SPRC Symposium 2024:

Conference program and abstracts

Organized by Stanford Photonics Research Center and NTT-Research Inc.

Sept 16-18, 2024, The James H. Clark Center, Stanford

Contents

Chapter 1

Symposium agenda

1.1 Monday: Life sciences, environmental & quantum sensing

8:30am **Doors open**

9:00am **Keynote & Welcome**

- W. E. Moerner: *What can you do with single molecules and light to study bioscience?*
- Armand Niederberger: *Welcome and Monday overview*

10:00am **Coffee discussion**

10:45am **Session 1: Life sciences**

- Daniel Palanker: *Prosthetic vision in patients with retinal degeneration*
- Mark Schnitzer: *Imaging neural spiking and brain waves with fluorescent voltage indicators*
- Adam Bowman: *Nanosecond optics for microscopy*

12:00pm **Lunch at Greenfish@NeXus (show name tag)**

1:30pm **Session 2: Environmental sensing**

- Jennifer Dionne: *Emerging nanophotonic platforms for molecular sensing, sequencing, & synthesis*
- Cassandra Huff: *Enhancing Methane Emissions Monitoring with Optical Sensors*
- Hubert Stokowski: *Advanced integrated light sources in thin film lithium niobate*

2:30pm **Coffee discussion**

3:30pm **Session 3: Quantum sensing**

- Igor Teper: *Enabling new capabilities with quantum sensors*
- Avikar Periwal: *Programming entanglement between atoms for quantum-enhanced sensing*
- Shaun Burd: *Nonlinear microscopy approaching the quantum limit*

4:30pm **Poster session**

1.2 Tuesday: Novel materials & photonic design

8:30am **Doors open**

9:00am **Keynote & Welcome**

- Ray Beausoleil: *Research on foundations of 21st-century information technology*
- Armand Niederberger: *Welcome and Tuesday overview*

10:00am **Coffee discussion**

10:45am **Session 1: Novel materials**

- Mark Brongersma: *Metasurfaces for future sensing and imaging technologies*
- Di Liang: *Next-generation data interconnect and computing with heterogeneous photonic integration*
- Sonny Vo: *Immersity on any device*

12:00pm **Lunch at Greenfish@NeXus (show name tag)**

1:30pm **Session 2: Theory and photonic design**

- Shanhui Fan: *Nonlocal metasurface*
- Geun Ho Ahn: *Scalable and high-performance integrated light sources for optical interconnects*
- Jonathan Fan: *Machine learning methods for designing and modeling photonic systems*

2:30pm **Coffee discussion**

3:30pm **Session 3: Integrated photonics & advanced computing**

- Olav Solgaard: *Low power silicon photonics*
- Ryohei Urata: *Optical interconnect and switching technologies for datacenter and machine learning networks*
- Ashkan Seyedi: *Interconnect challenges for next-gen AI processors*

6:00pm **Conference dinner**

- Jason Hartlove: *New Realities: Opportunities and Challenges for Optics and Photonics in AR & MR*

1.3 Wednesday: Computation, artificial intelligence, & communications

8:30am **Doors open**

9:00am **Keynote & Welcome**

- Julie Eng: *Commercial laser applications and challenges*
- Armand Niederberger: *Welcome and Wednesday overview*

10:00am **Coffee discussion**

10:45am **Session 1: Industry perspective and tools**

- Yoshihisa Yamamoto: *Optical computing: new prospects with machine learning and TFLN*
- Joaquin Matres: *Revolutionize your chip design with GDSFactory*
- Prash Kharel: *Re-architecting simulation tools in a compute-abundant world*

12:00pm **Lunch on Spilker Terrace, 2nd floor**

1:30pm **Session 2: Future technologies**

- Joseph M. Kahn: *Novel photonics enabling ultra-efficient coherent optical communications*
- Joonhee Choi: *Neutral atom quantum computing*
- Eileen Otte: *Information carried in the structure of light*

2:30pm **Coffee discussion**

3:30pm **Session 3: Broader perspective and outlook**

- S. J. Ben Yoo: *Can we realize a computing system with comparable energy-efficiency, scalability, and flexible learning capability of the brain?*
- Jonathan Doylend: *Wisdom begins in wonder - a few things I wish I'd appreciated as a graduate student*
- Jon Simon: *Optics challenges at the quantum computing frontier*

Chapter 2

Abstracts and speaker biographies

All speakers listed in order of presentation.

2.1 W. E. Moerner

Harry S. Mosher Professor and, by courtesy, of Applied Physics
Departments of Chemistry and Applied Physics, Stanford University

Interests and expertise:
Single-molecule microscopy, Super-resolution microscopy, Biophysics, Novel cellular imaging

Keynote, Monday, September 16, 2024

What can you do with single molecules and light to study bioscience?

A single molecule is ridiculously tiny, about 1 nanometer, roughly 100,000 times smaller than the diameter of a human hair. Yet individual molecules rule the nanoscale activity and structure in our cells and in many nanoscale materials. Thirty years ago, single molecules were first detected optically, but how was this done, and how do we really detect a single molecule today, and even more importantly, what good is it? It is an amazing fact that you can even detect single molecules with your own eyes. When a new regime of science is breached, surprises often occur: single molecules show amazing dynamics, blink on and off, and can be controlled by light. Far from being only an esoteric effect, these “switching properties” of molecules can now be used to obtain “super-resolution” to see the tiny nanoscale structures inside cells. Essentially, with tiny single-molecule light sources decorating a structure, the on/off process is used to light up only subsets at a time. A pointillist display then reveals the hidden nanometer-scale structure, opening up a new frontier for understanding and applications. This makes it possible to more fully believe Yogi Berra when he said, “You can observe a lot by just watching!” Even the key RNA molecules of a coronavirus infection look like galaxies inside infected cells. Single molecules can also help improve the information available from electron microscopy images by answering the question: “Where is my protein?”

Bio: W. E. Moerner is renowned for his contributions to single-molecule spectroscopy, which earned him the 2014 Nobel Prize in Chemistry. His groundbreaking work, first demonstrated in 1989 while at IBM, involved detecting the light absorption of a single molecule, specifically pentacene, in a crystal. This innovation challenged the long-established diffraction limit of optical microscopy, allowing scientists to resolve individual molecules, previously impossible with conventional methods.
Moerner’s research laid the foundation for super-resolution techniques like STED microscopy and PALM, which leverage the ability to control and image individual fluorescent molecules. His methods provided unprecedented insights into molecular behavior, driving advancements in fields such as biophysics and cell biology, including the study of green fluorescent proteins (GFP) used in live-cell imaging.
Now at Stanford University, Moerner continues his research in single-molecule biophysics, exploring the dynamics of biomolecules and protein interactions at nanoscopic scales. His work remains pivotal for both the scientific understanding of molecular processes and the development of cutting-edge imaging technologies

2.2 Daniel Palanker

Professor of Ophthalmology and, by courtesy, of Electrical Engineering
Department of Ophthalmology and Hansen Experimental Physics Laboratory, Stanford University

Interests and expertise:
Optical and electronic technologies for diagnostic, therapeutic, surgical and prosthetic applications, primarily in ophthalmology.

Session 1, Monday, September 16, 2024

Prosthetic vision in patients with retinal degeneration

Retinal degenerative diseases lead to blindness due to loss of photoreceptors, while neurons in the inner retinal layers are preserved. We developed a system substituting the lost photoreceptors with photovoltaic arrays. Visual information captured by a camera is projected onto the retina from augmented-reality glasses using pulsed near-infrared (880nm) light. Subretinal pixels convert light into electric current, stimulating the second-order retinal neurons. This approach preserves many features of natural vision, avoids the use of bulky electronics and wiring, and allows scaling the number of electrodes to thousands.
Two clinical trials were conducted in Europe: a single-site feasibility trial with 5 participants and a multi-site trial with 38 participants. Patients with geographic atrophy (GA) of at least 3 optic disk diameters due to age-related macular degeneration (AMD) were implanted subretinally with 2x2mm wireless photovoltaic arrays of 100μm pixels (PRIMA, Pixium Vision). Prosthetic visual acuity was measured using Landolt C letters and ETDRS charts. Performance of the next generation implant with pixels down to 20μm was assessed in rats using electrophysiology.
Clinical trials demonstrated central prosthetic vision with a letter acuity closely matching the 100μm pixel size of the PRIMA implant (20/420). Remarkably, central prosthetic vision is perceived simultaneously with the peripheral natural vision. Using electronic zoom, patients significantly improved their reading ability – up to the letter size corresponding to acuity of 20/63.
To reduce the pixel size while providing sufficiently deep stimulation of the inner retina, we developed various strategies for shaping the electric field, including current steering and 3-dimensional electrodes. Grating acuity with 75, 55 and 40μm pixels in rats matched the pixel pitch, while with 20μm, it reached their natural resolution limit of 28μm. If successful in clinical trials, this next-generation implant with 20μm pixels may increase acuity up to 20/80. Electronic zoom enables further decrease of the font size, albeit on account of a reduced visual field.

