CENTER FOR INTEGRATED ACCESS NETWORKS

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In This Issue

MESSAGE FROM THE DIRECTOR

Nasser Peyghambarian

I would like to thank everyone who participated in CIAN's NSF site visit held April 13-15, 2011. This was an especially important visit as it was our renewal year. The good news: NSF has recommended continued funding for CIAN.

With regard to our research program, NSF noted the high caliber of our research team and our productivity as evidenced by publications in high-profile journals. It was noted that CIAN has defined transformative solutions to major bottlenecks for both data centers and aggregation networks. NSF also cited significant progress in establishing "substantive" and "impactful" collaborations among our research groups.

The site visit team acknowledged that our Innovation Ecosystem is "progressing nicely," a reflection of CIAN's success in recruiting several cash-paying Industry Partners just over the past year. The team also expressed support of CIAN's efforts to engage the Optoelectronics Industry Development Association (OIDA) to develop technology roadmaps for optical networking.

Finally, NSF noted several important educational accomplishments, including the development and implementation of our novel Super Course on Photonics Communication Engineering and our successful Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET) programs. The team also cited CIAN's pre-college outreach efforts, particularly to the Native American community.

In May, more than 20 graduate students and postdocs attended our workshop on commercializing CIAN innovations. It was the first of a series of such workshops.

I look forward to seeing everyone at the CIAN retreat this November.

2011 NSF Site Visit Report Summary & Highlights

Feedback from the NSF Review Team

The Center for Integrated Access Networks (CIAN), an NSF Engineering Research Center (ERC), focuses on enabling end-user access to emerging real-time, on-demand, high-data-rate network services, anywhere and at any time, at low cost and with high energy efficiency. This drives a need for scalable, optically-based aggregation systems to collect and redistribute traffic across the globe. The CIAN effort is examining this problem from a broad perspective, including network architectural and network element functionality bottlenecks, and new enabling subsystems, devices and materials.

Recognizing current and emerging bottlenecks in networks to support emerging mobile, video and other forms of content delivery, the Center adapts the aggregation vision into two distinct, yet pervasive environments:

- Data centers, with homogeneous localized services; and
- Multi-service aggregation networks that address heterogeneous systems, including wireline and wireless.

These two environments are manifested as separate working groups that drive vertically-integrated research across three thrusts: optical communications and systems; subsystem integration; and nano-photonics and device physics. While the working groups focus on distinct research challenges, especially at the system level, they also share key properties that will drive common solutions and complement each other in optimization.

In today's commercial environment, we are also beginning to see a merging and/or blurring of the business models that formerly saw distinct infrastructures and services for data centers and networks (i.e., the "cloud"). Therefore, the Site Visit Team (SVT) expects merging and co-development across the working groups as CIAN matures. There is no other center of research that explores this broad range of inter-related problems, together with a comprehensive suite of range-of-technology solutions, under a cohesive management. CIAN seeks to provide a solution to this timely problem. CIAN researchers are identifying challenging barriers and potential optical-layer solutions that are not being addressed in a sufficiently aggressive manner by industry due to *risk* and *diminished R&D budgets*.

Year 3 Significant Achievements

Knowledge: CIAN researchers have identified a number of architectural opportunities for data center information systems that may provide significant enhancements in bisection bandwidth at lower power and lower cost. In more fundamental and underlying physical-layer research, CIAN is providing an in-depth understanding of quantum optic phenomena at the nanoscale, including the Purcell effect and photon-matter interaction, which can lead to high-efficiency integrated light sources.

Technology: Major achievements in technology include electro-optic devices, systems/networks as well as novel applications. Electro-optic modulators were fabricated with record-breaking modulation speed. A technique to characterize the waveforms of ultra-high-speed optical signals was developed to help characterize high-speed modulators and to monitor transmission performance of high-capacity optical systems.

Education: New curriculum and courses, including a novel Super Course on Photonics Communication Engineering, and a Master's degree in Photonics Communication, have been created to serve as knowledge foundations to support CIAN's educational mission.

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NSF Site Visit 2011

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Today's data centers are beginning to face issues of scale leading to prohibitive cost and energy consumption that are causing companies like Amazon, Google and Microsoft to build data centers close to sources of cheap, available power. The data center market has a standard practice of relying on commodity technology that was developed by the telecommunications industry, but was not optimized for their application. As a result, industry can benefit broadly from the research being done in CIAN.

