MONDAY, SEPTEMBER 16

8:00 – 8:15 Welcome Remarks  
Anton Muscatelli, Univ of Glasgow

8:15 – 9:00 Plenary: Black Silicon: From Serendipitous Discovery to Devices  
Eric Mazur, Harvard University

Session 1: Ultrafast Materials Science  
Faculty Coordinator: Aaron Lindenberg

9:00 – 9:30 Turntable Ultrafast Responses in Graphene  
Feng Wang, UC Berkeley

9:30 – 10:00 Separating Electronic and Structural Phase Transitions in VO₂ with THz-Pump X-Ray Probe Spectroscopy  
Alex Gray, Stanford University

Coffee Break  
10:00 – 10:30

Session 2: Laser Particle Accelerators  
Faculty Coordinator: Bob Byer

10:30 – 11:00 Recent Advances in Laser Acceleration of Particles  
Chan Joshi, UCLA

11:00 – 11:15 Electron Acceleration in a Laser-Driven Dielectric Micro-Structure  
Edgar Peralta, Stanford

11:15 – 11:45 All Laser-Driven Compton X-ray Light Source  
Donald Umstadter, Univ of Nebraska

11:45 – 12:00 Beam Control in Microaccelerators  
Ken Soong, Stanford

12:00 – 12:30 Poster Introductions

Lunch & Poster Session  
12:30 – 2:00

Session 3: X-Ray Imaging  
Faculty Coordinator: Bert Hesselink

2:00 – 2:30 Recent Results in Differential Phase Contrast Imaging  
Rebecca Fahrig, Stanford

2:30 – 2:45 Differential Phase Contrast Imaging for Aviation Security Applications  
Max Yuen, Stanford

2:45 – 3:15 Structured Illumination and Compressive X-ray Tomography  
David Brady, Duke University

3:15 – 3:30 Photo Electron X-ray Source Array  
Yao-Te Cheng, Stanford

Coffee Break  
3:30 – 4:00

Session 4: Emerging Photonic Devices  
Faculty Coordinator: Zhenan Bao

4:00 – 4:30 Advanced Cell Technologies for Concentrated Photovoltaics  
Homan Yuen, Solar Junction

4:30 – 5:00 High-Efficiency and Stretchable Polymer OLEDs  
Qibing Pei, UCLA

5:00 – 5:30 Materials Make the PV Module  
Homer Antoniadis, Du Pont

6:00 – 7:00 Reception @ Stanford Faculty Club

7:00 – 8:15 Banquet

8:15 Gravity from the Cradle to the Grave  
Jim Hough, Glasgow University

SPRC 2013 Agenda
SPRC 2013 Annual Symposium
September 16-18, 2013
Li Ka Shing Conference Center, Stanford University

TUESDAY, SEPTEMBER 17

8:00 – 8:45 Plenary: Optical Approaches to Restoration of Sight to the Blind
Dan Palanker, Stanford University

Session 1: Imaging in Stem Cell Science and Regenerative Medicine
Faculty Coordinator: Renee Reijo Pera

8:45 – 9:00 Characterization of novel transcripts in pluripotent stem cells using mRNA reprogramming in combination with single-cell gene expression analysis
Jens Durruthy Durruthy, Stanford

9:00 – 9:30 Routes to iPS cells
Keisuke Kaji, University of Edinburgh

9:30 – 9:45 Neurology and Stem Cells
Alex Shcheglovitov, Stanford

9:45 – 10:15 Definitive Genetic Therapy for Inherited Disorders
Tony Oro, Stanford University

Coffee Break
10:15 – 10:45

Session 2: Functional Molecular/Cellular Imaging
Faculty Coordinator: Manish Butte

10:45 – 11:15 Non-invasive intravital imaging of stem cell differentiation with a bright red-excitable fluorescent protein
Michael Lin, Stanford

11:15 – 11:30 Asymmetric Adherns Junctions as Guidance Signals for Collective Endothelial Cell Migration
Arnold Hayer, Stanford

11:30 – 11:45 4Pi Fluorescence Detection and 3D Particle Localization with a Single Objective
Jörg Schnitzbauer, Stanford

11:45 – 12:00 Sensing Binding Interactions in Solution with a Single-Molecule Trap
Quan Wang, Stanford

12:00 – 12:15 Bridging the gap: from technological advancements in light microscopy to their use in biological discoveries
Nico Stuurman, UCSF

Lunch & Poster Session
12:15 – 2:00

Session 3: Novel Optical Tools in the Clinic
Faculty Coordinator: Chris Contag

2:00 – 2:30 Intraoperative optical-sectioning microscopy for guiding brain-tumor resection
Jon Liu, SUNY

2:30 – 3:00 Imaging PET radiotracers at the single cell level with radioluminescence microscopy
Guillem Pratx, Stanford

3:00 – 3:15 Wide-field Fluorescence to Guide In-Vivo Microscopy
Steven Sensarn, Stanford

3:15 – 3:30 Raman tools for Colon Cancer Detection
Ellis Garai, Stanford

Coffee Break
3:30 – 4:00

Session 4: Photonics in Data Centers
Faculty Coordinator: Joseph Kahn

4:00 – 4:30 Optics for Future Scaling of Data Centers
Hong Liu, Google

4:30 – 5:00 Evolution of Optical Interfaces for Data Centers
Chris Cole, Finisar

5:00 – 5:30 Hybrid Datacenter Networks with Microsecond Optical Circuit Switches
George Papen, UCSD

SPRC 2013 Agenda
WEDNESDAY, SEPTEMBER 18

8:30 – 8:45  Overview of the National Photonics Initiative  Thomas Baer, NPI Committee Chair

Session 1: Industrial Fiber Laser Applications
Faculty Coordinator: Olav Solgaard

8:45 – 9:15  New Potentials of Fiber Lasers  Andrei Babushkin, IPG Photonics
9:15 – 9:45  Lasers in Smart Phone Manufacturing – enabling the mobile revolution  Magnus Bengtsson, Coherent
9:45 – 10:15  The Role of Pulse Duration and Pulse Shape in Laser Processing of Materials  Mathew Rekow, ESI

Coffee Break
10:15 – 10:45

Session 2: Lasers Detecting Atoms and Molecules
Faculty Coordinator: Leo Hollberg

11:15 – 11:45  New Adventures in Optical Spectroscopy: High Performance Molecular and Stable Isotope Analysis in the Great Outdoors  Chris Rella, Picarro
11:45 – 12:15  Airborne Precision Laser Sensing for Atmospheric Research  Dirk Richter, Univ of Colorado, Boulder

Lunch & Poster Session
12:15 – 2:00

Afternoon Workshop: Advances in Digital Photography

2:00 – 2:30  Advances in Digital Photography  Dave Henry, Canon USA
2:30 – 3:00  What’s Behind the Picture? Top 5 Things to Remember When Choosing and Using Scientific Imaging Cameras  Stephanie Fullerton, Hamamatsu Camera Products Group
3:00 – 3:30  Light Fields and the Future of Photography  Ren Ng, Lytro
Executive Summary

The SPRC Symposium features invited talks on a wide range of photonics research topics presented by leading researchers from around the world, including several SPRC faculty and student members who present the latest results from their research efforts. The 2013 Symposium begins with opening remarks by the Principal of the University of Glasgow, Anton Muscatelli, and closes with a special workshop on Advances in Digital Photography. During the three-day conference, there are plenaries by Eric Mazur of Harvard University and Dan Palanker of Stanford University, as well as an overview of the National Photonics Initiative presented by the Chairman of the NPI Committee and Executive Director of SPRC, Tom Baer.

The 2013 Symposium consists of 10 sessions:

- Ultrafast Materials Science
- Laser Particle Accelerators
- X-Ray Imaging
- Emerging Photonic Devices
- Imaging in Stem Cell Science and Regenerative Medicine
- Functional Molecular/Cellular Imaging
- Novel Optical Tools in the Clinic
- Photonics in Data Centers
- Industrial Fiber Laser Applications
- Lasers Detecting Atoms and Molecules

Poster sessions are scheduled for each day of the conference.

We are fortunate again this year to have industry sponsors lend their support to the Annual Symposium. SPRC wishes to thank Newport/Spectra-Physics, Toptica, Photonics Spectra, and SPIE for their generous contributions. Please take time during the SPRC Symposium to meet with sponsor representatives and visit their tabletop displays.

We also want to thank our Affiliate Member companies for their ongoing and generous support of photonics research at Stanford: Agilent Technologies, Coherent, Corning, Halliburton, IPG Photonics, OptiMedica, Pfizer, and Topcon.

The Stanford Photonics Research Center

The Stanford Photonics Research Center is an Industrial Affiliates Program that builds strategic partnerships between the Stanford University photonics research community and industry companies and organizations in research areas including photonics, optics, fundamental science and related fields. SPRC is a critical element of the teaching and research programs at Stanford. SPRC promotes interaction between Stanford and the community, often leading to joint research and the development of new directions in photonics research. SPRC promotes such interaction and facilitated access by our affiliates to photonics research on campus, benefiting our partners as well as our advanced degree students. We encourage you to become a member of SPRC to support and benefit from research and teaching in all aspects of photonics at Stanford.

Thank you for joining us at the 2013 SPRC Annual Symposium.

Robert L. Byer  
Martin M. Fejer  
David A. B. Miller  
SPRC Co-Directors

Thomas M. Baer  
SPRC Executive Director

Sara Lefort  
Assistant Director

Stanford Photonics Research Center

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http:// photonics.stanford.edu
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About SPRC

The Stanford Photonics Research Center (SPRC) builds strategic partnerships between the Stanford University photonics research community and corporations and other organizations active in photonics or employing lasers and optical technologies in their research and product development activities. Member companies gain facilitated access to Stanford faculty, students and researchers by participating in SPRC events, supporting and collaborating on specific research projects, mentoring students, and visiting research labs. Member benefits also include priority alerting for Stanford photonics invention disclosures. SPRC promotes member company recruitment of Stanford students, and facilitates research interactions with Stanford PhD students, faculty, and other researchers. In turn, Stanford students establish connections with scientific experts and business leaders in the photonics industry that continue beyond their Stanford experience.

SPRC faculty and student members belong to one or more working groups which are best aligned with their research interests. These working groups cover a wide range of research areas and technologies, including:

- Solar cell technologies
- Information Technology
- Telecommunications
- Neuroscience
- Microscopy and Molecular Imaging
- High power laser sources
- Quantum Information Science
- Nanophotonics
- Automotive
- Entrepreneurship

SPRC corporate members interact directly with faculty working groups conducting research in areas most directly related to company interests.

Membership

Membership in the Stanford Photonics Research Center is available to companies interested in establishing mutually-beneficial relationships with the Stanford photonics community. Membership fees directly support research and teaching in photonics at Stanford; in turn, members gain facilitated access to Stanford photonics students, faculty, and current and emerging areas of research at Stanford.

There are four levels of membership in SPRC:

- **Founding Membership**
  Founding Members help set the strategic direction of SPRC and may participate on the SPRC Advisory Board. Founding Membership involves a multi-year commitment to membership dues at the Senior Member level (see below) plus a capital donation of $2M. Founding Members receive all benefits of other membership levels.

- **Senior Membership**
  In addition to the benefits listed below for all membership levels, Senior Members may participate on the SPRC Advisory Board, may send a scholar/researcher to Stanford for up to six months per year to work with a collaborating Stanford faculty member and
research group. Senior members may also support multiple Stanford photonics research
groups in accordance with SPRC Advisory Board and University policy.
The annual fee for Senior Membership is $150,000.

Standard Membership

In addition to the benefits listed below for all membership levels, Standard Membership
offers companies the opportunity to send a visiting scholar/researcher to Stanford for up
to one month per year to work with a collaborating Stanford faculty member and research
group. Regular members may also support a Stanford photonics working group in
accordance with SPRC Advisory Board and University policy.
The annual fee for Standard Membership is $50,000.

Introductory Membership

The Introductory Membership level is for companies and organizations that wish to join
SPRC but do not wish to financially support a specific faculty or research group at the
outset.
This is a two-year commitment, with the first year fee of $25,000, before a second year at
the standard rate.

Basic Benefits for all Members

In addition to the specific benefits stated above for each membership level, all member companies receive
the following basic benefits:

- Facilitated access to Stanford photonics research activities and results
- Prompt alerting for Stanford invention disclosures in photonics
- Customized courses delivered via Web or in-person by Stanford photonics faculty
- Discounted Symposium registration fee and complimentary registration to workshops
- Priority notification of, and invitations to, all SPRC events
- Access to photonics students' resumes for recruitment
- Online access to all SPRC event publications and proceedings
Contact Information

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Member Companies

SPRC thanks our member companies for their continued support of photonics research at Stanford University.
The SU²Partnership

The Universities of Strathclyde, St. Andrews, Heriot-Watt and Glasgow, together with Stanford University and the California Institute of Technology (Cal Tech), are collaborating in a project supported by Research Councils UK (RCUK), the Scottish Funding Council and Scottish Enterprise.