Bio: Professor Palanker received his Ph.D. in Applied Physics in 1994 from the Hebrew University of Jerusalem, Israel, and postdoctoral training in Physics at Stanford University in 1996-1998. Dr. Palanker studies interactions of electric field with biological cells and tissues, and develops optical and electronic technologies for diagnostic, therapeutic, surgical and prosthetic applications, primarily in ophthalmology. In the field of electro-neural interfaces, he is working on photovoltaic retinal prosthesis for restoration of sight and on other implants for electronic control of organs. In the field of optics, he develops interferometric imaging of physiological signals for non-invasive and label-free imaging of neural signaling in-vivo.
Several of his developments are in clinical practice world-wide, including Electrosurgical system (PlasmaBlade, Medtronic), Pattern Scanning Laser Photocoagulator (PASCAL, Iridex) and Femtosecond Laser-assisted Cataract Surgery (Catalys, J&J). Photovoltaic retinal prosthesis for restoration of sight (PRIMA, Science Corp.) is in clinical trials.

2.3 Mark Schnitzer

Professor of Applied Physics, Biology and Neurosurgery, Stanford University & Investigator, Howard Hughes Medical Institute
Stanford University & Howard Hughes Medical Institute

Interests and expertise:
Light microscopy, neuroscience, biophysics, brain imaging.

Session 1, Monday, September 16, 2024

Imaging neural spiking and brain waves with fluorescent voltage indicators

Fluorescent genetically encoded voltage-indicators report the membrane voltages of targeted cell-types. Recent advances in the development of these indicators have enabled optical voltage-imaging experiments capturing the spiking dynamics of up to 3 neuron classes at once in the brains of behaving mammals. Fluorescent voltage-indicators also have the capability to reveal the brain's electrical oscillations and waves. However, until recently, voltage-imaging instrumentation lacked the sensitivity to track spontaneous or evoked high-frequency voltage oscillations in neural populations. I will describe optical voltage-sensing technologies that capture neural oscillations up to 100 Hz. With these techniques, we have uncovered synchronized coupling between electrical oscillations of distinct frequencies in specific neuron-types of the hippocampus and neocortex. We have also imaged sensory-evoked excitatory-inhibitory neural interactions and traveling electrical waves in the visual cortex, and discovered previously unreported forms of traveling voltage waves in the hippocampus. Overall, optical voltage-imaging has widespread applications for probing spiking patterns, oscillations, and neuron-type interactions in healthy and diseased brains.

Bio: Mark J. Schnitzer is a Professor of Applied Physics, Biology & Neurosurgery at Stanford University and an Investigator of the Howard Hughes Medical Institute. His research group invents optical technologies for imaging brain activity. The group uses these innovations to study the principles of neural circuit operation and how the activity patterns of large ensembles of individual neurons underlie sensory perception, memory, and motor control, in both healthy and diseased brain states.

Over the past 15 years, the Schnitzer lab has created several technologies that are now commercially available. These include tiny microscopes that are small enough to be mounted on the head of a freely behaving mouse, developed in collaboration with Stanford Professor Abbas El Gamal. This technology won The Scientist's Top Innovation of 2013 and 2019 Method of the Year from Nature Methods. Two spinout companies from Stanford have successfully commercialized the lab's innovations, and over 1000 neuroscience labs worldwide use imaging and/or data analytic methods invented by the group. One of these inventions received an FDA approval for clinical usage in Dec. 2023. With support from a 2022 Vannevar Bush Faculty Fellowship from the U.S. Dept. of Defense, the Schnitzer lab is creating new technologies to reveal how cells in multiple brain areas interact concertedly in behaving mammals.

Schnitzer was a member of the NIH Director's Advisory Committee that wrote the BRAIN 2025 report, the blueprint for the NIH BRAIN Initiative, and of the National Academy of Sciences Committee that authored the 2022 Decadal Survey of Biological Physics. His lab's former trainees include 2 CEOs and >20 professors or junior group leaders who are now leading their own research teams at prestigious universities and research institutes in the USA, China, Israel and Europe.

2.4 Adam Bowman

Fellow
Salk Institute for Biological Studies

Interests and expertise:
Microscopy and physics

Session 1, Monday, September 16, 2024

Nanosecond optics for microscopy

Optical microscopy provides powerful tools for probing biological structure, but achieving quantitative measurements of biological function – for example transmembrane voltage or chemical concentration – has proven challenging in living organisms. It is desirable to move beyond standard intensity-based readouts for these biological signals to develop quantitative measurement protocols. I will introduce optical techniques we developed to capture nanosecond time on standard CMOS camera sensors using electro-optic modulators. These have allowed us to measure the excited state lifetime of fluorescent probes with orders of magnitude higher throughput than existing detectors. Using our electro-optic fluorescence lifetime microscopy technique (EO-FLIM), we imaged the nanosecond lifetimes of single molecules and we also recorded action potentials and millisecond voltage dynamics in the brain using fluorescent voltage indicators. Lifetime readout provides immunity to intensity noise artifacts and provides an additional dimension which can be used to extract more information per fluorescence photon, providing a path towards quantitative and multiplexed measurements in vivo. The capability to control nanosecond time in an all-optical imaging system also promises broad applications beyond fluorescence microscopy including gated detection, LIDAR, and label-free imaging.

Bio: Adam Bowman completed his Ph.D. in applied physics at Stanford with Mark Kasevich developing new techniques for fluorescence lifetime microscopy and quantum imaging. He recently started his lab at the Salk Institute for Biological Studies in San Diego focusing on fluorescence lifetime and high-speed imaging techniques to improve measurements of cellular signals in living organisms.

2.5 Jennifer Dionne

Professor of Material Science and Engineering, and, by courtesy, of Radiology
School of Engineering, Stanford University

Interests and expertise:
Biophotonics, machine learning, nanophotonics, label-free molecular-to-cellular detection, photocatalysis.

Session 2, Monday, September 16, 2024

Emerging nanophotonic platforms for molecular sensing, sequencing, & synthesis

We present development of scalable, Si-compatible nanophotonic platforms that enable early disease onset, help inform optimal treatment, and uncover new biological pathways associated with personal, population, and ecosystem-level health. These sensors are based on our "Very-large-scale Integrated high-Q Nanophotonic Pixels" (VINPix), which provide millions of uniquely addressable sites for molecular sensing, sequencing, and synthesis at the single-cell to single-molecule level. Often, photonic resonators face a trade-off between their quality-factor (Q -factor), mode-volume, and ability to control far-field radiation. Our VINPix demonstrate that this perceived compromise is not inevitable – high-Q, subwavelength mode volumes, and controlled dipole-like radiation can be achieved, simultaneously. We describe how we achieve Q-factors ranging from the thousands to millions, with resonator densities exceeding 10M/cm2. By combining VINPix arrays with acoustic bioprinting for local chemical functionalization, we develop chips that detect multi-omic signatures on the same platform. We discuss integration of these sensors with workflows in Stanford's Clinical Virology Laboratory, as well as with autonomous underwater robots from Monterey Bay Aquarium Research Institute (MBARI) for real-time ocean biodiversity monitoring. Then, we describe how these chips can be used for label-free peptide sequencing. By tailoring each resonator for strong Raman enhancement, we demonstrate high-resolution identification of wildtype and mutated human leukocyte antigens. We also show how VINPix can be converted into reaction sites for molecular synthesis by integrating optically absorbing heating elements. Reactions at each of the nanoantennas can be activated by a unique combination of optical wavelength and polarization, eliminating errors seen in other solid-state synthesis platforms due to misalignment. Further, the high-Q of each VINPix prevents spectral and spatial crosstalk between the nanoantennas, enabling maximum molecular sequence diversity with minimal error. Finally, we combine Raman spectroscopy and deep learning to accurately classify bacteria by both species and drug susceptibility in a single step. With ML models optimized for spectral analysis, we achieve species identification and antibiotic susceptibility accuracies similar to leading mass spectrometry techniques. We show how this technique can be applied to rapid tuberculosis antibiotic susceptibility testing, as well as to waste-water monitoring of bacterial pathogens.

