Imaging and Applied Optics Congress Program

24–27 June 2019

Messe München

Munich, Germany

Table of Contents

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Thank you to all the Committee Members for contributing many hours to maintain the high technical quality standards of OSA meetings.

General Information

Registration

Main West Entrance, Munich International Trade Fairs

The Imaging and Applied Optics Congress registration fee includes admission to Imaging Congress and World of Photonics Congress Technical Sessions, the Plenary and Poster Sessions, admission to the LASER World of PHOTONICS Trade Fair, Coffee Breaks, the Imaging Congress Reception, the Laser World of Photonics Bier & Brezel Reception and Happy Hour.

Registration Hours

Sunday, 23 June	12:00–18:00
Monday, 24 June	08:00–18:00
Tuesday, 25 June	08:00–18:00
Wednesday, 26 June	08:00–18:00
Thursday, 27 June	08:00–16:00

Wireless Connectivity

Free wireless connectivity will be provided in the Congress Centre from Sunday to Friday for the convenience of the Congress participants.

How it works:

- Switch on the WiFi function on your terminal device.
- Search for wireless networks and connect to the messeWifi network.
- Start your internet browser.
- Enter any internet address.
- The portal page of the free WiFi will appear on screen.
- Once you have accepted the General Terms and Conditions, you may access the internet.
- You only need to register one time during the entire event.

Speaker Presentation Upload

Presentation management system will be provided at the Congress. This software distributes and relays all lectures onto the laptops in the conference rooms and displays the overview of the ongoing program on the information screens inside and outside the rooms. **Your own laptop cannot be connected in the rooms**. **The upload of a presentation at the laptop in the conference room is not possible**. For this reason, all presentations must be uploaded in advance or onsite!

Presentation upload

After your presentation has been received by the scientific societies, you automatically receive an e-mail from us with your personal login data for our presentation server. This occurs automatically – you do not have to do anything.

Speaker's check-in

Prior to giving your presentation you visit our speakers' check-in – here your presence is noted and you can check your presentation again and update it as required. Your final presentation will be relayed directly to the conference room. You then proceed to your conference room where your presentation is already waiting for you on the laptop.

Online Access to Technical Digest

Full Technical Attendees have both EARLY and FREE continuous online access to the Congress Technical Digest including the Postdeadline papers through OSA Publishing's Digital Library. The presented papers can be downloaded individually or by downloading .zip files, (.zip files are available for 60 days).

- Visit the conference website at www.osa.org/ImagingOPC
- Select the "Access digest papers" link on the right hand navigation.
- Log in using your email address and password used for registration. You will be directed to the conference page where you will see the .zip file link at the top of this page. [Note: if you are logged in successfully, you will see your name in the upper right-hand corner.]

Poster Presentation PDFs

Authors presenting posters have the option to submit the PDF of their poster, which will be attached to their papers in OSA Publishing's Digital Library. If submitted, poster PDFs will be available about two weeks after the meeting. While accessing the papers in OSA Publishing's Digital Library look for the multimedia symbol shown above.

About OSA Publishing's Digital Library

Registrants and current subscribers can access all of the meeting papers, posters and postdeadline papers on OSA Publishing's Digital Library. The OSA Publishing's Digital Library is a cutting-edge repository that contains OSA Publishing's content, including 18 flagship, partnered and co-published peer reviewed journals and 1 magazine. With more than 370,000 articles including papers from over 700 conferences, OSA Publishing's Digital Library is the largest peer-reviewed collection of optics and photonics.

Anti-harassment Policy and Code of Conduct

All OSA guests, attendees, and exhibitors are subject to the Code of Conduct policy, the full text of which is available at osa.org/codeofconduct. Conference management reserves the right to take any and all appropriate actions to enforce the Code of Conduct, up to and including ejecting from the conference individuals who fail to comply with the policy.

If you wish to report bullying, discrimination, or harassment you have witnessed or experienced, you may do so through the following methods:

- use the online portal osa.org/IncidentReport (or email CodeOfConduct@OSA.org)
- contact any OSA staff member (if onsite at an event or meeting)

Plenary Speakers

Tuesday, 25 June

08:30–10:00
ICM, Room 14B

Domenico Bonaccini Calia, *European Southern Observatory, Germany*

The Ongoing Adaptive Optics Revolution

Domenico Bonaccini Calia has been working as a physicist at the European Southern Observatory (www.eso.org) for over 24 years, where he currently has an international member staff position.

He obtained his Masters in physics at the University of Florence, Italy, then completed a PhD in astrophysics, and a postdoc period at the Sac Peak National Solar Observatory in New Mexico, USA. On his return to Italy, Domenico held for 8 years a staff position at the Arcetri Astrophysical Observatory, in Florence, where he formed the adaptive optics group in 1990, before moving to ESO, Germany, in 1995.

At ESO he worked in the adaptive optics group and in 2000 he has formed the Laser Guide Star Systems Department, serving as Head of Department until 2010. He has contributed to two laser guide star facilities now installed on the ESO Very Large Telescopes in Chile, is supporting the ESO ELT activities for the new design of its six laser guide star units, and is currently responsible for the laser guide star systems research and development activities at ESO, under the Technology Development program. D. Bonaccini Calia received the innovation award from the german Leibinger Stiftung in 2016, became a Fellow of The Optical Society in 2018 for his contribution to the progress of photonics in astronomical instrumentation, shared the 2018 Paul F. Forman Team Engineering Excellence Award and as been inventor in 4 different patents related to wavefront correctors and novel laser systems.

Dongheui Lee, *Technical University of Munich (TUM), Germany*

Robot learning from Human Guidance

Dongheui Lee is Associate Professor of Human-centered Assistive Robotics at the TUM Department of Electrical and Computer Engineering. She is also director of a Human-centered assistive robotics group at the German Aerospace Center (DLR). Her research interests include human motion understanding, human robot interaction, machine learning in robotics, and assistive robotics.

Previously, she was an Assistant Professor at TUM (2009-2017), Project Assistant Professor at the University of Tokyo (2007-2009), and a research scientist at the Korea Institute of Science and Technology (KIST) (2001-2004). She obtained a PhD degree from the department of Mechano-Informatics, University of Tokyo, Japan in 2007. She was awarded a Carl von Linde Fellowship at the TUM Institute for Advanced Study (2011) and a Helmholtz professorship prize (2015).

OSA Award, Honors + Special Recognition

OSA C.E.K. Mees Medal

Bahram Javidi, *University of Connecticut, USA*

Recognized for pioneering multidisciplinary contributions to information-optics with diverse applications in bio-photonics, 3D imaging and displays, photon-counting imaging and cyber-physical security.

The Optical Society (OSA) established this medal in 1961 in memory of OSA charter member C.E.K. Mees, who contributed preeminently to the development of scientific photography. The Mees family endowed the medal to recognize achievements that exemplifies the thought that "optics transcends all boundaries.

Awards for Outstanding Student Papers

The topical meetings will award prizes for outstanding papers by students during the Imaging and Applied Optics Congress Plenary session on Tuesday morning. Thank you to our sponsors Southern Methodist University's Lyle School of Engineering and MZA Associates Corporation.

Special Events

Monday, 24 June

CLEO/Europe Plenary Session WoP

08:30–09:45
ICM Room 1

Silicon Photonics

Michal Lipson, Eugene Higgins Professor of Electrical Engineering and professor of Applied Physics at Columbia University, is one of the main pioneers in the field of silicon photonics. Among many of her discoveries she has demonstrated the first silicon photonics GHz modulator for transmitting electronic signals over large distances with low power.

World of Photonics Congress Opening and Plenary Session WoP

09:45–11:00
ICM Room 1

Listening to the Universe with Gravitational Waves

Karsten Danzmann is director at Max Planck Institute for Gravitational Physics (Albert Einstein Institute) and head of the division Laser Interferometry and Gravitational Wave Astronomy. He is Director of the Institute of Gravitation Physics at Leibniz Universität Hannover.

Nobel Prize Plenary Talk A Passion for Extreme Light WoP

18:00–19:00
ICM Room 1

Gérard Mourou, *L'Ecole Polytechnique, France*

Prof. Gérard Mourou will take part at this year's World of Photonics Congress and hold a Nobel Prize Plenary Talk about his research.

The Nobel Prize in Physics 2018 was awarded to Arthur Ashkin, Gérard Mourou and Donna Strickland. Strickland und Mourou received the award "for their method of generating high-intensity, ultra-short optical pulses".

Beir & Brezel Congress Get Together (Sponsored by SPIE) WoP

19:00–20:00
ICM Foyer and Hall B0, Ground Floor

Network with your colleagues during this happy hour while enjoying beer and pretzels. This reception is open to all attendees of the Congress

Tuesday, 25 June

Imaging Congress Plenary Session

08:30–10:00
ICM - 1st Floor, Room 14B

The Plenary Session will feature riveting talks by Domenico Bonaccini Calia of *European Southern Observatory and Dong-heui Lee of Technical University of Munich (TUM)*

Future of Biophotonics from Lab Prototypes to Wearable Chips Panel Discussion

12:00 –13:30
Room A42

OSA Members are exclusively invited to join OSA's Nonimaging Optics Design Technical Group for a special panel discussion. Short presentations from our panelists that are in academia, industry, and medical fields highlighting emerging topics on the future of integrated photonics for biomedical devices. Following the conclusion of the panel discussion, members are invited to join the technical group for a small reception to network with colleagues over refreshments.

OIDA/OSAF Professional Development & Networking Lunch and Learn

12:15–13:30
Room A32

This program will provide a unique opportunity for students and early career professionals, who are close to finishing or who have recently finished their doctorate degree, to interact with key industry and academic leaders in the community. Students interested in all career paths – from those seeking an academic position, to those wishing to start a technology business, to those interested government/public service, to those looking to translate their benchwork skills to product development – are encouraged to attend. Students will have an opportunity to discuss their ongoing research and career plans with the attending leaders, while they will share their professional journey and provide useful tips to those who attend. This workshop is complimentary for OSA Members and space is limited. Advanced registration is required.

OIDA Leaders Include:

Jürgen Niederhofer, *General Manager, MKS Instruments, Germany*

Donald A. Pearson II, *Vice President Sales, Apre Instuments, USA*

Joachim Sacher, *Managing Director, Sacher Lasertechnik, GmbH, Germany*

Hosted by: OSA Foundation; OSA Industry Development Associates

Sponsored by: GoFoton

Conference Reception

18:30-20:00

Königlicher Hirschgarten, Hirschgarten 1, 80639 München

Join your colleagues in a charming and idyllic location for drinks, networking and thoughtful discussion. Enjoy traditional Bavarian cuisine while networking with conference attendees from around the world. The reception is open to all registered Imaging Congress Full Technical attendees and is included in your Imaging Congress registration fees. Conference attendees may purchase extra tickets for their guest at registration.

How to Get There:

- From Messe Munich (Messestadt West), take the U2 in the direction of Feldmoching.
- Get off at Sendlinger Tor.
- Transfer to the 16 train in the direction of Romanplatz.
- Exit at Kriemhildenstrabe.
- Walk 500 m to Guntherstrabe to Hirschgarten 1.

Wednesday, 26 June

Imaging Optical Design Technical Group Networking Event

10:00–11:00

Room A110

Join OSA's Imaging Optical Design Technical Group for a networking opportunity to learn more about the technical group and to connect with fellow members. Gianni Nteroli, Applied Optics Group will discuss opportunities in joining the imaging optical design technical group.

Rapid Fire Poster Previews

10:30–11:15

Emmett Leith

Room 4 - Hall A1, Ground Floor

A select number of poster presenters offer Rapid-fire Oral Presentations, which consist of a brief oral presentation accompanied by slides. This format enables poster presenters to preview key results from their research in brief, two-minute segments. View the poster sessions in the abstracts for the symbol indicating Rapid-fire Oral Presentations. RAPID FIRE

Hot Topics Discussions

11:15–12:30

Emmett Leith

Room 4 - Hall A1, Ground Floor

Join your colleagues for informal discussions on a selection of current hot topics. This session encourages participation and engagement on current issues and topics considered "hot" in Science.

Posters Session

12:30–14:00

ICM Foyer and Hall B0, Ground Floor

Attend the Posters Sessions and view more than 50 posters scheduled for presentation. Poster presentations communicate new research findings in an intimate setting that encourages lively and detailed discussion between presenters and attendees.

Laser Systems Technical Group Meet and Greet

17:00–18:00

Room A110

Join OSA's Laser Systems Technical Group for an opportunity to network, build professional relationships, and share innovative ideas for group activities. Chair, Mark F. Spencer, Air Force Research Laboratory will discuss opportunities in joining the imaging optical design technical group.

Thursday, 27 June

Postdeadline Presentations

14:00–15:30

Room A12

Discover cutting-edge research in Imaging and Optical Science. The purpose of Postdeadline Papers is to give participants the opportunity to hear new and significant material in rapidly advancing areas. Only those papers judged to be truly excellent and compelling in their timeliness were accepted. Accepted Postdeadline Presentations will be announced on the conference Update sheet.

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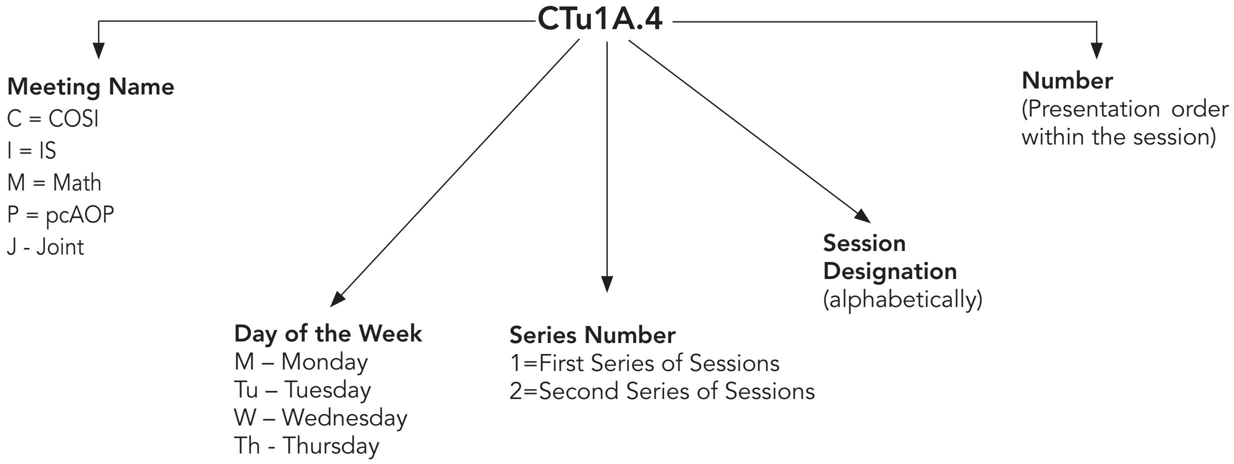
Your source for the best jobs and the best candidates in the industry. WORKinOPTICS provides a state-of-the-art platform that efficiently connects employers and job seekers within the optics and photonics community. Your next career opportunity or new hire is just a click away. OSA Industry Development Associates (OIDA) Members receive 20 free job postings.

Explanation of Session Codes



The first letter of the code designates the meeting (For instance, C=COSI, J=Joint). The second element denotes the day of the week (Monday=M, Tuesday=Tu, Wednesday=W). The third element indicates the session series in that day (for instance, 1 would denote the first parallel sessions in that day). Each day begins with the letter A in the fourth element and continues alphabetically through a series of parallel sessions. The lettering then restarts with each new series. The number on the end of the code (separated from the session code with a period) signals the position of the talk within the session (first, second, third, etc.).

For example, a presentation coded CW1A.4 indicates that this paper is part of the Imaging meeting (C) and is being presented on Wednesday (W) in the first series of sessions (1), and is the first parallel session (A) in that series and the fourth paper (4) presented in that session.

Invited papers are noted with **Invited**

Plenaries are noted with **Plenary**

World of Photonics Programs **WoP**

Online Access to Technical Digest

Full Technical Attendees have both EARLY and FREE perpetual access to the digest papers through OSA Publishing's Digital Library.

To access the papers go to

www.osa.org/ImagingOPC and select the "Access Digest Papers"

As access is limited to Full Technical Conference Attendees only, you will be asked to validate your credentials by entering the same login email address and password provided during the Conference registration process.

If you need assistance with your login information, please use the "forgot password" utility or "Contact Help" link.