The partnership is designed to capitalize on leading research in the photonics sector, in fields including life sciences and renewable energy, and the commercial opportunities the research offers. It also aims to bolster existing links between universities and businesses in Scotland and the US.

<table>
<thead>
<tr>
<th>Key Pillars of Activity in the Project</th>
<th>Key research themes will each have a working group</th>
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<tbody>
<tr>
<td>• Development Projects</td>
<td>• Biophotonics (including stem cell imaging and neuroscience photonics)</td>
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<td>• Entrepreneurial Fellowships</td>
<td>• Solar cell devices</td>
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<td>• Researcher Exchanges</td>
<td>• Integrated photonics</td>
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<tr>
<td>• Investor Network</td>
<td>• Solid-state laser engineering and nonlinear optics</td>
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<tr>
<td>• Industrial Affiliates</td>
<td>• Photonics sensors (including atom, quantum optic and environmental sensors)</td>
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It will also enable businesses in the US and the UK to share ideas and expertise with academics in both countries. The project will give talented young researchers the opportunity to experience working in laboratories in California.

Building on the success of the Stanford Industrial Affiliates scheme and various similar Scottish academic industrial collaborations, there is an opportunity being extended to UK companies to participate and gain real benefits from the SU²P Industrial Affiliates Program.

The program will improve companies’ competitive position by providing a range of activities including facilitated interaction with leading US- and UK-based researchers and entrepreneurs.

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Solid state lasers, adaptive optics, nonlinear optics

Martin M. Fejer
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Nonlinear and guided-wave optics, microstructured materials, optical signal processing, tunable and ultrafast sources

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Photonics Core Faculty/Senior Researchers
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Steven Block
Professor of Applied Physics and Biological Sciences
Single-molecule biophysics, laser-based optical traps, biological motors

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Digital imaging and wireless networks

Audrey Ellerbee
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Microscopy, optical coherence tomography, optofluidics, low-cost diagnostics

Shanhui Fan
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Professor of Chemistry
Dynamics and intermolecular interactions of molecules in liquids, and liquid crystals

Robert Feigelson
Professor of Materials Science and Engineering, Emeritus
Nonlinear optical materials

Ronald K. Hanson
Professor of Mechanical Engineering
Laser-based diagnostics and sensors, combustion and gas dynamics applications

James S. Harris
Professor of Engineering, Materials Science and, by courtesy, Applied Physics
Semiconductor optoelectronic materials, devices and applications, quantum information

Stephen Harris
Professor of Electrical Engineering & Applied Physics
Fundamentals of photonics and nonlinear optics

SPRC Faculty
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Professor of Electrical Engineering and, by courtesy, of Applied Physics
Nanophotonics and ultra-high density optical data storage

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Professor of Electrical Engineering
Optical fiber communications, free-space optical communications, associated devices and subsystems

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High accuracy navigation and gravimetric sensors based on de Broglie wave interferometry; Future atom optics sensors which exploit the novel coherence properties of Bose-Einstein condensates

Leonid Kazovsky
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Optical telecommunications and network systems

Thomas W. Kenny
Associate Professor of Mechanical Engineering
Microsensors based on silicon micromachining

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Michael McGehee
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W. E. Moerner
Professor of Chemistry
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Daniel Palanker
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Biomedical optics and electronics

Peter Peumans
Assistant Professor of Electrical Engineering
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Calvin F. Quate
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Alberto Salleo
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Krishna Saraswat
Professor of Electrical Engineering
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Mark Schnitzer
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Biophotonics.

Anthony E. Siegman
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Olav Solgaard
Associate Professor of Electrical Engineering
Optical micromechanical devices and applications

Jelena Vuckovic
Assistant Professor of Electrical Engineering
Photonic crystal-based optical and quantum optical devices and their integration; solid-state photonic quantum information systems

Brian A. Wandell
Professor of Psychology, and by courtesy, of Electrical Engineering
Image system engineering and visual neuroscience

Yoshihisa Yamamoto
Professor of Electrical Engineering and Applied Physics
Fundamental optoelectronic physics, structures, and devices, quantum computing, quantum information
SPRC FACILITIES

The New Science & Engineering Quad (SEQ)

The SEQ was designed to provide state-of-the-art facilities for science, engineering, and medicine. We are striving to build a vibrant community and to break down barriers across the disciplines. We offer a range of high quality shared administrative services and support the University's Initiative on Human Health and the Initiative on the Environment and Sustainability. The quad consists of four buildings: The Jerry Yang and Akiko Yamazaki Environment and Energy Building, the Jen-Hsun Huang Engineering Center, the James and Anna Marie Spilker Engineering and Applied Sciences Building, and the Bioengineering and Chemical Engineering Building (in planning).

SPRC is now located in the James and Anna Marie Spilker Engineering and Applied Sciences Building.

Center for Nanoscale Science and Engineering (Nano)

The Nanoscience and Engineering Center features the most advanced equipment available to explore matter at the nanoscale—such as an e-beam lithography tool and an atomic force microscope—much of it located underground to provide the stringent control of vibration, light, and cleanliness that is essential for nanoscale research. The nano center makes these labs available to more than 70 researchers from all over campus, including leaders in the natural and physical sciences, engineering, and medicine, who are exploring nanoscale properties and devices with potential applications as diverse as water purification, energy conservation, drug delivery, and national security. The center is the home of the Ginzton Laboratory and the proposed Institute for Nanoscience and Technology, and its labs will complement the nearby Stanford Nanocharacterization Lab and Stanford Nanofabrication Facility.

SPRC Optical Materials Characterization Facility

With initial DARPA/URI support, the Optical Materials Characterization Facility was established in 1992 as part of Stanford's Center for Nonlinear Optical Materials. This facility contains a variety of coherent sources and characterization tools that make possible the rapid measurement of the properties of optical materials and devices. The Characterization Facility is currently operated with funds derived from the SPRC Affiliates' Program, members of which have access to its facilities for support of research on optical materials and devices.

The measurement capability of the SPRC Optical Materials Characterization Facility is summarized below. Contact Dr. Roger Route through the SPRC office/web page for detailed information about the characterization equipment and for access to the facility.
SPRC characterization capabilities:

1. spatially and temporally resolved spectroscopic absorption measurement,
2. photoconductivity and photovoltaic currents at high optical intensities
3. scatter loss at 633 nm and 1064 nm (TMA Inst.),
4. waveguide refractive index profiles (Metricon),
5. variable angle spectroscopic reflectivity and ellipsometric measurements of thin films, waveguides and multilayers (SOPRA GESP) in the 250 - 1750 nm waveband,
6. spectrophotometric measurements with (Cary 500 and Hitachi U4001) UV-VIS-NIR grating spectrophotometers and (Bio Rad) mid-IR and far-IR Fourier transform spectrophotometers
7. photorefractive gain, diffraction efficiency, and response rates.

Coherent sources in the SPRC Characterization Facility include:

1. Spectra-Physics MOPO 730 Nd:YAG /BBO OPO system, ns pulses 1.84 – 0.21 \( \mu \)m
2. Coherent Mira femtosecond Ti:Sapphire laser system
3. Positive Light Spitfire Ti:S regenerative amplifier, with SHG and THG
4. Spectra-Physics Tsunami femto-second Ti-sapphire laser system
5. Spectra-Physics OPAL femto-second OPO (1.3 - 2 µm),
6. Coherent Sabre tunable argon lasers

UV and Ultrafast Materials Characterization

The SPRC Optical Materials Characterization Facility has an ultra-fast and UV materials characterization capability with a tunable Coherent Mira/Sabre Ti:Sapphire laser pumping a Positive Light Spitfire/Merlin regenerative amplifier with a frequency doubler/tripler option. Single Gaussian mode pulses, either <130 fs or ~1 ps in duration, at a 1 KHz rep. rate are available from 950 to 233 nm, and sum-frequency generation is possible to generate wavelengths shorter than 200 nm. Stretched, flat-top pulses are also available from the harmonic package through the use of a longer set of doubling and tripling crystals. The high spatial and temporal quality output beam was used recently to study UV degradation in nonlinear optical materials such as BBO.

Our ultra-fast capabilities also include a Spectra-Physics OPAL-Tsunami system. Tsunami is a femtosecond, actively mode-locked tunable Ti:sapphire laser producing <130 fs pulses at repetition rate of 80 MHz with average power > 1.5 W. OPAL is a synch-pumped OPO generating <130 fs pulses in a wavelength range covering 1.3 - 2 µm, with average power > 150 mW.

Spectroscopic Measurement of Absorption Loss

The spectroscopic absorption loss apparatus is known as a photothermal common-path interferometer (PCI). It uses the thermo-optic refractive index changes induced by absorbed optical power to monitor the thermalized optical absorption. In its simplest configuration, a pump beam at the wavelength at which the absorption is to be measured is focused coaxially with, but with a smaller waist than, a low-power probe beam. A phase shift is imposed on the central portion of the probe beam by the photothermal index change induced by the local temperature rise resulting from the absorbed pump power. The key feature of the device is a Fourier transforming lens that converts this localized phase shift into an intensity variation. This common path approach is much more robust than conventional methods based on Mach-Zehnder
interferometry, and it makes possible near shot-noise limited measurements of the induced phase in a simple, tabletop system. Sensitivities to thermalized optical absorption in the range of 10-6 cm-1 have been demonstrated. A variety of pump lasers have been used, including 1.06 \( \mu \)m and 532 nm Nd:YAG based systems and various Ar-ion laser lines, though the method is applicable with almost any convenient pump laser.

![Crossed-beam setup for low absorption spectroscopic loss measurements.](image)

Fig. 1: Crossed-beam setup for low absorption spectroscopic loss measurements.

Modifications to the PCI apparatus in the SPRC facility make use of crossed pump and probe beams, illustrated in Fig. 1, which allows spatially localized measurements for studying inhomogeneous bulk absorption, as well as surface and coating absorption effects. Through the use of two simultaneous pump lasers, we have characterized induced absorption effects such as gray tracking in KTP and green-induced IR absorption (GRIIRA) in LiNbO3. The relatively rapid time response, faster than 100 ms, allows observation of transient absorption effects as well.

Direct measurement of photoconductivity and photovoltaic current

Characterization of photorefractive transport properties, including photoconductivity and photovoltaic currents, at the high intensities characteristic of nonlinear optical devices are difficult by conventional holographic methods. We have developed a transparent contact (liquid electrolyte) cell to measure photocurrents for the characterization of LiTaO3 and LiNbO3. The cell design allows unambiguous measurement with the light beam collinear with the induced current but without the complication of charge accumulation on the surfaces of the samples. Measurements with this apparatus have led to considerable insight into the behavior of stoichiometric lithium niobate and stoichiometric lithium tantalate.

Characterization of materials using spectroscopic ellipsometry

Spectroscopic and multiple angle of incidence ellipsometry is a valuable tool for the determination of the optical constants (n, k) of materials and the characterization of surface and interface morphologies. While optical transmittance and reflectance measurements provide information on bulk sample properties, ellipsometry has great sensitivity to the properties of the reflecting surface and interfaces in the case of multiple layers. When the optical constants of the materials studied are known, the technique can be used to characterize surface and interface roughness. On the other hand, the measurements can also be used to yield the optical constants of materials. The sample morphology must then be characterized by other techniques, since an accurate reduction of ellipsometric data to the physical quantities of interest requires knowledge of the thicknesses of the constituent layers.
A schematic of the experimental set-up is shown above in Fig. 2. The measurement consists in analyzing the change of polarization resulting from reflection off the surface studied. Wavelengths from 0.25-1.7µm and angles of incidence from 6-90º are accessible using our SOPRA instrument model GESP, which is of rotating polarizer type. The spectra consist of the ellipsometric angles ($\psi, \Delta$), measured typically at 200 points. Experimental data is fit using a linear regression with the purpose of minimizing an error function consisting of the difference between calculated and measured values of the quantities ($\psi, \Delta$). The ellipsometric angles are defined in terms of the ratio, where $r_p, r_s$ are the complex reflection coefficients for light polarized parallel and perpendicular to the plane of incidence. The reflection coefficients are related to the refractive index $n$ and extinction coefficient $k$ through Fresnel’s equations. The optical constants are related to the microscopic properties of the material studied through the dielectric function which is a direct function of the material band structure. Anticipated imperfections, such as rough interfaces and surfaces are described as layers constituted of mixed materials.

$$\rho = r_p/r_s = \tan \psi e^{i\Delta}$$

---

**Fig. 2** Schematic layout of spectroscopic ellipsometer.
SPRC Optical MEMS fabrication

The Stanford research community in photonics has access to the Stanford Nanofabrication Facility (SNF) which is a state-of-the-art, shared-equipment, open-use resource in the heart of Stanford campus (http://snf.stanford.edu/). Most wafers are silicon or silicon-on-insulator (SOI) wafers but processing is also possible using quartz or glass wafers. The standard size is 4” but new machines for 6” wafers are being installed.