Bio: Jennifer (Jen) Dionne is a Professor of Materials Science and of Radiology at Stanford. She is also a Chan Zuckerberg Biohub Investigator, deputy director of Q-NEXT (a DOE-funded National Quantum Initiative), and co-founder of Pumpkinseed, a company developing improved T-cell mediated therapies. From 2020-2023, Jen served as Stanford's Inaugural Vice Provost of Shared Facilities. Jen received her B.S. degrees from WashU in St. Louis, her Ph. D. at Caltech, and her postdoctoral training at Berkeley. As a pioneer of nanophotonics, she is passionate about developing methods to observe and control chemical and biological processes as they unfold nanometer scale resolution, emphasizing critical challenges in global health and sustainability. Her work has been recognized with the Alan T. Waterman Award, a NIH Director's New Innovator Award, and the Presidential Early Career Award for Scientists and Engineers, and was featured on Oprah's list of "50 Things that will make you say 'Wow'!".

2.6 Cassandra Huff

Graduate Student
Department of Electrical Engineering, Stanford University

Interests and expertise:
Environmental sensing, spectroscopy, optics, electronics

Session 2, Monday, September 16, 2024

Enhancing Methane Emissions Monitoring with Optical Sensors

Methane is a potent greenhouse gas with a high potential to cause immediate temperature increases; therefore, quantifying emissions from sources of methane is crucial for addressing climate change. However, the global methane budget shows large uncertainties in the emissions coming from natural sources, in part due to the heterogeneity of methane emissions in space and time. Reducing these uncertainties requires measurement methods that better capture the contribution from large area, dispersed sources with relevant spatial and temporal resolution. I will report on the ability for optical sensors to bridge this gap in understanding through the development of new sensors and the importance of industry support. In the Hollberg lab we have demonstrated the ability to monitor diurnal changes in atmospheric methane concentrations over multi-week field trials at Jasper Ridge Biological Preserve. Our approach not only enhances methane monitoring in wetlands but also paves the way for low-cost, continuous surveillance of methane emissions, offering a valuable tool for advancing climate science and mitigation strategies. This work has been enabled by a grant from the Woods Institute and by the unique position Stanford is in to bridge different communities. It is a collaboration between the Hollberg group in Physics and in Geophysics and Alison Hoyt's group in Earth System Science. This collaboration is in conjunction with a partnership with the Jasper Ridge Biological Preserve, which has made critical field research possible.

Bio: Cassandra is a PhD Candidate in the Department of Electrical Engineering at Stanford working with Prof. Leo Hollberg in the Physics Department and Prof. Arun Majumdar in the Department of Mechanical Engineering. Her research focuses on building low-cost, robust optical sensors for detecting methane over large areas like wetlands and rice farms. She has past experience working on 2D materials and microscopy. She received her MS in Electrical Engineering from Stanford in 2023 and her BS in Electrical and Computer Engineering from The University of Texas at Austin.

2.7 Hubert Stokowski

Postdoctoral Scholar
Department of Applied Physics, Stanford University

Interests and expertise:
Integrated photonics, sensing

Session 2, Monday, September 16, 2024

Advanced integrated light sources in thin film lithium niobate

On-chip integrated photonic devices constitute the backbone of the systems we use to interface with technology. Semiconductor devices enable the transmission of information from every modern smartphone, wearable device, home appliance, and car directly to our eyes. On the other hand, an increasing number of consumer electronics use photonic components to collect information necessary for their functions, such as face recognition in phones, health monitoring in wearables, and autonomous driving. Moreover, integrated photonics is common in specialized applications like data centers, the Internet, and pollution monitoring. Developing new types of integrated light sources will enable unexplored applications and advances in the existing ones.

In this talk, I will describe our recent advancements in developing chip-integrated nonlinear optical light sources using lithium niobate. The optical nonlinearity of lithium niobate provides a versatile alternative to existing semiconductor technologies for light source engineering. I will discuss how we used this platform to create a new type of optical frequency comb source, an on-chip frequency-modulated optical parametric oscillator. It produces a flat-top frequency comb composed of hundreds of distinct frequencies, which is ideal for applications in spectroscopy and datacom. Our device is designed to operate with low power consumption and high efficiency, paving the way for deployable, battery-powered photonic sensors and transceivers. While our early demonstrations operate in the telecom frequency range, the flexibility of the lithium niobate platform paired with dispersion engineering allows the extension of our work to broadband frequency combs spanning from 1.5 to 4μm, a spectral region critical for many sensing applications.

Bio: Hubert is a postdoctoral scholar in the group of Prof. Amir Safavi-Naeini at Stanford, where he also earned his Ph.D. in 2024. His research focuses on designing, fabricating, and characterizing nonlinear nanophotonic devices like optical parametric oscillators, optical frequency comb generators, quantum light sources, and frequency converters. His current work on advanced integrated light sources stems from the periodically poled thin film lithium niobate platform developed as a part of his Ph.D.

In his research, he is motivated by new photonic technologies that emerge from the fundamental science, including photonics-based quantum computing, quantum-enhanced metrology, environmental and medical sensing using mid-infrared light.

2.8 Igor Teper

Chief Technology Officer
AOSense, Inc.

Interests and expertise:
Quantum sensing, quantum timing, enabling technologies for quantum

Session 3, Monday, September 16, 2024

Enabling new capabilities with quantum sensors

Quantum inertial and gravitational sensors are currently being transitioned to field applications, where they promise to enable revolutionary capabilities. Recent years have seen significant maturation of prototypes and growing sophistication of field demonstrations. I will give an overview of the current state of these technologies, key applications, and remaining challenges.

Bio: Igor Teper is the Chief Technology Officer of AOSense, with over 20 years' experience in the development of quantum sensors. He has led numerous research efforts to transition quantum inertial sensors and optical atomic clocks to field use.

2.9 Avikar Periwal

Graduate Student
Department of Physics, Stanford University

Interests and expertise:
AMO Physics, Quantum Information

Session 3, Monday, September 16, 2024

Programming entanglement between atoms for quantum-enhanced sensing

Atoms are the basis of some of the most precise magnetometers, interferometers, and clocks ever constructed. These sensors have been engineered with such precision that they are limited primarily by quantum uncertainty. By engineering entangled states of many atoms, it is possible to squeeze the quantum fluctuations, reducing uncertainty in a single parameter of interest at the expense of increased uncertainty in a conjugate observable. However, many applications, including vector and ac magnetometry, require precision measurement of multiple observables, and thus control over the structure of engineered entanglement. We demonstrate a versatile toolbox for engineering the graph of entanglement in an array of atomic ensembles, combining nonlocal interactions between atoms, mediated by an optical cavity, with single-site rotations. We first demonstrate quantum-enhanced sensitivity to spatially varying fields. We use these two ingredients to entangle a reference region with a sensing region and leverage the prepared state to subvert the local Heisenberg uncertainty relation on the sensing region. The demonstrated protocols are scalable, opening avenues for engineering quantum states tailored to specific tasks, with prospects in fundamental tests of physics and next generation quantum-enhanced sensors.

Bio: Avikar Periwal recently received his Ph.D. from Stanford University, working in the group of Prof. Monika Schleier-Smith. He completed his undergraduate degree at Caltech, where he worked in the Hutzler group on producing ultracold molecules. At Stanford, he worked with an optical cavity to mediate interactions between neutral atoms, studying how nonlocal interactions can be harnessed for quantum information science. He will begin a Harvard Quantum Initiative postdoctoral fellowship this fall.

2.10 Shaun Burd

Postdoctoral researcher
Department of Physics, Stanford University

Interests and expertise:
Experimental quantum physics, quantum metrology, nonlinear optics

Session 3, Monday, September 16, 2024

Nonlinear microscopy approaching the quantum limit

Optical microscopy has transformed our understanding of the natural world. However, the light that is used for optical imaging can alter or even damage the sample under study. This is particularly important for imaging sensitive, living biological samples. It is therefore of fundamental importance to optimize the information that can be extracted for a given dose of light to the sample.
In this talk, I will describe how this can be achieved. I will also present our recent results demonstrating multipassed nonlinear microscopy with improved imaging sensitivity compared to conventional microscopy. A multi-pass microscope interrogates a sample multiple times in a cyclical and deterministic fashion resulting in a reduction in damage imparted to biological samples or improved image acquisition speed. The approach compares favorably with imaging techniques using squeezed or entangled quantum states of light, but avoids the technical complexity associated with the production of such states.