Agenda of Sessions — Monday, 24 June

	Room 4 Emmett Leith	Room 5 Marie Curie	A11 Gordon Gould	A12 Max Born
	COSI	IS	pcAOP	MATH
08:00–18:00	**Registration,** *Entrance West*			
08:30–09:45	**CLEO/Europe Plenary Session,** *ICM Room 1* WoP			
09:45–11:00	**World of Photonics Congress Opening and Plenary Session,** *ICM Room 1* WoP			
11:00–11:30	**Coffee Break,** *ICM and A1 Foyer*			
11:30–13:00	**CM1A • Phase Retrieval / Wavefront Sensing**	**IM1B • Neuromorphic Imaging**	**PM1C • Atmospheric Turbulence I**	**MM1D • Image Restoration**
13:00–14:00	**Lunch Break**			
14:00–15:45	**CM2A • Indirect / Non Line-of-Sight Imaging**	**IM2B • Deep Learning and AI**	**PM2C • Atmospheric Turbulence Profiling** (starts at 14:30)	**MM2D • Multi-Dimensional Imaging** (starts at 14:30)
15:45–16:15	**Coffee Break,** *A1 Foyer*			
16:15–18:00	**CM3A • Quantum Computational Imaging**	**IM3B • Telescopes and Superresolution**	**PM3C • Atmospheric Turbulence II**	**MM3D • Super-Resolution**
18:00–19:00	**Gerard Mourou Noble Prize Talk,** *ICM Room 1* WoP			
19:00–20:00	**Beir & Brezel Congress Get Together (Sponsored by SPIE),** *ICM Foyer and Hall B0, Ground Floor*			

Key to Conference Abbreviations

COSI	Computational Optical Sensing and Imaging
IS	Imaging Systems and Applications
MATH	Mathematics in Imaging
pcAOP	Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

Agenda of Sessions — Tuesday, 25 June

	Room 4 Emmett Leith	Room 5 Marie Curie	A11 Gordon Gould	A12 Max Born
	COSI	IS	IS/pcAOP/COSI	pcAOP/MATH
08:00–18:00	**Registration,** *Entrance West*			
08:30–10:00	**Imaging Congress Plenary Session,** *ICM - 1st Floor, Room 14B*			
10:00–10:30	**Coffee Break,** *ICM and A1 Foyer*			
10:30–12:30	**CTu2A • Compressed Sensing - State of the Art**	**ITu2B • 3D Image Acquisition and Display: Technology, Perception and Applications I**	**ITu2C • Augmented Reality / Virtual Reality** (starts at 11:00)	**PTu2D • Imaging**
12:00–13:30	**Future of Biophotonics from Lab Prototypes to Wearable Chips Panel Discussion,** *Room A42*			
12:15–13:30	**OIDA / OSAF Professional Development & Networking Lunch and Learn,** *Room A32*			
12:30–14:00	**Lunch Break**			
14:00–15:30	**CTu3A • Learning based Approaches to Computational Imaging**	**ITu3B • Spectral Imaging**	**PTu3C • Adaptive Optics & Wavefront Sensing I**	**MTu3D • New Methodological Tools**
15:30–16:00	**Coffee Break,** *A1 Foyer*			
16:00–18:00	**CTu4A • Imaging through Turbid and scattering Media**	**ITu4B • Imaging (Diffractive and Single Pixel)**	**CTu4C • Advances in Microscopy / Digital Holographic Microscopy** (start at 16:15)	**MTu4D • Phase Retrieval**
18:30–20:00	**Imaging Congress Reception,** *Königlicher Hirschgarten, Hirschgarten 1, 80639 München* **How to Get There:** • From Messe Munich (Messestadt West), take the U2 in the direction of Feldmoching. • Get off at Sendlinger Tor. • Transfer to the 16 train in the direction of Romanplatz. • Exit at Kriemhildenstrabe. • Walk 500 m to Guntherstrabe to Hirschgarten 1.			

Key to Conference Abbreviations

COSI Computational Optical Sensing and Imaging
IS Imaging Systems and Applications
MATH Mathematics in Imaging
pcAOP Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

Agenda of Sessions — Wednesday, 26 June

	Room 4 Emmett Leith	Room 5 Marie Curie	A11 Gordon Gould	A12 Max Born
	COSI	IS/Joint	IS/pcAOP	MATH
08:00–18:00	**Registration,** *Entrance West*			
08:45–10:00	**CW1A • Applications of Deep Learning to Computational Imaging** (starts at 09:00)	**IW1B • 3D Image Acquisition and Display: Technology, Perception and Applications II**	**IW1C • Industrial Imaging**	**MW1D • Imaging System Analysis**
10:00–10:30	**Coffee Break,** *A1 Foyer*			
10:00–11:00	**Imaging Optical Design Technical Group Networking Event,** *Room A110*			
10:30–11:15	**Rapid Fire Poster Previews,** *Room 4, Emmett Leith*			
11:15–12:30	**Hot Topics Discussions,** *Room 4, Emmett Leith*			
12:30–14:00	**Posters Session,** *ICM Ground Floor, Hall B0*			
14:00–15:30	**CW3A • Advances in Ptychography and Emerging Applications** (starts at 14:15)	**IW3B • Novel Imaging**	**PW3C • Adaptive Optics & Wavefront Sensing II**	**MW3D • Imaging in Complex Media**
15:30–16:00	**Coffee Break,** *A1 Foyer*			
16:00–18:00	**CW4A • Advances in Computational Microscopy**	**JW4B • Compressed Sensing / Multi-aperture Imaging**	**PW4C • Wavefront Sensing & Optical Links**	**MW4D • Tomography**
17:00–18:00	**Laser Systems Technical Group Meet and Greet,** *Room A110*			

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Agenda of Sessions — Thursday, 27 June

	Room 4 Emmett Leith	Room 5 Marie Curie	A11 Gordon Gould	A12 Max Born
	COSI	IS	IS/COSI/pcAOP	pcAOP
08:00–18:00	**Registration,** *Entrance West*			
08:30–10:00	**CTh1A • Computed Tomography**	**ITh1B • 3D Image Acquisition and Display: Technology, Perception and Applications III**	**ITh1C • Microscopy**	**PTh1D • Turbulence Characterization I**
10:00–10:30	**Coffee Break,** *A1 Foyer*			
10:30–12:30	**CTh2A • Advances in Macroscopic 3D Sensing (including LiDAR)**	**ITh2B • Optical Coherence Tomography**	**CTh2C • Holography / Phase Retrieval** (starts at 10:45)	**PTh2D • Beam Propagation**
12:30–14:00	**Lunch Break**			
14:00–15:30	**CTh3A • Computational Micro and Nano-Optics**	**ITh3B • Biophotonics**	**PTh3C • Turbulence Characterization II**	**Postdeadline Presentations**
15:30–16:00	**Coffee Break,** *A1 Foyer*			
16:00–18:00	**CTh4A • Circumventing Traditional Imaging Limits**	**ITh4B • Biophotonics**	**PTh4C • Underwater and Marine Environment**	

Imaging and Applied Optics Congress Themes

This Congress has themes that span across the topical meetings. Listed below is a selection of the themes and the sessions that will feature these themes.

3D Imaging
3D Image Acquisition and Display: Technology, Perception and Applications I (ITu2B)
3D Image Acquisition and Display: Technology, Perception and Applications II (IW1B)
3D Image Acquisition and Display: Technology, Perception and Applications III (ITh1B)
Circumventing Traditional Imaging Limits (CTh4A)

Atmospheric Turbulence
Atmospheric Turbulence I (PM1C)
Atmospheric Turbulence Profiling (PM2C)
Atmospheric Turbulence II (PM3C)

Biophotonics / OCT
Biophotonics (ITh3B)
Biophotonics (ITh4B)
Microscopy (ITh1C)

Deep learning
Applications of Deep Learning to Computational Imaging (CW1A)
Deep Learning and AI (IM2B)
Image Restoration (MM1D)

Imaging in Complex, Turbid, Scattering Media
Imaging in Complex Media (MW3D)
Imaging through turbid and scattering media (CTu4A)
Indirect / Non Line-of-Sight Imaging (CM2A)
Quantum Computational Imaging (CM3A)

Microscopy
Advances in Computational Microscopy (CW4A)
Advances in Microscopy / Digital Holographic Microscopy (CTu4C)
Microscopy (ITh1C)

Ptychography / Tomography
Advances in Ptychography and Emerging Applications (CW3A)
Computed Tomography (CTh1A)
Tomography (MW4D)

Wavefront Sensing
Adaptive Optics & Wavefront Sensing I (PTu3C)
Adaptive Optics & Wavefront Sensing II (PW3C)
Phase Retrieval / Wavefront Sensing (CM1A)

Room 4 Emmett Leith	Room 5 Marie Curie	A11 Gordon Gould	A12 Max Born
Computational Optical Sensing and Imaging	Imaging Systems and Applications	Propagation Through and Characterization of Atmospheric and Oceanic Phenomena	Mathematics in Imaging

08:00–18:00 Registration, *Entrance West*

08:30–09:45 CLEO/Europe Plenary Session, *ICM Room 1* WoP

09:45–11:00 World of Photonics Congress Opening and Plenary Session, *ICM Room 1* WoP

11:00–11:30 Coffee Break, *ICM and A1 Foyer*

11:30–13:00
CM1A • Phase Retrieval / Wavefront Sensing
Presider: Prasanna Rangarajan; Southern Methodist Univ., USA

CM1A.1 • 11:30 Invited
Phase Retrieval for Image Reconstruction, James R. Fienup[1]; [1]*Univ. of Rochester, USA.* Our development of phase retrieval for image reconstruction is reviewed, including both passive and active imaging, in both optics and x-rays, enabling imaging from the nano-scale to the astronomical scale.

CM1A.2 • 12:00
Physics Embedded Deep Neural Network for Phase Retrieval under Low Photon Conditions, Mo Deng[1], Alexandre Goy[1], Kwabena Arthur[1], George Barbastathis[1]; [1]*Massachusetts Inst. of Technology, USA.* We design a deep neural network architecture where the known physical forward operator is explicitly embedded and apply it to phase retrieval under low photon conditions to achieve better performance over the end-to-end approach.

CM1A.3 • 12:15
Rotational Diffractive Shear Interferometry for extreme ultraviolet Imaging, Anne de Beurs[1,2], Xiaomeng Liu[1,2], Matthijs Jansen[1,2], Kjeld Eikema[2,1], Stefan Witte[1,2]; [1]*ARCNL, Netherlands;* [2]*Physics, Vrije Universiteit, Netherlands.* We present spectrally resolved extreme ultraviolet lensless imaging using laterally sheared coherent diffraction patterns. We show that diffraction patterns recorded at multiple rotations with respect to an asymmetric illumination enable image reconstruction without prior knowledge.

11:30–13:00
IM1B • Neuromorphic Imaging
Presider: Michael Groenert; US Army RDECOM CERDEC, USA

IM1B.1 • 11:30 Invited
Neuromorphic Vision Systems: Event-based Imaging and Processing, Greg Cohen[1]; [1]*Western Sydney Univ., Australia.* We discuss and demonstrate our work on using neuromorphic event-based cameras for space imaging tasks and show their uses for satellite tracking, orbit determination, adaptive optics, and high-speed tracking.

IM1B.2 • 12:00 Invited
Event based Sensing: Low Cost Super High Temporal Resolution Machine Vision, Ryad B. Benosman[1]; [1]*UPMC-Vision Inst., France.*. The talk presents neuromorphic concepts in recent developments in optical sensing and processing driven and controlled by events happening within the scene resulting in high temporal resolution, dynamic range and low redundancy of acquired data.

11:30–13:00
PM1C • Atmospheric Turbulence I
Presider: Sukanta Basu; Technische Universiteit Delft, Netherlands

PM1C.1 • 11:30
Fifty years of strong scintillation theory, Mikhail Charnotskii[1]; [1]*None, USA.* We present a brief review of the strong scintillation theory, and give several examples of important results of this theory. We discuss practical use of these results in conjunction with the traditional perturbation theory.

PM1C.2 • 11:45 Invited
Enhanced Backscatter: The Exploitation of Turbulence, Gisele Bennett[1]; [1]*Florida Inst. of Technology, USA.* Although propagation through atmospheric turbulence causes phase distortions, a phenomenon known as enhanced backscatter can compensate for those distortions. Coherence theory is the key to the analysis and understanding of this phenomenon.

PM1C.3 • 12:15
Wave Optics Simulation Studies of the Fried Parameter for Weak to Strong Atmospheric Turbulent Fluctuations, Hanyu Zhan[1], Erandi Wijerathna[1], David G. Voelz[1]; [1]*New Mexico State Univ., USA.* Wave optics simulations are conducted for modeling the long exposure point spread function through atmospheric turbulence. The results indicate that analytic expressions for the Fried parameter are accurate even in the strong turbulence fluctuation regime.

11:30–13:00
MM1D • Image Restoration
Presider: Nelly Pustelnik; Ecole Normale Supérieure de Lyon, France

MM1D.1 • 11:30 Invited
Flexible space-variant directional regularization for image restoration problems, Fiorella Sgallari[1]; [1]*Alma Mater Studiorum - Università di Bologna, Italy.* In this talk we will discuss recent space-variant and directional variational regularization terms for image restoration problems based on explicit statistical assumptions on the gradients of the target image. Compared to TV, the new regularizers are much more flexible and their several space-variant parameters are automatically computed. The numerical solution of the corresponding image restoration models will be presented and discussed.

MM1D.2 • 12:00
Closed-Form Solution to Disambiguate Defocus Blur in Single-Perspective Images, Majed El Helou[1], Marjan Shahpaski[1], Sabine E. Susstrunk[1]; [1]*EPFL, Switzerland.* Depth-from-defocus techniques suffer an ambiguity problem where depth planes on opposite sides of the focal plane have identical defocus. We solve the ambiguity by relying on the wavelength-dependent relationship between defocus and depth. We conduct a robustness analysis and validation on consumer lenses.

MM1D.3 • 12:15
Blind-Deblurring: Learning Based Approach, Valentin Debarnot[1], Paul Escande[2], Thomas Mangeat[3], Pierre Weiss[1]; [1]*ITAV, France;* [2]*Institut de Mathématiques de Marseille (I2M), France;* [3]*CBI, CNRS, France.* We propose a scalable method to find a subspace of low-rank tensors that simultaneously approximates a set of integral operators, e.g. spatially varying blur. This aims to improve the identifiability of complex linear operators in blind inverse problems.

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

CM1A • Phase Retrieval / Wavefront Sensing—Continued

CM1A.4 • 12:30
A model for classical wavefront sensors and snapshot incoherent wavefront sensing, Congli Wang[1], Qiang Fu[1], Xiong Dun[1], Wolfgang Heidrich[1]; [1]*King Abdullah Univ. of Science & Tech., Saudi Arabia.* A new formula is derived to connect between slopes wavefront sensors (e.g. Shack-Hartmann) and curvature sensors (based on Transport-of-Intensity Equation). Experimental results demonstrate snapshot simultaneous phase and intensity recovery on an incoherent illumination microscopy.

CM1A.5 • 12:45
Accuracy in Optical Phase Retrieval, Daniel S. Acton[1]; [1]*Ball Aerospace & Technologies, USA.* Experimental results are presented regarding the practical limits on achievable accuracy in Optical Phase Retrieval. Techniques are presented for measuring "Q," determining the diversity and incorporating the pupil amplitude into the retrieval.

Room 5 Marie Curie

Imaging Systems and Applications

IM1B • Neuromorphic Imaging—Continued

IM1B.3 • 12:30
Graph Based Event Processing, Tim Welsh[1], Guido Zarrella[1], Pam Bhattacharya[1], Steven Shearing[1]; [1]*The MITRE Corporation, USA.* Using directed graphs, we demonstrate efficient and robust filtering of event-based imagery for velocity segmentation, noise suppression, optical flow, and manifold estimation. Applications to high-speed robotic control and space situational awareness will be discussed.

IM1B.4 • 12:45
Use of Neuromorphic Sensors for Satellite Material Characterisation, Andrew Jolley[1], Greg Cohen[2], Andrew Lambert[1]; [1]*Univ. of New South Wales, Australia;* [2]*Western Sydney Univ., Australia.* We demonstrate the use of an event-based asynchronous pixel array sensor for characterising common satellite materials. Very high spatial and temporal resolution are leveraged to produce broadband photometric intensity and colour curves as a function of observation angle. Clear material-dependent features in the curves indicate potential to identify satellite material types on orbit.

A11 Gordon Gould

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

PM1C • Atmospheric Turbulence I—Continued

PM1C.4 • 12:30
Spherical Wave Scintillation in Atmospheric Turbulence: A Comparison of Analytical Models and Simulation Results, Erandi A. Wijerathna[1], David G. Voelz[1], Andreas Muschinski[2,3], Hanyu Zhan[1]; [1]*New Mexico State Univ., USA;* [2]*NorthWest Research Associates, USA;* [3]*Aerospace Engineering Dept., Univ. of Colorado Boulder, USA.* Wave optics simulation results of scintillation index and log amplitude variance differ from analytic models in the saturation regime. A spherical wave and point receiver are assumed in turbulence without inner and outer scales.

PM1C.5 • 12:45
Toward an Isoplanatic Angle for Image Restoration, David Carrara[3], Richard Paxman[3], Daniel A. LeMaster[1], Russell Hardie[2]; [1]*US Air Force Research Laboratory, USA;* [2]*Univ. of Dayton, USA;* [3]*Radiant Solutions, USA.* We propose an isoplanatic angle definition that is tied to restoration of turbulence-degraded imagery. This new metric is intended to guide patch size selection in post-processing for restoration without adapti ve optics.

A12 Max Born

Mathematics in Imaging

MM1D • Image Restoration—Continued

MM1D.4 • 12:30 Invited
Size-Adaptive Dictionary Learning, Karin Schnass[1]; [1]*Univ. of Innsbruck, Austria.* In this talk we will show how to use theoretical insights into the convergence behaviour of dictionary learning to design a practical algorithm that can learn dictionaries without being given information about the dictionary size or the sparsity level and show some examples on image data.

13:00–14:00 Lunch Break

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

14:00–15:45
CM2A • Indirect / Non Line-of-Sight Imaging
Presider: Marc Christensen; Southern Methodist University, USA

CM2A.1 • 14:00 Invited
A Personal Vision for Computational Imaging, Predrag Milojkovic[1]; [1]*US Office of Naval Research Global, USA.* Starting from examples of Computational Imaging systems I worked on, I will provide a notional framework for the future of CI, and will discuss an example of such novel imaging system.

CM2A.2 • 14:30
High Resolution Non-Line-of-Sight Imaging with Superheterodyne Remote Digital Holography, Florian Willomitzer[1], Fengqiang Li[1], Muralidhar Madabhushi Balaji[2], Prasanna V. Rangarajan[2], Oliver S. Cossairt[1]; [1]*Northwestern Univ., USA;* [2]*Southern Methodist Univ., USA.* We present a novel technique for Non-Line-of-Sight imaging that borrows ideas from Multi-Wavelength Interferometry and Remote Digital Holography. Our method reaches a resolution of a few mm, which by far surpasses the resolution of conventional methods.