The optical MEMS fabrication capabilities of SNF are summarized below. Contact Olav Solgaard through the SPRC office/web page for detailed information about the fabrication equipment and for access to the facility.

SPRC optical MEMS fabrication capabilities:
1. optical lithography
2. thin film deposition by chemical vapor deposition (CVD)
3. oxidation and annealing
4. metallization and sputtering
5. dry etching
6. wet etching

Optical lithography
In addition to automatic and manual coating resist spinners (Headway, Laurell and SVG), the SNF has contact exposure machines (Karlsuss, EV aligner) as well as steppers (Nikon, Ultratech).

Thin film deposition by chemical vapor deposition (CVD)
Low pressure chemical vapor tubes allow deposition of polysilicon, silicon nitride, silicon germanium, low temperature oxide (LTO) either undoped or doped with phosphorus (BPSG).

Oxidation and annealing
Atmospheric horizontal tubes (Tylan) are used for oxidation, doping, and annealing heat treatment.

Metallization and sputtering
Several sputtering machines or evaporators (Gryphon, Innotec, Metallica, SCT) can be used to deposit gold, aluminum or other standard microelectronics metals.

Dry etching
Dry etchers is mostly used to perform anisotropic etching. Many machines (AMT, Drytek, Plasma Quest,...) with an extended library of process recipes gives a wide choice that can be tailored to the specific fabrication process in development.
Two Deep Reactive Ion Etchers (DRIE) are available in SNF. They allow researchers to etch vertically deep into the wafers, which is common when fabricating optical microsystems.

Wet etching
Anistropic etchants such as KOH or TMAH can be used at a wetbench to define optical quality mirror surfaces with anisotropic etching.
Cleaning processes before going into a furnace or a lithography step can be performed at these wet benches too.

Characterization tools
The material properties can be tested inside SNF using, among other measurement tools, an ellipsometer, non-contact spectrophotometers or surface profilometers.
2013 Speaker Abstracts & Biographies

in order of presentation
Welcome Remarks

Anton Muscatelli, University of Glasgow

Anton Muscatelli is a graduate of the University of Glasgow who began his post as Principal on 1 October 2009. Anton Muscatelli studied at the University, where he graduated MA in Political Economy and with a PhD in Economics. He was a lecturer in Economics from 1984 and Daniel Jack Professor of Economics from 1992 until 2007. He was Dean of the Faculty of Social Sciences, 2000 to 2004, and Vice-Principal (Strategy, Budgeting and Advancement) from 2004 until 2007. He then moved to Heriot-Watt University where he was Principal and Vice-Chancellor from 2007 to 2009.
Shining intense, ultrashort laser pulses on the surface of a crystalline silicon wafer drastically changes the optical, material and electronic properties of the wafer. The process has two effects: it structures the surface and incorporate dopants into the sample to a concentration highly exceeding the equilibrium solubility limit. This femtosecond laser "hyperdoping technique" enables the fabrication of defect- and bandgap engineered semiconductors, and laser texturing further enhances the optical density through excellent light trapping. Hyperdoped silicon opens the door for novel photodectors and for Earth-abundant, semiconductor-based solar energy harvesters with the potential for both low cost and high photoconversion efficiency. The material has found applications in highly sensitive imaging detectors and arrays.

**Eric Mazur** is the Balkanski Professor of Physics and Applied Physics at Harvard University and Area Dean of Applied Physics. An internationally recognized scientist and researcher, he leads a vigorous research program in optical physics and supervises one of the the largest research groups in the Physics Department at Harvard University. Dr. Mazur has made important contributions to spectroscopy, light scattering, the interaction of ultrashort laser pulses with materials, and nanophotonics.

In 2008 Mazur received the Esther Hoffman Beller award from the Optical Society of America and the Millikan Medal from the American Association of Physics Teachers. Dr. Mazur is a Member of the Royal Academy of Sciences of the Netherlands. He holds a honorary doctorate from the University of Montreal and the École Polytechnique de Montréal. He holds honorary professorships at the Institute of Semiconductor Physics of the Chinese Academy of Sciences, the Beijing Normal University, and the Beijing University of Technology, and has held appointments as Visiting Professor or Distinguished Lecturer at Princeton University, Vanderbilt University, the University of Leuven in Belgium, National Taiwan University in Taiwan, Carnegie Mellon University, and Hong Kong University.

Mazur holds numerous patents and has founded several companies. One of them, SiOnyx, is SiOnyx is commercializing a patented semiconductor process, discovered in Mazur's lab, that dramatically enhances the infrared sensitivity of silicon-based photonics. Another, Learning Catalytics, a company developing a software platform for interactive teaching, was recently acquired by Pearson.

In addition to his work in optical physics, Dr. Mazur is interested in education, science policy, outreach, and the public perception of science. He believes that better science education for all -- not just science majors -- is vital for continued scientific progress. Dr. Mazur's teaching method has developed a large following, both nationally and internationally, and has been adopted across many science disciplines.
Turntable Ultrafast Responses in Graphene

Feng Wang, UC Berkeley

It has been shown that linear optical properties in graphene can be varied with electrostatic gating and layer-layer interactions. In this talk, I will discuss how the ultrafast responses can be tuned in monolayer and bilayer graphene. I will show that transient conductivity from hot carriers in monolayer graphene can change sign upon electrical gating, corresponding to a transition from metal-like to semiconductor-like behavior. I will also discuss transient infrared transmission through dual-gated-bilayer graphene when a tunable band gap is opened.

Professor Feng Wang leads the Ultrafast Nano-Optics Group at UC Berkeley. They are interested in light-matter interaction in condensed matter physics, with an emphasis on novel physical phenomena emerging in nanoscale structures and at surfaces/interfaces.
Separating Electronic and Structural Phase Transitions in VO$_2$ with THz-Pump X-Ray Probe Spectroscopy

Alexander Gray, Stanford Institute for Materials and Energy Sciences, Stanford University and SLAC National Accelerator Laboratory

The electric-field control of conductivity in strongly-correlated oxides is currently considered to be one of the most promising avenues towards realizing next-generation energy-efficient electronic devices. We demonstrate that an ultrafast insulator-to-metal transition in thin epitaxial vanadium dioxide film can be induced by an intense electric-field pulse from a terahertz laser, and investigate the femtosecond-scale lattice and electronic structure dynamics of such electric-field-induced transition using LCLS-based time-resolved hard x-ray diffraction and THz-pump IR-probe measurements. The results reveal vastly different characteristic timescales for the electric-field-induced electronic structure switching happening virtually simultaneously with the sub-picosecond-scale THz pulse, in contrast with a much slower structural-transition dynamics occurring on tens-of-picoseconds timescale. Evidence of the transient conducting monoclinic phase is observed during the first few picoseconds following the THz pulse, suggesting that pure electronic-structure switching of conductivity in strongly correlated oxides may be possible without energy-dissipative lattice transformations, which has a far-reaching impact on future energy-efficient electronic devices utilizing ultrafast electronic switching. Alex Gray is a research associate at SLAC National Accelerator Laboratory. His research interests include ultrafast nanoscale electron and spin dynamics, and the development of new x-ray photoemission techniques for studies of buried layers and interfaces.

Alexander Gray received his doctoral degree from the University of California Davis in 2011. While working in Chuck Fadley’s research group at Davis and at the Lawrence Berkeley National Laboratory, he has developed two new photoemission-based techniques for studying electronic structure of buried layers and interfaces – hard x-ray angle-resolved photoemission and standing-wave angle-resolved photoemission. For his achievements in the field he was recently awarded the Young Scientist Award by the SPring-8 Japanese National Synchrotron Radiation Lightsource, and the Margaret Burbidge Award for Best Experimental Research by the American Physical Society. Currently, Dr. Gray is working at the Stanford Linear Accelerator Center in the research group of Joachim Stöhr and Hermann Dürr, investigating ultrafast dynamics of the metal-to-insulator transitions in correlated oxides with freeelectron laser techniques.
Recent Advances in Laser Acceleration of Particles

Chan Joshi, UCLA

I will explain why future particle accelerators may be powered by lasers rather than microwaves and then describe different techniques that can be used to transfer energy from laser photons to free electrons. I will then present latest results on one particular laser particle accelerator scheme that uses plasma as an intermediate medium to efficiently couple the laser power to the accelerating electrons.

Professor Chan Joshi is currently a Distinguished Professor of Electrical Engineering at UCLA and a pioneer in the field of laser-plasma acceleration of charged particles.
Electron Acceleration in a Laser-Driven Dielectric Micro-Structure

Edgar Peralta, Stanford University

We report the first observation of high-gradient acceleration of electrons in a lithographically fabricated micron-scale dielectric optical accelerator driven by a mode-locked Ti:sapphire laser. The observed acceleration gradients far exceed those of conventional microwave accelerator structures. Additionally, we have verified the dependence of the observed acceleration gradient on: the laser pulse energy, the laser-electron temporal overlap, the polarization of the laser, and the incidence angle of the laser. In all cases, we have found good agreement between the observed results, the analytical predictions, and the particle simulations.

Edgar A. Peralta received his B.S. degree in Engineering Physics from Cornell University in 2008. Edgar is currently a graduate student at Stanford in the department of Applied Physics. Edgar’s research focuses on developing Dielectric Laser Accelerator (DLA) micro-structures for charged particle beam manipulation. Edgar is a Stanford H&S Fellow and a Gates Millennium Scholars Fellow.
We report the experimental demonstration of an all-laser-driven Compton x-ray light source. A single high power (100-TW) laser system generates intense laser pulses that are used for both electron acceleration and scattering. The x-rays produced are shown to have beam characteristics that are in some cases similar to, and in other cases different from, conventional sources. The peak brightness is 1,000-times higher, and accelerator gradient is 1,000 times shorter. The x-rays are quasi-monoenergetic (~50% FWHM), tunable (~70 keV to 1 MeV), and predicted to have femtosecond pulse duration. This performance has advantages for several important x-ray radiological applications, in research, medicine, industry, security, and defense. The device can also serve as a test-bed for the experimental study of extreme nonlinear optics and quantum electrodynamics in the highly relativistic regime.

**Dr. Donald Umstadter** studied laser-driven electron accelerators for his physics PhD at UCLA, and then laser generated x-ray sources while a postdoc at AT&T Bell Laboratories. As a professor at the University of Michigan, he used ultra-high-intensity lasers to investigate relativistic nonlinear optics. Dr. Umstadter was appointed Olson Professor in the Physics and Astronomy Department at the University of Nebraska, Lincoln, where he founded the Extreme Light Laboratory, now home of the petawatt-peak-power Diocles laser. He now studies the physics and applications of novel laser-driven hyper-spectral radiation sources. He is a fellow of the American Physical Society.
Beam Control in Micro-Accelerators

Ken Soong, Stanford University

Recent success at SLAC and Stanford has demonstrated the first proof-of-principle of the laser-driven dielectric accelerator concept. While this is a momentous occasion, the road to a complete particle accelerator-on-a-chip is still an arduous journey. In this talk, we will describe our on-going efforts to develop and demonstrate dielectric microstructures for particle beam control and monitoring.

Ken Soong studied physics as an undergraduate at Cornell University where he won the Kieval Prize in Physics. He received his master of science in applied physics at Stanford University and is currently completing his doctorate as a Stanford Graduate Fellow, as well as a Siemann Graduate Fellow. He is currently working under Professor Robert L. Byer at both Stanford University and SLAC National Accelerator Laboratory. His research focuses on advanced accelerator concepts, specifically laser-driven particle acceleration in dielectric micro-structures. His accomplishments include the world-first demonstration of direct laser-driven acceleration and the conception of a sub-nanometer resolution beam position monitor.
Recent Results in Differential Phase Contrast Imaging

Rebecca Fahrig, Stanford University

Abstract unavailable

Rebecca Fahrig is an Associate Professor of Radiology and, by courtesy, of Bioengineering at Stanford University. Her areas of interest include MRI techniques, interventional MRI, rapid MR imaging, motion corrected MRI, and reduction MRI.
Differential Phase Contrast Imaging for Aviation Security Applications

Max Yuen, Stanford University

X-ray Differential Phase Contrast Imaging (X-ray DPC) allows the measurement of the real and imaginary part of the refractive index by the application of Talbot-Lau interferometry with three x-ray gratings. This allows for a greater contrast between materials with similar x-ray attenuation coefficients with the additional bonus that the dark field signal can be recovered from a DPC experiment. We present the results for the measurement of the real and imaginary part of the index of refraction of 30 liquids and powders and sort them using Principal Component Analysis. Future experiments would be adapted to identify liquids in containers obscured by clutter in the baggage examination scenario.