Likewise, for the integrated aggregation network focus, the rapid proliferation of handheld technologies, and improved performance of wired devices such as high-definition television and high-density storage systems, have caused dramatic changes in how consumers and businesses receive and deliver content. This drives tremendous metro-network bandwidth growth, while increasing the challenge of supporting heterogeneous traffic and providing quality on-demand video delivery. Today's data centers are growing so fast that it is increasingly clear they will 'hit a wall' beyond which they will not be supported by conventional telecommunication commodity network technology. Such challenges cross traditional network layer boundaries, and they are leading to industry gaps that could be filled by CIAN's cohesive, vertically-integrated yet broadly-positioned research suite.

These circumstances make the targeted contributions of CIAN both timely and important, and they are well suited to an NSF ERC. If successful, the advances envisioned by CIAN will be critical in radically changing the way content is delivered across the globe – reducing costs and saving energy while supporting a richer set of experiences and capabilities for end users.

CIAN principal investigators (PIs) are among the top in their field, and well regarded for the creativity and innovation of their past and present work. The research in CIAN is of high quality. Over three years, 243 CIAN publications have been published in peer-review journals, and in its third year, nearly *half* of CIAN publications included co-authors from multiple institutions.

CIAN has educational programs that are focused on preparing graduates to be more effective in practice. Innovative curriculum, such as the Super Course, uniquely provides vertically integrated material that allows students to review prerequisite material and study ahead as needed. CIAN's test beds also improve students' practical effectiveness by training them in current commercial techniques and technologies in a hands-on setting. CIAN is developing some exceptional students who are demonstrating cross-disciplinary creativity through their collaborations with other institutions. CIAN now has students driving working group meetings and forging the kind of creative solutions to problems that eventually lead to CIAN group publications. A case in point is the insertion of the Time-Stretch Enhanced Recording (TiSER) technology into the Columbia testbed, which was heavily driven by students and resulted in a conference paper.

Multiple CIAN institutions are participating actively in Research Experiences for Teachers (RET) and Research Experiences for Undergraduates (REU) activities that provide rich experiences for teachers and students, and CIAN is actively tracking the success and progression of the students.

The CIAN leadership has shown itself to be highly adaptable and alert to opportunities for improved focus and higher impact. The CIAN team has strong competence in materials, devices, subsystems, and physical-layer optical networking technologies, and has enhanced their expertise by adding faculty members at the higher layers and leveraging other enterprises, such as the Global Environment for Network Innovations (GENI), an NSF-sponsored project. There is strong and desirable synergy between Working Groups 1 and 2 regarding their needs at the Thrust 2 and Thrust 3 levels in materials, devices and subsystems integration. The team also has very high-quality test bed resources that are available to CIAN researchers for validating their architectural concepts and subsystem technologies for both Working Groups.

RESEARCH HIGHLIGHT

Holographic Telepresence: From Science Fiction to Reality

A group of CIAN researchers has developed a holographic system that can transmit a series of 3D images in near-real time – a precursor to holographic videoconferencing and holographic telepresence. The system allows an object in one location to be viewed holographically in 3D in another location transmitted via the Internet. The system incorporates a novel plastic screen that can rapidly refresh holographic images and is scalable for production. It is coupled with a unique system for recording and transmitting 3D images of individuals and objects.

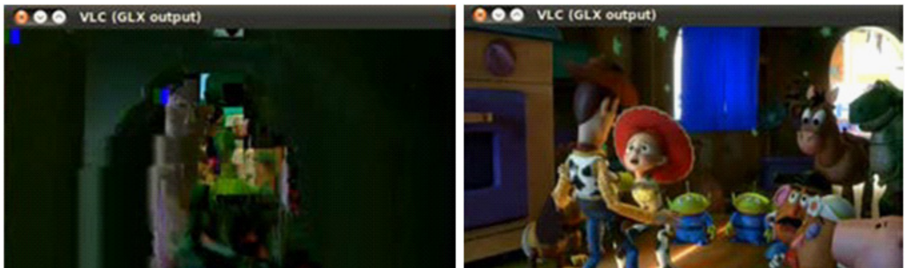
The work was reported as a major breakthrough in a cover story of the Nov. 4, 2010, issue of the journal *Nature.*

Demonstration of rapid refresh holographic 3D telepresence. The Nature cover depicts three different perspective images of an object (one of the researchers on the project) sent through the Internet. A person in one location is displayed in another location in 3D and in near-real time.

