Biomedical Technology

Title: Wireless Photonic Organ Interfaces

Author and Presenter: Philipp Gutruf, Biomedical Engineering, University of Arizona, Tucson, Arizona, United States

Abstract: Materials and fabrication concepts for the creation of soft electronics coupled with miniaturization of wireless energy harvesting schemes enable the construction of high-performance electronic and optoelectronic systems with sizes, shapes and physical properties to match its biological host. Translation of these approaches towards neuroscience tools enable advanced insight into the central and peripheral nervous system, however, require means to enable full subdermal implantation and operation to enable naturalistic behavior which often is the readout of circuit level behavioral experiments that are critical to decipher function. This talk introduces the science and engineering approaches for the creation of soft devices with near field power transfer and data communication capabilities and discusses application in photonic stimulation and recording of the organ systems such as the brain, the peripheral nervous, cardiovascular and the musculoskeletal system. We present a series of advances in subdermally implantable device technologies that enable digitally controllable platforms with multimodal optogenetic and electrical stimulation capabilities with the ability to provide activation without the physical penetration of the blood brain barrier. Additional to these stimulation capabilities we demonstrate advanced biointerfaces with the cardiovascular and musculoskeletal system that enable recording of organ health as well as closed loop operation chronically in freely moving subjects. Because of the minimally invasive nature of these tools, we show chronic operation over months in freely moving subjects enabling digital disease models as well as platforms for the investigation of chronic neuromodulation effects and material schemes that can enable translation to large animal models.

Title: Scattering-based Light Sheet Microscopy for Human Tissue Imaging

Authors: Jingwei Zhao[1,*], Brooke Liang[2], Yong Jun Kim[3], Momoka Sugimura[1], Kenneth Marcelino[1], Rafael Romero[1], Michelle J. Khan[2], Eric Yang[2] and Dongkyun Kang[1,3]

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Presenter: Jingwei Zhao

Abstract: *In vivo* microscopy allows for non-invasive visualization of disease-associated cellular morphologic changes in intact human tissues. However, existing clinically-viable *in vivo*

microscopy technologies are facing challenges of simultaneously achieving high-resolution, large field of view (FOV). For example, the commercial reflectance confocal microscopes for skin imaging have a high lateral (1.25 µm) and axial resolution (5 µm) but a limited FOV (500 – 750 µm), which poses challenges in imaging the entire suspicious tissue region. While optical coherence tomography (OCT) typically has a larger FOV (approximately 2 – 3 mm), it has a limited resolution (10 – 20 µm), making it more suitable for imaging architectural features than cellular and sub-cellular features. Light sheet microscopy (LSM) is another microscopy approach that has been mainly used for imaging fluorescence-labeled samples (e.g., organoids, small animals) with sub-cellular resolution (<1 µm) in basic life science research. We have adapted LSM for imaging unstained, intact tissues using the intrinsic scattering contrast of cellular and subcellular structures. By optimizing the imaging optics numerical apertures and immersion condition, we developed a scattering-based LSM (sLSM) setup that achieved both high lateral resolution (1 – 2 µm), similar to confocal microscopy, and large FOV (1.5 – 2 mm), similar to OCT. The sLSM setup was used to visualize cellular features in excised animal tissues. In this talk, we will present our progress on sLSM research, including the investigation of optimal wavelength, reduction of speckle noise, imaging of human anal tissues, and development of a handheld sLSM probe.

Title: Assessment of Polarized Light Imaging and Optical Coherence Tomography for Improved Esophageal Cancer Detection

Authors: Justina Bonaventura, Natzem Lima, Aws Alameri, Shivanand Bomman, Bhaskar Banerjee, Hemanth Gavini, Travis Sawyer

Presenter: Justina Bonaventura

Abstract: Esophageal cancer, among other gastric cancers, has seen an increase in diagnosis and resulting death in recent decades. Early detection is key as esophageal cancer has high rates of malignancy, with the five-year survival rate reducing from 47% when found at the localized stage down to 6% when the cancer has metastasized. Additionally, esophageal cancer rates see disparities in race and gender, so a better understanding of the causes of these disparities could lead to more fine-tuned screening criteria and ultimately better early detection of the cancer.

Screening techniques typically involve an endoscopic examination of the esophageal tissue which opens the possibility of various imaging modalities, among them polarized light imaging (PLI) and optical coherence tomography (OCT) both of which can probe structural information about the tissue. In this study we image both healthy and cancerous esophageal tissue from 15 human patients with PLI and OCT systems in order to identify which metrics of those modalities are key to distinguishing between the two tissue types. In this case we examine polarimetric properties such as the retardance and depolarization of the tissue from the PLI system and texture features from the OCT system and assess their correlation to demographic information about the patients. This is done with the aim of determining how best to incorporate these imaging methods into endoscopic imaging devices for improved esophageal cancer detection.