Max Yuen is a Ph.D. candidate in Dept of Applied Physics under the direction of Prof. Lambertus Hesselink. He graduated with a BS Applied Physics from Caltech in 2001. His research interests currently include x-ray differential phase contrast imaging and computed tomography fractal apertures for ultrahigh localization of electromagnetic energy application of Nano-apertures to Fluctuation Correlation Spectroscopy single molecule techniques.
Structured Illumination and Compressive X-ray Tomography

David Brady, Duke University

Coding and sampling strategies for x-ray imaging allow substantial reduction in exposure and scatter noise while also enabling molecular imaging.

David J. Brady is the Michael J. Fitzpatrick Endowed Professor of Photonics at Duke University, where he leads the Duke Imaging and Spectroscopy Program, which builds computational imaging systems. Current DISP projects focus on snapshot gigapixel photography using multiscale optics, x-ray scatter tomography, millimeter wave diffraction tomography, focal tomography and compressive spectral imaging.
Photoelectron X-Ray Source Array

Yao-Te Cheng, Stanford University

X-ray differential phase contrast (DPC) imaging has potential for better material discrimination in medical and aviation security applications. However, several obstacles prevent it from being able to use high X-ray energy for higher transmission in dense materials. We are developing an optically driven X-ray source, which is capable of X-ray source patterning, better DPC imaging contrast and better field of view as well as more energy and cost efficiency. We have demonstrated a proof-of-concept X-ray source using a CsBr coated metal photocathode driven with an inexpensive 405 nm laser diode.

Yao-Te Cheng is a Ph.D. student in the Hesselink group at Stanford University. He defended his Ph.D. thesis on nanoscale photoemission in 2013. He is currently developing a novel X-ray source based on photocathodes.
The concentrating photovoltaic (CPV) industry is expected to be the fastest growing segment within solar through at least 2020. CPV has two levers to drive down the cost of energy: concentration and increases in solar cell efficiency. The efficiency of a solar cell in a CPV system has a very large impact on that system’s energy production costs.

Current silicon and thin film technologies see annual efficiency gains measured in tenths of a percent. CPV systems use multi-junction III-V solar cells where efficiency increases come from improvements in material quality and from new cell architectures. The typical commercial multi-junction cell used in many CPV systems today has an average efficiency of about 39%. However, calculations have shown that it may be possible to extend practical multi-junction cell efficiencies to 50% (and possibly beyond), an 11% absolute efficiency gain over today’s products, if materials with other bandgaps are used and the number of junctions is increased.

Commercially available triple-junction solar cells utilize a combination of InGaP, InGaAs, and Ge based junctions and has a well-known efficiency limitation of ~40%. Higher efficiencies can be achieved by changing the effective bandgaps of the junctions, but the selection of materials and approaches to do so is very limited. Solar Junction has adopted the dilute nitride material system to obtain these new bandgaps and smash the 40% efficiency barrier. The unique and powerful advantage of dilute nitrides is that the bandgap can be tuned and varied while maintaining lattice-matched conditions to Ge or GaAs. The dilute nitride technology in Solar Junction’s first commercial product has enabled a significant improvement in efficiencies by using the optimal set of bandgaps. Commercial Solar Junction concentrator cells with efficiencies of 44.1% have been independently verified by NREL and Fraunhofer. These higher efficiencies are generally the result of higher output voltage, not higher current, which keep system-level resistive wiring losses in check. This has led to significant CPV system improvements with several customers setting records. In addition the dilute nitride material system enables a roadmap to 50% and Solar Junction has demonstrated the world record for 4 and 6 junction devices.

**Dr. Homan Yuen** co-founded Solar Junction in 2007 and is currently Vice President and a member of the Board of Directors. He brings over a decade of corporate and financial strategy, management, intellectual property, and technical experience to Solar Junction and leads the efforts on production of the world’s most efficient solar cell. On the technical front, he has years of experience in materials deposition and device physics for a wide range of applications including solar cells, optoelectronics, silicon photonics, and CMOS electronics. He received his Ph.D. in Materials Science & Engineering from Stanford University for developing the dilute nitride material system for semiconductor laser diodes. Homan also has an M.S. in Electrical Engineering from Stanford University and a B.A in Physics from the University of California at Berkeley. Prior to Solar Junction, Homan held a senior research position at Translucent Inc. developing rare-earth oxide films. He has over 13 years of experience in materials science and device technology with over 50 technical publications, 15 patent filings, and numerous invited speaking engagements.
High-Efficiency and Stretchable Polymer OLEDs

Qibing Pei, UCLA

Indium tin oxide coating on glass (ITO/glass) has been ubiquitously employed as the transparent conductor for optoelectronic devices including organic light emitting diodes (OLEDs). I will present our efforts in develop a polymer composite to provide high surface conductivity and visual transparency. The mechanical properties of the composite are determined by the polymer matrix employed, and ranges from being rigid to flexible and elastomeric. Polymer OLEDs fabricated on the composite exhibit higher current efficiencies than control devices on ITO/glass. OLEDs having a simple three-layer sandwich structure: two composite electrodes sandwiching an emissive polymer layer can be deformed by greater than 30% linear strain without damaging the electroluminescent property. Such (almost) all polymer OLEDs could be fabricated in a solution-based process at ambient conditions.

Qibing Pei is Professor of Materials Science and Engineering at the University of California, Los Angeles. He specializes in organic electronic materials, polymer light emitting diodes, electromechanically transducing polymers and devices, with over 120 peer-reviewed journal publications. He is the inventor or co-inventor of 39 issued US patents. His current research activities include synthesis of conjugated polymers, stretchable polymer electronics, nanostructured composites, and dielectric elastomers for actuation and power generation. Dr. Pei received a B.S. degree from Nanjing University, China, and a PhD from the Institute of Chemistry, Chinese Academy of Science, Beijing. He was a postdoctoral scientist in Linköping University, Sweden, a senior chemist at UNIAX Corporation (now DuPont Display), Santa Barbara, and a senior research engineer at SRI International, Menlo Park, California. He has been on the UCLA faculty since 2004.
Materials Make the PV Module

Homer Antoniadis, Du Pont

The efficiency, lifetime and overall system costs for photovoltaic (PV) modules are driven in large part by the materials specified in their production. Advanced materials are more important than ever in helping today’s solar cell and module manufacturers differentiate their products with superior power output and longer life performance that deliver increased investment rates of return to PV system owners and financiers. Under the current climate of increasing cost pressures, module producers – even some of those deemed “bankable” – are considering, and sometimes taking, shortcuts to substitute unproven materials to help manage short-term costs. Poor material selection presents a significant risk not only to module performance, but also to the quality and reputation of module manufacturers. Ultimately, this has the potential to jeopardize the credibility of the entire PV industry at this critical time in its development.

The presentation will concentrate on DuPont™ PV materials that are being adopted by the majority of the PV industry today. More specifically the successful adoption of Lightly Doped Emitter (LDE) c-Si cell architectures based on the most recent DuPont™ Solamet® metallization platform will be described together with the proven PV field data for DuPont™ Tedlar® based backsheets that extends module lifetime.

Dr. Homer Antoniadis is the global technology director for DuPont Photovoltaic Solutions responsible for accelerating the introduction of next-generation DuPont materials into the solar energy market. He joined DuPont in 2011 with the acquisition of Innovalight, Inc., where he was Chief Technology Officer & VP of Engineering. Prior to Innovalight, his 20-year career included positions with Osram Opto Semiconductors, Hewlett-Packard Labs and Xerox.

Widely recognized in the PV industry, he regularly serves as a lecturer and conference chair at leading industry events. Dr. Antoniadis has more than 60 publications in crystalline and amorphous silicon photovoltaics, OLEDs, and polymer materials and has 25 issued U.S. patents. He earned a B.S. in Physics from Ioannina University in Greece and his Ph.D. in Physics from Syracuse University.
Gravity from the Cradle to the Grave

James Hough, University of Glasgow

My talk will give a personal perspective on the excitement of devising and applying precision measurement techniques in a challenging field – the search for Gravitational Radiation.

Jim Hough is a graduate of the University of Glasgow where he became Professor of Experimental Physics in 1986 and is currently the emeritus holder of the Kelvin Chair of Natural Philosophy. JH has been Director of the University's Institute for Gravitational Research from 2000 to 2009, is now CEO of the Scottish Universities Physics Alliance and the initiator and director of the first International Max Planck Partnership worldwide. This partnership, between five Scottish Universities and five Max Planck Institutes in Germany, is centred on Observation and Measurement at the Quantum Limit and is planned to boost the academic and innovative impact of Scottish Physics in the area of quantum measurement and information.

Research interests are centered on laser instrumentation and delicate mechanical systems as applied to Gravitational Wave Detection on ground (GEO 600 in Germany and Advanced LIGO in the USA) and in space (eLISA).

A JILA Fellow in 1983 he was, along with Karsten Danzmann, winner of a Max-Planck research prize in 1991, was elected to the Royal Society of Edinburgh in 1991 and to the Royal Society of London in 2003, was awarded the Duddell Prize of the Institute of Physics in 2004 and the Gunning Victoria Prize lectureship of the Royal Society of Edinburgh in 2008. He was elected to Fellowship of the Institute of Physics in 1993 and of the American Physical Society in 2001, and was awarded Fellowship of the International Society for General Relativity and Gravitation in 2010, and Fellowship of the Royal Society of Arts in 2012.
Optical and Electronic Approaches to Restoration of Sight to the Blind

Daniel Palanker, Department of Ophthalmology and Hansen Experimental Physics Laboratory, Stanford University, Stanford, CA

Retinal degenerative diseases lead to blindness due to loss of the “image capturing” photoreceptors, while neurons in the “image-processing” inner retinal layers are relatively well preserved. Information can be reintroduced into the visual system using electrical stimulation of the surviving inner retinal neurons. Some electronic retinal prosthetic systems have already been tested in human patients and approved for clinical use, while more advanced technologies are being developed. Alternatively, light sensitivity can be artificially introduced into retinal neurons using optogenetic or pharmacological methods. Several optogenetic approaches have been successfully tested in animal models of retinal degeneration. I will review the current state of art with each of these approaches, their challenges, technological solutions and perspectives of restoration of sight to the blind.
Characterization of novel transcripts in pluripotent stem cells using mRNA reprogramming in combination with single-cell gene expression analysis

Jens Durruthy-Durruthy, Stanford University

Nuclear reprogramming is complex, dynamic and likely to follow a specific set of sequential events involving epigenetic changes combined with the conversion of an entire transcriptional network. The pioneering work of Prof. Shinya Yamanaka has shown that four key transcription factors - OCT3/4, SOX2, KLF4, cMYC - are sufficient to promote reprogramming into induced pluripotent stem cells (iPSCs), functionally equivalent to Embryonic Stem Cells (ESCs). Since then, additional factors and chemical inhibitors have been shown to play pivotal roles during such process and to facilitate the conversion from a differentiated to that of an undifferentiated state.

Here, we investigate a number of transcripts, expressed by novel and non-annotated gene loci, that we found specifically expressed by pluripotent stem cells. By using in vitro transcribed modified mRNAs we reprogrammed somatic cells into iPSCs. Using high-throughput single-cell gene expression analysis we profiled 76 genes including the novel transcripts at various stages during the reprogramming process. Activation of expression of novel factors was detected late during reprogramming (day 10 – 12) or in fully reprogrammed iPSCs. Correlation and network analysis suggest that a subset of novel transcripts play a crucial role in establishing the pluripotency network and maintaining the undifferentiated state.

Jens Durruthy-Durruthy is a second year graduate student in Dr. Renee Reijo-Pera's lab. Originally from Germany, he started as a Visiting Researcher at Stanford to complete his Master Thesis in Developing and Optimizing integration free iPSCs using modified mRNAs. He primarily focuses on molecular mechanisms behind nuclear reprogramming. Using single cell analysis and information obtained regarding normal human embryonic development he seeks to shed light on molecular key events in the transition from a somatic differentiated cell into a pluripotent cell type.
Generation of induced pluripotent stem cells (iPSCs) is a novel technology with the great potential to revolutionize medicine. While iPSCs have already been widely used for drug screening and disease modeling, little is known about the mechanism of this cellular reprogramming. The low efficiency and the heterogeneity of this de-differentiation process have hampered further molecular analysis. To overcome this problem, we took a strategy called ‘secondary reprogramming’. Briefly, using mouse embryonic fibroblasts (MEFs), we first generated an iPSC line with random integration of a piggyBac transposon carrying a doxycycline (dox)-inducible polycistronic reprogramming factors (c-Myc, Klf4, Oct4, Sox2 linked with 2A-peptides = MKOS). This iPSC line was used to generate MEFs (secondary MEFs) which can reprogram upon addition of dox. This strategy enabled us to achieve more homogeneous reprogramming factor induction. In combination with novel cell surface markers, CD44 and ICAM1, and a pluripotency marker Nanog-GFP reporter, we demonstrate that reprogramming progresses in a step-wise manner and the behavior of each intermediate subpopulation is predictable. RNA-sequencing analysis of these populations demonstrates two waves of pluripotency gene upregulation, and unexpectedly, transient upregulation of several epidermis-related genes, demonstrating that reprogramming is not simply the reversal of the normal developmental processes. This novel high-resolution analysis enables the construction of a detailed reprogramming route map, and the improved understanding of the reprogramming process will lead to new reprogramming strategies.