RESEARCH HIGHLIGHTS

QoS-Aware Video Transmission over Cross-Layer-Conrolled Metro-Scale Network

Using an optical network in North Carolina in collaboration with the Global Environment for Network Innovations (GENI), CIAN researchers at Columbia University have demonstrated the transmission of video which can dynamically recover due to signal- quality degradations. The cross-layer network architecture allows the reconfigurability of video streaming, even in the presence of power loss and impairments in the physical layer. Novel cross-layer communication and control capabilities are integrated into the Breakable Experimental Network (BEN) along with the SILO service-oriented architecture and a NetFPGA optical control plane (OCP). A programmable optical layer can compensate for dynamic power fluctuations in the fiber channel. This work was presented at the Optical Fiber Communication/National Fiber Optic Engineers Conference (OFC/NFOEC) 2011.

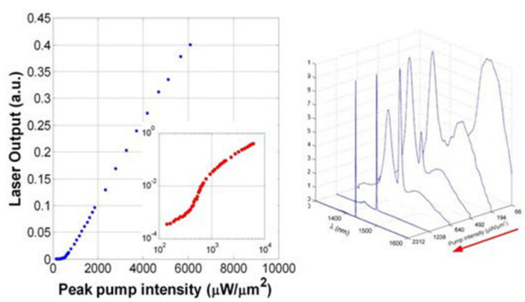


Demonstration of video transmission on the Breakable Experimental Network (BEN): Left figure shows the signal quality under optical impairments; on the right, these impairments are controlled using programmable optical devices via cross-layer interactions, thus preserving the video quality.

Room Temperature Nanoscale Metallo-Dielectric Lasers

CIAN researchers have broken the limits on semiconductor laser size by demonstrating 3D subwavelength nanolasers that are capable of emitting at telecommunication wavelengths while operating at room temperature. The devices utilize a specially designed cavity consisting of metal and dielectric layers encapsulating a semiconductor core.

In this work, which appeared in the May 2010 issue of *Nature Photonics,* researchers at UC San Diego demonstrated that by incorporating a silica (silicon dioxide) shield layer between the metal and a semiconductor gain disk, and optimizing the silica thickness, the gain threshold of the laser can be reduced so substantially as to allow the laser to operate at room temperature. The improvement stems from the tendency of a low-index shield to push the electromagnetic mode toward a high-index inner core and away from metal walls, reducing the mode-metal overlap and hence resistive loss. Using this approach, the researchers demonstrated lasing from devices that are about 1 micron in each direction and emit at 1.5 microns – achieving a record. The devices are fabricated using Indium Gallium Arsenide Phosphide (InGaAsP) multiple quantum wells grown on Indium Phosphide (InP) wafers.



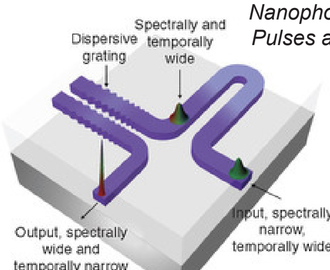
(Left) Light-light curve of laser, indicating lasing with a threshold of 500 W/m2;

(Right) Evolution of nanolaser spectrum from photoluminescence to lasing.

Monolithic Nonlinear Pulse Compressor on a Silicon Chip

A group of CIAN researchers have developed an integrated sub-system to provide strong compression of optical pulses and realized on a CMOS compatible materials platform. The work was reported as a major breakthrough in the Nov. 16, 2010 issue of *Nature Communications*.

The compressor is monolithically integrated on a silicon chip, providing large compression factors at low input powers. Implementation on a CMOS compatible wave guiding platform ensures seamless integration with other electronics and other photonic components.