Title: SREndo: Leveraging Super-Resolution Techniques on Endoscopic Datasets for Enhanced Surgical Procedures

Authors: Eung-Joo Lee[1], Seok Bong Yoo[2]
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[2]Department of Artificial Intelligence Convergence, Chonnam National University, Gwangju, South Korea
Presenter: Eung-Joo Lee

Abstract: In minimally invasive surgery, surgeons primarily use endoscopic camera images as their source of guidance. This imaging system has been widely applied in practical surgical scenarios. One significant challenge when analyzing surgical scenes through endoscopic datasets is the frequent movement of the laparoscope. Such movement often results in unstable and suboptimal visuals, making it difficult for clinicians to detect critical conditions, thereby impacting the surgical procedure's efficacy. A promising solution to this challenge is to apply super-resolution techniques, which have been extensively studied in natural image datasets to produce clearer visuals. These techniques transform low-resolution images into more detailed, high-resolution images. In this study, we propose a novel framework employing a super-resolution technique to optimize the surgical environment by providing higher-resolution images. Our proposed method extends a low-resolution source image to an arbitrary-scale high-resolution target in the discrete cosine transform spectral domain. Particularly, to use memory efficiently, it exploits the weight modulation transformer consisting of the depthwise multi-head attention and depthwise feed-forward network. We evaluate our proposed approach by using the Cholec80 dataset, a publicly available dataset of 80 cholecystectomy surgery videos. By applying our super-resolution network to the Cholec80 dataset, we demonstrate the efficacy of our proposed method, providing enhanced image clarity. This not only aids in detecting conditions that may be challenging to discern with conventional endoscopes but also helps refining treatment processes with superior image quality.

Title: Evaluation of Safety and Feasibility of Imaging Normal Fallopian Tubes with an Experimental OCT-MFI Microendoscope

Authors: Andrew D. Rocha[1], William K. Drake[1], Photini F. Rice[2], Dilara J. Long[2], Mary N. Reed[3], Dominique Galvez[1], John M. Heusinkveld[4], Jennifer K. Barton[1,2]
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[3]The University of Arizona, Clinical and Translational Services, Tucson, Arizona, United States
[4]The University of Arizona, Dept. of Obstetrics and Gynecology, Tucson, Arizona, United States
Presenter: Andrew D. Rocha

Abstract: High grade serous ovarian cancer (HGSC) is a deadly gynecological cancer and early detection is crucial for improving patient outcomes. The fallopian tubes (FTs) are believed to be the site of origin for most HGSC. The falloposcope, an experimental microendoscope, was developed with the long-term goal to detect ovarian cancer using multispectral fluorescence imaging (MFI) and optical coherence tomography (OCT). A pilot study was performed to evaluate the safety and feasibility of using the falloposcope to image fallopian tubes prior to standard salpingectomy in 20 normal-risk volunteers. The FTs of these participants were imaged in vivo and ex vivo using the falloposcope. Safety of the device was determined by in vivo device usage reports and by evaluating histology of FT tissue for damage. Eighteen volunteers were successfully imaged with the falloposcope, with in vivo imaging generally limited to the proximal FT. Quantifiable in vivo and ex vivo MFI data was obtained for approximately half of the participants, and in vivo and ex vivo OCT images were obtained from 12 participants. Reasons for missing data included unrelated clinical conditions and technical challenges. The quality of the obtained in vivo and ex vivo data was promising. No reportable events occurred, and only non-significant epithelium loss was observed in histology. The study findings support the safety and feasibility of the falloposcope for imaging normal FT tissue. Improvements made throughout the study enhanced the reliability of the device. Future design changes will enhance trackability through the FTs.

Title: Complete Reflectance Polarimetry Can Differentiate Microscale and Macroscale Anisotropy in the Ferret Optic Chiasm

Authors: Rhea Carlson[1], Courtney Comrie[1], Justina Bonaventura[2], Kellys Morara[1], Noelle Daigle[2], Elizabeth Hutchinson[1], and Travis W. Sawyer[1,2]
[1]Biomedical Engineering, University of Arizona, Tucson, Arizona, United States
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Presenter: Elizabeth Hutchinson

Abstract: Polarized light imaging (PLI) may provide a useful tool for ground truth measurement of tissue structure – especially for validation of diffusion MRI (dMRI) applications. Unfortunately, existing use of this technology relies on transmission imaging of thin tissue slices and only reports retardance, ignoring other relevant polarization metrics such as diattenuation or depolarization. In this study we use complete reflectance polarimetry to capture

diattenuation and retardance and compare features across dMRI metrics in thick tissue specimens.