Bio: Shaun's research focuses on experimental quantum-enhanced metrology using atoms and photons and exploring biological imaging at the fundamental limits set by quantum mechanics. He obtained his Ph.D. in 2020 from the University of Colorado Boulder, working in the group of David Wineland at the National Institute of Standards and Technology. He is currently a postdoctoral scholar in the group of Mark Kasevich at Stanford University.

2.11 Ray Beausoleil

Senior Fellow and Senior Vice President
Hewlett Packard Labs

Interests and expertise:
Classical and quantum optics

Keynote, Tuesday, September 17, 2024

Research on foundations of 21st-century information technology

Over the next several decades, how should we think about the research needed to truly revolutionize information technology? In the 19th century, scientists built “top-down” theories of macroscopic phenomena by making painstakingly detailed observations, building phenomenological models, and then developing theories that allow us to make predictions about the results of experiments. For example, centuries of observations of birds eventually resulted in an abstract understanding of the forces and controls shared by all flying machines, leading directly to dramatic advances in aviation. The science of thermodynamics arose from a need to improve the efficiency of early steam engines, and resulted in a fully-developed physical theory that related heat, temperature, and entropy to work and energy. From this top-level theory, the field of statistical mechanics was developed to provide a microscale understanding of the laws of thermodynamics and act as a bridge to 20th-century quantum mechanics. Incredible advances in microscopic physics through experimental and theoretical investigations of the quantum universe literally changed the macroscopic world. Examples include nanoscale integrated circuits and nuclear energy, fields where scientists were able to bridge the gap between microscale, mesoscale, and macroscale phenomena. In practice, this bottom-up approach to science and technology seems to be very difficult, because it’s generally not obvious what physics is needed to move from (e.g.) the microscale to the mesoscale. How does the Lagrangian for quantum electrodynamics lead to the BCS Hamiltonian for superconductivity? Is there a macroscopic theory of “Infodynamics” that could describe an information equivalent of a “Carnot Engine?” This talk won’t provide answers to these questions—after all, we’ll be talking about the future—but will build on them to discern the impact that top-down approaches to machine learning could lead to an understanding of the manifestation of intelligence and the promise of human augmented intelligence.

Bio: Ray Beausoleil received the B.S. degree from Caltech, Pasadena, CA, USA, in 1980, and the Ph.D. degree from Stanford University, Stanford, CA, in 1986, both in physics. He is currently a Senior Fellow and Senior Vice President at Hewlett Packard Enterprise (HPE), Milpitas, CA, where he is the Director of the Large-Scale Integrated Photonics Lab in Hewlett Packard Labs. He is a Fellow of the American Physical Society, the Optical Society of America, the Institute of Electrical and Electronics Engineers, and the American Association for the Advancement of Science, and the recipient of the 2016 APS Distinguished Lectureship on the Applications of Physics. He has contributed to more than 600 papers and conference proceedings and five book chapters. He has more than 160 patents issued, and more than four dozen pending.

2.12 Mark Brongersma

Stephen Harris Professor, Professor of Materials Science and Engineering and, by courtesy, of Applied Physics
Department of Materials Science and Engineering, Stanford University

Interests and expertise:
Nanophotonics

Session 1, Tuesday, September 17, 2024

Metasurfaces for future sensing and imaging technologies

Metamaterials are a new, emerging class of high-performance materials that derive their unique, physical properties from the way they are structured. In this presentation, I will focus on the creation of 2-dimensional metamaterials (i.e. metasurfaces) by nanopatterning glass, semiconductor and metal films. I will first argue that these metasurfaces are ideal building blocks for the next generation of optical elements and optoelectronic devices. I will then highlight how metasurface functionalities can start to impact a variety of optical sensing, imaging technologies. For example, I will show how one can create transparent optical sensors on glass substrates that can extract valuable information from an optical scene. I will also discuss the use of integrated metasurfaces can enable new imaging modalities, such as the imaging of texture. The proposed optical elements can be fabricated by scalable fabrication technologies, opening the door to many commercial applications.

Bio: Mark Brongersma is the Stephen Harris Professor of Materials Science and Applied Physics at Stanford University. He received his PhD from the FOM-Institute AMOLF in Amsterdam, The Netherlands, in 1998. From 1998-2001 he was a postdoctoral research fellow at the California Institute of Technology. He coined the terms Plasmonics and Mie-tronics for the fields of science and technology that aim to manipulate light with metallic and high-index nanostructures and below the diffraction limit. He has authored/co-authored over 265 publications, including papers in many papers in Science, Nature Photonics, Nature Materials, and Nature Nanotechnology. He is a highly-cited researcher as identified by Clarivate Analytics and has an h-factor over 100 according to Google Scholar. He was a founder of Rolith Inc that was acquired by Metamaterials Technology Inc in 2016. He also holds a number of patents in the area of nanophotonics. Brongersma received a National Science Foundation Career Award, the Walter J. Gores Award for Excellence in Teaching, the International Raymond and Beverly Sackler Prize in the Physical Sciences (Physics) for his work on plasmonics, and is a Fellow of OPTICA, MRS, SPIE, and APS.

2.13 Di Liang

Professor
University of Michigan, Ann Arbor

Interests and expertise:
Integrated Photonics

Session 1, Tuesday, September 17, 2024

Next-generation data interconnect and computing with heterogeneous photonic integration

The advent of data computation and transmission technologies has ushered humanity into the modern era. However, the era of Moore's Law, which has long guided advancements in computation and driven demand for ever-larger communication bandwidth, is slowing as we near the physical and economic limits of silicon scaling. Simply shrinking transistors no longer delivers the same efficiency or performance gains. Compounding this issue is the growing challenge of interconnect-limited computation, where data transmission between processing units or memory becomes the primary bottleneck in system performance. As data rates surge, conventional electrical interconnects face inherent limitations in speed, bandwidth, and power efficiency. These bottlenecks are particularly acute in data centers, high-performance computing (HPC), and artificial intelligence (AI) workloads, where vast amounts of data must be moved and processed across distributed computing resources. Many of these challenges stem from the limitations of the underlying materials, such as silicon and its associated fabrication processes. The heterogeneous integration of multiple functional materials, along with the seamless combination of computing and interconnect capabilities, presents both a critical challenge and an exciting opportunity. What are the optimal solutions for achieving optical modulation beyond 100 Gbaud, while maintaining miniature size, energy efficiency, and minimal latency? Can we develop a heterogeneous electronic-photonic neuromorphic computing system that leverages the strengths of both platforms? Is 3D stacking of all functional layers the ultimate integration strategy? These are complex questions that invite us to think creatively and explore unconventional solutions.

Bio: Di Liang is currently a Professor in the Electrical Engineering and Computer Science Department at the University of Michigan, Ann Arbor. Prior to that, he was a Director / Senior Staff Engineer in the Alibaba Group – US, and was a Distinguished Technologist at Hewlett Packard Labs in Hewlett Packard Enterprise where he led the advanced research of silicon and compound semiconductor integrated photonics for energy-efficient optical interconnect and high-performance computing. He received his Bachelor degree from the Zhejiang University, China, and Master and Ph.D. degrees from the University of Notre Dame, US. He has (co)authored 1 edited book, 7 book chapters, over 300 journal and conference papers, and was granted by more than 60 patents with several dozen pending. He is a Fellow of Optica, and editor of Light: Science and Applications (Nature Publishing Group), senior editor of Journal of Selected Topics in Quantum Electronics (IEEE), associate editor of Photonics Research (Optica) and Journal of Quantum Electronics (IEEE).

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2.14 Sonny Vo

Vice President
Leia, Inc.

Interests and expertise:
Nanotechnology, quantum computing, photonics, pab prototype to total market product-fit realization.