CM2A.3 • 14:45
Far Field Focusing of Scattered Light for Out-of-sight Lidar Applications, Illia Starshynov[1], Omair Ghafur[1], Daniele Faccio[1]; [1]*Physics and Astronomy, Univ. of Glasgow, UK.* We utilize coherent wavefront shaping to refocus laser pulse scattering in reflection from a wall, to a spot that can be scanned behind a wall to achieve non-line-of-sight imaging with 100 um resolution.,

CM2A.4 • 15:00 Invited
Computational Periscopy without Time-Resolved Sensing, Charles Saunders[1], John Murray-Bruce[1], Vivek K. Goyal[1]; [1]*Boston University, USA.* We demonstrate non-line-of-sight imaging using only a single ordinary digital photograph. A hidden scene partially occluded from a visible surface by an opaque occluding object is recovered from the penumbra of the occluder.

Room 5 Marie Curie

Imaging Systems and Applications

14:00–15:45
IM2B • Deep Learning and AI
Presider: Todd Sachs; Apple Inc., USA

IM2B.1 • 14:00 Invited
Deep Learning in Optical Microscopy and Image Reconstruction, Aydogan Ozcan[1]; [1]*Univ. of California Los Angeles, USA.* We will discuss emerging applications of deep learning methods in optical microscopy and microscopic image reconstruction, which enable new transformations among different modalities of microscopic imaging, driven entirely by image data.

IM2B.2 • 14:30 Invited
Cognitive vision systems in security and cryptography, Marek R. Ogiela[1], Lidia Ogiela[2]; [1]*AGH Univ. of Science and Technology, Poland;* [2]*Pedagogical Univ. of Cracow, Poland.* During presentation will be described innovative solutions for security and cryptography, which will be based on application of cognitive, and bio-inspired approaches. Such techniques allow to create crypto-biometric solutions and define a new personalized security procedures.

IM2B.3 • 15:00
All-dielectric metalens array for optical multi-parameters detection, Ming Zhao[1], Xiuhua Yuan[1], Zhen Yu Yang[1]; [1]*Huazhong Univ. of Science and Technology, China.* Here, we show a design and fabrication of all-dielectric metalens array to achieve the state of polarization and the phase gradient detection operating at 1550 nm in transmission mode. Furthermore, we demonstrate detections of a radially polarized beam, an azimuthally polarized beam and a vortex beam. Each metalens (numerical aperture of 0.32) has an average focusing efficiency of about 45% at 1550 nm.

IM2B.4 • 15:15
Structural Color due to Interference of Totally Internally Reflected Light in Bi-Phase Droplets, Sara N. Nagelberg[1], Amy Goodling[2], Bryan Kaehr[3], Mathias Kolle[1], Lauren Zarzar[2]; [1]*Massachusetts Inst. of Technology, USA;* [2]*The Pennsylvania State Univ., USA;* [3]*Sandia National Laboratories, USA.* We demonstrate theoretically and experimentally structural color due to interference of light undergoing total internal reflection along concave interfaces, particularly within tunable bi-phase droplets allowing for adjustable and responsive coloration.

A11 Gordon Gould

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

14:30–15:45
PM2C • Atmospheric Turbulence Profiling
Presider: David Voelz; New Mexico State Univ., USA

PM2C.1
Withdrawn

PM2C.2 • 14:30
In-Situ, Field Profiling of Optical Turbulence using 3D Sonic Anemometers, Steven Fiorino[1], Santasri Bose-Pillai[1], Kevin Keefer[1]; [1]*Air Force Inst. of Technology, USA.* Paper demonstrates use of sonic anemometers for direct measurement of velocity structure function, C_v^2, as sonic anemometers are sensitive to pressure perturbations of turbulent eddies passing the sensor arrays regardless of temperature and humidity gradients.

PM2C.3 • 14:45
Comparing measurements of RTD probe systems and sonic anemometers, Miranda van Iersel[1], John R. Rzasa[1], Daniel A. Paulson[1], Nathaniel Ferlic[1], Christopher C. Davis[1], Jonathon Spychalski[2], Joseph Coffaro[2], Franklin Titus[2], Robert Crabbs[2]; [1]*Univ. of Maryland, USA;* [2]*Univ. of Central Florida, USA.* Ground to air temperature gradients are the drivers of optical turbulence. Different systems can measure temperature fluctuations. CT2 and Cn2 are derived from RTD probe systems and sonic anemometers mounted at several heights and compared.

PM2C.4 • 15:00
Comparison between scintillation-based atmospheric turbulence profiling instruments, Timothy Butterley[1], Marc Sarazin[2], James Osborn[1], Miska Le Louarn[2], Julio Navarrete[2]; [1]*Univ. of Durham, UK;* [2]*European Southern Observatory, Germany.* We investigate systematic discrepancies between turbulence profiles from MASS and stereo-SCIDAR instruments at Paranal Observatory. End-to-end Monte Carlo simulations of MASS are used to verify MASS profile recovery and eliminate several possible error sources.

PM2C.5 • 15:15
***PEPITO*, atmospheric optical turbulence profiling from long-exposure aniokinetism-affected images of star fields,** Nazim A. Bharmal[1], Olivier Beltramo-Martin[2,3], Carlos Correia[3]; [1]*Centre for Advanced Instrumentation, Durham Univ., UK;* [2]*Laboratoire d'Astrophysique de Marseille, Université d'Aix-Marseille, France;* [3]*ONERA, France.* A novel technique to measure C_n^2 and L_0 in the atmosphere from anisokinetism in tip/tilt corrected images of star fields by fitting parameter-based PSF models, enabling a low-complexity 24×7 capability.

A12 Max Born

Mathematics in Imaging

14:30–15:45
MM2D • Multi-Dimensional Imaging
Presider: Karin Schnass; Univ. of Innsbruck, Austria

MM2D.1
Withdrawn

MM2D.2 • 14:30
Location Estimation for Light Field Microscopy based on Convolutional Sparse Coding, Pingfan Song[1], Herman Verinaz Jadan[1], Peter Quicke[2,3], Carmel L. Howe[2], Amanda J. Foust[2,3], Pier Luigi Dragotti[1]; [1]*Dept. of Electronic and Electrical Engineering, Imperial College London, UK;* [2]*Dept. of Bioengineering, Imperial College London, UK;* [3]*Centre for Neurotechnology, Imperial College London, UK.* In this work, we propose an algorithm to estimate the depth location of objects from lightfield microscopy data by leveraging the sparsity of Epipolar Plane Images (EPIs) and convolutional sparse coding.

MM2D.3 • 14:45
Markov Chain Modeling for High-Flux Single-Photon Detection with Dead Times, Joshua Rapp[1,2], Yanting Ma[1], Robin M. Dawson[2], Vivek K. Goyal[1]; [1]*Boston University, USA;* [2]*Charles Stark Draper Laboratory, USA.* Accurate modeling of high-flux single-photon counting systems requires accounting for the dependence of photon detection times. The limiting distribution of the resulting Markov chain can be used for lidar depth estimation and histogram correction.

MM2D.4 • 15:00 Invited
Title to be Determined, Oliver S. Cossairt[1]; [1]*Northwestern Univ., USA.* Abstract not provided.

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

CM2A • Indirect / Non Line-of-Sight Imaging—Continued

CM2A.5 • 15:30
Non-Line-of-Sight Imaging using Plenoptic Information, Di Lin[1], James Leger[1], Connor Hashemi[1]; [1]*University of Minnesota, USA.* We present a passive technique for recovering the conventional imagery of a non-line-of-sight scene using the spatial and angular components of the scattered light field along a homogeneous surface.

Room 5 Marie Curie

Imaging Systems and Applications

IM2B • Deep Learning and AI—Continued

IM2B.5 • 15:30
3D RGB Non-Line-Of-Sight Single-Pixel Imaging, Gabriella Musarra[1], Ashley Lyons[1], Enrico Conca[2], Federica Villa[2], Franco Zappa[2], Yoann Altmann[3], Daniele Faccio[1]; [1]*Univ. of Glasgow, UK;* [2] *Politecnico di Milano, Italy;* [3]*Heriot-Watt Univ., UK.* We experimentally demonstrate a 3D, full colour imaging of a Non-Line-Of-Sight scene with sub-second acquisition times by using a high efficiency, time-resolved, single-pixel camera, paving the way for real-time 3D imaging of hidden scenes.

A11 Gordon Gould

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

PM2C • Atmospheric Turbulence Profiling—Continued

PM2C.6 • 15:30
Utilizing the Ascent Rates of Weather Balloons to Estimate Optical Turbulence (C_n^2) Profiles, Sukanta Basu[1]; [1]*Technische Universiteit Delft, Netherlands.* We propose an approach to estimate a proxy for the outer length scale, and in turn C_n^2, by utilizing the ascent rates of radiosondes. For validation, we use observational data from the T-REX field campaign.

A12 Max Born

Mathematics in Imaging

MM2D • Multi-Dimensional Imaging—Continued

MM2D.5 • 15:30
On optimal sampling, minimizing measuring time, in point-by-point surface metrology, Sergio Barbero[1], Manuel Ritore[2]; [1]*Instituto de Optica (CSIC), Spain;* [2]*Dept. de Geometria y Topologia, Universidad de Granada, Spain.* A relevant problem in point-by-point surface metrology is to find the set of points minimizing the overall measurement time. We show, through mathematical arguments, that selecting the sampling points along circle involutes is a good choice.

15:45–16:15 Coffee Break, *A1 Foyer*

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

16:15–18:00
CM3A • Quantum Computational Imaging
Presider: Marc Christensen; Southern Methodist Univ., USA

CM3A.1 • 16:15 Invited
Computational and Quantum Imaging, Daniele Faccio[1], Ashley Lyons[1], Hugo Defienne[1], Piergiorgio Caramazza[1], Francesco Tonolini[1], Roderick Murray-Smith[1]; [1]*University of Glasgow, UK.* Recent progress in computational techniques and quantum detection technologies provide a series of unique opportunities for imaging in challenging situations. Examples include imaging around corners, through opaque media and fibres and quantum distillation of images.

CM3A.2 • 16:45
Controlling the propagation of quantum entanglement through a scattering medium by wavefront shaping, Hugo Defienne[2,1], Matthew Reichert[2], Jason W. Fleischer[2]; [1]*School of Physics and Astronomy, Univ. of Glasgow, UK;* [2]*Dept. of Electrical Engineering, Princeton Univ., USA.* We generalize optical wavefront shaping to the quantum domain and use it for reconstructing spatial entanglement between photon pairs that have been randomized after propagation through a scattering medium.

CM3A.3 • 17:00
Quantum holography with twin photons of large spatial dimensionality, Fabrice Devaux[1,2], Alexis Mosset[2], Florent Bassignot[3], Eric Lantz[1,2]; [1]*Universite de Franche-Comte, France;* [2]*Optics, Femto-st Insitute, France;* [3]*Femto Engineering, France.* We report results of quantum holography where spatial information stored in phase hologram is retrieved by measuring spatial coincidences between two images formed by spatially entangled twin photons of high-dimensionality transmitted by the hologram.

CM3A.4 • 17:15 Invited
Correlation Plenoptic Imaging, Milena D'Angelo[1,2], Francesco Di Lena[1,2], Augusto Garuccio[1,2], Francesco V. Pepe[2], Alessio Scagliola[1]; [1]*Dept. di Fisica-Univ.degli studi di Bari, Italy;* [2]*INFN, Italy.* We present recent advances in Correlation Plenoptic Imaging, a novel technique employing spatio-temporal correlations in the lighfield to enable the typical tasks of plenoptic imaging, such as refocusing and 3D imaging, while preserving diffraction-limited resolution.

Room 5 Marie Curie

Imaging Systems and Applications

16:15–18:00
IM3B • Telescopes and Superresolution
Presider: Christopher Dainty; FotoNation, Ireland

IM3B.1 • 16:15 Invited
Instrumentation for Direct Imaging of Exoplanets, Elsa Huby[1]; [1] *Observatoire de Paris, France.* Direct detection of exoplanets is a challenging goal, as it requires high dynamic range at high angular resolution. This presentation will review the dedicated instrumentation techniques, such as coronagraphy and aperture masking.

IM3B.2 • 16:45
Analysis and Design of the IONA (Innovative Optics for a Novel Adaptive) Telescope, Charlotte E. Guthery[1], Michael Hart[1]; [1]*Univ. of Arizona, USA.* The IONA telescope is a trailer-mounted 0.8m system, which allows for adaptivity and mobility. The project will use parts of the existing system to provide a unique high-quality test-bed for a range of observational projects.

IM3B.3 • 17:00
Characterisation of Geosynchronous satellites through the Analysis of On-Sky Polarimetric Signatures obtained with a Micropolariser Array Image Sensor, Manuel Cegarra Polo[1], Israel Vaughn[1], Tahseen Kamal[1], Andrew Lambert[1]; [1]*UNSW Adfa, Australia.* We measured passive polarisation of reflected sunlight coming from satellites of the geosynchronous orbit, and analysed the polarisation in unresolved images obtained using a micropolariser array camera, to better characterise them. Our results show the presence of polarimetric signatures when observing different objects, which indicates the potential for their identification and classification in terms of different attributes, like, aging of materials, attitude and geometry of the spacecraft.

IM3B.4 • 17:15
A Holistic Registration Approach to Fusion of Interpolated Frames, Michael Rucci[1], Russell Hardie[2]; [1]*Air Force Research Laboratories, USA;* [2]*Electrical Engineering, Univ. of Dayton, USA.* This paper focus on turbulence restoration in varying strengths of turbulence and aliasing.

A11 Gordon Gould

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

16:15–18:00
PM3C • Atmospheric Turbulence II
Presider: Steven Fiorino; Air Force Inst. of Technology, USA

PM3C.1 • 16:15 Invited
Understanding Optical Turbulence Using Coordinated Atmospheric Measurements and Large Eddy Simulation (LES) Modeling, Qing Wang[1], Benjamin J. Wauer[1], Ryan Yamaguchi[1], Oswaldo Alvarenga[2], Lian Shen[3], Robert Crabbs[4]; [1]*Naval Postgraduate School, USA;* [2]*Naval Air Warfare Center Weapons Division, USA;* [3]*Univ. of Minnesota, USA;* [4]*Univ. of South Florida, USA.* Extensive in situ measurements and modeling initiatives are planned to improve meteorological forecast in support of High Energy Laser (HEL) weapon operations. The key is to understand the atmospheric boundary layer processes affecting optical turbulence.

PM3C.2 • 16:45
Simulation of the Unstable Atmospheric Boundary Layer with Emphasis on Index of Refraction Fluctuations, Kyle P. Judd[1], Robert A. Handler[2], Josh Toepfer[2]; [1]*Naval Research Laboratory, USA;* [2]*Mechanical Engineering, George Mason Univ., USA.* The structure of the atmospheric boundary layer (Ekman layer) was examined using direct numerical simulation. The influence of the resulting turbulent structures, velocity, humidity, and temperature fields on the induced index of refraction are explored.

PM3C.3 • 17:00
Kolmogorov's and coherent turbulence in the atmosphere, Vladimir P. Lukin[1]; [1]*Russian Academy of Sciences, Russian Federation.* The results of long-term studies of the optical characteristics of the atmosphere in the noncolmogorov coherent turbulence of the mountain boundary layer of the atmosphere by optical and acoustic methods are presented. The properties of single coherent structures and their mixtures are established. It is shown that, in the coherent turbulence, there is a weakening of in light fluctuations.

PM3C.4 • 17:15
Global turbulence forecasts using a General Circulation Model, James Osborn[1]; [1]*Department of Physics, Durham Univ., UK.* We demonstrate and exploit a global forecast of atmospheric turbulence. This is critical to understand the availability and feasibility of free-space optical communication links.

A12 Max Born

Mathematics in Imaging

16:15–18:00
MM3D • Super-Resolution
Presider: Pierre Weiss; Université de Toulouse, CNRS, France

MM3D.1 • 16:15 Invited
A sampling theorem for deconvolution in two dimensions, Carlos Fernandez-Granda[1]; [1]*New York Univ., USA.* In this talk we consider the inverse problem of recovering a superposition of two-dimensional point sources from samples of their convolution with a blurring kernel. We show that a convex program achieves exact recovery under a minimum separation condition on the sources, as long as the sampling grid is dense enough.

MM3D.2 • 16:45
Fundamental Limits on Imaging the Orientational Dynamics of Dipole-Like Emitters, Oumeng Zhang[1], Matthew D. Lew[1]; [1]*Electrical and Systems Engineering, Washington Univ. in St. Louis, USA.* Photon shot noise causes unavoidable bias in estimating the rotational motions of fluorescent molecules. We quantify the bias of common 2D and 3D methods for imaging orientation, showing that they perceive the same 3D motion differently.

MM3D.3 • 17:00
Multipole Spatio-angular Fluorescence Microscopy, Talon Chandler[1], Patrick La Riviere[1]; [1]*Univ. of Chicago, USA.* We model a wide class of spatio-angular fluorescence microscopes as linear Hilbert space operators. Our framework is general enough to model multipole absorber/emitters, polarized structured illumination, polarized detection, and multiview methods.

MM3D.4 • 17:15 Invited
Combining Scale-free Descriptors and Nonsmooth Optimization for Texture Segmentation, Nelly Pustelnik[1]; [1]*Ecole Normale Supérieure de Lyon, France.* Texture segmentation still constitutes an on-going challenge, especially when processing large-size images. We investigate procedures integrating scale-free descriptors into a non-smooth convex optimization framework leading to strongly convex objective function being able to deal with large size images as encountered in multiphasic flow experiments. In this contribution, we study the impact of the penalization and the resolution of the images onto the accuracy of the extracted parameters and we compare to state-of-the-art methods usually employed for studying multiphasic flow.

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

CM3A • Quantum Computational Imaging—Continued

CM3A.5 • 17:45
X-ray computational ghost imaging with single-pixel detector, Yishay Klein[1], Aviad Schori[1], Igor Dolbnya[2], Kawal Sawhney[2], Sharon Shwartz[1]; [1]*Physics Dept. and Inst. of Nanotechnology and advanced Materials, Bar-Ilan Univ., Israel;* [2]*Diamond Light Source Ltd., Harwell Science & Innovation Campus, UK.* We demonstrate computational x-ray ghost imaging with only one single-pixel detector by using a known designed mask as a diffuser. We discuss the implications and limitations of using partially coherent sources for x-ray ghost imaging.