Keisuke Kaji obtained a PhD degree in Tokyo Institute of Technology, Japan, and joined Dr Brian Hendrich’s lab in Institute for Stem Cell Research (ISCR), University of Edinburgh, UK, in 2003. In this group, he discovered that Mbd3, a component of the NuRD co-repressor complex, is required for ES cell differentiation (Kaji, et al., Nature Cell Biol, 2006) and important for the development of pluripotent cells in peri-implantation embryos (Kaji, et al., Development, 2007). In January 2008, he started his own group in ISCR and succeeded in making a non-viral single vector reprogramming system, which has been applied to both mouse and human cells using the piggyBac transposon in collaboration with Prof. Andras Nagy in Toronto (Kaji, et al., Nature, 2009, Wolljen, et al., Nature, 2009). These works have been cited over 800 times since 2009. In 2010, He was awarded a prestigious European Research Council (ERC) starting grant to investigate molecular mechanisms of reprogramming and expand his research group in the MRC centre for regenerative medicine. In 2013, his group demonstrated that reprogramming of mouse embryonic fibroblasts is not simply the loss of fibroblastic genes and gain of pluripotency genes, but also includes transient up- and down-regulation of unexpected genes including multiple epidermis genes. The findings published in Nature also demonstrated for the first time that generation of iPSCs does not take simply a reversal route of normal development process.
Neurology and Stem Cells

Alex Shcheglovitov, Stanford University

Induced pluripotent stem cells (iPSCs) hold great promise for improving our understanding of complex human genetic disorders. The major advantage of iPSCs is that they can be generated from accessible somatic cells of patients and can be differentiated into cell types that are difficult or impossible to obtain. We differentiated iPSCs into functional forebrain neurons and used iPSC-derived neurons to investigate cellular and molecular phenotypes associated with 22q13 deletion syndrome. In my presentation, I will describe the methodology we used to study functional properties of iPSC-derived neurons and the phenotypes we detected in neurons derived from patients.

Alex Shcheglovitov received his bachelor degree in applied physics and master in biophysics from the Department of Physics and Technology at the National Technical University of Ukraine. He earned his PhD in biophysics from the Bogomoletz Institute of Physiology, Kyiv, Ukraine in 2002. He studied the biophysical and pharmacological properties of voltage-gated calcium channels. Alex spent two years as postdoctoral research associate at the University of Virginia, where he investigated structural-functional properties of voltage-gated calcium channels. Currently, he is a postdoctoral research associate in the Departments of Neurobiology at Stanford University. The main goal of his project is to characterize cellular phenotypes associated with 22q13 deletion syndrome using neurons derived from induced pluripotent stem cells of patients with this disorder.
Definitive Genetic Therapy for Inherited Disorders

Tony Oro, Stanford University

Advances in stem cell biology and the pathways that regulate tissue stem cells have led to an deepening of our understanding how the body can repair and regenerate itself, as well as the cancers that form when key stem cell pathways are expressed inappropriately. Increasingly these insights have translated into novel regenerative medicine using small molecules or cell based therapies. New approaches important for correction of genetic mutations in stem cell populations allow the promise of definitive genetic therapy for inherited skin diseases like Epidermolysis bullosa.

Dr. Anthony Oro is a Professor of Dermatology and a member of the Institute for Stem Cell Biology and Regenerative Medicine and the Stanford Cancer Institute at Stanford University. He trained in the medical scientist program at the Salk Institute under Ron Evans lab, working on functions of novel orphan nuclear receptors in model systems. During Dermatology residency/fellowship in Matthew Scott’s lab at Stanford, he helped solidify the link between the hedgehog pathway and human cancer. In his own lab in the Program in Epithelial Biology at Stanford, Dr. Oro has extended the original studies focusing on the role of skin stem cells to understand in tissue regeneration and carcinogenesis. He has a longstanding interest in the mechanisms of hedgehog signaling in hair follicle regeneration, and in the pathogenesis of the most common human tumor, basal cell carcinoma of the skin. He has continued his interest in the mechanisms of human skin development and early ectodermal differentiation by developing in vitro human skin differentiation from embryonic stem cells with the goal of producing corrected human epidermal sheets from patient-specific iPS cells.
Non-invasive intravital imaging of stem cell differentiation with a bright red-excitible fluorescent protein

Michael Z. Lin, Stanford University

Non-invasive imaging of cell populations in animal disease models would greatly facilitate the development of cell-based therapies. Optical imaging of fluorescent proteins (FPs) that can be excited by red light in the “optical window” above 600 nm is one potential method for tracking implanted cells. However, previous efforts to engineer FPs with peak excitation beyond 600 nm have resulted in undesirable reductions in brightness. I will discuss the engineering and application of mCardinal, a new bright red-shifted fluorescent protein with an excitation maximum in the optical window. Using fluorescence macroscopy of mCardinal, we visualize stem cell derivatives in living mice with high anatomical detail, allowing for easy, non-invasive, and longitudinal tracking of muscle regeneration.

Michael Lin received an A.B. degree in Biochemistry summa cum laude from Harvard and an M.D. degree from UCLA. After PhD training in biochemistry with Michael Greenberg at Harvard Medical School, Dr. Lin began research on fluorescent proteins with Roger Y. Tsien at UCSD. In 2009, Dr. Lin was appointed Assistant Professor of Pediatrics and Bioengineering at Stanford and initiated a new research program on engineering fluorescent proteins for in vivo imaging, neuronal activity sensing, and controlling protein activities with light.
Collective endothelial cell migration is required for blood vessel formation, for the regulation of vascular permeability, and for repair following injury. While directional signals guiding collective cell movement are thought to be transmitted mechanically from one cell to another via cell-cell junctions, little is known about how forces applied to the junction locally by one cell are sensed by its neighbor and converted into a signaling output. Using monolayers of primary human umbilical vein endothelial cells (HUVEC) as a model system, we found that endothelial cell-cell junctions were asymmetrically organized with actin-rich, filopodia-like protrusions extending from the rear of migrating cells. 3D-structured illumination fluorescence microscopy (3D-SIM) and field emission scanning electron microscopy (FE-SEM) revealed that these “actin fingers” reached into the cytoplasm of the following cell, where they were anchored to the actin cytoskeleton by junctional VE-cadherin. The highly curved membrane surfaces thus generated were selectively recognized by curvature-sensing BAR domain modules. The negative curvature sensing I-BAR module was enriched at the back of the leading cell, whereas the positive curvature sensing N-BAR module was selectively recruited to incoming actin fingers in the following cell. In search for a regulator that translates asymmetric curvature information present at cell-cell junctions into a signaling output, we identified ARHGAP29, an F-BAR and RhoGAP containing protein, as a critical component of the collective guidance machinery. The F-BAR domain of ARHGAP29 bound specifically to the positively curved surface of actin fingers and ARHGAP29 depleted cells had defects in junctional architecture and collective migration behavior. Therefore, force-induced, asymmetric membrane deformation at the endothelial cell-cell junction serves as a guidance signal by recruiting a curvature-sensing signaling component that locally impacts on RhoGTPase activities.
4Pi Fluorescence Detection and 3D Particle Localization with a Single Objective

Jörg Schnitzbauer, Stanford University

Coherent detection through two opposing objectives (4Pi configuration) improves the precision of three-dimensional (3D) single-molecule localization substantially along the axial direction, but suffers from instrument complexity and maintenance difficulty. To address these issues, we have realized 4Pi fluorescence detection by sandwiching the sample between the objective and a mirror, and create interference of direct incidence and mirror-reflected signal at the camera with a spatial light modulator. Multifocal imaging using this single-objective mirror interference scheme offers improvement in the axial localization similar to the traditional 4Pi method. We have also devised several PSF engineering schemes to enable 3D localization with a single emitter image, offering better axial precision than normal single-objective localization methods such as astigmatic imaging.

Jörg Schnitzbauer studied physics at the University of Konstanz and Freie Universität Berlin in Germany. A visit in the laboratory of Dr. Carlos Bustamante at UC Berkeley to study DNA rotation during viral packaging created his interest in biophysics. Hence, his master thesis in the laboratories of Dr. Ulrike Alexiev (FU Berlin) and Dr. Carlos Bustamante addressed DNA synthesis by primase RepB'. Since 2011, he is pursuing his doctoral work in the laboratory of Dr. Bo Huang at UC San Francisco, developing new tools for super-resolution fluorescence microscopy.
Biomolecule interactions are critical to many biological processes. We developed a general method to follow these processes in vitro with single-molecule resolution in an aqueous environment. Our method is based on the intuitive idea that when a molecule binds or unbinds in solution, its hydrodynamic radius (size) and/or the amount of electric charges are likely to be altered and these changes in physical properties lead to measurable changes in the target molecule’s diffusive and electric-field induced motions in solution. To sense these changes in transport properties, we used a single-molecule electrokinetic trap and developed a statistical learning algorithm to model the fast motion of the molecule in the trap. As an example, we used the method to study the hybridization kinetics of a 10-base ssDNA with its complementary partner and characterize the destabilizing effect of a single-base mismatch.

Quan Wang received his B.S. in physics from University of Science and Technology of China in 2005 and M.S. in Optical Science and Engineering from the University of New Mexico in 2007. He is currently a Ph.D. student in Electrical Engineering at Stanford University, working with Prof. W. E. Moerner on developing new tools to study single molecules in solution.
Bridging the gap: from technological advancements in light microscopy to their use in biological discoveries

Nico Stuurman, UCSF

The last few decades have seen a flurry of advancements in optical microscopy that have dramatically increased resolution, acquisition speed, and enabled quantitative analysis of microscope images. Traditionally, such developments originate in university laboratories and are made available to other scientists through commercial companies that often package technologies in turn-key systems (such as two-photon microscopes, structured illumination microscopes, TIRF microscopes, etc). Although highly useful in many cases, downsides of this system are the long time between invention and commercial availability, lack of commercial availability for many useful inventions, impossibility to modify commercial equipment, and the presence of proprietary components that may influence the outcome of scientific experiments. Our laboratory uses light microscopes for a variety of biological assays and is eager to implement new microscopy technologies. We promote direct transfer of microscopy technologies by providing open source software for microscope image acquisition (Micro-Manager: http://micro-manager.org) and disseminating know-how through courses, both physical and on-line (http://ibioseminars.org).

Nico Stuurman grew up in the Netherlands and studied Chemistry at the University of Amsterdam. He obtained a Ph.D. in Cell Biology at the same University in 1991, based on his studies of the nuclear matrix with Dr. Roel van Driel. He then studied the structure and function of nuclear lamins in Drosophila as a post-doc, first with Paul Fisher at SUNY Stony Brook, and then with Ueli Aebi at the BioZentrum in Basel, Switzerland. Nico was a staff scientist at the University of Leiden from 1997-2001 and then joined the laboratory of Ron Vale at the University of California San Francisco where he combines his interest in computer programming and microscopy in various projects including the Open Source software Micro-Manager (http://micro-manager.org).
Intraoperative optical-sectioning microscopy for guiding brain-tumor resection

Jonathon Liu, SUNY

Our lab is developing optical strategies for biomedical diagnostics and therapy. These endeavors require multi-disciplinary advances in optical devices, contrast agents, image processing, and preclinical/clinical studies. For example, over the past few years, our lab has published on the simulation and development of a miniaturized advanced volumetric microscopy technology to enable real-time point-of-care pathology, as well as the development of a molecularly targeted fluorescent contrast agent to guide tumor resection in the brain. These complementary technologies have the potential to revolutionize patient care by providing surgeons with a real-time alternative to invasive biopsy and frozen-sectioning pathology for confirming the status of tissues at the final stages of surgery. This talk will motivate the need for high-resolution microscopy to guide brain tumor resection and will describe our core imaging technology, the MEMS-scanned dual-axis confocal microscope. Results will be presented from preclinical studies utilizing a mouse model of medulloblastoma as well as preliminary studies with human low-grade gliomas.