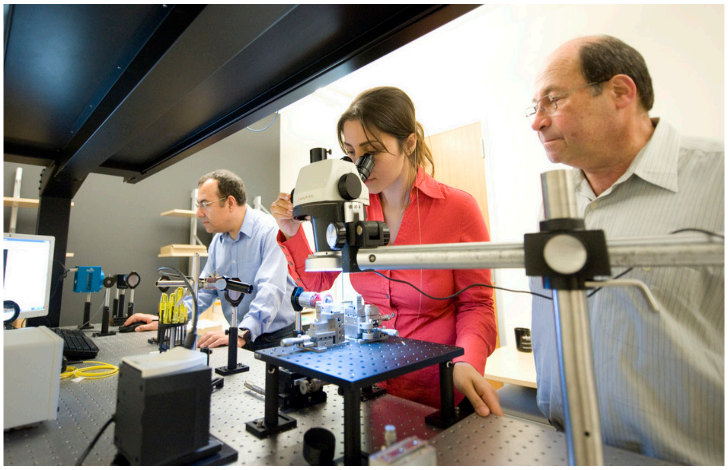


Nanophotonic pulse compressor. Pulses at the input are spectrally broadened due to self phase modulation via the Kerr nonlinearity in the highly confined silicon nanowire waveguide. The pulse is then compressed by the dispersive grating, leading to spectrally wide and temporally narrow output pulses.

WG1: Scalable and Energy Efficient Data Centers

The Working Group strategic plan consists of the following integrated tasks:

- Develop architectures and systems that will meet the needs of future data centers in terms of scalability, cost and energy efficiency.
- Critical assessment of the required photonic technologies that will support these systems and enable next-generation services and end-user applications.
- Build and evaluate Data Center Testbed using state-of-the-art photonic technologies.
- Provide continuous feedback to the research in the three thrusts.
- Insert and evaluate CIAN research results from Thrusts 1, 2 and 3 into the CIAN Testbeds, including chip-scale photonic testing.



Chip-Scale Photonic Testing Facility at UCSD is led by CIAN Deputy Director Shaya Fainman (at right), pictured with project scientist Maziar Nezhad (left) and postdoc Mercedeh Khajavikhan.

The CIAN Data Centers and Chip-Scale Photonic Testing Facility at UC San Diego were leveraged by a $2 million NSF MRI project, the Scalable Energy Efficient Datacenter (SEED) Testbed, and most recently by a $250,000 research gift from Google to explore the potential of WDM networking approaches in data center environments.

Next-Generation Data Centers

Interconnecting multiple computers electronically within a single data center is straightforward as long as the number of machines remains in the tens to the hundreds. Beyond this point, delivering large aggregate communication bandwidth between arbitrary nodes in a single data center is difficult or impossible with modern electronic switching technologies. For instance, machines interconnected by commodity, inexpensive Gigabit Ethernet switches cannot sustain gigabit communication rates to arbitrary remote computer nodes in a data center consisting of thousands to tens of thousands of nodes. This is especially problematic in a modern Internet data center where the retrieval of a single web page can require coordination and communication with literally hundreds to thousands of individual sub-services running on remote nodes.

Existing solutions based on hierarchical switching fabrics can scale to clusters of thousands of nodes with high bandwidth. However, these solutions do not leverage commodity parts (and are hence more expensive). They are not natively compatible with TCP/IP applications, and they require different management infrastructure than what it available in most business environments today.
The second choice leverages commodity Ethernet switches and routers to interconnect cluster machines. This approach supports a familiar management infrastructure along with unmodified applications, operating systems and hardware. Managing the core switch fabric can achieve major reductions in both cost and energy. Unfortunately, aggregate cluster bandwidth scales poorly with cluster size, and achieving the highest levels of bandwidth incurs non-linear cost increases with cluster size.

Current design guidelines for large-scale data center networks call for oversubscription ratios of 10-250. That is, two arbitrary hosts in the same cluster may only have 1/10 to 1/25 of the available Network Interface Card (NIC) bandwidth to one another. This bandwidth limitation arises from limited aggregate bandwidth at the root of multi-level switch topologies that underlie modern data center networks. Building larger clusters (e.g., pushing into tens of thousands of nodes) will only increase the oversubscription ratio.

> The research agenda of WG1 is specifically geared toward designing data center systems using advanced optical technologies, building functional testbeds for realizing various applications to drive chip-scale photonic technologies that are being developed in CIAN to meet the demands of future systems in terms of scalability, energy efficiency and cost.

Given these fundamental scaling considerations and challenges, it is evident that future construction of high-bisection bandwidth data centers that can support all-to-all communications and that are scalable, fault tolerant and energy efficient will require novel photonic technologies. Photonic devices, transport and switching technologies based on Wavelength Division Multiplexing (WDM) are unique in that the energy to switch an input/output pair is independent of the data rate on each port. Thus, using this technology in the core switch of a data center has the potential to dramatically reduce both the cost and energy per switched bit.