Room 5 Marie Curie

Imaging Systems and Applications

1IM3B • Telescopes and Superresolution—Continued

IM3B.5 • 17:30
Superresolution Far-Field Imaging by Coded Phase Reflectors, Angika Bulbul[1], A. Vijayakumar[1], Joseph Rosen[1]; [1]*Ben Gurion Univ. of the Negev, Israel.* We present a synthetic aperture imaging system with two physical sub-apertures with an area less than 0.5% of the full synthetic aperture but with a resolution same as that obtained from the complete synthetic aperture.

IM3B.6 • 17:45
Nanostructured substrates for super-resolution imaging, Maia Brunstein[1], Anne Talneau[2], Minh-Chau Nguyen[3], Pascal Berto[3], Anne-Laure Fehrembach[4], Anne Sentennac[4], Martin Oheim[1]; [1]*Paris Descartes, France;* [2]*C2N, CNRS, France;* [3]*Institut de la vision, France;* [4]*Institut Fresnel, France.* Structured Illumination Microscope allows resolutions of 120 nm or 100 nm when combined with TIRF. Here we present an elegant and simple way of further increasing this resolution to <75nm, adding a nanostructured substrate.

A11 Gordon Gould

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

PM3C • Atmospheric Turbulence II—Continued

PM3C.5 • 17:30 Invited
The role of aerosols in electro-optical propagation, Alexander van Eijk[1], Karin Stein[2]; [1]*TNO, Netherlands;* [2]*Fraunhofer IOSB, Germany.* An overview is given of the interaction between electro-optical radiation and atmospheric aerosols. Techniques and models to infer the atmospheric concentration and composition of these aerosols will be discussed.

A12 Max Born

Mathematics in Imaging

MM3D • Super-Resolution—Continued

MM3D.5 • 17:45
Exit pupil position estimation using a thin-film based spectral camera, Thomas Goossens[1,2], Chris Van Hoof[2,1]; [1]*KU Leuven, Belgium;* [2]*imec vzw, Belgium.* We present a new method to estimate the exit pupil position using a thin-film based spectral camera. This position is required to correct undesired wavelength shifts in measured spectra, which is essential for many applications.

18:00–19:00 Gerard Mourou Noble Prize Talk, *ICM Room 1* WoP

19:00–20:00 Beir & Brezel Congress Get Together (Sponsored by SPIE), *ICM Foyer and Hall B0, Ground Floor* WoP

Room 4 Emmett Leith	Room 5 Marie Curie	A11 Gordon Gould	A12 Max Born
Computational Optical Sensing and Imaging	Imaging Systems and Applications	Imaging Systems and Applications	Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

08:00–18:00 Registration, *Entrance West*

CM - 1st Floor, Room 14B

08:30–10:00
Imaging Congress Plenary Session

08:30–9:00 • JTu1A.1 Plenary
The Ongoing Adaptive Optics Revolution, Domenico Bonaccini Calia, *European Southern Observatory, Germany.* We will review together the status of Adaptive Optics Technologies. Some of the most beautiful technological and application achievements will be shown, including recent developments obtained observing our Universe, with novel Laser Guide Star Adaptive Optics installations at the largest, more remote astrophysical observatories in the world.

09:15–09:45 • JTu1A.2 Plenary
Robot learning from Human Guidance, Dongheui Lee, *Technical University of Munich (TUM), Germany.* As a fundamental cornerstone in the development of intelligent robotic assistants, the research community on robot learning has addressed autonomous motor skill learning and control in complex task scenarios. Imitation learning provides an efficient way to learn new skills through human guidance, which can reduce time and cost to program the robot. Robot learning architectures can provide a comprehensive framework for learning, recognition and reproduction of whole body motions.

10:00–10:30 Coffee Break, *ICM and A1 Foyer*

10:30–12:30
CTu2A • Compressed Sensing - State of the Art
Presider: Jun Ke; Beijing Inst. of Technology, China

CTu2A.1 • 10:30
Single-shot Compressed Ultrafast Holography, Ruibo Shang[1], Geoffrey Luke[1]; [1]*Dartmouth College, USA.* A novel two-dimensional time-resolved ultrafast imaging technique, compressed ultrafast holography, is proposed to reconstruct the optical field of the ultrafast dynamic events with a frequency-modulated phase mask, a streak camera and a single camera snapshot.

CTu2A.2 • 10:45
Sparse Recovery of Under-Sampled Fiber Bundle Images for In-Vivo Endoscopy, Simon Mekhail[1], Bianca Sieveritz[1], Teresa Hernandez-Flores[1], Nilupaer Abudukeyoumu[1], Jonathan Ward[1], Gordon Arbuthnott[1], Sile Nic Chormaic[1]; [1]*Okinawa Inst. of Science & Technology, Japan.* To overcome the low resolution of fiber bundles in endoscopy we attempt to reconstruct recorded images with compressive sensing where our measurement basis is dictated by the fiber core placement and coupling.

CTu2A.3 • 11:00
Withdrawn.

CTu2A.4 • 11:15
Single-point LIDAR: Full-3D single-frame LIDAR from a single-pixel, Alex Turpin[1,2], Gabriella Musarra[1], Ilya Starshynov[1], Ashley Lyons[1], James Brooks[1], Daniele Faccio[1]; [1]*Univ. of Glasgow, UK;* [2]*Leibniz Inst. of Photonic Tech., Germany.* We report a new paradigm for LIDAR. We demonstrate full-3D information of a flash-illuminated scene from a single temporal histogram, measured with a single SPAD detector, via deep learning.

10:30–12:30
ITu2B • 3D Image Acquisition and Display: Technology, Perception and Applications I
Presider: Seung-Whan; University of Rochester, USA

ITu2B.1 • 10:30 Invited
Holographic Imaging for 3D Visualization and Metrology of Liquid Bubbles, Pietro Ferraro[1]; [1]*Inst. of Intelligent Systems CNR, Italy.* Computation tools allow to enforce 3D imaging through thus making digital holography a powerful metrology instrument in science and technology of liquid bubbles and films.

ITu2B.2 • 11:00 Invited
Multidimensional Integral Imaging for Sensing, Visualization, and Recognition in Degraded Environments, Bahram Javidi[1], Xin Shen[1], Adam Markman[1], Myungjin Cho[2], Manuel Martinez Corral[3], Artur Carnicer[4], Adrian Stern[6], José Martinez Sotoca[5], Pedro Latorre-Carmona[5], Filiberto Pla[5]; [1]*Univ. of Connecticut, USA;* [2]*Hankyong National Univ., Korea (the Republic of);* [3]*Univ. of Valencia, Spain;* [4]*Univ. of Barcelona, Spain;* [5]*Univ. of James I, Spain;* [6]*Ben Gurion Univ., Israel.* An overview of multidimensional integral-imaging for sensing, visualization, and recognition in degraded-environments is presented. Applications include 3D visualization, photon starved imaging, material inspection, IR imaging, passive depth estimation, automated human gesture recognition, and long-range imaging.

11:00–12:30
ITu2C • Augmented Reality / Virtual Reality
Presider: Rajesh Menon; University of Utah, USA

ITu2C.1
Withdrawn

ITu2C.2 • 11:00 Invited
Optics for VR, Ying M. Geng[1]; [1]*Oculus VR LLC, USA.* Viewing optics for VR near-eye displays can be improved for a more comfortable and immersive experience. We will share how to improve on form factor, field-of-view, resolution, contrast, pupil swim, and screen door.

10:30–12:30
PTu2D • Imaging
Presider: Daniel LeMaster; US Air Force Research Laboratory, USA

PTu2D.1 • 10:30 Invited
Linear Perturbation Model for Simulating Imaging through Weak Turbulence, Guy Potvin[1]; [1]*Defence R&D Canada, Canada.* A first-order linear perturbation model for simulating imaging through weak turbulence is introduced and developed. We apply it to a Lambertian target with smooth derivatives and discuss the limitations of the model.

PTu2D.2 • 11:00 Invited
Image Scintillation of Extended Objects Illuminated by Partially Coherent Light, Dario G. Perez[1]; [1]*P. Universidad Catolica de Valparaiso, Chile.* Extending previous results, we show that the pixel-based scintillation index is independent of the coherence degree of the source illuminating the observed target. Moreover, the pixel-scintillation histogram is dependent on the shape of the object.

Tuesday, 25 June

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

CTu2A • Compressed Sensing - State of the Art—Continued

CTu2A.5 • 11:30
Speckle-based Compressive Imaging in Ultrafast Spectroscopy, Ondrej Denk[1], Kaibo Zheng[2,3], Donatas Zigmantas[2], Karel Zidek[1]; [1]*TOPTEC research center, IPP CAS, Czechia;* [2]*Lund Univ., Sweden;* [3] *Technical Univ. of Denmark, Denmark.* We present a straightforward implementation of compressive imaging in femtosecond pump-probe spectroscopy. By using laser speckles as random patterns we built a single-pixel camera experiment capable of imaging processes with temporal resolution <100 fs.

CTu2A.6 • 11:45
Snapshot Compressive Spectral Light Field Tensor Imaging, Miguel Marquez[2], Hoover Rueda[3], Esteban Vera[1], Henry Arguello[3]; [1]*P. Universidad Catolica de Valparaiso, Chile;* [2]*Dept. of Physics, Universidad Industrial de Santander, Colombia;* [3]*Dept. of Computer Science, Universidad Industrial de Santander, Colombia.* This work proposes a novel compressive spectral light field imaging architecture along with a tensor-based reconstruction algorithm to estimate the four-dimensional image source from a set of compressed measurements.

CTu2A.7 • 12:00
Compressive spectral imaging with resonators devices, Yaniv oiknine[1], Isaac August[1], Adrian Stern[1]; [1]*Ben Gurion Univ. of the Negev, Israel.* Compressive spectral imaging with spectral only encoding may exhibit several advantages over spatial-and-spectral encoding methods. We overview compressive spectral imaging systems that use modified Fabry-Perot resonators that perform only spectral encoding.

CTu2A.8 • 12:15
Dual-waveband Temporal Compressive Imaging, Gun Zhou[1], Jun Ke[1], Edmund Y. Lam[2]; [1]*Beijing Inst. of Technology, China;* [2]*Univ. of Hong Kong, Hong Kong.* In this paper, to relax the requirement of data readout speed, we study a dual-waveband temporal compressive imaging (TCI) method to achieve high-speed imaging in two wavebands simultaneously.

Room 5 Marie Curie

Imaging Systems and Applications

ITu2B • 3D Image Acquisition and Display: Technology, Perception and Applications I—Continued

ITu2B.3 • 11:30 Invited
Fundamentals of Macroscopic and Microscopic Plenoptic Imaging and Display Systems, Manuel Martinez Corral[1]; [1]*Univ. of Valencia, Spain.* Plenoptic imaging is a promising technology for its ability to capture and display 3D images of polychromatic scenes, under incoherent or ambient light, and for scenarios from macroscales to microscales. In this contribution we provide a scheme with the fundamental principles as well as the most advanced concepts of plenoptic technology.

ITu2B.4 • 12:00 Invited
Digital Holography for Shape and Deformation Measurements Under Extreme Environmental Condition, Giancarlo Pedrini[1]; [1]*Universität Stuttgart, Germany.* High speed two wavelengths digital holography is used for shape measurement of objects located at long distance (25 m). Furthermore, the holographic techniques allow deformation measurements in presence of strong vibrations and high temperatures (400 °C).

A11 Gordon Gould

Imaging Systems and Applications

ITu2C • Augmented Reality / Virtual Reality—Continued

ITu2C.3 • 11:30
Light field imaging with a hand-held smartphone camera for portable augmented reality applications, Minseok Kim[1], Gil Ju Lee[1], Hyun Myung Kim[1], Hyuk Jae Jang[1], Young Min Song[1]; [1]*GIST, Korea (the Republic of).* We present light-field imaging using a smartphone camera integrated with customized microlens arrays. The prototype of mobile light-field camera exhibit unique imaging properties including different viewpoints which cannot be achieved from the conventional smartphone cameras.

ITu2C.4 • 11:45
SLM based holographic projection system without moving elements, Jeffrey A. Davis[2], Ignacio Moreno[1], Jason Sorger[2], María del Mar Sánchez-López[1], Don M Cottrell[2]; [1]*Universidad Miguel Hernandez de Elche, Spain;* [2]*Dept. of Physics, San Diego State Univ., USA.* We present a holographic projection system based on the encoding of computer-generated holograms onto a spatial light modulator. We show how the size, location, and polarization state of the output can be controlled electronically, without physically moving any element. Experimental results are included in all cases.

ITu2C.5 • 12:00
A Method for Increasing the Resolution of Holographic Display Using LED, Dukho Lee[1], Seokil Moon[1], Byounghyo Lee[1], Byoungho Lee[1]; [1]*Seoul National Univ., Korea (the Republic of).* In this paper, we propose a method to increase the resolution of holographic display using LED. The method increases the spatial coherence of the reference wave for holographic display. The proposed method is experimentally verified.

ITu2C.6 • 12:15
Nanomaterials - Effective Nonlinear Filters for Real-Time Image Processing, Anna Kudryavtseva[1], Mikhail Shevchenko[1], Nikolay Tcherniega[1]; [1]*P.N. Lebedev Physical Inst., Russian Federation.* Fourier-spectrum and volume image of 3-D object were reconstructed in the beams of stimulated low-frequency Raman scattering excited in nanomaterials by laser pulses. Varying experimental conditions and scattering materials properties enabled to obtain image processing.

A12 Max Born

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

PTu2D • Imaging—Continued

PTu2D.3 • 11:30
Straightness metric for warping strength in atmospheric turbulence affected images, Julia Hofmann[1], Szymon Gladysz[1], Daniel A. LeMaster[2]; [1]*Fraunhofer IOSB, Germany;* [2]*Air Force Research Laboratory, USA.* Reliable no-reference image quality metrics are indispensable in many research areas. In this paper, a metric for image warping due to atmospheric turbulence is presented. Its mechanism is the quantification of "straightness" in distorted images.

PTu2D.4 • 11:45
Possible 3D-reconstructions of ice particles from a pair of interferometric out-of-focus images, Marc Brunel[1], Mohamed Talbi[1], Barbara Delestre[1]; [1]*Universitaire du Madrillet CORIA, France.* The volume of ice particles generated in a freezing column is estimated using a multiview interferometric out-of-focus imaging setup. The influence of possible errors in the 3D-reconstruction process of particles is evaluated.

PTu2D.5 • 12:00 Invited
Image reconstruction applied to simulated scene-based wave front sensing for downlooking adaptive optics imaging, Michael C. Roggemann[1]; [1]*Michigan Technological Univ., USA.* Abstract not Provided.

12:00–13:30 Future of Biophotonics from Lab Prototypes to Wearable Chips Panel Discussion, *Room A42*

12:15–13:30 OIDA / OSAF Professional Development & Networking Lunch and Learn, *Room A32*

12:30–14:00 Lunch Break

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

14:00–15:30
CTu3A • Learning Based Approaches to Computational Imaging
Presider: Edmund Lam; Univ. of Hong Kong, Hong Kong

CTu3A.1 • 14:00 Invited
Optimization and Learning for Computational Imaging, Wolfgang Heidrich[1]; [1]*King Abdullah Univ. of Science & Tech., Saudi Arabia.* Computational imaging systems are based on the joint design of optics and associated image reconstruction algorithms. Historically, many such systems have emloyed simple transform-based reconstruction methods. Modern optimization methods and priors can drastically improve the reconstruction quality in computational imaging systems. Furthermore, learning-based methods can be used to design the optics along with the reconstruction method, yielding truly end-to-end optimized imaging systems.

CTu3A.2 • 14:30
Learning for lensless mask-based imaging, Kristina Monakhova[1], Nick Antipa[1], Laura Waller[1]; [1]*Univ. of California Berkeley, USA.* We demonstrate a learned, unrolled image reconstruction algorithm for lensless mask-based cameras. We train on simulated data and test on experimental data, showing a 10X improvement in reconstruction speed.

CTu3A.3 • 14:45
Deep learning approach to scalable imaging through scattering media, Yunzhe Li[1], Yujia Xue[1], Lei Tian[1]; [1]*Boston University, USA.* We propose a deep learning technique to exploit ``deep speckle correlations''. Our work paves the way to a highly scalable deep learning approach for imaging through scattering media.

CTu3A.4 • 15:00
Digital holographic imaging via deep learning, Zhenbo Ren[2,1], Tianjiao Zeng[1], Edmund Y. Lam[1]; [1]*Univ. of Hong Kong, Hong Kong;* [2]*Northwestern Polytechnical Univ., China.* We propose an end-to-end deep learning method for holographic reconstruction. Through this data-driven approach, it is possible to reconstruct a noise-free image that does not require any prior knowledge.

Room 5 Marie Curie

Imaging Systems and Applications

14:00–15:30
ITu3B • Spectral Imaging
Presider: Kevin Gemp; MITRE Corp., USA

ITu3B.1 • 14:00 Invited
ERIS - high contrast imaging and spectroscopy for infrared astronomy, Angela Cortes[1]; [1]*Max-Planck-Gesellschaft, Germany.* The ERIS instrument will provide infrared imaging and integral field spectroscopy with the world-class adaptive optics on an 8m telescope, bringing leading edge on high-angular and spectral resolutions that are key elements in forefront astronomy.

ITu3B.2 • 14:30
Advances in Mid-Infrared Hyperspectral Imaging Enabled by Supercontinuum Lasers, Jakob Kilgus[1], Ivan Zorin[1], Robert Zimmerleiter[1], Gregor Langer[1], Christian Rankl[1], Markus Brandstetter[1]; [1]*RECENDT, Austria.* Mid-infrared hyperspectral imaging is advanced by the application of novel supercontinuum laser technology enabling short acquisition times and high SNR. Diffraction limited microscopic as well as macroscopic measurements at standoff distances are presented.