Ferret optic chiasm specimens (n=3) were imaged by both dMRI mapping of macroscale and microscale anisotropy and tractograms as well as PLI mapping of diattenuation and retardance values and angles using a Nikon BX41 Mueller Matrix Polarimeter to collect images with five visible wavelengths (405nm, 445nm, 473nm, 543nm, 632nm) using a fiber-coupled multi-LED light source, 5x microscope objective and variable polarization states to capture the full polarization interaction of the sample. The sixteen Mueller Matrix parameters were calculated for each pixel by the Lu-Chipman Decomposition technique resulting in diattenuation and retardance maps for each sample.

Comparison of retardance and diattenuation metrics to dMRI metrics revealed that retardance was sensitive to microstructural anisotropy rather than macroscopic geometry. A comparison of angular polarimetry metrics determined that diattenuation angle differentiates crossing and coherent fiber orientations.

Taken together, we've shown that complete reflectance polarimetry is a promising tool for dMRI validation and that metrics of diattenuation and retardance show promising sensitivity to micro and macro architecture that inform its ability to validate dMRI estimations of anisotropy and orientation.

Astronomy

Title: The Large Fiber Array Spectroscopic Telescope: Status Update of the Prototype Telescope
Author and Presenter: Chad Bender, Steward Observatory, University of Arizona, Tucson, Arizona, United States
Abstract: The Large Fiber Array Spectroscopic Telescope (LFAST) will provide a large, scalable collecting area, equivalent to or greater than other ELTs under construction, at a much reduced cost. LFAST will carry out scientific investigations that require spectroscopy with high-signal-to-noise or of faint objects. LFAST is an array telescope, combining light from hundreds of 0.76m diameter prime focus telescopes into a single fiber-fed spectrograph. Twenty telescopes will be mounted on a common alt-az mount, and we are currently constructing the first prototype twenty-unit system. In this talk we will present status and updates from the first 2.5 years of the LFAST project, and describe plans for large arrays, including a 200-unit system in the next few years and a 2,640 unit system in the future.

Title: The Imaging Technology Laboratory at the New Applied Research Building
Author and Presenter: Michael Lesser, Steward Observatory, University of Arizona, Tucson, Arizona, United States
Abstract: After 22 years in an off-campus facility, the University of Arizona Imaging Technology Laboratory (ITL) has moved to the newly built Applied Research Building (ARB) on campus. While there is a significant downsizing of floor space, the new facility is much better suited for image sensor production and integration activities. Laboratories include a large cleanroom, a cleanroom wet chemistry lab, and a camera testing lab. In this talk we describe our capabilities in the new facility and our plans for future process growth and project development. We will briefly describe the major equipment which is available for our research and development efforts and well as for external contracting. And finally, we discuss a few of the most recent projects we completed before the facility relocation.

Title: Performance Specifications of the COSMOS Large Format sCMOS Camera for Ground-Based Astronomy
Authors: Jason McClure[1], Jon Kurvits[1], Jason Nottingham[2], Jose Segovia[3]
[1]Teledyne Princeton Instruments
[2]Teledyne Photometrics
[3]Teledyne e2v/AnaFocus
Presenter: Sebastian Remi, PhD, Teledyne Princeton Instruments
Abstract: Built on a track record stretching decades of providing state-of-the-art, visible to mid-IR sensors for both ground and space astronomy applications, Teledyne Digital Imaging recently launched the COSMOS sCMOS camera for ground-based astronomy featuring a 8K x 8K format sensor providing extremely large field of view. Salient features reviewed of the sensor

developed by Teledyne for the COSMOS camera are a 10m pixel pitch with dual conversion gain HDR (>100dB), very low temporal noise (< 1erms), deep cooling and very low dark current (<0.05 e-/p/s at -25oC), greater than 90% quantum efficiency, as well as excellent linearity and response uniformity. Here we will update on the latest results of characterization suggesting that this sCMOS camera is not only capable of the high-speed operation traditionally associated with sCMOS but also offers dark current and long stare capabilities traditionally associated with CCDs.

Title: Exoplanet Imaging: Finding One Photon in Billions

Author and Presenter: Ewan S. Douglas, Assistant Professor of Astronomy, Steward Observatory, University of Arizona, Tucson, Arizona, United States

Abstract: Learn more about astronomical high-contrast imaging, the extreme optical challenge of separating light reflected light from planets from the ten billion times brighter glare of their host stars. Ground and space-based instrumentation will be briefly motivated, the planned future of high-contrast imaging from space will be summarized, and open-source simulation tools for extreme optical regimes will be discussed.