Session 1, Tuesday, September 17, 2024

Immersity on any device

Leia Spatial Reality (LeiaSR™) brings immersive 3D experiences to any display. Our technology transforms traditional 2D displays—ranging from mobile devices to tablets, laptops, and monitors—into switchable 2D-to-3D displays. LeiaSR™ integrates patented switchable display technology with advanced AI-driven face tracking and seamless content conversion, delivering captivating 3D visuals that make viewers feel part of the action. Importantly, LeiaSR™ enhances 3D content without compromising the display's original quality and remains fully compatible with the broader 3D and XR ecosystem.

Bio: Sonny Vo earned his undergraduate degree in low-temperature experimental physics from UCLA and went on to complete a Ph.D. in Applied Physics at Stanford University, specializing in semiconductor lasers, micro- and nanofabrication, and photonics under the mentorship of Professors James S. Harris and Robert Byer. Following this, he joined Hewlett-Packard Laboratory in Palo Alto as a Postdoctoral Research Fellow in Dr. Ray Beausoleil's Photonics and Quantum Laboratory, where he contributed to experimental work in optical communication, quantum computing, and next-generation LCD displays. A key innovation from this research was the development of a directional backlight for efficient light coupling. Under the guidance and leadership of his mentor, Dr. David Fattal, this work appeared on the cover of Nature in March 2013 for its breakthrough in glasses-free 3D display technology, which laid the foundation for the Silicon Valley startup Leia Inc. Currently, Sonny serves as the Vice President and Director of Advanced R&D at Leia Inc.'s Micro & Nanotechnology Laboratory.

2.15 Shanhui Fan

Joseph and Hon Mai Goodman Professor of the School of Engineering and, by courtesy, of Applied Physics
Edward L. Ginzton Laboratory, Stanford University

Interests and expertise:
Nanophotonics

Session 2, Tuesday, September 17, 2024

Nonlocal metasurface

Nonlocal metasurface aims to tailor the transport properties of an optical thin film as a function of frequency and wavevector. In this talk, we discuss some of the potential application nonlocal metasurface, including the compression of free space, and the generation of light bullet – a class of wavepacket that can propagate in free space with any velocity and with strongly suppressed dispersion and diffraction.

Bio: Shanhui Fan is the Joseph and Hon Mai Goodman Professor in the School of Engineering, a Professor of Electrical Engineering, a Professor of Applied Physics (by courtesy), and a Senior Fellow of the Precourt Institute for Energy, at the Stanford University. He received his Ph. D in 1997 in theoretical condensed matter physics from the Massachusetts Institute of Technology (MIT). His research interests are in fundamental studies of nanophotonic structures, especially photonic crystals, plasmonic structures, and meta-materials, and applications of these structures in energy and information technology applications. He has published approximately 700 refereed journal articles, has given over 400 plenary/keynote/invited talks, and holds over 70 US patents. He is a co-founder of two companies aiming to commercialize high-speed engineering computations and radiative cooling technology respectively. His recent awards include a Vannevar Bush Faculty Fellowship from the U. S. Department of Defense (2017), a Simons Investigator in Physics (2021), and the R. W. Wood Prize from the Optica (2022). He is a member of the National Academy of Engineering (elected 2024), and a Fellow of the IEEE, the American Physical Society, the Optica, and the SPIE.

2.16 Geun Ho Ahn

Postdoctoral researcher
Department of Electrical Engineering, Stanford University

Interests and expertise:
Integrated photonics, optoelectronics, AI hardware

Session 2, Tuesday, September 17, 2024

Scalable and high-performance integrated light sources for optical interconnects

Optical interconnect systems require high performance integrated light sources. Realizing a high-performance integrated laser system requires developing and engineering the on-chip version of all individual laser components. Key components include laser gain media, low loss laser cavity, and optical isolators. During this talk, I will present how we realize all of these key components on a fully integrated photonic platform through scalable, CMOS-compatible silicon nitride photonics.

Bio: Geun Ho Ahn is a postdoctoral researcher at Stanford University. He earned his Ph.D. in Electrical Engineering from Stanford University, where he was a STMicroelectronics Stanford Graduate Fellow under the guidance of Professor Jelena Vučković. He previously obtained his B.S. in Electrical Engineering and Computer Sciences from the University of California, Berkeley, as a Haas Fellow. His research spans the intersection of integrated photonics, material sciences, and computational optimization to enable novel integrated photonic-electronic systems.

2.17 Jonathan Fan

Associate Professor
Department of Electrical Engineering, Stanford University

Interests and expertise:
Scientific computing, computer aided design, machine learning, surrogate solvers, large language models, metasurfaces, metamaterials, photonics

Session 2, Tuesday, September 17, 2024

Machine learning methods for designing and modeling photonic systems

We will cover computational algorithms based on deep neural networks that can accelerate the design and simulation of nanophotonic devices, using metasurfaces and metamaterials as a model system. We will discuss the use of generative networks to perform population-based optimization and elucidate how the neural network architecture can be tailored to effectively perform freeform optimization. We will also discuss how physics-augmented deep networks can be trained with a combination of data and physics constraints to serve as accurate surrogate electromagnetic solvers. Finally, we will discuss ongoing efforts to leverage large language models to create photonic modeling and design tools with ChatGPT-like interfaces.

Bio: Jonathan Fan is an Associate Professor in the Department of Electrical Engineering at Stanford University, where he is researching topics at the intersection of algorithms, materials science, and photonics. He received his bachelor's degree with highest honors from Princeton University and his doctorate from Harvard University. He is the recipient of the Sloan Foundation Fellowship in Physics, Packard Foundation Fellowship, and the PECASE.

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2.18 Olav Solgaard

Director, Edward L. Ginzton Laboratory and Robert L. and Audrey S. Hancock Professor in the School of Engineering
Electrical Engineering, Stanford University

Interests and expertise:
Interests

Session 3, Tuesday, September 17, 2024

Low power silicon photonics

Silicon Photonics has the potential to provide low-power consumption systems for sensing, signal processing, and communications. State-of-the-art Silicon Photonics systems are, however, far from meeting the promise of low-power operation. At present the dominant implementation used by Silicon Photonics foundries is based on Mach-Zehnder interferometers controlled by thermal phase shifters. These thermal phase shifters function by dissipating electrical power in local ohmic heaters that change temperature in, or in the vicinity of, optical waveguides that in response change their effective index and therefore their phase delays. Each phase shifter requires several milliwatt of continuous power in operation, leading to watt level power consumption even for modest sized systems. The solution to this problem is to develop MEMS phase shifters and/or MEMS tunable directional couplers that require low switching energy and no holding power. Both these types of Silicon Photonic MEMS components can be driven by electrostatic actuators.

In this talk we describe Silicon Photonic systems for implementation of optical neural networks and for high-contrast sensing, and we demonstrate how MicroElectroMechanical Systems (MEMS) can improve the power requirements of such systems. We detail the design of low-loss MEMS phase shifters and MEMS tunable directional couplers, and we describe how they can be implemented using reproducible and efficient fabrication technologies, available in standard silicon foundries, developed for a number of other MEMS devices and systems, notably accelerometers, gyros, and projection displays.

Finally, we outline how Power MEMS combined with Silicon Photonics will enable powerful, autonomous, sensing and edge-computing systems.

Bio: Olav Solgaard earned his Ph.D. degree from Stanford University in 1992. From 1992 to 1995 he was a Postdoctoral Fellow at the University of California, Berkeley, and in 1995, he became a professor in the Electrical Engineering Department of the University of California, Davis. In 1999 he joined Stanford University where he is now a Professor of Electrical Engineering and the Director of the Ginzton Laboratory.

Professor Solgaard's research interests include optical MEMS, Silicon Photonics, optical sensors, and dielectric laser accelerators. He has authored more than 400 technical publications and 90 patents. Professor Solgaard is a Fellow of the IEEE, the Optical Society of America, the Royal Norwegian Society of Sciences and Letters, and the Norwegian Academy of Technological Sciences.

2.19 Ryohei Urata

Principal Engineer/Director
Platforms Optics Group, Google, Inc.

Interests and expertise:
Networking for Datacenters and Machine Learning (ML)

Session 3, Tuesday, September 17, 2024

Optical interconnect and switching technologies for datacenter and machine learning networks

In this presentation, we will describe the world's first large-scale production deployment of lightwave fabrics composed of optical circuit switches (OCSes) and WDM interconnect, used in Google's datacenter and machine-learning (ML) systems. We will then discuss the scaling challenges for future ML systems.