ITu3B.3 • 14:45
Spectral imaging system for money counterfeit detection, Ilze Oshina[1], Janis Spigulis[2]; [1]*Univ. of Latvia, Latvia.* A prototype with three different wavelength lasers (448nm, 532nm and 659nm) for money counterfeit illumination, analyzation and detection using RGB crosstalk correction and comparing spectral image ration for different banknote elements will be presented.

ITu3B.4 • 15:00
Shortwave Infrared Fourier Multispectral Imaging, Matthew D. Howard[1], Andrew Sarangan[2], Keigo Hirakawa[2]; [1]*Air Force Research Laboratory, USA;* [2]*Univ. of Dayton, USA.* We present a shortwave infrared Fourier multispectral system with approximately sinusoidal spectral transmission filters using single cavity thin film resonators. The prototype was evaluated using single narrow-band and broadband spectra with atmospheric absorption characteristics.

A11 Gordon Gould

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

14:00–15:30
PTu3C • Adaptive Optics & Wavefront Sensing I
Presider: Szymon Gladysz; Fraunhofer Inst. IOSB, Germany

PTu3C.1 • 14:00 Invited
Laser beacon adaptive optics, a brief history, Robert L. Johnson[1]; [1]*Starfire Optical Range, USA.* We have also developed four different sodium-wavelength lasers, all of which were based on diode-pumped, sum-frequency Nd:YAG oscillators. In 2016, we combined light from two commercial sodium wavelength lasers to form a single beacon. These commercial lasers, which use resonant-frequency doubling of light from a Raman fiber-amplifier, were initially built by Toptica Photonics AG, under a contract from the European Southern Observatory. In 2017, we started research into VECSELs as a potential way to decrease the cost and size of sodium-wavelength lasers. In 2019, we started to develop and procure a 75-watt sodium-wavelength laser to enable better correction of turbulence in poor seeing. In this talk, we will review the history of laser beacon adaptive optics and discuss prospects for the future.

PTu3C.2 • 14:30
Observation of Sodium Recoil Over Starfire Optical Range, Keith Wyman[1], David Ireland[1], Mark Eickhoff[1], Lee Kann[1], Eddie Hilburn[1], Gordon Masten[1], Olivia Byrd[1], Frank Lison[2], Domenico Bonaccini Calia[3], Robert L. Johnson[1]; [1]*Starfire Optical Range, USA;* [2]*Toptica Photonics, Germany;* [3]*European Southern Observatory, Germany.* Using Starfire Optical Range's unique two laser configuration for creating cw sodium beacons, we report observations of increased photon returns along with increased AO performance after partially mitigating for the effects of sodium recoil.

PTu3C.3 • 14:45
Theoretical Analysis of a Polychromatic Rayleigh Laser Guide Star, Lennon Reinhart[1], Michael Hart[1]; [1]*University of Arizona, USA.* Tilt is a significant portion of the aberrations caused by atmospheric turbulence. A polychromatic Rayleigh beacon allows for object-independent tilt correction and has advantages over polychromatic sodium beacons. A theoretical analysis is presented.

PTu3C.4 • 15:00
Theory and Design of a Hybrid Wave-front Sensor for Adaptive Optics, Charlotte E. Guthery[1], Michael Hart[1]; [1]*University of Arizona, USA.* The Hybrid Wave-front Sensor has been simulated as a combination of Pyramid and Shack-Hartmann systems. The output has the unique advantage of being linear, highly sensitive, and accurate over a wide dynamic range of aberrations.

A12 Max Born

Mathematics in Imaging

14:00–15:30
MTu3D • New Methodological Tools
Presider: Ulugbek Kamilov; Washington Univ. in St. Louis, USA

MTu3D.1 • 14:00 Invited
Robust Algorithmic Weakening for Solving Big Data-driven Inverse Problems in Medical Imaging, Mohammad Golbabaee[1]; [1]*University of Bath, UK.* We study the convergence of the iterative projected gradient algorithm for arbitrary (possibly non-convex) sets when both the gradient and projection oracles are computed approximately. We apply our results to accelerate solving a class of data driven compressed sensing problems, where we replace iterative exhaustive searches over large data sets by fast approximate nearest neighbor search strategies based on the cover tree data structure.

MTu3D.2 • 14:30 Invited
Bayesian inversion for inverse problems in imaging through machine learning, Ozan Oktem[1]; [1]*KTH Royal Inst. of Technology, Denmark.* The talk outlines how to use neural networks in image restoration. Emphasis is network architectures that include physics-based models for data. Next, is to show how to use generative adversarial networks for uncertainty quantification.

MTu3D.3 • 15:00
Learning Biological Structures from Birefringence images with Deep Neural Networks, Syuan-Ming Guo[1], Anitha Krishnan[1], Jenny Folkesson[1], Jim Karkanias[1], Shalin B. Mehta[1]; [1]*Chan Zuckerberg Biohub, USA.* Multiplexed analysis of biological structures detected by label-free imaging is becoming tractable with deep learning. We demonstrate improved learning of ordered structures from quantitative birefringence images using a deep convolutional neural network.

Tuesday, 25 June

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

CTu3A • Learning Based Approaches to Computational Imaging—Continued

CTu3A.5 • 15:15
Projecting light through complex media with machine learning, Alex Turpin[1,2]; [1]*Univ. of Glasgow, UK;* [2]*Leibniz Inst. of Photonic Technology, Germany.* We report a technique based in machine learning to control the delivery of light through complex media, including through multimode fibers, thus opening the door to spatial division multiplexing and endoscopy with multimode fibers.

Room 5 Marie Curie

Imaging Systems and Applications

ITu3B • Spectral Imaging—Continued

ITu3B.5 • 15:15
Reflection Grating Spectrometer Based on AOTF, Qian Tang[1], Baochang Zhao[2]; [1]*School of Science, Xi'an Jiaotong Univ., China.* As for detecting the atmosphere, this article proposed a spectrometer based on AOTF (Acoustic-Optic Tunable Filter) which spectrum range is 1500nm~2400nm. This scheme combined AOTF and reflection grating to realize the resolution of 0.1nm.

A11 Gordon Gould

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

PTu3C • Adaptive Optics & Wavefront Sensing I—Continued

PTu3C.5 • 15:15
Wavefronts Obtained by Measuring Beam-profiles through Atmospheric Turbulence: the *PPPP* method applied to bistatic measurements of returns from the EOS SS DLR, Nazim A. Bharmal[1], Craig Smith[2], Mark Blundell[2], James Webb[3]; [1]*Durham Univ., UK;* [2]*EOS Space Systems, Australia;* [3]*Australian National Univ., Australia.* The implementation of an experiment to test the *PPPP* technique is discussed alongside challenges and developed solutions, in order to perform wavefront sensing using backscattered returns from the EOS-SS Debris Laser Ranging 1.8m telescope.

A12 Max Born

Mathematics in Imaging

MTu3D • New Methodological Tools—Continued

MTu3D.4 • 15:15
Classical Optics and Ray-Wave Duality: treading in the path (integral) of Feynman, James Babington[1]; [1]*Qioptiq, UK.* We show how the Feynman path integral representation can be used to map between ray and wave descriptions in classical optics and look at a GRIN system and the Gouy phase anomaly from this perspective.

15:30–16:00 Coffee Break, *A1 Foyer*

Room 4
Emmett Leith

Computational Optical Sensing and Imaging

16:00–18:00
CTu4A • Imaging Through Turbid and Scattering Media
Presider: Giuliano Scarcelli; Univ. of Maryland at College Park, USA

CTu4A.1 • 16:00 Invited
See-through Lensless Cameras to Deep-Brain Microscopy: Exploring the fruits of computational imaging, Rajesh Menon[1]; [1]*Univ. of Utah, USA.* In this presentation, we will treat imaging as an information-transfer process and explore the potential of co-optimizing numerical methods with hardware to enable unusual imaging systems, including a needle microscope, hyperspectral cameras and optics-less cameras.

CTu4A.2 • 16:30
Seeing through a scattering medium using a folded-wave coherence interferometer, Xiaohang Sun[1], Yaotian Wang[1], Jason W. Fleischer[1]; [1]*Princeton Univ., USA.* We image through a thin scattering medium using a folded-wavefront interferometer. The method gives several improvements over speckle-correlation imaging, including separation of multiple objects and a field of view beyond the memory effect.

CTu4A.3 • 16:45
Single-shot Multispectral Color Imaging Through Scattering Media, Xiaohan Li[1], Joel A. Greenberg[1], Michael E. Gehm[1]; [1]*Duke Univ., USA.* Memory effect (ME) imaging forms high-fidelity, diffraction-limited images through scatter without any prior knowledge. Here we demonstrate compressive ME imaging by extracting a color image of a scatter-obscured object from a single coded monochrome exposure.

CTu4A.4 • 17:00
Exploiting speckle statistics in random media beyond the diffusion limit, Chen Bar[1], Marina Alterman[1], Ioannis Gkioulekas[2], Anat Levin[1]; [1]*Technion, Israel;* [2]*CMU, USA.* Using a new MC simulator, we study statistics of speckle fields in scattering media. This allows understanding the Memory Effect limits, and using speckle correlations to improve our ability to see through random media.

Room 5
Marie Curie

Imaging Systems and Applications

16:00–18:00
ITu4B • Imaging (Diffractive and Single Pixel)
Presider: Maitreyee Roy; Univ. of New South Wales, Australia

ITu4B.1 • 16:00 Invited
The phasor approach to FLIM And hyperspectral imaging for predicting embryo health, Michelle Digman[1]; [1]*Univ. of California Irvine, USA.* We developed a non-morphological a machine learning algorithm, Distance Analysis, to derive an index (EVI) for distinguishing pre-implantation embryo health based on the FLIM distribution patterns the phasors and hyperspectral microscopy.

ITu4B.2 • 16:30 Invited
Computational Single-photon Imaging, Gordon Wetzstein[1]; [1]*Stanford Univ., USA.* Time-of-flight imaging systems enable 3D scene acquisition at long range using pulsed illumination and single-photon detectors. This is useful for autonomous driving, robotic vision, human-computer interaction and many other applications. In this talk, we discuss a new class of computational cameras based on single-photon detectors. These enable efficient ways for non-line-of-sight imaging and efficient depth sensing as well as other unprecedented imaging modalities.

ITu4B.3 • 17:00
Metalenses or diffractive lenses for imaging?, Sourangsu Banerji[1], Monjurul Meem[1], Berardi S. Rodriguez[1], Rajesh Menon[1]; [1]*Univ. of Utah, USA.* There is currently an explosion of interest in the use of metalenses for imaging. We demonstrate via rigorous simulations and exemplary experiments that metalenses offer no advantage over appropriately designed diffractive lenses in most cases.

A11
Gordon Gould

Computational Optical Sensing and Imaging

16:00–17:30
CTu4C • Advances in Microscopy / Digital Holographic Microscopy
Presider: Andrew Harvey; Univ. of Glasgow, UK

CTu4C.1 • 16:00
Withdrawn.

CTu4C.2 • 16:15
Memory-efficient, Global Phase-Retrieval of Fourier Ptychography with Alternating Direction Method, Yujia Huang[1], Antony C. Chan[1], An Pan[1], Changhuei Yang[1]; [1]*California Inst. of Technology, USA.* We propose to use alternate direction method of multipliers (ADMM), to improve computational robustness of Fourier ptychographic microscopy (FPM). This method is highly parallel so it can be run efficiently on GPU or distributed CPUs.

CTu4C.3 • 16:30
Fast-physical optics modeling of two-photon microscopy with 3D-structured illumination, Rui Shi[1,2], Site Zhang[2], Christian Hellmann[3], Frank Wyrowski[1]; [1]*Univ. of Jena, Germany;* [2]*LightTrans International UG, Germany;* [3]*Wyrowski Photonics UG, Germany.* We perform a fast-physical optics modeling of two-photon microscopy with 3D-structured illumination. We analyze the contrast, inhomogeneity and the temporal focusing of the 3D-structured illumination pattern, which should be accounted for in image processing.

CTu4C.4 • 16:45
Theoretical and Experimental Demonstration of a State-of-the-Art Dark-Field Holographic Microscope for Advanced Semiconductor Metrology, Christos Messinis[1,2], Vasco Tenner[1,2], Johannes de Boer[1], Stefan Witte[2], Arie den Boef[3,1]; [1]*Vrije Universiteit, Netherlands;* [2]*ARCNL (Advanced Research Center for NanoLithography, Netherlands;* [3]*ASML, Netherlands.* We describe a dark-field holographic microscope, that aims to surpass metrology requirements with novel phase-DBO measurements. We present parameters that improve overlay (OV) metrology and test the validation of our analysis with an experimental demonstration.

CTu4C.5 • 17:00
Noise Analysis of Dual-wavelength Digital Holographic Microscopy, Xuhui Zhang[1], Yuhui Yang[1], Edmund Y. Lam[2], Zhimin Xu[1]; [1]*Sharpsight Ltd., Hong Kong;* [2]*The Univ. of Hong Kong, Hong Kong.* Dual-wavelength digital holographic microscopy (DHM) can provide subnanometer resolution for sample profile characterization. We analyze the noise requirement for extension of the vertical measuring range and the noise suppression methods in DHM.

A12
Max Born

Mathematics in Imaging

16:00–18:00
MTu4D • Phase Retrieval
Presider: Ozan Oktem; KTH Royal Inst. of Technology, Denmark

MTu4D.1 • 16:00 Invited
Reconstruction Differences Between X-Ray Ptychography and X-Ray Fourier Ptychography, Andreas Menzel[1], Klaus Wakonig[2]; [1]*Paul Scherrer Institut, Switzerland;* [2]*ETH Zurich, Switzerland.* Limitations of sources, optical elements and detectors pose challenges in both x-ray ptychography and x-ray Fourier ptychography. Differences in reconstruction and alignment parameters are revealing in regard to ptychography's stability and susceptibility to errors.

MTu4D.2 • 16:30 Invited
Estimation from Nonlinear Observations via Convex Programming, Sohail Bahmani[1]; [1]*Georgia Inst. of Technology, USA.* Motivated by applications such as the phase retrieval and the blind deconvolution in imaging, we formulate and analyze a novel class of computationally scalable convex programming approaches for estimation from randomized nonlinear observations.

MTu4D.3 • 17:00
Phase retrieval from local correlation measurements with fixed shift length, Oleh Melnyk[1,2], Frank Filbir[1], Felix Krahmer[2]; [1]*Helmholtz Center Munich, Germany;* [2]*Technical Univ. of Munich, Germany.* Motivated by applications in ptychography, we generalize a recent method for phase retrieval from local correlation measurements with unit length shifts to any fixed length. Our algorithm is complemented by recovery guarantees.

Tuesday, 25 June

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

CTu4A • Imaging Through Turbid and Scattering Media—Continued

CTu4A.5 • 17:15
Combined Optical Raytrace and Monte-Carlo Simulation of Complex Biological Imaging, Guillem Carles[1], Andrew R. Harvey[1]; [1]*Univ. of Glasgow, UK.* We report the first holistic modelling of optical systems for imaging in turbid media. Using a user-friendly commercial optical-design programme, we report hybrid ray-tracing and Monte-Carlo propagation to optimise optical fluorescence microscope systems and ophthalmoscopes.

CTu4A.6 • 17:30
Performance Analysis of an Adaptive Optics System with Scintillation-Resistant Phase-Contrast Wavefront Sensor, Behzad Bordbar[1], Nathan H. Farwell[2], Mikhail A. Vorontsov[1,2]; [1]*Univ. of Dayton, USA;* [2]*II-VI Optical Systems Optonicus, USA.* An adaptive optics system based on a novel high-resolution, scintillation resistant wavefront sensor that utilizes phase contrast (Zernike-filter arrangement) visualization technique for operation in deep turbulence conditions is introduced and analyzed using wave-optics numerical simulations.

CTu4A.7 • 17:45
Real-time active underwater polarization descattering, Kui Yang[1], Fei Liu[1], Pingli Han[1], Yi Wei[1], Xiaopeng Shao[1]; [1]*Xidian University, China.* Underwater imaging's promising but challenging. This paper addresses a method to realize real-time underwater imaging by estimating DOP of backscatter automatically based upon polarization signatures of images. The results demonstrate the achievability of video processing.

Room 5 Marie Curie

Imaging Systems and Applications

ITu4B • Imaging (Diffractive and Single Pixel)—Continued

ITu4B.4 • 17:15
A broadband achromatic metalens array for integral imaging in the visible, Zhi-Bin Fan[1], Hao-Yang Qiu[1], Han-Le Zhang[2], Xiao-Ning Pang[1], Li-Dan Zhou[1], Lin Liu[1], Hui Ren[2], Qiong-Hua Wang[2], Jianwen Dong[1]; [1]*Sun Yat-sen Univ., China;* [2]*Beihang Univ., China.* We realize a polarization-insensitive silicon-nitride metalens-array in visible frequency spectrum, in which there is a set of broadband achromatic metalenses. The achromatic focusing and the achromatic integral imaging are demonstrated for white light.

ITu4B.5 • 17:30
Single-Shot Dual-Wavelength Digital Holography Using a Diffraction Grating, Byounghyo Lee[1], Byoungho Lee[1]; [1]*Seoul National Univ., Korea (the Republic of).* Using a single diffraction grating, a compact dual-wavelength digital holographic system is presented. The wavelength dependence of the diffraction angle makes multiplexed interferometer realized with a grating. The proposed method is experimentally demonstrated using a 928 nm height sample.

ITu4B.6 • 17:45
Off-Axis Digital Hologram Retrieval Based on Single-Pixel Optical Imaging, Yin Xiao[1,2], Lina Zhou[1,2], Wen Chen[1,2]; [1]*Dept. of Electronic and Information Engineering, The Hong Kong Polytechnic Univ., China;* [2]*The Hong Kong Polytechnic Univ. Shenzhen Research Inst., China.* We present a method for retrieving off-axis digital hologram based on single-pixel imaging. High-quality hologram is first retrieved, and the object is further recovered.