Title: Challenging Optical Alignments Made Easy with Computer-Generated Holograms (CGHs): An Overview of CGH-based Alignment Schemes for Aspera and FIREBall2

Author and Presenter: Aafaque Raza Khan on behalf of the FIREBall2 and Aspera teams, University of Arizona, Tucson, Arizona, United States

Abstract: In this talk we describe the application of custom Computer-Generated Holograms (CGHs) developed in collaboration with Arizona Optical Metrology to align complex optical systems for two NASA funded space astronomy missions.

The Faint Intergalactic-medium Redshifted Emission Balloon (FIREBall-2) is a stratospheric balloon-borne UV telescope (1-m primary) with a multi-object spectrograph (MOS) designed for direct detection of the faint circum-galactic medium (CGM) of low-redshift galaxies. During its multiple flights, this suborbital mission has also served as a test bed for enhancing Technology Readiness Level (TRL) of key technologies such as UV-optimized photon counting detector, anamorphic UV grating, and a wide-filed UV spectrograph. During the 2018 flight, FIREBall-2 crash landed due to a flight anomaly and sustained damage to key optical elements including a high conic Focal corrector (FC) assembly. In this talk, we will provide an overview of how we used customized CGHs to realign two highly aspheric optics of the FC assembly for the 2023 flight campaign. The simplified alignment process and higher precision meteorology achieved with the CGHs was pivotal in significantly improving the optical performance of the payload while meeting a demanding flight schedule.

Our next big endeavor is Aspera, a NASA astrophysics Pioneers Small Sat mission designed to achieve unprecedented detection and mapping of OVI emission from nearby galaxy halos. The instrument has twin spectrographs that use innovative UV detector and optical coating technologies to achieve high UV throughput and sensitivity. Each channel is equipped with an off axis primary mirror and a toroidal diffraction grating to achieve a spectral resolution

of R~2000 at 1035 Å and spatial resolution of 120” (FWHM) within 30’ slit field of view. While the optical configuration is simple, the compact form factor leads to demanding tolerances. The alignment is challenging due to the operational wavelength of Aspera and the highly contamination sensitive nature of optical coatings. In the second half of this talk, we will briefly describe our novel application of CGH nulls to achieve the demanding alignment of two channels of Aspera. We first align optics using visible laser and custom CGH to position the parabolic primaries and toroidal gratings in zeroth order followed by a vacuum UV alignment process for focusing the Microchannel plate detector. While significant prototype testing is underway the flight optics alignment and integration will begin in early 2024.

Title: Crystalline Materials for Photonics in Astronomical Applications

Author and Presenter: Gordon von der Gönna, Director, Sales, Marketing and Business Development, Hellma Materials GmbH, Moritz-von-Rohr-Straße 1, 07745 Jena, Germany

Abstract: Talking about optical materials is always talking about glass, maybe glass ceramics as substrates for mirrors. Intrinsic properties of optical glasses, especially the transmittance range, limit the field of use. Crystalline fluorides are materials with a transmittance from deep UV to MWIR overcoming these limitations. Zinc based optical ceramics make even the LWIR accessible.

Gamma Ray detectors and Compton cameras use crystalline materials as energy converters for a subsequent energy dispersive spectroscopy. Effectiveness of this conversion and a low intrinsic background, as achieved with Cerium Bromide, is key, when every gram of a space instrument counts.

We will present how these materials are made on an industrial scale, what sets them apart from glass and where they are used in ground based, airborne and space astronomy.

Title: Chemical Imaging Spectroscopy Using CTIS

Author and Presenter: Keith Hege, PhD, MKS Imaging Technology LLC, United States

Abstract: CTIS is a 2D optical phased array etched on a high index of refraction solid-state substrate (OPA) which projects the 3D Electro-Magnetic field tensor (Object) at the 2D field-stop of a digital focal plane (FPA). That data cube is sensed as a 2D 7x7 array of spectral-spatial multiplexed information (Ctiogram) which is de-multiplexed by FLASH (Fast, Light Attribute Sensing, Hyperspectroscopy) an estimator of CISUC, the chemical image spectrogram using CTIS. The zeroth order, perpendicular to the EM-Plane, Poynting's vector is the polychromatic image of the Object. This is a consensus-extending discovery that P Cygni, as long expected, is even more than a Binary Star. The calibration and analysis, CISUC of P Cyg AB, is presented and defended.