Bio: Dr. Ryohei Urata is currently a Principal Engineer/Director in the Platforms Optics Group, where he has defined/developed Google's datacenter optical technologies and corresponding roadmap for the past decade. Prior to joining Google, he was a research specialist at NTT Photonics Laboratories, Japan. He has over 150 patents, publications, and presentations in the areas of optical interconnect, switching, and networking. He received the B.S. degree in engineering physics from the University of California at Berkeley (Highest Honors), and the M.S. and Ph.D. degrees in electrical engineering from Stanford University (Stanford Graduate Fellow). He was elected an Optica/OSA Fellow in 2022.

2.20 Ashkan Seyedi

Director, LinkX Products
nVidia

Interests and expertise:
Optical interconnects and optical logic circuits

Session 3, Tuesday, September 17, 2024

Interconnect challenges for next-gen AI processors

As bandwidth density requirements for processors increase to meet the demand for next-gen GenAI workloads, the boundary of problems that must be solved simultaneously become blurred. More now than ever, various domain expertise like mechanical, thermal, signal integrity, photonics, etc. must work together to enable the future. In this talk, I will review some of these challenges to motivate the industry and focus effort.

Bio: Ashkan Seyedi received a dual bachelor's in electrical and computer engineering from the University of Missouri-Columbia and a Ph.D. from University of Southern California working on photonic crystal devices, high-speed nanowire photodetectors, efficient white LEDs, and solar cells. With a decade of industry experience at Intel, Hewlett Packard Enterprise and now nVidia, Dr. Seyedi has been working on developing high-bandwidth, efficient optical interconnects for exascale, and high-performance computing applications.

2.21 Jason Hartlove

Vice President, XDO
Meta, Reality Labs

Interests and expertise:
Optics, Photonics, III-V/II-IV Materials, Quantum Dots, Sensors and Displays

Evening Plenary, Tuesday, September 17, 2024

New Realities: Opportunities and Challenges for Optics and Photonics in AR & MR

As we approach 2030, the world is on the cusp of a technological revolution that will transform the way we interact with technology. With advancements in mixed reality displays and contextual AI, we are moving beyond the confines of 2D screens to engage our senses in a profoundly richer way. In this talk, Jason Hartlove will guide us on an exploration of the challenges and opportunities that lie ahead in integrating photonic technology into AR glasses, and how contextual AI is advancing at a pace that surpasses even our wildest dreams. We will discuss collaborations with industry partners to develop advanced photonics that are helping bring us closer to passing the Visual Turing test. We will also delve into the rapid progress of contextual AI, which has made tremendous strides thanks to the emergence of Large Language Models and work on personal timelines, ultra-low-friction input, and always-on sensing. This game-changing development represents the killer app for AR/VR and enables remarkable new and compelling use models that are helping develop the market even ahead of the realization of immersive displays that pass the Turing Test. Join us as we embark on a journey to the next frontier of human-centric technology.

Bio: Jason Hartlove is Meta's Vice President of XDO, the R&D organization within Reality Labs responsible for developing and delivering complete display, sensing and optical systems for Meta's next generation of AR and MR products. He leads a cross-functional global organization specializing in perceptual image science, image processing, semiconductors, light engines, optics, waveguides, sensors, prescription lenses, and novel process technologies including optical additive manufacturing.

With more than 35 years of experience introducing optical systems and technologies to market, Jason was most recently CEO of Nanosys, where he pioneered quantum dot technology for displays, shipping 60 million units across 800 consumer and IT SKUs prior to its acquisition. Jason previously led product development teams at Hewlett Packard, was VP of Agilent's CMOS image sensor solutions unit, and was a founding EVP at MagnaChip Semiconductor, focusing on display driver ICs and CMOS image sensors, setting the company on a successful path to IPO.

Jason received SID's David Sarnoff Prize in 2023, and the Hewlett Award in 2005 and is a prolific inventor named on more than 150 patents, including the multibillion-selling optical mouse. He holds a BSEE from UCLA and lives in the Bay Area with his wife and twin sons.

2.22 Julie Eng

Chief Technology Officer
Coherent

Interests and expertise:
Fiber optics, fiber optic transceivers, fiber optics for AI, industrial lasers, commercialization of lasers, lasers for biophotonics and medical applications

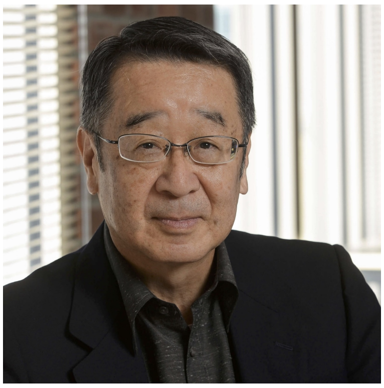
Keynote, Wednesday, September 18, 2024

Commercial laser applications and challenges

This talk will review multiple commercial examples of lasers: compound semiconductor lasers for communications applications including artificial intelligence, and for sensing applications; optically pumped semiconductor lasers for semiconductor capital equipment, gene sequencing, and flow cytometry; excimer lasers for annealing; CW and high-speed fiber lasers for cutting, welding, muti-photon microscopy, and optogenetics. Challenges in research and development, manufacturing, and the business of lasers will be discussed.

Bio: Julie Sheridan Eng was named Chief Technology Officer (CTO) of Coherent in 2022. Prior to becoming CTO, Dr. Eng served as Senior Vice President and General Manager of Coherent/II-VI's Optoelectronic Devices and Modules Business Unit. Prior to joining II-VI through the II-VI acquisition of Finisar, Dr. Eng worked at Finisar, serving most recently as Executive Vice President and General Manager of Finisar's 3D Sensing Business Unit, and prior to that, as Executive Vice President of Datacom Engineering. Prior to joining Finisar, Dr. Eng was part of AT&T/Lucent/Agere, where she managed datacom transceivers.
Dr. Eng is a Past Chair of the IEEE Committee on Women in Engineering and presently serves on the Board of Directors of Optica (formerly the Optical Society of America). She holds a B.A. degree in Physics from Bryn Mawr College and a B.S. degree in Electrical Engineering from the California Institute of Technology (Caltech). She earned M.S. and Ph.D. degrees in Electrical Engineering from Stanford University. In 2022, she was elected Fellow of Optica for distinguished contributions to the advancement of optics and photonics.

2.23 Yoshihisa Yamamoto



Director of Physics & Informatics Laboratories
NTT Research, Inc.

Interests and expertise:
Quantum information processing, physics of quantum-to-classical transition, and coherent Ising machines

Session 1, Wednesday, September 18, 2024

Optical computing: new prospects with machine learning and TFLN

In the past decade, the back propagation algorithm revitalizes a machine learning approach as a practical technology for image and language processing but introduces a serious problem of energy cost and CO2 emission in AI data centers. The thin film lithium niobate (TFLN) hardware platform revolutionizes a whole field of nonlinear optics due to its spatial and temporal confinement of optical fields. In this talk we will discuss how the two game changers may change a prospect of “notorious” optical computing in spite of the repeated failures in the psst efforts.

Bio: Yoshihisa Yamamoto is the Director of PHI (Physics & Informatics) Laboratories, NTT Research, Inc. He received B.S. degree from Tokyo Institute of Technology and M.S. and Ph.D. degrees from the University of Tokyo in 1973 and 1978, respectively, and joined NTT Basic Research Laboratories in 1978. He became a Professor of Applied Physics and Electrical Engineering at Stanford University in 1992 and also a Professor at National Institute of Informatics (NII) in 2003. He is currently a Professor (Emeritus) at Stanford University and NII. His past research areas include coherent communications, squeezed states, quantum non-demolition measurements, exciton-polariton BEC, single photon and spin-photon entanglement generation, and mesoscopic transport noise. He has received many distinctions for his past work, including Carl Zeiss Award (1992), Nishina Memorial Prize (1992), IEEE/LEOS Quantum Electronics Award (2000), Medal with Purple Ribbon (2005), Hermann A. Haus Lecturer of MIT (2010), Okawa Prize (2011) and Willis E. Lamb Award (2022). His current research interest focuses on quantum information processing, physics of quantum-to-classical transition and coherent Ising machines.

