

The latest advances build on development of wideband optical mixers, a key technology of this effort. UC San Diego research led to a new technique capable of mapping dispersive fluctuations in fiber that are on the order of the diameter of a molecule. The technique maps an optical fiber's geometry for any variations of more than a couple of nanometers. "Once you can do that," said Radic, "you can synthesize a parametric mixer with true bandwidths exceeding tens of Terahertz." In the past, the use of a fluctuating nonlinear waveguide limited the mixer bandwidth and efficiency to a point that researchers coined the term 'stochastic mixer barrier' to describe it.

The sensitivity of conventional waveguide mapping techniques was off by orders of magnitude and could not address the mixer waveguides even in principle. The technique developed at UC San Diego can map nearly dispersionless fiber with 100-fold higher resolution and sensitivity. The dispersive mapping technique is now the subject of a pending patent application, and is expected to revolutionize general mixer construction. The research will be described at invited talks at this week's Photonics West conference and at OFC 2009 this March in San Diego.

Armed with the new class of optical mixer, the UC San Diego system can process more than eight duplicates of the 320Gb/s data stream simultaneously - allowing for the use of much slower gating devices. With multiple replicas of a signal, sections of a signal can be captured, routed or changed at a much lower rate than if dealing with just one original.

"Having duplicates of the stream is critical to all-the-data-all-the-time processing, versus today's systems that can only capture and store the signal for later analysis," explained Radic.

The technology bridges the gap between transmission speed and processing speed. "Transmission speeds presently are at a Terabit-per-second scale, while electronic processing speeds are just approaching Gigabits per second," said the UC San Diego professor. "So this technology will take a Terabit-scale signal and download it to parallel streams for concurrent processing, with nearly no latency."

Looking to the future, Radic said he expects to demonstrate the scaling of the technology to 640 Gb/s, and eventually to hit 1 Tb/s by the end of the four-year DARPA contract.

Radic attributes much of the credit for the team's progress to the advanced facilities available in Calit2's 2,000-square-foot Photonics Systems Lab that he directs. "The facility at Calit2 was absolutely critical, and especially having a telecom-class space for supporting multicasting, synchronization, sampling and system integration in one place, which was absolutely fundamental," explained Radic. "The laboratory closely emulates the Bell Laboratories model and has no equivalent in a university setting."

The researcher played a key role in designing the lab, which was modeled on large, modular industrial research labs where he worked previously: Corning Research (1995-98) and Bell Labs (1998-2003). Later in 2003, Radic joined the UCSD Jacobs School of Engineering faculty, after briefly holding a chair at Duke University. He earned his Ph.D. from the Rochester, NY-based Institute of Optics in 1995.

The project is a collaborative effort and relies on critical work by ECE professor Shayan Mookherjea; Calit2 research scientist Nikola Alic; postdoctoral researchers Andreas Wiberg, Camille Bres, Jose Chaves Boggio, Sanja Zlatanovic; and four graduate students.

In one of the more exciting prospects of this research, the flow of the new processor can be reversed in order to accomplish ultrafast synthesis -- enabling arbitrary channel generation at Terabit scale. Said Radic:

"You can synthesize very high data streams by reversing the forward processor flow."

DARPA's Parametric Optical Processes and Systems (POPS) program aims to demonstrate all-optical processing based on Four Wave Mixing in optical fibers and silicon waveguides to achieve data rates up to 1Tb/s. This will require development of components such as wavelength-shifting wideband amplifiers, tunable optical delays, and parametric sampling.

Recent and upcoming papers co-authored by Radic and his team at UC San Diego outline the group's recent research findings. They include:

- **RZ Pulse Source for Optical Time Division Multiplexing Based on Self-Phase Modulation and Four Wave Mixing**
  A.O.J. Wiberg, C-S. Bres, J.R. Windmiller, N. Alic, and S. Radic
  IEEE LEOS Winter Topical Meeting 2009, NS, Innsbruck, Austria 1/2009
- **Parametric Multicasting of 320 Gbps OTDM Data**
  C.S. Bres, A.O.J. Wiberg, J.R. Windmiller, N. Alic and S. Radic
  IEEE LEOS Winter Topical Meeting 2009, NS, Innsbruck, Austria 1/2009
- **Tunable 2.5W Continuous-Wave Optical Source Based on Efficient Parametric Conversion in Highly Nonlinear Fiber**
  J.M. Chavez Boggio, S. Moro, J.R. Windmiller, A.J. Anderson, J.X. Zhao, N. Alic, and S. Radic
  IEEE LEOS Winter Topical Meeting 2009, NS, Innsbruck, Austria 1/2009
- **Spatially Resolved Measurement in Waveguides With Arbitrary Chromatic Dispersion**
  Myslivets, E.; Alic, N.; Radic, S.;
  Photonics Technology Letters, IEEE, Volume 20, Issue 21,

Nov.1, 2008 Page(s):1793 - 1795

- **Synthesis of Equalized Broadband Parametric Gain by Localized Dispersion Mapping**
  Moro, S.; Myslivets, E.; Windmiller, J. R.; Alic, N.; Chavez Boggio, J. M.; Radic, S.;
  Photonics Technology Letters, IEEE, Volume 20, Issue 23, Dec.1, 2008 Page(s):1971 - 1973

Provided by University of California, San Diego