Sensing and Metrology

Title: The Technology-Enabling Power of Dynamic Interferometry
Author and Presenter: Joanna Schmit, Principal Optical Engineer, 4D Technology: An Onto Innovation Business, 3280 E Hemisphere Loop Suite 146, Tucson, Arizona 85706, United States
Abstract: By capturing 3D surface height data in a single frame of video, one finds that information about shape and wavefront are limited by issues like exposure time, wavelength, depth of field, and field of view—and all of those are adjustable. This presentation will introduce methods for highly precise, yet extremely rapid, measurements of surfaces and wavefront properties. We will introduce dynamic interferometry, how to implement, and how it can be configured for various applications. We will also present various capabilities enabled by dynamic interferometry, including measuring in extreme environments and on the shop floor, measuring dynamically changing surfaces, hand-held 3D measurement, and the transformative ability to automate for large and complex parts.

Title: Photonics Manufacturing & Test: Tracking Semiconductors' Script
Author and Presenter: Scott Jordan, Head of Photonics, Physik Instrumente (PI)
Abstract: One attraction of Silicon Photonics is how it leverages materials, processes and tools familiar from semiconductor manufacturing to fabricate photonic circuitry alongside microelectronics. This promises scalability and savings even as functionalities escalate in complexity and sophistication. Still, key differences were immediately encountered, unfamiliar cost-drivers were confronted, and fresh roadblocks were identified that required new thinking and solutions… and in many cases still do.

In a way, this is yet another parallel between photonics and semiconductors. In the case of semiconductor manufacturing, its early years in the 1980s saw heavily labor-intensive processes for test and packaging give way to bespoke automation solutions devised by teams of integrators. From this developed the robust ecosystem of tool-builders we know today. In Silicon Photonics, we witness a similar transition from meticulous handwork to full automation for test and assembly. Key to this trend is the advent of novel solutions that cost-effectively address the critical need for nanoscale-accurate alignment of photonic components. The next step--the rise of a toolmaker ecosystem--is happening now. This profoundly impacts the economics of photonics manufacturing and will enable the industry's ability to serve emerging volume applications ranging from biosensors to LiDAR to quantum computing.

Title: Lens Centering Without a Rotary Table
Author and Presenter: Robert E. Parks, Optical Perspectives Group, LLC, 7011 E Calle Tolosa, Tucson, Arizona 85750, United States
Abstract: Traditionally, lens centering is done with a rotary table because the axis of rotation serves as the reference axis to which the lenses are aligned. We show that a Bessel beam also serves as a reference axis because it propagates through a lens system like a paraxial ray.

By using a pair of coincident Bessel beams to serve as a reference axis for centering we eliminate the need for the rotation axis. A pair of beams is needed because it gives 2 reference points, enough to determine the location and angle of a line, or axis. By eliminating a rotary table for centering, all adjustments and measurements are simple distances in the x-y plane perpendicular to the Bessel beams measured at various axial conjugate positions. This makes for quick and easy centering during assembly, and simple quantitative quality measurement of assembled lenses.

To show the method's validity, we perform simulations to illustrate a comparison of the rotational axis and Bessel beam methods. Finally, we demonstrate with experiments using both a rotary table and Bessel beams to show that the methods yield the same results.

Title: Improvements in InGaAs Based Detectors Used in Spectroscopy and LiDAR Applications
Authors: Arshey Patadia, Product Manager at Laser Components Detector Group Inc, Chandler, Arizona 85225, United States; PhD Candidate, Electrical Engineering, Arizona State University, Dr. Shankar Baliga, Sr. Product Manager at Laser Components Detector Group Inc, Chandler, Arizona 85225, United States, Kyle Ward, Lead Engineer at Laser Components Detector Group Inc, Chandler, Arizona 85225, United States, Alex Grothusen, Engineer at Laser Components Detector Group Inc, Chandler, Arizona 85225, United States
Presenter: Arshey Patadia
Abstract: The improved extended InGaAs p-i-n detector described in this study can operate under reverse bias with guaranteed linear behavior at higher operating voltages. Superior detection capabilities for CO_2 gas and Low-Density Polyethylene using these 2.6 µm extended InGaAs detectors is demonstrated. This detector exhibits linear behavior with a low leakage dark current of 20 µA at operating voltages as high as 1 Volt for a 1.3 mm active area. Further improvement demonstrated in this detector is 3 times higher shunt resistance of 7 to 10 kOhms for 0 Volt bias applications. Such an advancement translates to a lower N.E.P., evident as decreased noise in spectrometer scans of gases and solids. Ultimately, this heightened performance paves the way for the creation of more sensitive instrumentation along with faster measurement times.

The high gain InGaAs avalanche photodiode discussed exhibits an industry leading dynamic operational range of 8 Volts from M=10 to breakdown voltage which is characterized by 10 µA of dark current allowing for device operation over a wide voltage range resulting in a high signal-to-noise ratio. It operates with a high quantum efficiency between 1400nm to 1650nm wavelengths. It is experimentally demonstrated here that the detector can operate at high gains (M>100), which is 10 times the typical operational range for such detectors. The

typical capacitance at operating voltage for a 200 µm active area is measured to be 1.7 pF. It has a low temperature coefficient of 0.08 V/ºC making it an ideal choice for temperature critical systems. With a low dark current of 3 to 10 nA at M=10 it exhibits an extremely low excess noise factor (F) of 3.5.