2.24 Joaquin Matres

Photonics engineer
GDSFactory and Google-X

Interests and expertise:
Photonics chip design

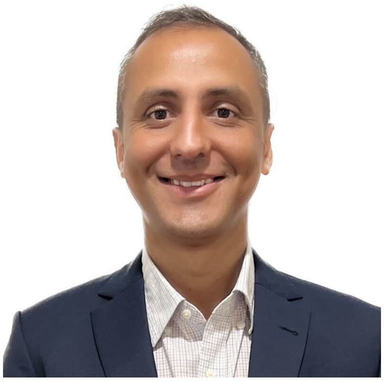
Session 1, Wednesday, September 18, 2024

Revolutionize your chip design with GDSFactory

GDSFactory is a powerful Python library for designing a wide range of complex systems, including photonic circuits, analog devices, quantum components, MEMs, 3D printed objects, and PCBs. With GDSFactory, you can create and refine your designs using Python or YAML, perform rigorous verification through Design Rule Checking (DRC), Layout Versus Schematic (LVS) checks, and simulations. Additionally, it facilitates automated lab testing to ensure that your fabricated devices meet precise specifications, streamlining the entire design-to-fabrication workflow.

Bio: Joaquin is a seasoned chip designer with a 15-year tenure of crafting advanced silicon solutions at prestigious organizations including Intel, Hewlett Packard Labs, PsiQuantum, and Google X. With a passion for leveraging Python in chip design, he started the groundbreaking open-source project, GDSFactory, in 2019. Aimed at revolutionizing chip design in Python, GDSFactory has achieved remarkable success, amassing over 2 million downloads to date. Joaquin's commitment to innovation extends to his collaboration with Google's "Build Your Own Silicon" program. Here, he plays a pivotal role in mirroring the triumphant ecosystem established by TensorFlow in the realm of machine learning for the field of open-source chip design tools since 2016. Joaquin's work not only pushes the boundaries of chip technology but also fosters a collaborative and open environment for silicon innovation.

2.25 Prash Kharel



Technology Strategist
Flexcompute

Interests and expertise:
Photonics and advanced computing

Session 1, Wednesday, September 18, 2024

Re-architecting simulation tools in a compute-abundant world

Driven by advancements in GPUs, the world has seen unprecedented growth in compute capability. While this has enabled impressive AI applications like ChatGPT and Stable Diffusion, all seeking to build better world models, it also presents enormous opportunities for directly simulating physical phenomena. These simulations, akin to building accurate digital twins of real-world systems, are instrumental in designing everything from semiconductor chips to aircraft wings. In photonics, such simulations are crucial for developing advanced optical components, integrated photonic circuits, and novel sensing technologies. Given the anticipated abundance in compute driven by AI infrastructure, this talk will explore how this computational revolution is reshaping the simulation industry. We'll discuss new possibilities in simulating complex photonic systems, breakthroughs in design optimization, and the challenges that lie ahead as we harness this computational power to advance our understanding and modeling of the physical world.

Bio: Dr. Prashanta Kharel is a Technology Strategist at Flexcompute, where he leads partnerships with foundries and helps develop cutting-edge simulation tools for the photonics industry. Dr. Kharel earned his Ph.D. in Physics from Yale University, specializing in nonlinear optics and quantum technologies. In his previous role as Head of Devices and a founding team member at HyperLight, Dr. Kharel worked on commercializing the Thin-Film Lithium Niobate photonics platform for diverse markets, ranging from optical communications to test and measurement. Dr. Kharel has authored over 22 journal articles and holds 13 patents, blending academic insight with industry experience in photonics.

2.26 Joseph M. Kahn

Professor of Electrical Engineering
E. L. Ginzton Laboratory and Department of Electrical Engineering, Stanford University

Interests and expertise:
Coherent optical communications, Free-space optical communications, Modulation, coding, detection and signal processing methods, Electro-optic frequency combs, Multimode and multicore fibers, amplifiers and passive components, Modeling and control of multimode propagation, Optimization-based photonic design.

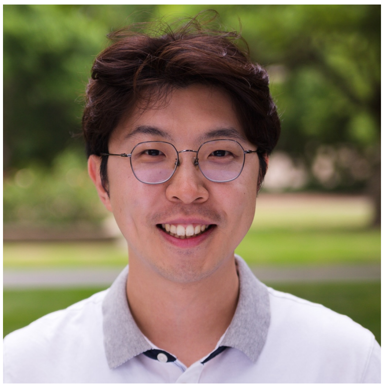
Session 2, Wednesday, September 18, 2024

Novel photonics enabling ultra-efficient coherent optical communications

I will present current research on energy-efficient photonic devices and their application to coherent optical communication systems ranging from short to very long distances. The need to scale data center links to terabit-per-second rates motivates the use of coherent detection in these short-reach systems. Minimizing power consumption motivates us to consider new system designs, such as integrated coherent transceivers using electro-optic frequency comb generators as both transmitter and local oscillator multi-wavelength light sources. By exploiting the mutual coherence of the comb lines, we can synchronize all the comb lines using just two optical phase-locked loops. At the opposite extreme, the need to scale long submarine cables to petabit-per-second capacities has necessitated new design approaches. Given the limited electrical power that can be fed through a cable to power its numerous optical amplifiers, cable capacity is maximized by using many channels in parallel, each carrying relatively low optical power and data rates. Amazingly, well-designed cables can convey information over distances exceeding 10,000 km with an energy cost under 10 pJ/b. Future cables can be greatly simplified by replacing the numerous single-mode fibers and amplifiers by a much smaller number of multi-mode fibers and amplifiers. We have developed new optimization-based methods to design multi-mode fibers and amplifiers that achieve ultra-low group delay spread and mode-dependent gain.

Bio: Joseph M. Kahn is a Professor of Electrical Engineering at Stanford University, where he leads the Optical Communications Group. He received a Ph.D. in Physics from the University of California, Berkeley in 1986. His achievements include: first successful synchronous (i.e., coherent) detection using semiconductor lasers (1989); first probabilistic shaping in optical communications (1999); founding of StrataLight Communications, market leader in first-generation phase-modulated fiber transmission systems (2000); first electronic compensation of fiber Kerr nonlinearity (2002), which led to digital backpropagation (2008); and elucidation of principal modes in multimode waveguides (2005), which led to statistics of strongly coupled modal group delays and gains/losses in multimode systems (2011). Kahn's current research interests include spatial multiplexing in ultra-long-haul submarine links, optical frequency comb generators, coherent data center links, and modal multiplexing and atmospheric turbulence compensation methods for free-space optical communications. Kahn received the National Science Foundation Presidential Young Investigator Award (1991) and is a Fellow of the IEEE (2000).

2.27 Joonhee Choi



Assistant Professor
Department of Electrical Engineering, Stanford University

Interests and expertise:
Quantum optics, nanophotonics, quantum information science

Session 2, Wednesday, September 18, 2024

Neutral atom quantum computing

The potential of quantum computation lies in exploiting quantum superposition and entanglement, enabling large-scale computations beyond the capabilities of classical systems. Various hardware platforms, including superconducting, quantum dot, trapped ion, photonic, and neutral atom devices, are currently under development in both academia and industry to realize the promise of quantum computing. However, achieving robust, large-scale quantum hardware scalable to a million or more qubits remains a significant challenge across all these platforms. Neutral atom quantum devices show particular promise, as recent experiments have demonstrated precise control over more than 6,000 atomic qubits, offering potential advantages for quantum error correction and the construction of fault-tolerant quantum computers. The complexity of quantum error correction, especially with physical error rates around 10^{-4}, underscores the need to combine high-fidelity quantum logic operations with the capacity to integrate large numbers of physical qubits. Arrays of neutral atoms with real-time transport, independent qubit control, and smaller footprints emerge as a potentially optimal platform for large-scale quantum computing. In this talk, we will discuss neutral atom quantum processors and their potential impact on the evolving landscape of quantum technologies.

Bio: Joonhee Choi is an Assistant Professor of Electrical Engineering at Stanford University. Joonhee received his Ph.D. and master's from Harvard University, as well as master's and bachelor's degrees from Korea Advanced Institute of Science & Technology. Prior to joining Stanford, he worked as an IQIM postdoctoral fellow at the Institute for Quantum Information and Matter (IQIM) at Caltech. Joonhee's research focus has been on engineering the dynamics of quantum many-body systems for both exploring fundamental science and demonstrating practical quantum applications. Throughout his career, he has worked in a wide variety of fields, including nonlinear nano-optics, ultrafast phenomena, solid-state and atomic physics, as well as quantum many-body physics. His expertise extends to practical applications in quantum metrology, communication, and information processing. Joonhee is the recipient of the Outstanding Young Researcher Award from the Association of Korean Physicists in America, the winner of the 2024 KSEA Young Investigator Grant in Science, and has been appointed as a Terman Faculty Fellow in the School of Engineering at Stanford.