WG2: Intelligent Aggregation Networks

CIAN's vision for next-generation access/aggregation networks is driven by the accelerated growth in user-demanded broadband access amid the vast heterogeneity of applications, services, and emerging technologies. Specifically, CIAN Working Group 2 (WG2) is aiming to address the unprecedented requirements and capabilities of future networks by focusing on cross-layer intelligent access/aggregation networks, with the goal of optimizing the network's energy efficiency and access/aggregation capabilities.

The proposed WG2 vision will be achieved through the delivery of transformational systems concepts. WG2's optical switching research for realizing the required high bandwidths of future networks has evolved from an optical packet-switched (OPS) fabric testbed based at Columbia. Nanosecond switching of wavelength-striped optical messages has been demonstrated. A wavelength-striped packet format is used to route all the parallel payload wavelengths together cohesively from the input to the output of the network. The fundamental optical switching fabric testbed is a 4×4 optical network, comprised of non-blocking programmable wideband 2×2 photonic switching nodes. Optical messages are switched using semiconductor optical amplifier (SOA) gates organized in a gate-matrix structure, yielding fast switching speeds, broadband transmission, data transparency and packet-rate granularity. Although the network is all optical (the data payload information remains entirely in the optical domain), the header processing is performed electronically using a complex programmable logic device (CPLD). The flexibility of the network architecture was previously shown by implementing cross-layer information exchange between the OPS network and an interface buffer, thus mitigating unsuccessful transmission and packet loss through the network.

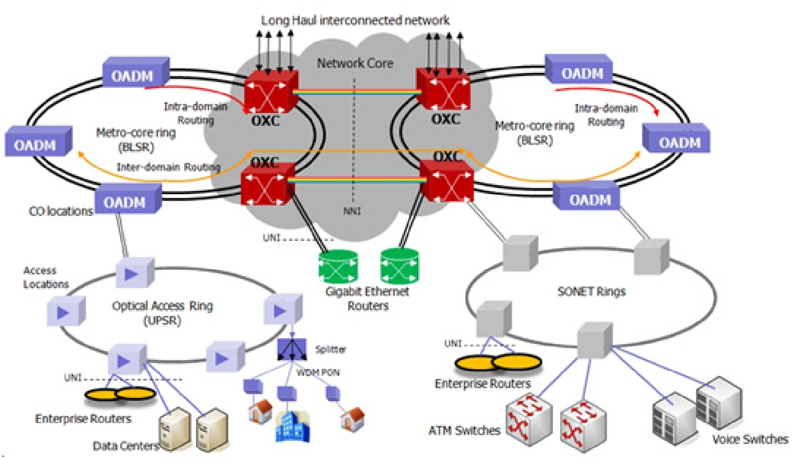
The research agenda of WG2 is specifically geared to developing a cross-layer information exchange that optimizes the network's energy efficiency, and to providing QoS/QoT via optical layer introspection on heterogeneous access aggregation traffics.

The design creates transparent lightpaths among network terminals, where the entire message, including the header and payload, is received by the switching nodes in a slotted manner. The actual routing decision in the nodes is based on the control header extracted from the packet. Each node decodes the control information immediately upon the reception of the packets' leading edge using fixed wavelength filters and low-speed photodetectors. The framing and address signals are recovered from the incoming optical packet and processed by high-speed electronic circuitry. A complex programmable logic device (CPLD) gates the appropriate SOA gates, and the optical messages are then routed to their desired destinations (or dropped upon contention).

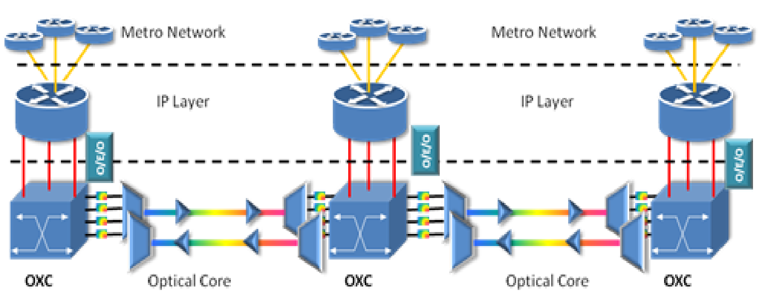
Due to the programmability of the architecture, the testbed has been shown to be flexible in supporting various packet formats and traffic flows. For example, although the test-bed was originally designed as a synchronous, slotted network, we have shown the asynchronous routing of varying-size packets and the support of QoS-based traffic routing. We have also shown its multi-terabit capacity through the transmission of 8×40-Gb/s wavelength-striped packets with error-free performance.