Title: A Novel IR Emitter with Increased Output at Longer Wavelengths

Authors: L. Taubert, L.-S. Oechler, S. Biermann, Micro Hybrid Electronic GmbH, Germany, J. Taubert, Micro-Hybrid Electronics, Inc., Tucson, Arizona, United States

Presenter: Dr. Lutz Taubert, Product Manager, Micro-Hybrid Electronics, Inc., 9030 S. Rita Rd, Ste 122, Tucson, Arizona, United States

Abstract: The potential of NDIR (non-dispersive infrared) gas sensors depends largely on the available IR radiation, and thus directly on the emission spectrum of the IR source used. A novel IR emitter with optimized performance in terms of optical power output at longer wavelengths was developed by the hidden champion, Micro-Hybrid, Inc. in Tucson, AZ, US. This emitter approximates at longer wavelengths ideal black body radiation, while maintaining a robust and long-term stable design. The extended spectrum improves measurements of gases with absorption maxima at longer wavelengths, for example anesthesia gases, ammonia, alcohol and sulfur hexafluoride.

Starting point for the development was the well-known series of Micro-Hybrid NAC (nano-amorphous carbon) emitters. Careful optimization of the active area resulted in significantly increased radiation output in the 7-12 µm wavelength range, while the overall time constant of the new configuration is still suitable for pulsed operation of the IR emitter.

Emission in the 4-5 µm range is reduced by approximately 30 % compared to standard thermal emitters, which approximate in this wavelength range the ideal spectral density described by Planck's law. The modification aims at obtaining a more homogenous optical power output to reduce the required electrical input power. This is beneficial for handheld applications. Emission at longer wavelengths is increased by more than 50% in the 8-9 µm target range, opening new possibilities for NDIR based gas measurement applications.

Title: Beyond Null Testing: 3 Unexpected Uses of CGHs

Author and Presenter: Shelby Ament, PhD, Senior Optical Engineer, Arizona Optical Metrology, Tucson, Arizona, United States

Abstract: Computer Generated Holograms, or CGHs, have been used for decades in the application of high-accuracy snapshot surface figure evaluation. In this talk, three additional CGH capabilities will be discussed which take advantage of the ability to multiplex a variety of diffractive patterns onto a single substrate. First, alignment patterns can be designed which ensure that the optic under test is being evaluated at a precisely known location in space. Secondly, a CGH can be used to drastically speed up alignment of systems and sub-systems and evaluate wavefront error of these systems once aligned. Finally, CGHs can be designed which enable analysis of wavefront error over multiple field angles simultaneously, without the need to move and realign the interferometer or test assembly.

Laser Technology

Title: The Principles of High-Power Diode Laser Fiber Coupled Modules
Author and Presenter: Steve Patterson, Chief Technology Officer, Leonardo Electronics US, Tucson, Arizona, United States
Abstract: TBD

Title: Novel Diode Lasers, LEDs and Systems – Innovative Strategies for Versatile Applications
Authors: Neysha Lobo-Ploch and Paul Crump, Ferdinand-Braun-Institut gGmbH, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany
Presenter: Neysha Lobo-Ploch, PhD
Abstract: III-V semiconductor-based diode lasers and light-emitting diodes (LED) are key technologies for novel applications ranging from medical technology, defense, high-precision metrology, and sensors to optical communications in space and integrated quantum technology. This presentation will begin with a brief overview of the broad range of diode laser and LED developments at the Ferdinand-Braun-Institute (FBH), that are tailored precisely to enable many of these applications. The portfolio ranges from basic research to the development of ready-to-use modules and prototypes. It comprises gallium arsenide-based diode lasers and modules, emitting from the infrared to the UV spectral range (frequency converted), as well as laser diodes and LEDs based on gallium nitride with emission from the violet into the far-UVC spectral range.

An overview will be presented of the development and realization at the FBH of innovative diode lasers and modules in the wavelength range between 620 nm and 1180 nm for applications that require high output powers in a narrow beam with simultaneously high efficiency. The diode modules are used directly or as pumps for solid-state, fiber and gas lasers, and are critical components in a wide range of established and emerging applications. Research efforts focus on scaling performance (e.g. higher power, efficiency, brightness, higher repetition rates) and enabling new industrial applications, from efficient aluminum-based additive manufacturing to mid-IR-pulse generation, from pumping of narrow lines to the generation of secondary sources of radiation.