2.28 Eileen Otte

Postdoctoral fellow
Geballe Laboratory for Advanced Materials, Stanford University

Interests and expertise:
Structured light, singular optics, nanophotonics, quantum optics, advanced imaging

Session 2, Wednesday, September 18, 2024

Information carried in the structure of light

When light interacts with media, it is spatially structured in its amplitude, phase, polarization, angular momenta, and more, depending on the properties of the media. With its interaction-dependent characteristics, this so-called structured light represents a powerful information carrier from the macro- down to the nanoscale. For instance, sunlight scattered in the blue daylight sky shows intriguing polarization patterns, carrying information about the location of the sun. Although we are not able to see this pattern, insect such as bees can use it as a means of orientation. At much smaller, molecular scales, we can observe that, e.g., the emission pattern of a single fluorescent molecule is highly dependent on its dipolar orientation. Hence, decoding this pattern can provide access to nanoscale features of molecules.
Inversely, we can also choose to encode information into structured light. In this case, structured light becomes an advanced tool in a broad range of applications, including optical micro- and nano-manipulation, material machining, and classical as well as quantum communication and encryption. For example, light fields spatially structured in phase and polarization can be used to increase the dimension of quantum key distribution schemes. This high-dimensional approach enables a higher information capacity per photon, greater resilience to noise, and longer transmission distances.
Although the diverse properties of structured light are widely known, its potential has not been fully exploited yet – especially if it comes to non-paraxial structured light and its interactions. We will explore how encoding and decoding information carried in structured light, especially in the non-paraxial regime, opens new avenues for advancing cutting-edge applications and recent technologies.

Bio: Eileen Otte is a postdoctoral fellow at the Geballe Laboratory for Advanced Materials (GLAM), Stanford University, advised by Prof. Mark Brongersma. Eileen's research concentrates on the fundamental properties and diverse applications of structured light fields, in areas such as singular optics, nanoscale imaging and sensing, quantum cryptography, optical manipulation, and more. In her postdoctoral research, Eileen focused on nanoscale light-matter interactions, combining structured light and nanophotonics.
Eileen has coauthored 24 peer-reviewed articles, including 14 first author publications. Her PhD work, performed at the University of Muenster, Germany, and WITS University, South Africa, was honored with summa cum laude and the WWU Dissertation Award, and published as a book in the Springer Theses series. She has also received the Research Award 2020 of the Industrial Club Duesseldorf, was appointed a junior class member of the NRW Academy of Sciences, Humanities, and the Arts, and was listed among the Emerging Leaders 2021 and Emerging Talents 2021 of IOP's Journal of Optics. Her postdoctoral research was supported by the PRIME program of the German Academic Exchange Service as well as the GLAM Postdoctoral Fellowship. In January, Eileen will join the Institute of Optics at the University of Rochester as a faculty member.

2.29 S. J. Ben Yoo

Distinguished Professor of Electrical and Computing Engineering
University of California, Davis; Joint Faculty of Lawrence Berkeley National Laboratory and UC Davis

Interests and expertise:
Optical Computing, Neuromorphic Computing, 3D Photonic-Electronic-Integrated Circuits, Nontraditional Computational Imaging, Photonic Networking, Photonic-Electronic Communication Systems, Elastic 5G/6G/THz/Optical Networking

Session 3, Wednesday, September 18, 2024

Can we realize a computing system with comparable energy-efficiency, scalability, and flexible learning capability of the brain?

The human brain has immense learning capabilities at extreme energy efficiencies and scale that no artificial system has been able to match. For decades, reverse engineering the brain has been one of the top priorities of science and technology research. Despite numerous efforts, conventional electronics-based methods have failed to match the scalability, energy efficiency, and self-learning capabilities of the human brain. On the other hand, very recent progress in the development of new generations of photonic and electronic memristive materials, device technologies, and 3D electronic-photonic integrated circuits (3D EPIC) suggest possible realization of brain-derived neuromorphic systems with comparable connectivity, density, energy-efficiency, and scalability. When combined with bio-realistic learning algorithms and architectures, it may be possible to realize an “artificial brain” prototype with general self-learning capabilities. In this talk, we will first discuss the complementary roles of photonics and electronics, and focus on how the *best-of-both-worlds-approaches* involving nanoscale photonics and electronics can possibly bring breakthroughs in computing, including hyper-spectral-hyper-dimensional computing. We will further discuss the possibility of reverse-engineering the brain through architecting a prototype of a brain-derived neuromorphic computing system consisting of artificial electronic, ionic, photonic materials, devices, and circuits with dynamicity resembling the bio-plausible molecular, neuro/synaptic, neuro-circuit, and multi-structural hierarchical macro-circuits of the brain based on well-tested computational models.

Bio: S. J. Ben Yoo is a Distinguished Professor at the University of California at Davis (UC Davis). His research at UC Davis includes 2D/3D photonic integration for future computing, cognitive networks, communication, imaging, and navigation systems, micro/nano systems integration, and the future Internet. Prior to joining UC Davis in 1999, he was a Senior Research Scientist at Bellcore, leading technical efforts in integrated photonics, optical networking, and systems integration. His research activities at Bellcore included the next-generation Internet, reconfigurable multiwavelength optical networks (MONET), wavelength interchanging cross connects, wavelength converters, vertical-cavity lasers, and high-speed modulators. He led the MONET testbed experimentation efforts, and participated in ATD/MONET systems integration and a number of standardization activities. Prior to joining Bellcore in 1991, he conducted research on nonlinear optical processes in quantum wells, a four-wave-mixing study of relaxation mechanisms in dye molecules, and ultrafast diffusion-driven photodetectors at Stanford University (BS’84, MS’86, PhD’91, Stanford University). Prof. Yoo is Fellow of IEEE, OSA, NIAC and a recipient of the DARPA Award for Sustained Excellence, the Bellcore CEO Award, the Mid-Career Research Faculty Award (UC Davis), the Senior Research Faculty Award (UC Davis), and numerous best paper awards from IEEE, ACM, and OPTICA conferences.

2.30 Jonathan Doylend

Optical Sensors
Kilby Labs, Texas Instruments

Interests and expertise:
Optics, Photonics, Sensors, Lasers

Session 3, Wednesday, September 18, 2024

Wisdom begins in wonder - a few things I'd appreciated as a graduate student

This informal talk will share some anecdotes and lessons learned.

Bio: Jonathan Doylend leads optical sensors research at Texas Instruments' Kilby Labs and teaches at Benedictine College. He previously directed optics strategy at Meta and led LIDAR development as a Senior Principal Engineer at Intel, where he also designed the lasers at the heart of the industry's first uncooled multiwavelength silicon photonics transceiver. His past includes a wide range of companies large and small, a post-doctoral fellowship at UC Santa Barbara, Ph.D. from McMaster University, B.Sc. from the University of Waterloo, and B.A. from Thomas Aquinas College.

2.31 Jon Simon

Professor of Physics and Applied Physics
Departments of Physics and Applied Physics, Stanford University

Interests and expertise:
Cavity arrays, Rydberg polaritons, topological photonics, quantum circuits, hybrid quantum systems, theory.

Session 3, Wednesday, September 18, 2024

Optics challenges at the quantum computing frontier

Jon will be discussing his insights on challenges and opportunities in optics in our quest to create powerful quantum computers.

Bio: Jon grew up fascinated with electronics, programming, simulating the world, and soccer. He went to Montgomery Blair for highschool, where he was captain of the game programming club and the chess team. As an undergraduate at Caltech, he led the Beavers to a 1-63 record (seriously- we were terrible) over his 3 seasons on the NCAA DIII soccer team, all while learning physics and building electronics. As a graduate student and postdoc at MIT & Harvard, Jon focused primarily on cavity QED and synthetic quantum matter in optical lattices, while achieving the distinction of coming in dead last in the Head of the Charles Regatta Club 8's. On weekends he kitesurfed on the cape.
Jon's passions for light, simulation, and circuits have combined in the study of quantum & classical matter made of light. In his spare time he grapples, flies drones, and trains his cat Emmy to perform tricks.