A11 Gordon Gould

Computational Optical Sensing and Imaging

CTu4C • Advances in Microscopy / Digital Holographic Microscopy—Continued

CTu4C.6 • 17:15
Lens-free Microscopy Using Acoustically Actuated Nanolenses and its Applications, Muhammad Arslan Khalid[1], Aniruddha Ray[2], Andriejus Demcenko[1], Steve Cohen[2], Manlio Tassieri[1], Julien Reboud[1], Aydogan Ozcan[2], Jonathan Cooper[1]; [1]*Univ. of Glasgow, UK;* [2]*Univ. of California, Los Angeles, USA.* An integration of acoustically actuated nanolenses into a lens-free microscopy enables a cost-effective platform for detection of nanoparticles and nanoliter volume rheology. Detection results of virus and bacteria are presented. Experiments of the rheology are analysed.

A12 Max Born

Mathematics in Imaging

MTu4D • Phase Retrieval—Continued

MTu4D.4 • 17:15
Coherent-Image Reconstruction Using Convolutional Neural Networks, Casey J. Pellizzari[1], Mark F. Spencer[2], Charles A. Bouman[3]; [1]*USA Air Force Academy, USA;* [2]*Air Force Research Laboratory, USA;* [3]*ECE, Purdue Univ., USA.* We describe a technique for incorporating convolutional-neural-network models into a comprehensive approach for coherent-image reconstruction in the presence of noise and phase errors using the consensus equilibrium framework.

MTu4D.5 • 17:30 Invited
Unlimited Sampling and Reconstruction, Ayush Bhandari[1], Felix Krahmer[2], Ramesh Raskar[3]; [1]*Imperial College London, UK;* [2]*Technische Universität Munchen, Germany;* [3]*MIT Media Lab, Massachussetts Inst. of Technology, USA.* This talk presents a new sensing principle with modulo non-linearity in the data capture process, the "Unlimited Sampling Framework". This approach allows for digital acquisition of signals and images beyond the dynamic range bottleneck.

18:30–20:00 Imaging Congress Reception, *Königlicher Hirschgarten, Hirschgarten 1, 80639 München*

How to Get There:

- From Messe Munich (Messestadt West), take the U2 in the direction of Feldmoching.
- Get off at Sendlinger Tor.
- Transfer to the 16 train in the direction of Romanplatz.
- Exit at Kriem hildenstrabe.
- Walk 500 m to Guntherstrabe to Hirschgarten 1.

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

Room 5 Marie Curie

Imaging Systems and Applications

A11 Gordon Gould

Imaging Systems and Applications

A12 Max Born

Mathematics in Imaging

08:00–18:00 Registration, *Entrance West*

09:00–10:00
CW1A • Applications of Deep Learning to Computational Imaging
Presider: Rajesh Menon; Univ. of Utah, USA

CW1A.1
Withdrawn

CW1A.2 • 09:00
Cell Imaging Using Glass-Air Disordered Optical Fiber and Deep Learning Algorithms, Jian Zhao[1], Yangyang Sun[1], Jose Enrique Antonio-Lopez[1], Rodrigo Amezcua Correa[1], Shuo Pang[1], Axel Schülzgen[1]; [1]*CREOL, Univ. of Central Florida, USA.* LED-illuminated cell imaging is demonstrated by combining a glass-air disordered transmission optical fiber with a deep learning algorithm. Artifact-free cell images can be recovered after being transmitted through a meter-long fiber sample.

CW1A.3 • 09:15
Hyperspecral Skin Imaging with Artificial Neural Networks Validated by Optical Biotissue Phantoms, Alexander Bykov[1], Evgeny Zherebtsov[1], Viktor Dremin[1], Alexey Popov[1], Alexander Doronin[2], Igor Meglinski[1]; [1]*Univ. of Oulu, Finland;* [2]*Victoria Univ. of Wellington, New Zealand.* The possibility of using Monte-Carlo modelling for neural network training in the problem of hyperspectral image processing has been demonstrated and validated using biotissue phantom and human skin *in vivo*. The proposed approach enables a tool combining both the speed of neural network processing and the accuracy and flexibility of Monte-Carlo modelling.

08:30–10:00
IW1B • 3D Image Acquisition and Display: Technology, Perception and Applications II
Presider: Michael Groenert; US Army RDECOM CERDEC, USA

IW1B.1 • 08:30 Invited
An Overview of Some Techniques for the Detection and Recognition of Objects in 3D Data, Abhijit Mahalanobis[1]; [1]*Univ. of Central Florida, USA.* We discuss the application of classical and new techniques based on convolutional neural nets (CNNs) for automatic target recognition (ATR) using 3D data such as those produced by LADAR sensors.

IW1B.2 • 09:00 Invited
Computational 3D Imaging with Diffractive Optical Elements, Atanas Gotchev[1]; [1]*Tampere Univ. of Technology.* We discuss a computational imaging design framework, which combines a camera employing diffractive element(s) with a convolutional neural network. We present state-of-the-art results for the depth of field extension problem and address further challenges in 3D imaging.

08:30–10:00
IW1C • Industrial Imaging
Presider: Kenneth Barnard; US Air Force Research Laboratory, USA

IW1C.1 • 08:30
Movement Analysis for Volitional Direction Change of Laboratory Mouse based on High-Speed Imaging, Seohyun Lee[1], Tomohiko Hayakawa[1], Chika Nishimura[2], Satoshi Yawata[2], Dai Watanabe[2], Masatoshi Ishikawa[1]; [1]*The Univ. of Tokyo, Japan;* [2]*Kyoto Univ., Japan.* To track volitional motion of a freely moving laboratory mouse, this paper suggests the angle gradient of the turning head as a quantitative criterion, based on markerless snout tracking using high-speed imaging system.

IW1C.2 • 08:45
3D tracking of mosquitoes: Results from a whole room imaging system in Tanzania, Christian Kröner[1], Catherine E. Towers[1], Josephine E. Parker[2], Charles Kakilla[3], Karen Nelwin[3], Alphaxard Manjurano[3], Philip McCall[2], David P. Towers[1]; [1]*School of Engineering, UK;* [2]*Vector Biology Dept., Liverpool School of Tropical Medicine, UK;* [3]*Mwanza Medical Research Centre, National Inst. for Medical Research, Tanzania, (United Republic of).* The design of an 8-camera imaging system is presented for monitoring mosquito behaviour throughout an interior room. 3D tracking results are obtained via a bespoke stereo configuration at a test facility in Tanzania.

IW1C.3 • 09:00
Determination of the optical properties of meso- and nanoporous ceramics, Benjamin Lindner[1], Florian Foschum[1], Annika Häffner[1], Alwin Kienle[1]; [1]*Institut for Laser Technology, Germany.* The optical properties of nano- and mesoporous ceramics were determined using three different measurement methods. We investigated the characterization of geometrical parameters such as mean pore size and roughness of the ceramic surface.

IW1C.4 • 09:15
Harnessing Inverse Fringe Patterns for Actual Industrial Inspection Applications, Michael Strohmeier[1], Christian Faber[2]; [1]*BMW Group, Germany;* [2]*Univ. of Applied Sciences Landshut, Germany.* The actual industrial application of well-known measurement techniques, especially in harsh production environments, often requires extensive additional effort. For inverse fringe projection as an example, a calibration free, fast and flexible method for pattern generation used in an inline inspection system for the automated detection of 3-dimensional defects in sheet metal forming is presented.

08:30–10:00
MW1D • Imaging System Analysis
Presider: Daniel Brunner; CNRS - FEMTO-ST, France

MW1D.1 • 08:30
Application of the Van Cittert-Zernike Theorem to Imaging with Dynamic Metasurface Apertures, Aaron V. Diebold[1], Mohammadreza F Imani[1], David R. Smith[1]; [1]*Duke University, USA.* We explore an interferometric method for incoherent near-field imaging using metasurface antennas without knowledge of the transmitted fields. This approach can alleviate requirements for accurate calibration and phase information in practical microwave and terahertz systems.

MW1D.2 • 08:45
Efficient PSF field estimation, tracing few rays, in axially symmetric optical systems, Sergio Barbero[1], Javier Portilla[1]; [1]*Instituto de Optica (CSIC), Spain.* We provide a method for efficiently computing the Point Spread Function field in axially symmetric optical systems tracing few rays. The method is based on the concept of effective object phase space and Chebyshev interpolations.

MW1D.3 • 09:00 Invited
Superresolution Imaging and Superoscillation Design, Markus E. Testorf[1]; [1]*Dartmouth College, USA.* Minimum weighted norm signal estimation is applied to superresolution imaging and spectral estimation. Functional designs of superresolving diffractive optical elements are obtained by translating techniques developed for superresolution imaging to the construction of superoscillating signals.

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

CW1A • Applications of Deep Learning to Computational Imaging—Continued

CW1A.4 • 09:30
Efficient Image Classification through a Multimode Fiber using Deep Neural Networks in presence of Wavelength Drifting, Eirini Kakkava[1], Navid Borhani[1], Babak Rahmani[2], Ugur Tegin[1,2], Christophe Moser[2], Demetri Psaltis[1]; [1]*Optics Laboratory, Ecole Polytechnique Federale de Lausanne, Switzerland;* [2]*Laboratory of Applied Photonic Devices, École Polytechnique Fédérale de Lausanne, Switzerland.* Wavelength drifting affects the propagation of inputs through a multimode fiber. We use Deep Neural Networks to recover the fiber input information from the speckle outputs in presence of wavelength fluctuations.

CW1A.5 • 09:45
Perceptual loss for light field reconstruction in high-dimensional convolutional neural networks, Nan Meng[1], Tianjiao Zeng[1], Edmund Y. Lam[1]; [1]*The Univ. of Hong Kong, China.* We explore the benefits of perceptual loss for light field (LF) spatial reconstruction in a high-dimensional convolutional neural network. The results outperform some state-of-the-art methods for LF or image super-resolution.

Room 5 Marie Curie

Imaging Systems and Applications

IW1B • 3D Image Acquisition and Display: Technology, Perception and Applications II—Continued

IW1B.3 • 09:30 Invited
Digital Wavefront Control in OCT, Rainer Leitgeb[1]; [1]*Medizinische Universität Wien, Austria.* An overview of multidimensional integral-imaging for sensing, visualization, and recognition in degraded-environments is presented. Applications include 3D visualization, photon starved imaging, material inspection, IR imaging, passive depth estimation, automated human gesture recognition, and long-range imaging.

A11 Gordon Gould

Imaging Systems and Applications

IW1C • Industrial Imaging—Continued

IW1C.5 • 09:30
Laser heterodyne probing as a method of imaging internal inhomogeneities in optical materials, Ilya S. Steinberg[1], Andrey Y. Belikov[1], Peter E. Tverdokhleb[1]; [1]*Inst. of Automation and Electrometry, Russian Federation.* A method for studying materials phase inhomogeneities by point-to-point three-dimensional heterodyne probing is proposed. The probe is a micrograting, formed by two focused overlapping beams. Imaging of phase inhomogeneities distribution in laser ceramics is demonstrated.

IW1C.6 • 09:45
Real-time optical imaging of physical fields in semiconductor materials, Anastasiya Deulina[1], Elena V. Cherkesova[1], Alexander M. Grigorev[1], Olga Velichko[1]; [1]*Laser Technology Center, Ltd, Russian Federation.* A method for real-time optical imaging of physical fields in semiconductor materials based on using light from the fundamental absorption edge is proposed. This method can be used to measure physical properties of the material.

A12 Max Born

Mathematics in Imaging

MW1D • Imaging System Analysis—Continued

MW1D.4 • 09:30 Invited
Role of Coherence in Fundamental Limits of Imaging, Amit Ashok[1]; [1]*Univ. of Arizona, USA.* Two point-source resolution limits (e.g. Rayleigh limit) are not fundamental and do not incorporate optical coherence. We explore fundamental limits for two point-sources separation and line source length estimation as a function of optical coherence.

10:00–10:30 Coffee Break, *A1 Foyer*

10:30–11:15 Rapid Fire Poster Previews, *Room 4, Emmett Leith*

11:15–12:30 Hot Topics Discussions, *Room 4, Emmett Leith*

Joint Poster Session

12:30–14:00
JW2A • Poster Session

JW2A.1
Withdrawn.

JW2A.2
Withdrawn.

JW2A.3
Single-Pixel Video Imaging with DCT Sampling, Anna Pastuszczak[1], Krzysztof M. Czajkowski[1], Rafal Kotynski[1]; [1]*Uniwersytet Warszawski, Poland.* Discrete cosine transform elements are highly efficient sampling patterns for compressive single-pixel video imaging. We discuss the influence of the ordering of these patterns on the quality of the reconstruction of a moving scene.

JW2A.4
All-in-one confocal and widefield fluorescence microscope to investigate membrane receptor dynamics, Marc Bathe-Peters[1], Paolo Annibale[1], Martin Lohse[1], Philipp Gmach[1]; [1]*Max Delbrück Center, Germany.* We present the setup of a fluorescence microscope combining TIRF and con-focal microscopy within one body to address multi-scale dynamics of GPCRs on plasma membranes of living cells with adequate spatial and temporal resolution.

JW2A.5
Denoising prior driven reconstruction of microscopy images with Poisson statistics, Jie Hu[1], Tao He[1], Yasheng Sun[1], Jin Qi[1], Haiqing Huang[1], Biao Chen[1]; [1]*Shanghai Jiaotong Univ., China.* We investigate a Plug-and-Play framework for microscopy image reconstruction under Poisson noise, by unfolding the reconstruction into a Newton iteration and a denoising-based algorithm. This method can flexibly embed various denoising priors into reconstruction tasks.

JW2A.6
Low Intensity LiDAR using Depth Aware Compressive Sensing and a Photon Number Resolving Detector, Yoni Sher[1], Lior Cohen[1], Daniel Istrati[1], Hagai S. Eisenberg[1]; [1]*The Hebrew Univ. in Jerusalem, Israel.* The biggest challenge for LiDAR systems is the trade-off between speed, resolution and range; but what if we could have them all? Compressive sensing photon counting LiDARs are still in their infancy, and we present several simple improvements for them.

JW2A.7
Blind structured illumination microscopy using saturated speckle patterns, Penghuan LIU[1]; [1]*China Jiliang Univ., China.* We can not achieve a higher resolution in blind structured illumination microscopy by substituting fully developed speckle with saturated speckle illuminations.

JW2A.8 RAPID FIRE
Snapshot Spectral Imaging with Generalized Photon Sieves, Süleyman Ayazgök[1], Figen S. Oktem[1]; [1]*Middle East Technical Univ., Turkey.* We develop a novel snapshot multi-spectral imaging modality using a generalized photon sieve. The spectral images are computationally formed from a single-shot measurement that contains the blurred copies of each spectral image.

JW2A.9
Convolutional Inverse Problems in Imaging with Convolutional Sparse Models, Didem DOGAN[1], Figen S. Oktem[1]; [1]*METU, Turkey.* We develop a fast reconstruction method with convolutional sparse models for general inverse problems involving convolutions.The effectiveness of the reconstruction method is demonstrated for an inverse problem in computational spectral imaging.

JW2A.10
Tomographic reconstruction of mm-size objects with a microfocus X-ray source, Margarita Chevalier[1], Pablo Perez-Vasallo[2], Eusebio Solórzano[2], Tatiana Alieva[1]; [1]*Universidad Complutense de Madrid, Spain;* [2]*Novadep Scientific S.L., Spain.* We demonstrate the tomographic reconstruction of mm-size organic and inorganic objects at micrometric resolution using a microfocus X-ray laboratory setup for biomedical and industrial material inspection applications.

JW2A.11
Influence of Spatial Power Spectrum Pattern Gray-level Distortion on Coherent Diffraction Imaging Reconstruction, Yanfang Guo[1], Wusheng Tang[2], Wenjun Yi[2], Mengzhu Li[1], Meicheng Fu[2], Mengjun Zhu[2], Xiaofeng Wang[2], Jubo Zhu[2], Jiying Liu[2], Ping Wang[2], Xiujian Li[2], Wei Wang[1]; [1]*Changsha Univ. of Science & Tech., China;* [2]*National Univ. of Defense Tech., China.* Based on experiment and simulation results, we find that the spatial power spectrum pattern gray-level distortion has much influence on the CDI reconstruction, and the acquired pattern distortion rate should be less than 0.1.

JW2A.12 RAPID FIRE
Few but alike: how correspondence ghost imaging works, Zhe Han[1], Junhui Li[1], Dongyue Yang[1], Qian Peng[2], Huixia Mo[1], Guohua Wu[1]; [1]*Beijing Univ. of Posts & Telecommunications, China;* [2]*Virtu Financial, USA.* Sensitivity analysis interprets why correspondence ghost imaging can restore better images by fewer reference patterns of larger bucket fluctuation: these selected patterns are the more alike ones with regard to the target.

JW2A.13
Wavefront Recovery: Shack-Hartmann Aberrometry vs PhaseLift Using a Single Binary Amplitude Modulating Mask, Varis Karitans[1,2], Edgars Nitiss[1], Andrejs Tokmakovs[1]; [1]*Inst. of Solid State Physics, Latvia;* [2]*Dept. of Optometry and Vision Science, Univ. of Latvia, Latvia.* We investigate whether a wavefront can be recovered by using a single mask rotated in four different positions. Results show that PhaseLift can recover the wavefront from intensity measurements using such a kind of modulation.

JW2A.14
How to Estimate Depth in Polarization 3D Imaging with the Monocular Vision Model, Fangyi Chen[1], Xuan Li[1], Fei Liu[1], Xin Li[1], Xiaopeng Shao[1]; [1]*Xidian Univ., China.* To solve depth information problem in 3D polarization imaging, we use monocular vision imaging model to get the actual depth of the object. Comparing to other methods, our method is more affordable and more convenient.