Title: Dual Comb Spectroscopy of Laser Produced Plasmas
Authors: Ryland G. Wala, University of Arizona, Tucson, Arizona, United States, Ryan Rhoades, John McCauley, S.S. Harilal, Jeremy Yeak, Mark C. Phillips, R. Jason Jones
Presenter: Ryland G. Wala
Abstract: Dual-Comb Spectroscopy (DCS) of Laser Produced Plasmas (LPPs) is a powerful method for elemental analysis of solid materials as well as proving the subsequent dynamics and chemistry of the plasma that evolves under extreme conditions. The key features of absorption spectroscopy using DCS is the simultaneous high temporal and spectral resolution

while covering a large spectral bandwidth. A LPP is formed by ablating a solid material with a high energy laser. By varying the ablation target and placing it in a chamber filled with an assortment of gases or liquids allows for a large variety of chemical products. By analyzing the formation of these products with DCS, we can obtain information regarding the composition of the ablation target itself as well as the fundamental physics of the chemical formation pathways. The identification of materials is a continuous issue for many industries such as mining and medicine, as well as applications in nuclear nonproliferation. Here, we present experimental results using DCS to measure high-resolution absorption spectra of atomic, ionic, and molecular oxide species formed in an LPP. The ability to measure time-resolved high resolution molecular absorption spectra in LPPs provides valuable information on chemical and thermal properties and dynamics of molecular formation. In addition to yielding information regarding the composition of the ablation target. Furthermore, high-resolution absorption spectra are useful to developing and validating spectral models for diatomic molecules.

Title: Leveraging the Multiphysics Capabilities of ANSYS Software to Enhance Optical Design and Simulations

Author and Presenter: Cynthia De La Rosa, Optical Engineer, PADT (Phoenix Analysis and Design Technologies), Tempe, Arizona, United States

Abstract: With the acquisition of Zemax into the Ansys ecosystem, optical designers have the chance to expand their designs beyond the limitations of sequential and non-sequential ray tracing within Zemax OpticStudio. The Ansys Optical Suite includes photonic and sub-wavelength multiphysics solvers with Lumerical, optical lens stack optimization and image simulation with Zemax OpticStudio, and environmental integration of optical systems with Speos.

From optomechanics to electro-optics and photonic integration, Ansys can now provide a complete workflow that scales across various physics. Optical system automation and optimization across multiple disciplines is also available to provide increased time to market. Currently, dynamic workflows between photonic solvers from Lumerical, CAD-integrated ray tracing with Speos, and automation with optiSLang are currently available through the Ansys suite in conjunction with Zemax OpticStudio. Infrared detection and tracking at the component level and mission level creates a more inclusive and effective way to conduct digital mission engineering through the Ansys AGI products.

The future of optical capabilities will continue to grow with continued investment into dynamic workflows between product suites. This presentation is meant to provide an overview of these multiphysics optical workflows to inform Zemax OpticStudio users of the potential made possible through integration of the most popular optical design software into the Ansys portfolio.

Title: Optics and Photonics International Policy & Workforce Development

Author and Presenter: Jennifer O’Bryan, Government Affairs Director for SPIE

Abstract: Jennifer O'Bryan, Government Affairs Director for SPIE, will share details on proposals to make changes to international export controls for various laser technology, as well as discuss the current issues regarding access to critical materials and US federal funding opportunities. Additionally, Jennifer will discuss STEM workforce shortages and potential solutions to this ongoing issue affecting the whole of the Optics and Photonics community.

Quantum Information Science

Title: Information in a Photon
Author and Presenter: Saikat Guha, Director, NSF-ERC Center for Quantum Networks, Peyghambarian Endowed Chair in Optical Sciences, University of Arizona, Tucson, Arizona, United States
Abstract: Light is quantum. Therefore, the fundamental precision limits in any application involving light carrying information---be it the capacity of deep-space laser communications, the resolving power of a telescope, precision limits of a beam deflection measurement, or the computational power of an all-optical computer---are all ultimately governed by the laws of quantum mechanics. Most conventional systems, which do not exploit the manifestly quantum properties of light---either at the illumination, processing or the detection stages---are limited to a classical precision limit that is often inferior to the corresponding quantum limit. In this talk, I will discuss three illustrative example applications of quantum photonics: novel receiver designs for deep space laser communications with orders of magnitude lower transmitter-peak power compared with conventional systems, using adaptive spatial mode transformations for resolving hitherto-unresolvable objects by an optical telescope, and ultra-precise atomic-force microscopy using squeezed light. We will discuss the classical-quantum performance gap for each of these applications, and associated quantum-device challenges and experimental progress in realizing such systems in our laboratories at the University of Arizona.