The programmability of the optical switching testbed will be further leveraged to demonstrate some of the energy-efficient routing algorithms and/or architectures designed through the network modeling project described in the next section, as well as through the collaborative effort between WG2 and Alcatel-Lucent.

The CIAN cross-layer box will be composed of multiple WG2 projects: optical performing monitoring (OPM); dynamic real-time degradation monitoring of traffic routing; non-blocking switches; enhanced return zero-differential phase shift keying receivers (RZ-DPSK); wireless-wireline conversion; and network modeling and simulations.



(Above) Architecture of the existing core-edge interface; (Below) Architecture of the IP-over-WDM network. CIAN researchers propose to investigate the simulation environments for the IP-over-WDM architectures shown below. Lightpaths create a virtual topology for the IP routing layer. Two methods of implementing IP-over-WDM networks can potentially achieve increased energy efficiency: optical non-bypass and optical bypass; and sleep modes.



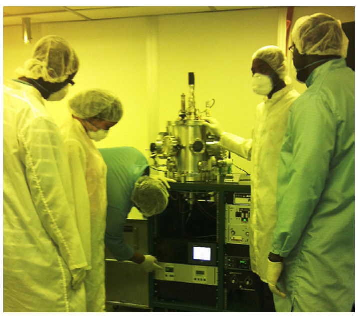
Education and Diversity

Pre-College Outreach

Two UA outreach programs in year 3 involved the Native American Science and Engineering Program (NASEP) and the Optics Summer Academy for Young Scholars (OSAYS). NASEP welcomed its second cohort of 16 Native American students. Students began preparing for their careers by attending a UA Native American student panel, speaking with Native American and non-Native American professionals in STEM fields, and by building their own personal desktop computer. Nineteen high school juniors and seniors participated in OSAYS' short lectures given by graduate students and faculty, research spotlights, and lab tours.

CIAN reaches out to Native American community through the Optics Summer Academy for Young Scholars (OSAYS).

Research Experiences for Undergraduates (REU)



Tuskegee's Research Experiences for High School Graduates gives a crash course in optical sciences.

During the summer of 2011, 11 undergraduate students participated in CIAN's Integrated Optics for Undergraduates (IOU) research experiences at U of A, UC San Diego, UCLA, and Columbia. For seven students, this was the first outside-the-classroom research experience and 70 percent reported no previous experience in research labs. When asked, "How has this summer's experience affected your future decisions?", students noted that they felt more confident in their decision to pursue a graduate degree, more interested in attending graduate school and conducting graduate-level research, and they were better able to re-evaluate their approach for entering graduate school and obtaining funding for their education. When asked about the most beneficial aspect of the program, one student commented, "I benefited greatly from the mentorship I received. Also, I greatly benefited from the freedom I was given to propose a research project which allowed me to think like a graduate student and overcome obstacles during the development stages of the project." Overall, all participants reported that the program met their expectations and over 75% rated the program as excellent and 22% as very good.

High-School Researchers

CIAN labs welcomed high school researchers through two programs, including the Research Experience for High School Graduates (REG) program at Tuskegee and the Young Scholars Summer Research Program at UCLA. Two high school seniors conducted summer research projects at the Photonics Laboratory at UCLA under the mentorship of CIAN faculty Bahram Jalali. The students received basic training in principles of numerical programming for simulations, learned the meaning of the Fourier transform, and how to implement it in numerical simulations. The four students participating in the REG program at Tuskegee University performed exploratory lab research in the field of optical sciences and electrical engineering and they were mentored by CIAN faculty Professor Kalyan Das and CIAN Master's student, Baruch Etzioni.

Research Experiences for Teachers (RET)

Nine teachers participated in CIAN's RET program, Research in Optics for K-14 Educators and Teachers (ROKET) at Caltech, U of A, and UC San Diego. A RET site award funds the partnership with the American Indian Language Development Institute (AILDI). In the ROKET program, teachers participated in AILDI courses concerning language, culture revitalization, and teaching methods to improve science education for Native American students. The science lessons created by ROKET teachers are linked with community participation and practices and include community values, needs, language, and experiences. Four of the nine RET teachers participated in the ROKET/AILDI partnership. At UC San Diego, two science teachers from Hilltop High School and High Tech High participated in the 6-week RET program from June 13 to July 22, 2011. With the aid of CIAN faculty, research scientists and graduate students, the teachers used a quick-setting polymer (PDMS) to make several devices, including diffraction gratings, prisms and plano convex and concave lens and a fluidic adaptable lens with excellent resolution and range of focus. The teachers worked together on a lesson plan involving refraction with optics they created with PDMS. Leveraging this experience, CIAN at UCSD plans to bring 10 more teachers from local middle and high schools this fall to build optics kits for their classrooms.