Dr. Jonathon Liu was born in Albany, NY and raised in Honolulu, HI, where he attended the Iolani School. He received degrees in mechanical engineering at Princeton University (B.S.E., 1999) and at Stanford University (M.S., 2000 & Ph.D., 2005). Dr. Liu was a postdoctoral fellow in the department of electrical engineering (Ginzton Labs) and the Molecular Imaging Program at Stanford (2005-2009), and was later appointed as an instructor within the Stanford University School of Medicine (2009-2010). Jonathan is currently an assistant professor in the biomedical engineering department at the State University of New York (SUNY) at Stony Brook. He received an award as the top graduate in mechanical engineering at Princeton, an NSF graduate research fellowship, a Canary Foundation / American Cancer Society postdoctoral fellowship, and a K99/R00 career-development award from the NIH. Dr. Liu’s lab develops custom microscopes and endoscopic imaging systems, along with molecularly targeted contrast agents, for diagnosing diseases and for guiding surgical interventions. Lab website: stonybrook.digication.com/liu
Imaging PET radiotracers at the single cell level with radioluminescence microscopy

Guillem Pratx, Stanford University

Molecular imaging with radionuclide probes provides sensitive, quantitative, and non-invasive characterization of molecular disease processes in vivo at a macroscopic scale. However, current imaging technology lacks the ability to visualize the tremendous heterogeneity exhibited by biological processes at the single-cell level. Little is known about the factors that modulate radiotracer uptake by single cells and explain observed cell-to-cell variations.

Guillem Pratx, PhD, is an assistant professor in Radiation Physics at Stanford University. His research efforts are focused on developing more precise and sensitive imaging methods for characterizing biological and molecular processes, either pre-clinically in small animals and cell cultures, or clinically in patients. To this end, his lab has developed several innovative approaches that utilize fundamentally new physical mechanisms to non-invasively interrogate molecular processes in living organisms.
Wide-Field Fluorescence to Guide In-Vivo Microscopy

Steven Sensarn

Miniaturized endoscopes and microscopes, in conjunction with targeted fluorescent molecular probes, offer the potential to locate tumors and confirm surgical margins at the point of care. Towards this goal, we demonstrate cancer detection using a wide-field fluorescence imaging fiberscope in a mouse model of colon cancer and a tissue-phantom model of brain cancer. By scanning the target sites with a dual-axis confocal (DAC) microscope, specific labeling of cancer on the cellular level can be confirmed. We envision endoscopic and surgical tools that combine wide-field and DAC imaging modalities in a miniature form factor compatible with current state-of-the-art clinical devices.

Steven Sensarn is a postdoctoral fellow in the Christopher H. Contag Lab at Stanford. His research interests include fluorescence imaging, microscopy, early cancer detection, and guided resection of cancer during surgery. He completed his Ph.D. in Electrical Engineering under Stephen E. Harris and continues to pursue his passion for optics, physics, and engineering in the realm of biomedical sciences.
Raman Tools for Colon Cancer Detection

Ellis Garai, Stanford University

A novel, opto-electro-mechanical Raman endoscope that has the potential to significantly improve the detection and diagnosis of certain early-stage cancers and inflammatory diseases has been developed. This is a platform technology, which utilizes a panel of targeting surface enhanced Raman scattering (SERS) nanoparticles, each with a uniquely detectable spectral fingerprint, in conjunction with a custom-built Raman fiber-optic device that can be used in combination with any endoscope or laparoscope. The aim is to provide the benefits of real-time diagnostic information during endoscopy or laparoscopy by employing molecular specificity, that build on the white-light imaging that is provided by today’s technology.

Ellis Garai is currently completing his PhD in Mechanical Engineering at Stanford University. Prior to that Ellis was a Fellow in the Stanford Biodesign Innovation Fellowship. Before arriving at Stanford, Ellis worked for Advanced Bionics (acquired by Boston Scientific) as part of the part of the R&D and Emerging Indications team. Ellis has also worked in product development at IDEO as well as Vibrynt, an early stage medical device company that was spun out of a Silicon Valley medical device incubator, ExploraMed. Ellis holds an M.S. in Mechanical Engineering from Stanford University with a focus in mechatronics and medical device design. He graduated summa cum laude from the UCLA with a B.S. in Mechanical Engineering with a concentration in design and manufacturing.
Optics for Future Scaling of Data Centers

Hong Liu, Google

Abstract unavailable

Hong Liu is a Principal Engineer at Google Platform Advanced Technology, where she is involved in the system architecture and interconnect for a large-scale computing platform. Her research interests include interconnection networks, high-speed signaling, optical access and metro design. Prior to joining Google, Hong was a Member of Technical Staff at Juniper Networks, where she worked on the architecture and design of network core routers and multi-chassis switches. Including, Juniper's flagship core router T640, the world's very first OC768 line card and the world's very first switch-matrix, TX640. She received her Ph.D in electrical engineering from Stanford University.
Evolution of Optical Interfaces for Data Centers

Chris Cole, Finisar

The presentation introduces data center links, including technology alternatives. Next, historical evolution of three data center link rates; 10 Gb/s, 40 Gb/s, and 100 Gb/s is presented, including likely future direction of each. Key technical innovations that drove past advances and will drive future advances are described. This includes material systems and modulation formats. Future data rates, 400 Gb/s and beyond, are then discussed and technical approaches required to support them are outlined.

Chris Cole is a Director at Finisar Corp., Sunnyvale, Calif. He received a B.S. in Aeronautics and Astronautics, and B.S. and M.S. in Electrical Engineering from the Massachusetts Institute of Technology. At Hughes Aircraft Co. (now Boeing SDC) and then M.I.T. Lincoln Laboratory, Chris contributed to multiple imaging and communication satellite programs such as Milstar. Later, he consulted on telecom ASIC architecture and design for Texas Instruments DSP Group and Silicon Systems Inc. (now Maxim.) Chris was one of the architects of the Sequoia coherent imaging ultrasound platform at Acuson Corp. (now Siemens Ultrasound), where he also managed hardware and software development groups. As a principal consultant with the Parallax Group he carried out signal processing analysis and product definition for several imaging and communication systems. At BBN, a Finisar acquisition, Chris developed 10 Gb/s and 40 Gb/s optical transceivers. He is now leading the development of 40 Gb/s, 100 Gb/s and 400 Gb/s optical standards and transceivers. He is a Senior Member of the IEEE.
Hybrid Datacenter Networks with Microsecond Optical Circuit Switches

George Papen, UCSD

We report on the development of a complete hybrid network for Data center applications that consists of a standard electrical packet-switched network and a parallel optical circuit-switched network that has a reconfiguration time of 11 microseconds. We discuss the design of the optical circuit switch and the challenges of implementing a reactive control plane that can control both types of networks.

George Papen joined the UCSD faculty in September 2002 from a full professorship at the University of Illinois at Urbana-Champaign. He arrived at UIUC in 1989 after earning his Ph.D. in Electrical and Computer Engineering from the University of Wisconsin. He has been actively involved in professional associations, and chaired recent conferences including the OSA Optical Remote Sensing Conference and High Speed Interconnects within Digital Systems conference, both in 2001. He is a co-holder of three patents.
Overview of the National Photonics Initiative

Thomas Baer, NPI Committee Chair

In 1998, the National Research Council released a report, "Harnessing Light: Optical Science and Engineering for the 21st Century," that presented a comprehensive view of the potential impact of optics and photonics on important industries. In response, several economies — including Germany, China, and the European Union — advanced their already strong optics and photonics sectors. The United States, however, did not develop a cohesive strategy, leaving us at risk of falling sharply behind.

In 2012, the National Research Council released a follow-up report to Harnessing Light - titled "Optics and Photonics: Essential Technologies for our Nation" - that called for an umbrella organization to identify and advance areas of photonics critical to maintaining competitiveness and national security. Heeding the call five organizations – the Optical Society (OSA); SPIE, the international society for optics and photonics; the IEEE Photonics Society (IPS); the Laser Institute of America (LIA); and the American Physical Society (APS) Division of Laser Science – worked together to form a National Photonics Initiative (NPI).

The NPI brings together experts from industry, academia and government to assemble recommendations that will help guide US funding and investment in five key photonics-driven fields: advanced manufacturing, communications & IT, defense & national security, energy and health & medicine. New opportunities in these fields — including solar power, high-efficiency lighting, genome mapping, high-tech manufacturing, nuclear threat identification, cancer detection and new optical capabilities vital to supporting the Internet’s growth — offer the potential for even greater societal impact in the next few decades. US investment in photonics will grow our economy, protect and improve the lives of our people, and position the United States as a global technology leader.

Dr. Thomas Baer is the Executive Director of the Stanford Photonics Research Center, a consulting professor in the Applied Physics Department, and an Associate Member of the Stem Cell Institute at Stanford University. His current scientific research is focused on developing imaging and biochemical analysis technology for exploring the molecular basis of human developmental biology and developing new technologies for protein engineering. Throughout his career Dr. Baer has been extensively involved with startup companies in Silicon Valley using lasers, quantum electronics, and biomedicine. Dr. Baer holds over 60 patents and his commercial products have received many industry awards for design innovation. He has been elected to the status of Fellow in two international scientific societies, the American Association for the Advancement of Science and The Optical Society of America (OSA) and served as the President of OSA in 2009. In 2012 he received an honorary Doctor of Science degree from Heriot Watt University in Edinburgh, Scotland and was awarded the Robert E. Hopkins Leadership Award by the Optical Society of America.
Lasers in Smart Phone Manufacturing – enabling the mobile revolution

Magnus Bengtsson, Coherent

Lasers have played a critical role in enabling advanced manufacturing processes crucial to the miniaturization of consumer electronics devices such as smart phones. An overview of laser processes in smart phone manufacturing will be presented, with special emphasis on flat panel and advanced packaging applications.

Magnus Bengtsson is the Director of Strategic Marketing at Coherent. He earned his M.Sc in Engineering Physics, at Lund University, Sweden and is a 17 year laser industry veteran, with senior positions in sales and marketing at leading laser and photonics companies.
Finding the right laser parameters for processing a particular material is often a lengthy process requiring evaluation of many different lasers. To make matters worse composite materials can require a different laser recipe or even a different laser for each material in the composite. Laminate microelectronics materials have vastly different laser parameter requirements for each material layer, making effective processing with a single laser difficult. In the case of thin films, often the distribution of energy within a single pulse has a profound impact on the resulting laser process. In this presentation we demonstrate “on the fly” switching of laser parameters to optimally process different PCB materials. We also demonstrate novel pulse duration and pulse shape dependant material interactions. Finally we show novel ways to use dynamic pulse control to gain insight into the physics of the laser material interaction.

Mathew Rekow has been applications laboratory manager with EOlite lasers (a subsidiary of ESI) since 2009. He has 20 years of experience in the laser and optics industry including co-founding Corelase OY, 8 years at Coherent Laser in product development, and 4 years in thermal imaging at Fluke Electronics. He holds a BS in physics and electrical engineering from the U. of Idaho and currently also a graduate student in Materials Engineering at Colorado State U.
Atom Trap, Krypton-81, and Global Groundwater

Zheng-Tian Lu, Argonne National Laboratory

The long-lived noble-gas isotope $^{81}$Kr is the ideal tracer for old water and ice in the age range of $10^5$ – $10^6$ years, a range beyond the reach of $^{14}$C. $^{81}$Kr-dating, a concept pursued over the past four decades by numerous laboratories employing a variety of techniques, is now available for the first time to the earth science community at large. This is made possible by the development of an atom counter based on the Atom Trap Trace Analysis (ATTA) method, in which individual atoms of the desired isotope are selectively captured and detected with a laser-based atom trap. ATTA possesses superior selectivity, and is thus far used to analyze the environmental radioactive isotopes $^{81}$Kr, $^{85}$Kr, and $^{39}$Ar. These three isotopes have extremely low isotopic abundances in the range of $10^{-16}$ to $10^{-11}$, and cover a wide range of ages and applications. In collaboration with earth scientists, we are dating groundwater and mapping its flow in major aquifers around the world. This work is supported by DOE, Office of Nuclear Physics, under contract DE-AC02-06CH11357.

Zheng-Tian Lu is a Senior Scientist in the Physics Division of Argonne National Laboratory and a Professor (part-time) in the Physics Department of The University of Chicago. He received a B.Sc. from the University of Science and Technology of China in 1987, and a Ph.D. from the University of California at Berkeley in 1994. He was a postdoc at JILA prior to joining Argonne in 1997. Throughout his career, Lu has been developing techniques of laser manipulation and laser spectroscopy of atoms, and applying these techniques to ultrasensitive trace analysis, studying nuclear structure, and testing fundamental symmetries. He received a PECASE award in 2000, was elected a Fellow of APS in 2006, and received the Society’s Francis M. Pipkin Award in 2009. He currently serves on the U.S. Nuclear Science Advisory Committee.
New Adventures in Optical Spectroscopy: High Performance Molecular and Stable Isotope Analysis in the Great Outdoors

Chris Rella, Picarro

Recent advances in optical methods of molecular analysis, such as cavity ringdown spectroscopy, have enabled scientists to perform laboratory-quality molecular analysis in the field, opening new avenues for research. The capabilities of these new optical techniques are discussed in the context of atmospheric measurements of fugitive methane emissions in natural gas production basins.