JW2A.15
Reducing motion blur in ghost imaging with Hessian enhancement filter, Chen Chang[1], Dongyue Yang[1], Junhui Li[2], Guohua Wu[1], Bin Luo[2], Longfei Yin[1], Hong Guo[3]; [1]*Beijing Univ. of Posts and Telecommunications, China;* [2]*Beijing Univ. of Posts and Telecommunications, China;* [3]*Peking Univ., China.* In ghost imaging with pseudo-thermal light, Hessian enhancement filter is applied in reference measurements to improve the image quality by reducing the motion blur caused by improper exposure settings at short coherence time.

JW2A.16
A Method of Fourier Ptychography Based on Variable Aperture Scanning, Wusheng Tang[1], Yanfang Guo[1], Wenjun Yi[1], Meicheng Fu[1], Mengjun Zhu[1], Mengzhu Li[1], Jinghan Pan[1], Xiaochun Wang[1], Xiaofeng Wang[1], Jubo Zhu[1], Jiying Liu[1], Ping Wang[1], Xiujian Li[1]; [1]*National Univ. of Defense Technology, China.* We report a novel variable-aperture Fourier ptychography based on 4-f optical system for reconstructing high-resolution images. Simulations and experiments are performed to demonstrate that the method is tolerant to aperture's inaccurate positioning and shape error.

JW2A.17
Self-calibrated four-axis high-precision polarimeter, Jesus del Hoyo[1], Luis Miguel Sanches-brea[1], Jose Antonio Gomez-Pedrero[1]; [1]*Universidad Complutense de Madrid, Spain.* We present a new method for calibrating a 4 stepper-motors polarimeter. This method does not require perfect polarizing elements or well-known samples. Experimental results have been obtained with errors lower than 0.1%.

JW2A.18
Maximum-likelihood localization of overlapping point sources in 3D microscopy using CLEAN, Michael Handley[1], Guillem Carles[1], Andrew R. Harvey[1]; [1]*Univ. of Glasgow, UK.* Precise 3D point localization is increasingly important in microscopy, but algorithms break down when PSFs overlap. We adapt the CLEAN algorithm from astronomical imaging to enable MLE localization of high-density datasets.

JW2A.19 RAPID FIRE
Computational multispectral imaging via one digital micromirror device, Mingjie Sun[1], Wen Chen[1]; [1]*Beihang Univ., China.* We develop a computational multispectral imaging system using a digital micromirror device as a spatial light modulator and a blazed grating. Multispectral images of 128 × 128 spatial resolution and ~40nm spectral interval are obtained.

JW2A.20
Coded Illumination in Compressive X-ray CT, Angela Cuadros[1], Xu Ma[2], Gonzalo R. Arce[1]; [1]*Univ. of Delaware, USA;* [2]*School of Optics and Photonics, Beijing Inst. of Technology, China.* This paper explores a new approach for spectral X-ray tomography that uses structured illumination for the reconstruction of energy-binned images from fewer measurements.

JW2A.21
Adaptive Compressive Sensing with Multiscale Hadamard Patterns, Vladislav Kravets[1], Adrian Stern[1]; [1]*Ben Gurion University of the Negev, Israel.* We introduce an efficient adaptive compressive sensing technique that utilizes the zero-trees concept. The method uses multiscale ordered Hadamard sampling and its relation to the Haar wavelet, therefore is particularly useful for single pixel imaging.

JW2A.22
A Novel Multiframe Compressive Spectral Imaging Architecture, Miguel Marquez[3], Pablo Meza[2], Henry Arguello[3], Esteban Vera[1]; [1]*P. Universidad Catolica de Valparaiso, Chile;* [2]*Universidad de La Frontera, Chile;* [3]*Universidad Industrial de Santander, Colombia.* This work proposes a novel compressive spectral architecture based on a deformable mirror and a colored-filter detector to acquire and estimate the three-dimensional spatio-spectral datacube from a set of multiple compressive projections.

JW2A.23
Withdrawn.

JW2A.24
Withdrawn.

JW2A.25
3D object position retrieval with the light-field camera and microscope, Gene Serabyn[1]; [1]*Jet Propulsion Laboratory, USA.* Light-field camera ray-trace simulations show that for sparse samples, the location, symmetry and size of the point-source response can provide lateral positions to a detector pixel size, and defocus to a lenslet focal length.

JW2A.26
3D Computational Imaging, Mengqi Du[1], Lars Loetgering[1], Kjeld Eikema[1], Stefan Witte[1]; [1]*ARCNL, Netherlands.* By combining coherent diffractive imaging (CDI) and optical coherence tomography (OCT), we develop 3D computational imaging of semi-transparent objects by taking both interferometric and non-interferometric (phase retrieval) approaches.

JW2A.27
Analysis of required alignment accuracy for gradient-index rod array, Akihiro Yamamura[2,1], Kazuhiko Oka[3,4], Norihiko Nishiguchi[3]; [1]*OKI DATA Corporation, Japan;* [2]*Dept. of Applied Physics, Hokkaido Univ., Japan;* [3]*Faculty of Engineering, Hokkaido Univ., Japan;* [4]*Faculty of Science and Tech., Hirosaki Univ., Japan.* Illuminance distribution of the image with a lens array which has a tilted Gradient-Index (GRIN) rod lens is investigated to clarify allowable degree of alignment accuracy of the GRIN rod.

JW2A.28
Non-Conventional Optical Technique to Determine Spatio-Temporal Characteristics of Objects with Specially Designed Apodizing Filter, Artur Martirosyan[1]; [1]*Inst. for Physical Research, Armenia.* A novel approach for detecting parameters of the single or structured objects by the radially-quadratic transmittance apodizing filter is described. In contrary to the image processing, the developed technique deals with non-matrix detection setup which operates in the linear sensitivity range.

Joint Poster Session

JW2A • Poster Session—Continued

JW2A.29 RAPID FIRE
Around the corner indirect passive imaging, Shu Yang[1], Kwan Kit Lee[1], Amit Ashok[1]; [1]*University of Arizona, USA.* In indirect passive imaging, the object of interest is occluded from the imager which has no control over illumination. Using a second-order (non-linear) image formation model we demonstrate (experimentally) the feasibility of passive indirect imaging.

JW2A.30
Preliminary study on remote sensing the relationship between the brightness temperature pulses observed with a ground-based microwave radiometer and the lightning action integra, Zhenhui Wang[1]; [1]*School of Atmospheric Physics, NUIST, China.* The integral of lightning current squared over time, named as the "lightning action integral", is an indicator of Joule heat generated by lightning discharge. The temperature of air molecules is thus increased, which can be observed by a ground-based microwave radiometer. The results from 7 effective events show that a relationship like DTB=exp(aX) may exist between the brightness temperature increment and the lightning action integral. The correlation coefficient is as high as 0.8863.

JW2A.31
Estimating mean spectral characteristics of energy of turbulent fluctuations from large scale atmospheric perturbations and wavefront measurements, Artem Shikhovtsev[1], Evgeny Kopylov[2], Pavel Kovadlo[1]; [1]*Inst. of solar-terrestrial physics, Russian Federation;* [2]*V.E. Zuev Inst. of Atmospheric Optics, Russian Federation.* The work is focused on the development of schemes to calculate characteristics of small scale turbulence using deformations the shapes of energy spectrum of turbulence and wavefront measurements.

JW2A.32
Method to restore the height profiles of atmospheric turbulence from measurements of the wavefront local slopes by a single Shack-Hartmann sensor, Artem Shikhovtsev[1], Maxim Shikhovtsev[2], Alexander Kiselev[1]; [1]*Inst. of Solar-Terrestrial Physics, Russian Federation;* [2]*Irkutsk state Univ., Russian Federation.* The method to estimate height profiles of the dimensionless characteristics of the atmospheric turbulence is proposed. Analyzing the wavefront local slopes by this method is one of the first practical implementations on a solar telescope.

JW2A.33
Research on the evolution of 40Gbps light pulses propagating through different levels of turbulence, XiuHua Yuan[1,2], Minghao Wang[1], Ji Huang[1]; [1]*Huazhong Univ. of Science & Tech., China;* [2]*Shenzhen Huazhong Univ. of Science and Tech. Research Inst., China.* In this letter we report the experimental results of the evolution of picosecond light pulses in the presence of different levels of turbulence and particles artificially generated within a chamber equipped with six fans. An applicable model is used to characterize the strengths of the generated turbulence. The impaired time-domain waveforms and the spectrum are observed and examined at the receiving end, then compared with the waveforms acquired in no-turbulence situation.

JW2A.34
Withdrawn.

JW2A.35
Designing, Building, and Testing of a Hybrid Wavefront Sensor for Adaptive Optics, Ryan J. Hamilton[1], Joseph A. Rice[1], Charlotte E. Guthery[1], Michael Hart[1]; [1]*University of Arizona OSC, USA.* A benchtop hybrid wavefront sensor is designed and built. Running a selective operation mode routine, the wavefront sensor will be tested in the laboratory for high dynamic range and high sensitivity performance while remaining linear.

JW2A.36 RAPID FIRE
The effect of intermittency of astronomical images in the high-altitude observations, Vladimir P. Lukin[1]; [1]*Russian Academy of Sciences, Russian Federation.* As a result of long-term expedition measurements in various climatic conditions and regions with a mountain and flat surface, we have accumulated an extensive experimental database of surface characteristics of atmospheric turbulence.

JW2A.37
1 kilometer atmospheric propagation studies of a 5 TW ultrashort pulse laser, Daniel J. Thul[1], Robert Bernath[1], Nathan Bodnar[1], Haley Kerrigan[1], Danielle Reyes[3], Jessica Peña[1], Patrick Roumayah[1], Shermineh Rostami Fairchild[2,1], Martin Richardson[1,2]; [1]*College of Optics and Photonics, Univ. of Central Florida, USA;* [2]*Dept. of Physics and Space Sciences, Florida Inst. of Tech., USA;* [3]*Dept. of Physics, Univ. of Central Florida, USA.* Field testing of the Mobile Ultrafast High-Energy Laser Facility is presented. This facility is located on a 1 km test range on Merritt Island and is equipped with a full suite of atmospheric diagnostic equipment.

JW2A.38
Comparison of adaptive free form lens with deformable mirrors, Martino Q. Quintavalla[1], Jacopo Mocci[2], Riccardo Muradore[2], Stefano Bonora[1]; [1]*IFN, CNR, Italy;* [2]*Universita di Verona, Italy.* We compared the performance of several deformable mirrors and deformable lenses as regard their capability of correcting static and dynamic aberrations both in open- and closed- loop. These tests highlighted notable differences between the devices as regards the performance in different cases, as well as their ease to use.

JW2A.39 RAPID FIRE
Water-cooled stacked-actuator deformable mirror for atmospheric phase distortions correction, Alexis Kudryashov[2], Vladimir Toporovsky[1,2], Vadim Samarkin[1,2], Julia Sheldakova[2,1], Alexey Rukosuev[2,1]; [1]*Akaoptics SAS, France;* [2]*Institue of Geosphere Dynamics, Russian Federation.* We developed the 121-elements stacked-actuator deformable mirror for atmospheric applications. The main advantages of the manufactured wavefront corrector are the possibility of the replacement of the broken actuators and the cooling of the mirror surface.

JW2A.40
Experimental Study on the Turbulence Resistant Properties of Custom Designed Beams Encoded with Multiple Vortices, Awakash Dixit[1,2], Sanjay K. Mishra[2]; [1]*Indian Inst. of Technology Madras, India;* [2]*DRDO-Instruments Research & Development Establishment, India.* In this paper, the turbulence resistant properties of custom designed beams are experimentally investigated with the help of two types of atmospheric turbulence simulators. These beams are encoded with multiple optical vortices and are generated by phase-only SLM.

JW2A.41
Nonlinear Diffraction Tomography without Iterations, Gregory Samelsohn[1]; [1]*Shamoon College of Engineering, Israel.* A number of models of nonlinear diffraction tomography are considered. All of them are based on a Radon-to-Helmholtz mapping and corresponding inversion procedures proposed by the author. Numerical simulations confirm that the reconstruction of the object is rather accurate, well beyond the limits of the Born or Rytov models.

JW2A.42
Aberration analysis and measurement of micro-offset free-form mirrors, Lo-Yu Wu[1], Pei-Jen Wang[1], Yuan-Chieh Cheng[2]; [1]*National Tsing Hua Univ., Taiwan;* [2]*National Applied Research Laboratories, Taiwan.* To verify the image quality of freeform lenses, Shack Hartmann wavefront measurement system plus MTF based Fourier optical system are employed for analysis of wavefront aberrations of the lenses.

JW2A.43 RAPID FIRE
Accurate solution of the transmission of intensity equation by the Hartmann on a chip, Mahdi Soudi[1]; [1]*Univ. of Zanjan, Iran (the Islamic Republic of).* The TIE is Non-Interferometric method with high spatial resolution to measure the phase of the wavefront. In this paper we intend to find optimum defocusing distance by using Hartmann wavefront sensor.

JW2A.44
Amplitude Static Filtering in Autostereoscopic Imaging Layout Based on Amplitude-Polarization Imager and Phase-Polarization Parallax Barrier, Vasily A. Ezhov[1], Peter I. Ivashkin[1]; [1]*GPI RAS, Russian Federation.* Amplitude-polarization imager (API) along with static phase-polarization parallax barrier (PPPB) allow implementing autostereoscopic imaging with full-screen resolution in each view. Additional amplitude static filtering eliminates crosstalk in the gaps between the API and PPPB columns.

JW2A.45
DMD camera and its application, Shou-Bo Zhao[1], Li-Yuan Liu[1], Ming-Yang Ma[1]; [1]*Harbin Univ. of Science and Tech., China.* We describe the architectrue and characteristic of DMD camera. According to its advantage in temporal resolution, spatial resolution and dynamic range imaging, we employ it into edge detection, dynamic imaging and 3D shape measurement.

JW2A.46
Fast Fourier Transform as Color Variation Descriptor for Imaging the Stress Field from Photoelasticity Videos, Juan C. Briñez de León[1], Alejandro Restrepo-Martínez[1], John W. Branch-Bedoya[1]; [1]*Universidad Nacional de Colombia, Colombia.* Analyzing the color behavior in photoelasticity videos has become into a powerful tool to describe the stress distribution. This paper uses the Fast Fourier Transform to describe such behaviors, and associate them to stress values.

JW2A.47 RAPID FIRE
Heterodyne Mixing Efficiency of a Digital Holography System, Douglas E. Thornton[1], Mark F. Spencer[2,1], Christopher A. Rice[1], Glen P. Perram[1]; [1]*Engineering Physics, Air Force Inst. of Technology, USA;* [2]*Air Force Research Labs, USA.* We experimentally measure the heterodyne mixing efficiency of a digital holog- raphy system using two separate calculations. The results show each calculation was within 4% of the expected value of 32.2%.

JW2A.48
Holographic imaging and acoustofluidics: an advantageous combination, Teresa Cacace[1,2], Vittorio Bianco[1], Pasquale Memmolo[1], Melania Paturzo[1], Massimo Vassalli[3], Massimiliano Fraldi[4], Giuseppe Mensitieri[4], Pietro Ferraro[1]; [1]*CNR-ISASI, Italy;* [2]*Univ. of Campania L.Vanvitelli, Italy;* [3]*Inst. of Biophysics, Italy;* [4]*Univ. of Naples Federico II, Italy.* The combination of Digital holography and acoustofluidics provides distinct advantages. While a transparent piezo assures optical investigation through the microchannel, we employ holographic imaging to assess the acoustic manipulation and to calibrate bulk acoustic waves.

JW2A.49
Particle characterization using forward elastic light scattering, Miguel A. Casas-Ramos[1,2], Gabriel E. Sandoval-Romero[1,2]; [1]*Universidad Nacional Autónoma de México, Mexico;* [2]*Sensores, Instituto de Ciencias Aplicadas y Tecnologia, Mexico.* The present work shows the design of an instrument to measure the forward extinction and light scattering for a particle monolayer by using a beam stop, which acts as spatial filter.

JW2A.50
Texture analysis for evaluating the Bayer and demosaicking effects in photoelasticity images, Hermes Fandiño[1,2], Juan C. Briñez de León[1], Alejandro Restrepo-Martínez[1], John W. Branch-Bedoya[1]; [1]*Universidad Nacional de Colombia, Colombia;* [2]*Instituto Tecnológico Metropolitano, Colombia.* Bayer filters and demosaicking methods applied to photoelasticity cause errors when imaging the stress field. This paper presents a texture analysis to quantify these errors.

JW2A.51
Achromatic Broadband Diffractive Lenses for Focusing and Imaging in LWIR, Sourangsu Banerji[1], Monjurul Meem[1], Apratim Majumder[1], Rajesh Menon[1], Berardi S. Rodriguez[1]; [1]*Electrical and Computer Engineering, Univ. of Utah, USA.* In contrast to conventional bulk optics, achromatic planar diffractive lenses operating in the LWIR (8um-12um) regime has been demonstrated in this work, which provides an efficient way for the development of compact, ultra-lightweight LWIR devices.

Room 4
Emmett Leith

Computational Optical Sensing and Imaging

14:15–15:30
CW3A • Advances in Ptychography and Emerging Applications
Presider: Oliver Cossairt; Northwestern Univ., USA

CW3A.1 • 14:00
Withdrawn.

CW3A.2 • 14:15
Spatially-Incoherent Lensless Imaging of Extended Objects Using Speckle Correlations and Ptychography, Dennis F. Gardner[1], Shawn Divitt[2], Abbie Watnik[1]; [1]*Naval Research Laboratory, USA;* [2]*KeyW Corporation, USA.* We image extended samples using speckle correlations. To enable this advance, we collected several speckle patterns from a sample while it is raster-scanned through the pseudothermal illumination and use ptychography to reconstruct an image.

CW3A.3 • 14:30
Experimental Demonstration of Time-Resolved Imaging by Multiplexed Ptychography (TIMP), Omri Wengrowicz[1], Or Peleg[1], Barry Loevsky[1], Bing Kuan Chen[1], Gil Ilan Haham[1], Oren Cohen[1]; [1]*Technion, Israel.* We demonstrate experimentally, for the first time, ptychographic reconstruction of multiple frames of a dynamical complex-valued object from data recorded in a single CCD exposure, an important step towards ultrahigh-speed high-resolution microscopy.