High school teachers Kevin Friday (left) and Peter Bishop spent the summer developing an optics teaching kit (above).

New CIAN Education Director

Kimberly Sierra-Cajas is CIAN's new Education Director. Since 2007 she has worked for the NSF Science and Technology Center MDITR, recruiting and coordinating education activities for graduate students, an undergraduate research program, and K-16 outreach. Sierra-Cajas created the UA Collaborative for Diversity in STEM with staff, faculty, administrators, and students to share best practices, encourage collaborations, and improve diversity recruitment and retention. She co-founded Arizona's Science, Engineering, and Math Scholars Program (ASEMS) to target retention of low-income, underrepresented freshmen and sophomores.

Industry Collaboration

Innovation Ecosystems

Technological innovation is fostered by an environment where a sound strategic plan is executed by the collaborative work between research leaders and research students working with industry partners. CIAN's vision is to create an ecosystem that maximizes this collaborative work to benefit business and job creation.

Industry partners are helping CIAN realize its goals by working with CIAN investigators to transfer technology from CIAN research to the optical communications industry. In year 3, CIAN had a substantial increase in new industry members. Members who contributed with cash memberships include Oracle/Sun, Alcatel Lucent, Nitto Denko Tech., Kotura, GigOptix, Fujitsu and VPI. Several companies have become members through substantial contributions to CIAN by providing critical equipment and advice needed to conduct research. These companies include Agilent Technologies, Yokogawa, Newport, Fiber Network Engineering and Luxdyne. CIAN researchers are also engaged in associated project research with industry, which contributes to their expertise and the richness of the ecosystem. Notable participations in associated projects are companies such as Google, NEC and Intel. The CIAN participant companies occupy several levels of the optical communications value chain and comprise industry leaders, small companies and entrepreneurial startups.

Industry Participation in 2011 NSF Site Visit

CIAN was pleased to have the participation of members of the Industrial Advisory Board (IAB) in the NSF Site Visit at the University of Arizona on April 13-15, 2010. Ashok Krishnamoorthy from Oracle/Sun and Rod Naphan from Fujitsu Network Communications gave presentations about industry perspectives to the NSF review panel. Marcus Nebeling from Fiber Network Engineering provided assistance to organize the meeting between the NSF review panel and the IABs, which yielded productive ideas on opportunities for CIAN going forward.

IAB Annual Meeting

CIAN held its 2010 Annual IAB Meeting in San Jose on November 2-4, 2010. Sixteen companies were represented, and more than 100 industry officials, researchers, staff and students attended the meeting. Several company representatives gave presentations on their plans and trends for future products, which helped keep the research team up-to-date on future market trends in industry. In addition, the IAB was a dynamic venue for the CIAN team to present information and benefits of CIAN memberships to new company participants in order to encourage them to become members of CIAN. Industry members held a private meeting to evaluate CIAN's performance and determine how to make improvements. Marcus Nebeling from Fiber Network Engineering summarized the results from the meeting in a SWOT analysis chart and presented the feedback to CIAN.

A student poster session allowed students to interact with industry participants. Students also presented 'elevator' pitches on their research projects and had the opportunity to receive helpful feedback on their presentations.

New CIAN Director for Industrial Collaboration & Innovation

Daniel Carothers' career spans more than 15 years in the semiconductor field. During this time he has worked across multiple disciplines, including process, simulation, device development, student education and facility operations. Before coming to the University of Arizona as a Professor of Practice, he held the position of Sr. Principal Physicist and Microelectronic integration group lead within the Technology Solutions function of BAE Systems. During his more than nine years at BAE, Carothers (left) led the push for the development of monolithic integrated photonic and electronic systems. This opportunity has allowed him to develop a wide array of semiconductor technologies from concept, through fabrication to final product. These technologies include antimonide-based MWIR lasers and high-frequency silicon electronics, as well as advanced focal planes and his cornerstone silicon-based electronic and photonic integrated circuit (EPIC) technology. As Carothers has advanced these technologies, their scopes of application and requirements have deepened, allowing him to apply them to a wider range of previously unimagined applications.