Chris Rella is a Research Fellow at Picarro, Inc., a manufacturer of gas analysis equipment based on cavity ringdown spectroscopy. His research focuses on spectroscopic techniques for molecular analysis, especially atmospheric measurements. He received his Ph. D. in Physics from Stanford University in 1996.
Airborne Precision Laser Sensing for Atmospheric Research

Dirk Richter, University of Colorado, Boulder

Today’s photonics tool chest is filled with key enabling components to build a range of high performance sensing systems applicable to atmospheric research. This talk will discuss examples of laser based instruments developed and applied for airborne atmospheric research, illustrating the advances, challenges, and integration of lasers, and linear and non-linear optical (fiber) components. Combined with an appropriate spectroscopic technique, a number of valuable and highly precise measurements including trace gases, aerosols, and wind, are being made. Examples of recent airborne campaigns will be presented.

Dirk Richter received his Ph. D. from Rice University, Houston, Texas in 2001 under direction of Prof. Frank K. Tittel. He was a Postdoc at the National Center for Atmospheric Research (NCAR) in 2001–2002. Dr. Richter co-established the Analytical Photonics and Optoelectronics Laboratory as one of the first appointed ladder research engineers at NCAR. Together with colleagues he pioneered the successful deployment of airborne DFG laser spectrometers with the highest spectroscopic performance reported for any non-laboratory technique. In 2012, Dr. Richter joined the Institute of Arctic and Alpine Research (INSTAAR) at the University of Colorado in Boulder

He is (co-)author of over 40 refereed publications, including two book chapters, has given more than 10 invited talks, and authored two patent applications. Dr. Richter is member of the Optical Society of America and has been past President of the Rocky Mountain Section of the Optical Society of America.
Advances in Digital Photography

Dave Henry, Canon USA

Abstract unavailable

Dave Henry has been a professional photographer for over 30 years and is an early adopter of digital photography. He began with Photoshop - Version 1 in 1991.

His early career in photography found him working for industry leaders Minolta, Leica and Canon. He's been shooting Canon since he joined the company in 1977. His talent eventually led to a 27-year career as a photographer for the Sacramento Bee.

His freelancing business and career at The Bee has allowed him to cover assignments on five continents and his client list is extensive. His work has been published in newspapers, magazines, and annual reports, on billboards and on-line.

Dave's portfolio includes architectural, advertising, travel and landscape photography. His popular annual Eastern Sierra fall foliage coverage in California has been featured in the newspaper and web site of The Sacramento Bee since 1979 and more recently on television and The Weather Channel.

For well over 30 years Dave has taught seminars and led photography workshops all over the world. He's known for his energetic and warm personal style. He enjoys helping photographers enhance their natural skills and talents.

Dave's hobby is creating stereographic images with 19th century camera equipment and vintage processes.
What’s Behind the Picture? Top 5 Things to Remember When Choosing and Using Scientific Imaging Cameras

Stephanie Fullerton, Hamamatsu Camera Group

Whether capturing stunning photos of fluorescently stained fixed tissue, visualizing the dance of molecular interactions or watching the lightning storm of brain activity in real time, scientific imaging delights us. It has the ability to turn science into art and elicit visceral reactions. It sparks curiosity and enhances our knowledge. But what’s behind the picture? Does understanding that highly engineered scientific camera make for better imaging and ultimately better science? Just like any other tool, having a bit of insight into how it works in the context of the project at hand…from the simplest brightfield to the most complex computational imaging… can be very useful. In this talk, I’ll discuss current advances in scientific imaging cameras and provide some unexpected rules of thumb for choosing the most appropriate camera and using the camera most effectively in your applications.

**Stephanie Fullerton** leads the sales and marketing efforts for Hamamatsu Cameras in North America. A biologist by training, Stephanie received her B.S. in Biochemistry from the University of Rochester, and Ph.D. in Neurobiology from Duke University. After spending many years in the field installing and supporting scientific cameras for researchers and consulting with life science product developers regarding OEM cameras, Stephanie moved into management where she enjoys the shaping Hamamatsu’s camera development and customer education. Stephanie has collaborated with Hamamatsu engineers on numerous SPIE presentations and was the co-author of Hamamatsu’s “Changing the Game” white paper comparing EMCCDs to sCMOS. In addition to thinking about scientific imaging, Stephanie is an avid photographer, an outdoor enthusiast and a lifelong athlete. She lives with her husband, two children, three dogs and twenty (or so) chickens in the East Bay near San Francisco, CA and can be reached at sfullerton@hamamatsu.com.
Light Fields and the Future of Photography

Ren Ng, Lytro

Light field photography is an imaging approach that collects and processes the full 4D light field in every shot. This approach provides fundamentally new capabilities, such as the ability to focus pictures after the shot. It also establishes a new technology roadmap to utilize and drive sensor resolution and lens power. This talk will present a technical overview of the approach, and ramifications for industry and creativity.

Ren Ng is the founder of Lytro, a startup in Mountain View that has introduced the first light field camera for consumers. Light field cameras provide many new capabilities, including the ability to focus pictures after the shot is taken. The underlying technology is based on Ren's PhD dissertation on light field photography, which he completed at Stanford University in 2006. Ren's dissertation won the ACM Doctoral Dissertation Award and Stanford's Arthur Samuel Award. Ren's leadership of Lytro also earned him a number of entrepreneurship honors, including Fast Company's 100 Most Creative People in Business and MIT Tech Review's TR35 and Entrepreneur of the Year.
2013 Poster Abstracts

& student author information
Silicon Photonic Crystal Mirrors Transfer-printed on Dual-axis MEMS scanner

Bryan Park

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Research Advisor: Olav Solgaard

Transfer-printing technology enables the integration of separately fabricated devices on a microelectromechanical system (MEMS) platform, allowing for more design flexibility of each component and enhanced functionality of the assembled device. Monolithic silicon photonic crystal (PC) mirrors have been fabricated in silicon wafers using thermal oxidation and a combination of directional reactive ion etching and isotropic etching, and then transfer-printed on two-axis electrostatic MEMS scanners. The final device exhibits broadband high-reflectivity with low angular and polarization dependence, and its optical characteristics can be easily tailored by selecting different PC mirrors designed to meet application requirements (e.g., wavelength, reflectivity, bandwidth). The good optical performance and robust, all-dielectric construction of the PC MEMS scanner, makes it a candidate for applications that require high optical power handling and/or operation in harsh environments.

I am a Ph.D. candidate student in E. L. Ginzton Laboratory, Department of Electrical Engineering, Stanford University (expected to graduate in December 2013).

My current research focuses on 'Photonic Crystal Slab Integration on Various Platforms' as described below:

1) Silicon Photonic Crystal slab fiber tip sensor: monolithic Si photonic crystal attached on a single mode optical fiber. This sensor is not only highly sensitive to the refractive index and temperature change of the environment but also robust enough to be applied in harsh environment applications such as high temperature measurement up to 700°C.

2) Transfer-printed Photonic Crystal Mirror on MEMS scanner
Quantitative Phase Imaging Applied in Time-Lapse Studies of Stem Cells

Christy Amwake, Nathan Loewke

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Research Advisor: Olav Solgaard

We hypothesize that the function and ultimate fate of pluripotent stem cells can be predicted by features tracked over time, such as their dynamic three-dimensional shape, behavioral trends, and social interactions. It is our goal to discover biomarkers via quantitative time-lapse imaging and use them to predict cell function and fate in order to reliably determine clinical viability. We use imaging technologies that avoid exogenous dyes in order to keep disturbances to the biological system to a minimum and develop a method that could be approved for clinical applications. We aim to monitor key processes in stem cell colony formation and differentiation, and to perform analysis via time-lapse quantitative phase imaging (QPI) to detect key signatures which will be correlated with gene expression analysis to develop predictive models of cell status and health. The aim of this imaging and analysis methodology is to predict cell safety and efficacy in therapies used to cure urinary incontinence. We aim to do this by monitoring the differentiation process of pluripotent stem cells through the entire differentiation process into smooth muscle cells, except for the terminal differentiation of the cells which will occur in the patient after surgery, and extract any cells that are not deemed healthy for the treatment. The monitoring of cells is important because injecting the wrong cells into patients could cause tumors or cancer, among other dangerous effects. We aim to apply this non-invasive quantitative approach to make this stem cell therapy safe and effective.

Nathan Loewke

I’ve been involved with biomedical technology and instrumentation research since 2008, and have been working with Stanford faculty on custom software for running miniature MEMS-based, dual-axis confocal (DAC) microscopes and on hardware modifications for various biomedical imaging applications since 2009. Now as I enter my second-year as an Electrical Engineering graduate student with Research Assistant appointments in the Solgaard and Contag Labs, my research interests include biomedical instruments and photonics, image processing and computer vision, MEMS, and their applications in cancer and stem cell biology.

Christy Amwake

I am a third year student in Electrical Engineering and have found my passion in optical imaging and techniques applied to study biology. Prior to coming to Stanford, I completed my Masters degree at the University of Southern California while I was working full time. From 2005-2010 I worked as a Comm Systems Engineer at Boeing Satellite Development Center in El Segundo, CA and from 2010 until starting my Ph.D. in 2011 I worked as an Antenna Design Engineer at Northrop Grumman in San Diego, CA. I completed 1 year of research as an undergraduate designing a coil for MRI applications at The Brain Institute at the University of Florida and another year before that as an RF technician at the National High Magnetic Field Laboratory in Tallahassee, FL.
Fiber optic pressure sensors are optical MEMS (microelectromechanical systems) devices used in a variety of industrial applications. Current sensors are assembled by affixing a silicon photonic crystal (PC) chip near an optical fiber-tip with a glass ferrule, which forms a Fabry-Perot (FP) cavity. However, environmental factors induce fluctuations in the cavity length, which decrease the sensor's stability. We introduce a method to reduce this variability by incorporating the construction of the FP cavity into the fabrication steps. To accomplish this, we pattern a silicon wafer and etch downward to form a PC, then etch isotropically to create overlapping spherical cavities. Through oxidation, the PC holes are filled with oxide, which creates a FP cavity between the PC layer and the bottom of the spheres. By successfully implementing this design, the pressure sensor's measurement reproducibility will improve.
Fundamental bounds on Fano resonance decay

Ken Wang

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Research Advisor: Shanhui Fan

Interference between a discrete state and a continuum gives rise to Fano resonance. We derive tight upper and lower bounds of the ratio between decay rates to two ports from a single resonance exhibiting the Fano interference, based on a general temporal coupled-mode formalism. The fundamental bounds imply that full reflection is always achievable at arbitrarily asymmetric but lossless Fano resonators. The analytic predictions are verified against full-field electromagnetic simulations.

Ken X. Wang has been focusing his research on photon management in solar cells, including photovoltaic and photoelectrochemical cells, with Prof. Shanhui Fan's group at Stanford University since 2010. He obtained an MASt in Math from University of Cambridge in 2012, and SB in Math and in Physics from MIT in 2010.
Ultrabroadband Nanophotonics to Achieve High-Performance Daytime Radiative Cooling

Aaswath Raman

Email: aaswath@stanford.edu
Research Advisor: Shanhui Fan

Applying nanophotonic techniques in a broadband way is of special interest for energy applications. In this poster we present two examples of our work using broadband nanophotonics to significantly improve, or fundamentally enable, energy conversion and energy efficiency techniques.

Light trapping is a technique widely used in current solar cells to improve their light absorption, and power conversion efficiency, thereby providing tremendous cost savings to solar cell manufacturers. In our work, we show that this conventional limit for light trapping enhancement can be far exceeded using nanoscale light management techniques (nanophotonics). Moreover, our recent work shows that such devices can exceed the conventional limit for all material absorptivities, making this relevant to all solar cells, not just organic and ultra-thin cells.

More recently, we have shown how an ultrabroadband photonic structure can, for the first time, enable macroscopic radiative cooling of terrestrial structures even under peak sunlight. Using a combination of phonon-polariton materials in the form of a 2D photonic crystal and a broadband dielectric reflector our designed structure is able to emit selectively in an atmospheric transparency window in the mid-IR while simultaneously strongly reflecting -- thus not absorbing -- sunlight. This enables the structure to achieve 100 W/m² of completely passive cooling power at ambient temperature. We believe this concept enables practical applications of radiative cooling for energy efficiency efforts for the first time.