Title: Quantum Information from Diamond Crystal Defect for Molecular Sensing
Author and Presenter: Mouzhe Xie, Assistant Professor, School of Molecular Sciences, Arizona State University, Phoenix, Arizona, United States
Abstract: A quantum bit, or 'qubit,' lies at the very essence of quantum information science. The nitrogen-vacancy (NV) defect hosted by the diamond crystal is a leading qubit platform due to its remarkable stability and long coherence at cryogenic and room temperatures. The preparation and manipulation of the NV spin quantum states are achieved through an interplay of laser and microwave pulses, and the quantum information is read out optically. In less than two decades, the NV qubit has emerged as a powerful testbed for quantum computing, quantum networks, quantum sensing, and high-precision measurement. One such endeavor is to use NV spin to probe extremely weak fluctuating magnetic fields, such as those generated by electronic spins or nuclear spins, realizing nanoscale EPR or NMR experiments for molecular detection. Biocompatible surface functionalization and material engineering of diamond have brought this quantum sensor one step closer to real-world biological and biomedical applications.

Title: Quantum RF Sensing & Practical Applications
Author and Presenter: Dr. William Clark, PhD, VP of Quantum Development, Infleqtion

Abstract: Rydberg atom-based RF (aka Quantum RF) signal detection and processing is a reality. This technology has evolved rapidly over the past decade, from laboratory research and proof of concept experiments to early prototypes now being evaluated for use in operationally relevant environments. The broad tuning capability, along with high sensitivity and dynamic range, and the physically small nature of the sensor will enable novel and disruptive applications in communications and sensing across the commercial and defense industries. Dr. William Clark will talk about the state of this technology, near and long-term applications and what's required to transition the technology to the field.

Title: The Optical Green Machine: A Super-Additive Optical Receiver for Deep-Space Laser Communications

Author and Presenter: Jack Postlewaite, PhD student, University of Arizona, Tucson, Arizona, United States

Abstract: This presentation introduces the "Optical Green Machine," a novel joint-detection receiver designed for optical communications. This device leverages the principles of superadditivity and nonlocality without entanglement to exceed the capacity of traditional symbol-by-symbol optical receivers. In the photon-starved regime, it achieves higher communication rates by utilizing a binary-phase-shift-keying (BPSK) modulated Hadamard code.

The Optical Green Machine stands out in its ability to surpass practical symbol-by-symbol receivers in low-received-photon-flux conditions, even after accounting for losses. This capability is critical for deep space laser communications, where conventional modulation formats like pulse-position modulation face limitations due to transmitter peak power requirements and susceptibility to phase noise such as atmospheric turbulence or platform vibrations. The Optical Green Machine's design effectively reduces the transmitter peak power requirement and demonstrates greater immunity to phase noise.

Our work marks the first practical demonstration of achieving superadditive capacity through a receiver capable of collective quantum measurements over multiple modulated symbols. By employing a passive linear Hadamard transform, the Optical Green Machine maps BPSK Hadamard codewords to pulse-position-modulation (PPM) codewords before detection. This unique approach not only showcases the potential of superadditive communications but also serves as a practical demonstration of the concept of nonlocality without entanglement.

The implications of this technology extend beyond its immediate application in optical communications. It represents a significant step towards realizing the ultimate Holevo limit of optical communications capacity and offers insights into the interplay between quantum information science, optical physics, and practical communication technologies.

Title: Transverse Displacement Sensing with Spatially Structured Coherent and Squeezed State

Author and Presenter: Wenhua He, University of Arizona, Tucson, Arizona, United States

Abstract: This presentation delves into the synergistic integration of classical resources and quantum entanglement, aiming to enhance the sensitivity of transverse displacement encoded

on optical beams. This task can be applied to many problems, for example, atomic force microscopy and free space communication Pointing, Acquisition, and Tracking (PAT). Our design strategy incorporates classical resources in the form of spatial modes and quantum resources in the form of entangled states. This approach is informed by insights derived from both quantum and classical Cramér-Rao lower bound analyses.

Employing a free space propagation model with soft Gaussian apertures, the study underscores the critical role of selecting an optimal spatial mode to put a state in. High-order spatial modes contain more high spatial frequency components and thus are more sensitive to transverse displacement. Simply using a coherent state in a properly designed spatial mode can provide us with significant sensitivity enhancement. Furthermore, with squeezed state illumination, we can get access to more enhancement entailed by quantum entanglement.

The theoretical framework is complemented by an experimental implementation featuring a 4-f system with a phase-only spatial light modulator, showcasing promising results. We use a conventional method to write complex spatial mode structure in a coherent state. The presented approach offers a practical and efficient strategy for advancing sensing capabilities in optical systems, providing a foundation for future developments in precision measurement and communication technologies.