CIAN Workshop on Creating Innovation for the Market

On May 23-24, in collaboration with the UC San Diego von Liebig Center, CIAN conducted a workshop to evaluate CIAN technologies for commercialization.

Over 20 students participated in this training exercise, which was also attended by the CIAN Innovation Management Team consisting of Nasser Peyghambarian (Director), Shaya Fainman (Deputy Director), Jorge Sanchez (Industry Liaison Officer), Bob Norwood, Kimberly Sierra-Cajas and Srinivas Sukumar. Xuemei Wang, the CIAN Education and Outreach coordinator, arranged the logistics for this meeting.

The workshop kicked off the process for systematically evaluating CIAN technologies for commercialization. The goal is to have a biannual follow-up of this process with additional training and involvement of the von Liebig Center and the graduate schools of business at CIAN participating universities. The CIAN Student Leadership Council was involved in organizing the workshop. Participants were given in advance the task to select ideas (based on their research) that could be commercialized. They did some basic research regarding technology competitiveness and viability before coming to the workshop.

After an introduction to Innovation and Commercialization by Svetlana Eremenko of the von Liebig Center, Dave Gibbons from the UCSD Technology Transfer Office gave an overview and emphasized the importance of Intellectual Property (IP) protection and the process by which this can be achieved. Bob Norwood, a Professor at University of Arizona and a founding member of CIAN, was the main instructor. He gave the participants ways of evaluating market opportunities.

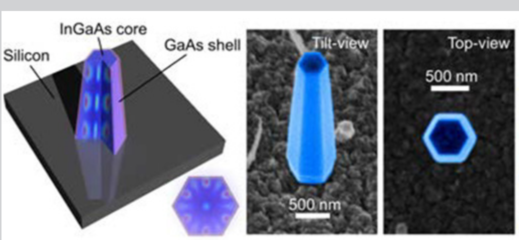
Attendees at the first workshop on commercialization of CIAN technologies on the UC San Diego campus

Kahveh Hushyar, CEO of Telemetria and a veteran of the telecom industry, and Ricardo Santos of Qualcomm and CIAN's Srinivas Sukumar (a former HP executive) engaged in a panel discussion regarding how companies promote targeted innovation. Nasser Peyghambarian gave a talk on company start-ups by students, postdocs or faculty. This was followed by a presentation on how to prepare for a meeting with venture capitalists by Tim Reuth, an angel investor associated with the von Liebig Center.

The rest of the evening was spent discussing, developing and preparing a presentation by student teams. The next morning five presentations by the teams were evaluated and critiqued by Bob Norwood, Srinivas Sukumar and Rosibel Ochoa, Executive Director of the von Liebig Center. In the participant evaluation of this workshop, the rating was mostly a 5 (extremely useful) with a few sprinklings of 4 (very useful).

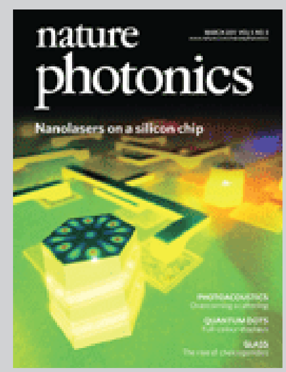
RESEARCH HIGHLIGHT

Nanolasers on Silicon: A Bright Future for Electronics



CIAN researchers have been able to grow nanolasers on silicon. Figures show schematic and various scanning electron microscope images of novel devices.

Optical devices provide certain capabilities that silicon electronics lack. By augmenting electronics with optics, powerful new optoelectronic functionalities can be realized. CIAN researchers at UC Berkeley have now developed a method for integrating nanolasers on silicon, taking a crucial step toward marrying photonic and electronic devices. A major application of silicon photonics is the use of optical rather than electrical signals to carry much more data on and between computer chips in an effort to maintain the rapid pace at which computing speed and efficiency are improving. More generally, lasers on silicon will enable any device that requires on-chip light sources, and they open the door to unforeseen technologies. Such prospective applications might include optical logic and signal processing, biochemical sensors, cost-effective silicon-based lighting and displays, as well as a cost reduction for existing optical technology. The work was published as the cover story of the March 2011 issue of *Nature Photonics.*



Academic Partners

The University of Arizona
Columbia University in the City of New York
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USC
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