Aaswath Raman is a postdoctoral scholar at the Ginzton Laboratory at Stanford University. He received his Ph.D. in Applied Physics from Stanford, and his A.B. and M.S. from Harvard University. He received the Sir James Lougheed Award of Distinction in 2011 from the Government of Alberta, and the SPIE Green Photonics Award for his work on light trapping.
Total absorption in graphene by critical coupling

Jessica R. Piper and Shanhui Fan

Email: unavailable  Research Advisor: Shanhui Fan

Graphene has great potential in integrated electro-optics, due to its unique properties including single-atom thickness, wavelength-independent absorption across the visible and near-infrared, and high carrier mobility. However, the low single-pass absorption of graphene (~2.3%) has posed a significant design challenge. In this work, we demonstrate total absorption in graphene at telecom wavelengths, by the mechanism of critical coupling between the graphene and the guided resonances of a photonic crystal slab backed by a PEC mirror.
A number of scientific space mission plan to use high stable lasers for astrophysical or fundamental physics measurements that demand an absolute optical frequency standard. High precision interferometry measurements in particular will use stabilized lasers for probing the isotropy of the velocity of light, for advanced spectroscopy of planetary atmospheres (where sampling is possible), precision international time synchronization, tests of general relativity and terrestrial ecology studies. The laser frequency/wavelength stability is a key parameter in these experiments as it directly determines the measurement resolution. While state-of-the-art technology is already capable of high levels of frequency stability in ground laboratories, similar standards are much more difficult to achieve in space. Within the NASA program Physics of the Cosmos, we are currently developing a laser stabilization system that uses a resonance of carbon monoxide as a reference and compatible with a technology readiness level required for launch and space operation (TRL4).
High-rep-rate x-ray scattering measurements at synchrotrons at 20 picosecond resolution

Michael Kozina

Email: mkozina@stanford.edu Research Advisor: David Reis

Time resolved x ray pump-probe capabilities have been developed at the Stanford Synchrotron Radiation Lightsource at megahertz repetition rates and with time-resolution less than 20 picoseconds, half an order of magnitude shorter than typical synchrotron x-ray pulses. A portable 1030 nm, 500 fs fiber laser system running at 1.28 MHz and synchronized to the electron bunches is used in conjunction with a low alpha lattice providing picosecond x-ray pulses. A unique hybrid low alpha mode enables high time-resolution measurements at high average currents enabling normal user experiments to be carried out in parallel. We have demonstrated the ability to perform laser pump/x ray probe experiments in both the standard operation of the ring and the low alpha mode configuration probing bismuth, BiFeO3, and Pb(Zr)TiO3 thin films. Experiments have been run at a number of different beamlines with both hard and soft x-rays. This source represents a complimentary source to x-ray free electron lasers, enabling high rep-rate measurements at lower peak powers.

Michael Kozina received a Bachelor of Arts in Mathematics and a Bachelor of Science in Physics from UC Santa Cruz in 2010. Currently he is a PhD candidate in the Applied Physics Department at Stanford University with Professor David Reis of the Photon Science and Applied Physics Departments. His research includes developing time-resolved x-ray diffraction capabilities at the Stanford Synchrotron Radiation Lightsource (SSRL).
Optical methods for measuring single-molecule orientation and position: implications for single-molecule super-resolution microscopy

Matthew Lew, Mikael P. Backlund, and Adam S. Backer

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Research Advisor: W. E. Moerner

Many optical methods exist for measuring the orientation and position of single fluorescent molecules. The light from these molecular beacons can provide a wealth of information about a biological structure of interest. Here, we explore two methods, namely a quadrated pupil and the double-helix point spread function, for orientation measurement that are compatible with widefield epifluorescence microscopy. These techniques can precisely and accurately measure the orientation of many molecules in parallel, both within abiological samples and within cells. Careful modeling of vectorial diffraction effects in the images of a high numerical aperture microscope reveals that serious position errors can occur in super-resolution optical microscopy if the single molecules in a sample are rotationally constrained. We demonstrate that the double-helix microscope can quantitatively measure orientation to remove these systematic position errors, thereby restoring the accuracy and precision of 3D super-resolution microscopy.

Matthew D. Lew is a Ph. D. candidate in electrical engineering, a 3Com Corporation Stanford Graduate Fellow, and a National Science Foundation Graduate Fellow at Stanford University. He received the B. S. degree with Honor in electrical engineering from the California Institute of Technology in 2008 and the M. S. degree in electrical engineering from Stanford University in 2010. His work in the Moerner Lab has involved the design and application of novel optical elements to more efficiently encode 3D position and molecular orientation in far-field fluorescence images. His research interests include single-molecule fluorescence, optical imaging systems, and point spread function engineering.
Sensing Binding Interactions in Solution with a Single-molecule Trap

Quan Wang

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Research Advisor: W.E.Moerner

Biomolecule interactions are critical to many biological processes. We developed a general method to follow these processes in vitro with single-molecule resolution in an aqueous environment. Our method is based on the intuitive idea that when a molecule binds or unbinds in solution, its hydrodynamic radius (size) and/or the amount of electric charges are likely to be altered and these changes in physical properties lead to measurable changes in the target molecule’s diffusive and electric-field induced motions in solution. To sense these changes in transport properties, we used a single-molecule electrokinetic trap and developed a statistical learning algorithm to model the fast motion of the molecule in the trap. As an example, we used the method to study the hybridization kinetics of a 10-base ssDNA with its complementary partner and characterize the destabilizing effect of a single-base mismatch.

Quan Wang received his B.S. in physics from University of Science and Technology of China in 2005 and M.S. in Optical Science and Engineering from the University of New Mexico in 2007. He is currently a Ph.D. student in Electrical Engineering at Stanford University, working with Prof. W. E. Moerner on developing new tools to study single molecules in solution.
Compact, High-Repetition Rate Mid-IR Frequency Comb Using a Fractional-Length Degenerate OPO

Kirk Ingold

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Research Advisor: Robert L. Byer

We demonstrate a degenerate mid-infrared frequency comb OPO with a fractional cavity length pumped by an ultrafast 100-MHz Er-fiber laser. This produces a 600-nm wide output near 3120 nm with a repetition rate of 500 MHz.

Kirk Ingold has been a research assistant in the Byer Group for the past 18 months. His research includes mid-infrared optical parametric oscillators and optical frequency combs for spectroscopy applications. He is funded by the United States Army and is at Stanford under the Advanced Civil Schooling Program. He is currently serving on active duty in the US Army as a Lieutenant Colonel.
Deep-Subwavelength Coupling of Surface Plasmon Polaritons Using Semiconductor Nanowires

Patrick Landreman

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Research Advisor: Mark Brongersma

We present a novel scheme for efficiently sourcing surface plasmon polaritons (SPPs) using high-refractive index, deep-subwavelength semiconductor nanowires. This method exploits the leaky optical resonances supported by these wires to manipulate field intensity distributions in a localized region near a metal surface. We demonstrate via Finite Difference Frequency Domain (FDFD) simulations and experimentally by Leakage Radiation Microscopy (LRM) that, when such a resonance is excited, free-space light is very effectively coupled into SPP waves. This efficiency is quantified by means of a coupling cross section, the magnitude of which can exceed twice the geometric cross section of the nanowire.

Patrick Landreman is a 4th-year PhD student at Stanford University. Principally interested in on-chip photonic devices, his current goal is to adapt phase change chalcogenide materials for dynamic nanophotonic structures. Mr. Landreman assisted in the development of semiconductor nanocrystal materials for lighting and displays at QD Vision, Inc. in Boston after completing his undergraduate research in Physics at Oberlin College.
Integrated structures for single photon down conversion.

Vahid Esfandyarpour

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In this work we are developing waveguide-based nonlinear optical devices to facilitate downconversion of single photons from visible to C-band wavelengths, thus enabling long-distance transmission of quantum states.

The noise photons generated by spontaneous scattering processes are an important issue for parametric single-photon conversion processes. To reduce these pump-power dependent noise photons, a long-wavelength pump source should be used. This requirement limits the wavelength-translation range which can be achieved in a single conversion step. This led to the development of integrated devices based on two cascaded parametric conversion processes. For the translation of photons from 650nm to 1550nm, a 2.2um pump is used with an intermediate frequency corresponding to 920nm.

To reduce the required pump power for complete conversion of the signal photon, we investigated the influence of propagation loss on waveguide design. To further reduce the pump-power requirement, the overall length of the waveguide needs to be expanded beyond the wafer diameter. This can be achieved by either using two distinct waveguide devices or by implementing a second pass on a single device using an integrated U-bend structure. The latter has the advantage of eliminating excess losses introduced by interface of separate devices, but is technologically more challenging in its implementation.

I got my bachelor's degree in Physics from Sharif University of Technology in 2010. In Sep 2010, I came to Stanford and joined Martin Fejer's group to pursue my PhD degree in Electrical Engineering. The project which I’m working on is nonlinear devices for single photon frequency conversion.
Borrowing from proven engineering methods and concepts, we develop and apply a set of tools to study the properties and dynamics of complex photonic circuit models. Our approach allows for the efficient synthesis of circuit models from a set of basic, well-characterized components. The resulting models enable the realization of non-trivial input-output behavior, such as classical logic applications, fully coherent filtering and control configurations, and graph-based inference schemes such as iterative, continuous-time decoding of low-density parity-check (LDPC) codes.

Born in Germany, Physik Diplom (MSc) 2010 from the University of Heidelberg, PhD student in the Department of Applied Physics at Stanford since 2011.
Adiabatic Conversion of Chi2 Interaction

Yu-Wei Lin

Email: unavailable  Research Advisor: Martin M. Fejer

The poster will present the theory of broadband-pulse second-harmonic-generation in the depleted-pump condition. Chi2 interaction is widely used in various nonlinear optics applications. In the undepleted-pump approximation, the interaction process can be formulated as a transfer-function relation. However, when the pump power cannot be treated as constant throughout the process, the interaction is shown here that it can be analoged to the Adiabatic Theorem in Quantum Mechanics.
Nonlinear Optics in (111)-GaAs Photonic Crystal Cavities

Marina Radulaski

Email: marina.radulaski@stanford.edu  Research Advisor: Jelena Vuckovic

We successfully perform second harmonic and sum frequency generation in L3 and crossbeam photonic crystal cavities fabricated in (111)-GaAs, observing an improvement over results in, the more standard, (001)-GaAs.

Marina Radulaski is a PhD student in Applied Physics at Stanford University, pursuing her interest in nonlinear optics in photonic crystal cavities under the supervision of Prof. Jelena Vuckovic. Marina is also an active member of Stanford Optical Society, and has been chairing its Outreach Committee since 2012.
Ge/GeSn double-heterostructure microdisk resonators have the potential to demonstrate lasing in an exclusively Group IV materials system with a compact footprint. However, first generation devices have suffered from inadequate mode overlap preventing optical gain in the GeSn region. To address this issue, we leverage a Ge/GeSn superlattice design to increase the overall thickness of the GeSn gain regions. Furthermore, the application of strain using an external silicon nitride stressor layer can tune the GeSn bandstructure for enhanced quantum efficiency. The ability to engineer GeSn microdisk resonators is key to enabling GeSn technology in an efficient on-chip light source.
THz-driven dynamics in multiferroic BiFeO3.

John Goodfellow, Ioannis Chatzakis, Frank Chen, Matthias Hoffman, Aaron Lindenberg.

Email: unavailable  Research Advisor: Aaron Lindenberg

THz excitation of ferroelectrics is of great interest as a means of directly coupling to lattice and vibrational degrees of freedom in the electronic ground state. We have investigated the dynamics of BiFeO3 thin films excited by THz pulses of peak amplitude 200 kV/cm, comparable to the coercive field of the material. THz pulses were generated by the tilted pulse front technique in a LiNbO3 crystal, with the resulting dynamics tracked by time resolved second harmonic generation using an 800 nm probe beam. A linear modulation in the second harmonic intensity is observed which follows the temporal profile of the THz field. This response is consistent with an electric field induced second harmonic (EFISH) effect which can be observed with DC fields. A 1.2 THz oscillation in the second harmonic response is observed after the THz pulse. MD simulations are performed to identify the origin of this effect. A further deviation from the EFISH response is observed as a function of 800 nm polarization, consisting of a temporal reshaping of the second harmonic response. This reshaping is a signature of a non-instantaneous coupling of the THz pulse to the ferroelectric order, which modulates the internal field of the film. The associated lattice displacement represents a significant fraction of the ferroelectric distortion.
Ultrafast optical and terahertz response of phase change materials

Michael Shu

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We have investigated the ultrafast response of GeSbTe phase change materials under optical and terahertz-frequency excitation. Using a pump-probe experimental setup, we measured the time-resolved change in reflectance and near-IR transmittance upon sub-threshold excitation by optical and terahertz-frequency pulses. Under optical excitation, after excited carriers have decayed, we observe a long-lived decrease in transmittance consistent with sample heating. A long-lived transmission decrease is also observed under terahertz excitation, where the dependence on terahertz field strength indicates a simple Joule heating process in crystalline GST and a multiple-step heating process in amorphous GST. This effect can shed light on the mechanisms behind electric field induced switching of phase change materials.
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