CW3A.4 • 14:45
Multi-camera Fourier Ptychographic Microscopy, Tomas Aidukas[1], Pavan Konda[2], Jonathan Taylor[1], Andrew R. Harvey[1]; [1]*Univ. of Glasgow, UK;* [2]*Biomedical Engineering, Duke Univ., USA.* We demonstrate aperture-synthetic diffracted field measurement using multiple mutually incoherent cameras in Fourier ptychography to provide a scaleable increase in data acquisition bandwidth. Our nine-camera system enables an order of magnitude improvement in image acquisition speed.

CW3A.5 • 15:00
Comparison of propagation-based and ptychographic phase retrieval, Lars Loetgering[1], Kjeld Eikema[1], Stefan Witte[1]; [1]*Vrije Universiteit & ARCNL, Amsterdam, Netherlands.* Propagation-based phase retrieval and ptychography are well-established techniques in wavefront sensing and imaging. Here we experimentally cross-validate and compare both methods for beam characterization and phase contrast microscopy.

Room 5
Marie Curie

Imaging Systems and Applications

14:00–15:30
IW3B • Novel Imaging
Presider: Michael Groenert; US Army RDECOM CERDEC, USA

IW3B.1 • 14:00
All-optical imaging architecture for snapshot demodulation of optical signals at radio-frequencies, Swapnesh Panigrahi[1], Julien Fade[1], Romain Agaisse[1], Hema Ramachandran[2], Mehdi Alouini[1]; [1]*Universite de Rennes I, France;* [2]*Raman Research Inst., India.* We report the design and experimental proof-of-principle of a novel snapshot quadrature demodulation imaging architecture, allowing retrieval of amplitude and phase of light modulated at radio frequencies, without synchronization between emitter and receiver, and with continuous frequency tuning capability.

IW3B.2 • 14:15
Speckle-Free Imaging Lidar without Motion Blur using Moderate-Coherence, Nanosecond-Pulsed Lasers, Austin W. Steinforth[1], J. G. Eden[1]; [1]*Univ. of Illinois at Urbana-Champaign, USA.* Rapidly-moving targets are illuminated and imaged from distances as far as five meters using a single five-nanosecond pulse from a moderate-coherence laser. The resulting images are free of speckle and motion blur.

IW3B.3 • 14:30
High Speed Thermal Image Processing for Real Time Control and Monitoring of Tailored Laser Energy Distributions Using FPGAs, Beñat Arejita[1], Javier Sanchez[1], Juan Isaza[1]; [1]*EXOM Engineering, Spain.* In high power laser-based material surface processing, it is important to control the energy distribution. In this work we present a highly parallel architecture that estimates laser energy distribution parameters based on high-speed thermal imaging.

IW3B.4 • 14:45
RF Cross Section Imaging and Range Detection, Ariel Schwarz[1], Amir Shemer[1]; [1]*Bar Ilan Univ., Israel.* RF imaging technique based on optical time multiplexing super resolution methods is presented. The system overcome both resolution limits associated with antenna size and the number of detection channels whole incorporate target range detection.

IW3B.5 • 15:00
Completely Asymmetric Freeform Systems: the view from Phase Space, James Babington[1]; [1]*Qioptiq, UK.* We discuss two completely asymmetric freeform systems (a prism and a two mirror system used as near to eye displays) that have been designed and analysed using phase space methods.

A11
Gordon Gould

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

14:00–15:30
PW3C • Adaptive Optics & Wavefront Sensing II
Presider: Mikhail Vorontsov; Univ. of Dayton, USA

PW3C.1 • 14:00 Invited
Collaborative research in deep turbulence, Mark F. Spencer[1,3], Casey J. Pellizzari[2], Douglas E. Thornton[3]; [1]*Directed Energy Directorate, Air Force Research Laboratory, USA;* [2]*Dept. of Physics, USA Air Force Academy, USA;* [3]*Dept. Engineering Physics, Air Force Inst. of Tech., USA.* This talk parameterizes the deep-turbulence problem and discusses some collaborative-research efforts being pursued with respect to this very hard problem. These efforts recently culminated in ground-breaking results using digital holography and deep learning.

PW3C.2 • 14:30
Wavefront Sensing for Distributed Turbulence, Samuel T. Thurman[1], Brian W. Krause[1], Kalle Anderson[1], Andrew Bratcher[1], Philip Gatt[1], Thomas G. Alley[1]; [1]*Lockheed Martin Coherent Technologies, USA.* We describe laboratory experiments that use digital holography measurements to sense range resolved wavefront errors along the line-of-sight of an optical system. Detailed results are reviewed for a case designed to have Rytov variance = 0.7. © 2019 Lockheed Martin Corporation.

PW3C.3 • 14:45 Invited
Quantitative characterisation and forecasting of sky conditions on ESO's Paranal observatory – seven years and learning, Florian Kerber[1]; [1]*European Southern Observatory, Germany.* I will present ESO's efforts to characterise the properties of the atmosphere above its Paranal observatory (Chile) using a microwave radiometer LHATPRO to measure precipitable water vapour and cloud properties in support of science operations.

A12
Max Born

Mathematics in Imaging

14:00–15:30
MW3D • Imaging in Complex Media
Presider: Lei Tian; Boston Univ., USA

MW3D.1 • 14:00 Invited
Fast wavefront control for imaging in complex media, Rafael Piestun[1]; [1]*Univ. of Colorado at Boulder, USA.* We present fast wavefront shaping and image reconstruction through complex media using random speckle illumination and high-speed spatial light modulators operating at 350KHz. We implement the techniques in dynamic scattering phantoms and multimode optical fibers.

MW3D.2 • 14:30
Generalized phase screen model that accounts for the generalized memory effect, Adrian Stern[1], Malkiel Haskel[1]; [1]*Ben Gurion Univ. of the Negev, Israel.* We overview a phase screen model we have recently introduced that accounts for the generalized optical memory effect, which implies shift wave correlations in addition to the well-known tilt correlation of the classical memory effect.

MW3D.3 • 14:45 Invited
Correlation-based Imaging in Adaptive Optics, Jonatan Lehtonen[1], Tapio Helin[2]; [1]*Univ. of Helsinki, Finland;* [2]*LUT Univ., Finland.* Adaptive optics is a technology utilized in modern ground-based optical telescopes to compensate for the wavefront distortions caused by atmospheric turbulence. Our work relates correlation-based imaging in inverse problems to next-generation adaptive optics.

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

CW3A • Advances in Ptychography and Emerging Applications—Continued

CW3A.6 • 15:15
Complex Imaging Reflectometry for Dopant Profile Measurements using Tabletop High Harmonic Light, Michael Tanksalvala[1], Christina L. Porter[1], Yuka Esashi[1], Galen P. Miley[2], Naoto Horiguchi[3], Robert Karl[1], Peter Johnsen[1], Charles Bevis[1], Nicholas W. Jenkins[1], Bin Wang[1], Xiaoshi Zhang[4], Seth Cousin[4], Daniel E. Adams[1], Michael Gerrity[1], Henry C. Kapteyn[4,1], Margaret M. Murnane[1,4]; [1]*Univ. of Colorado at Boulder, USA;* [2]*Northwestern Univ., USA;* [3]*imec, Belgium;* [4]*KMLabs, USA.* We present a tabletop-scale complex-imaging EUV reflectometer that uses grazing-incidence ptychographic imaging to non-destructively determine depth-dependent, spatially-resolved composition with high sensitivity to chemical makeup, thin film layer thickness, interface quality and dopant profiles.

Room 5 Marie Curie

Imaging Systems and Applications

IW3B • Novel Imaging—Continued

IW3B.6 • 15:15
Spatial Visualization of Pulse Wave Propagation using RGB Camera, Ryo Takahashi[1], Keiko Ochiai-Ogawa[2], Norimichi Tsumura[1]; [1]*Chiba Univ., Japan;* [2]*Kanazawa Univ. Hospital, Japan.* This study aimed to visualize spatial pulse-wave propagation on an RGB video of skin. Such spatial visualization gives us information about the stagnation of blood flow in the body.

A11 Gordon Gould

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

PW3C • Adaptive Optics & Wavefront Sensing II—Continued

PW3C.4 • 15:15
Multi-actuator adaptive lens for turbulence correction in small size astronomical telescopes, Martino Q. Quintavalla[1], Jacopo mocci[2], Riccardo muradore[2], Stefano Bonora[1]; [1]*IFN, CNR, Italy;* [2]*Universita di Verona, Italy.* Multi actuator adaptive lenses can replace deformable mirrors in the correction of time variant aberrations. We will show the results obtained on medium size telescopes and to improve the stability of complex laser systems.

A12 Max Born

Mathematics in Imaging

MW3D • Imaging in Complex Media—Continued

MW3D.4 • 15:15
Exploiting Fisher Information for Constructing an Efficient Nonlinear Optimization Scheme for Quantum Imaging, Anton Sakovich[1], Alexander B. Mikhalychev[1], Ilya L. Karuseichyk[1], Dmitri S. Mogilevtsev[1]; [1]*Centre for Quantum Optics and Quantum Information, B.I. Stepanov Inst. of Physics, Belarus.* Making use of Fisher information, we show that a broad class of object reconstruction problems can be accurately and efficiently solved by reconstructing the object iteratively, reconstructing only a subset of parameters at each step.

15:30–16:00 Coffee Break, *A1 Foyer*

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

16:00–18:00
CW4A • Advances in Computational Microscopy
Presider: Andrew Harvey; Univ. of Glasgow, UK

CW4A.1 • 16:00 Invited
Techniques for Methodical, Optical and Computational Automation in Light-sheet Microscopy, Marie-Caroline Muellenbroich[1,2], Ludovido Silvestri[2,3], Lapo Turrini[3], Antonino Paolo Di Giovanna[3], Irene Costantini[3], Giacomo Mazzamuto[3], Francesco Vanzi[3], Leonardo Sacconi[2,3], Chas Nelson[1], Jonathan Taylor[1], Francesco S. Pavone[3,2]; [1]*Univ. of Glasgow, UK;* [2]*National Research Council, National Inst. of Optics, Italy, Italy;* [3]*LENS, Italy.* Light-sheet microscopy excels in fast whole-organ acquisitions either in clarified mouse brains or intrinsically transparent zebrafish larva. Here, we present our technical and optical solutions for microscope automation including autofocusing, Bessel beams and prospective gating.

CW4A.2 • 16:30
Calculation of High Numerical Aperture Lightfield Microscope Point Spread Functions, Peter Quicke[1], Carmel L. Howe[1], Pingfan Song[1], Herman Verinaz Jadan[1], Pier Luigi Dragotti[1], Thomas Knöpfel[1], Amanda J. Foust[1], Simon R. Schultz[1], Mark Neil[1]; [1]*Imperial College London, UK.* 3D deconvolution of lightfield images enables high resolution reconstruction of sample volumes. Previous point spread function calculations assume low to moderate NA objectives. Here we present a simple vectorial calculation valid for high NA objectives.

CW4A.3 • 16:45
Deconvolution in Scatter-plate Microscopy, Stephan Ludwig[1], Giancarlo Pedrini[1], Wolfgang Osten[1], Alois Herkommer[1], Benjamin Le Teurnier[1,2]; [1]*ITO Univ. Stuttgart, Germany;* [2]*Institut d'Optique, France.* Scatter-plate microscopy is a lensless imaging method using a simple ground glass diffuser instead of a microscope objective. In this paper we describe further application of deconvolution improving both contrast and resolution of the acquired images.

CW4A.4 • 17:00
High-resolution Imaging of Nanoparticles in Wide-field Interferometric Scattering Microscopy, Celalettin Yurdakul[1], Oguzhan Avci[1], Alex Matlock[1], Lei Tian[1], Ekmel Ozbay[2], Selim M. Ünlü[1]; [1]*Boston Univ., USA;* [2]*Bilkent Univ., Turkey.* Single particle interferometric scattering microscopy has demonstrated great capability in label-free imaging of sub-wavelength dielectric nanoparticles (r<25 nm); however, it suffers from diffraction-limited resolution. Here, we demonstrated ~2-fold improvement in lateral resolution upon asymmetric illumination.

Room 5 Marie Curie

Joint

16:00–17:00
JW4B • Compressed Sensing / Multi-aperture Imaging
Presider: Figen Oktem; Middle East Technical Univ., Turkey

JW4B.1 • 16:00
Temporal Compressed Measurements for Block-wise Compressive Imaging, Jun Ke[1], Linxia Zhang[1], Edmund Y. Lam[2]; [1]*Beijing Inst. of Technology, China;* [2]*The Univ. of Hong Kong, Hong Kong.* In compressive imaging, the data acquisition speed of sensors is one of the restrictions limiting system imaging speed. To relax the speed requirement of sensors, we combine temporal and spatial compressive sensing idea for block-wise compressive imaging(BCI).

JW4B.2 • 16:15
Polarizer-free polarization-contrast compressive imaging, Julien Fade[1], Estéban Perrotin[1], Jérôme Bobin[2]; [1]*Universite de Rennes I, France;* [2]*IRFU, Service d'Astrophysique-SEDI, CEA , France.* We extend the single-pixel camera concept to enable polarization contrast compressive imaging without polarizer, from simultaneous detection of light reflected by a Digital Micromirror Device on two photodetectors, and using optimized bivariate signal reconstruction algorithms.

JW4B.3 • 16:30
Optimal Coding Patterns in Spatial Spectral Compressive Spectral Imagers, Edgar E. Salazar[1], Gonzalo R. Arce[1]; [1]*Univ. of Delaware, USA.* This paper develops the conditions required for optimal coded apertures used in the Spatial Spectral Compressive Spectral Imager (SSCSI), so as to maximize the quality of the recovered hyperspectral scenes.

JW4B.4 • 16:45
360° snapshot imaging with a convex array of long-wave infrared cameras, Laura Cowan[1], James Babington[2], Guillem Carles[1], Miguel Preciado[1], Andy Wood[2], Andrew R. Harvey[1]; [1]*Univ. of Glasgow, UK;* [2]*Qioptiq Ltd., UK.* Long-wave infrared imaging systems remain prohibitively expensive for many high-pixel-count applications, such as panoramic imaging. We present a computational imaging solution which allows for low-cost, 360° long-wave infrared panoramic imaging at video rate.

A11 Gordon Gould

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

16:00–18:00
PW4C • Wavefront Sensing & Optical Links
Presider: Italo Toselli; Fraunhofer IOSB, Germany

PW4C.1 • 16:00 Invited
Tomographic Wave Front Sensing using an Imaging Shack-Hartmann Wave Front Sensor, Stuart Jeffries[1]; [1]*Georgia State Univ., USA.* We show how the geometry of an imaging Shack-Hartmann wave front sensor and the temporal correlations in the recorded atmospheric wave front can be leveraged to provide 3D information on the wave front.

PW4C.2 • 16:30
Development of a Shack-Hartmann Sensor Based on Adaptable Diffractive Lens Arrays for Reduction of Scintillation Effects, Daniel Lechner[2,1], Andreas Zepp[2], Szymon Gladysz[2]; [1]*Karlsruher Institut für Technologie, Germany;* [2]*Fraunhofer Inst. of Optronics, System Technologies and Image Exploitation, Germany.* A Shack-Hartmann sensor which utilizes diffractive lens arrays displayed on a spatial light modulator was built. First measurements with different lens arrays were carried out. The sensor holds the premise of increased robustness against scintillation.

PW4C.3 • 16:45
Using event-based optical flow to determine the Shack-Hartmann spot displacements, Fanpeng Kong[1], Greg Cohen[2], Andrew Lambert[1]; [1]*Univ. of New South Wales, Australia;* [2]*Western Sydney Univ., Australia.* Event-based sensors output a continuous stream of time-tagged pixel locations where the change of integrated intensity exceeds a threshold. We use this spatio-temporal data to measure the displacement in a Shack-Hartmann spots pattern.

PW4C.4 • 17:00
Anisoplanatic Differential Tilt Measurements in the 2009 Laser Communications System Experiment, Jeremy P. Bos[1]; [1]*Michigan Technological Univ., USA.* I revisit the 2009 Laser Communication System Experiment and apply recently described methods that allow the recovering of a number of atmospheric parameters using differential tilt measurements from point sources. I confirm that the new methods match previous results for C_n^2 and may be used to recover other information about the atmospheric path from historical data.

A12 Max Born

Mathematics in Imaging

16:00–17:30
MW4D • Tomography
Presider: Markus Testorf; Dartmouth College, USA

MW4D.1 • 16:00 Invited
Limits and Applications of Diffractive Coupling, Daniel Brunner[1]; [1]*CNRS - FEMTO-ST, France.* Large-scale photonic networks are a long standing goal. We have created networks hosting 2000 photonic elements. Based on diffraction, the technique is scalable to 106 components and I will compare experimental, numerical and analytical results.

MW4D.2 • 16:30
Modelling of Errors and Uncertainties in Photoacoustic Tomography using a Bayesian Framework, Tanja Tarvainen[1,2], Teemu Sahlström[1], Jenni Tick[1], Aki Pulkkinen[1]; [1]*Univ. of Eastern Finland, Finland;* [2]*Univ. College London, UK.* Photoacoustic tomography is studied in the framework of Bayesian inverse problems. Modelling of errors and uncertainties using Bayesian approximation error modelling is investigated. The approach is tested with simulations.

MW4D.3 • 16:45
Full Hessian Based Reconstruction Scheme for SP_N-approximated Fluorescence Optical Tomography, Nishigandha Patil[1], Naren Naik[1,2]; [1]*Dept. of Electrical Engineering, Indian Inst. of Tech., Kanpur, India;* [2]*Center for Lasers and Photonics, Indian Inst. of Tech. Kanpur, India.* We present a full Hessian based predictor-corrector reconstruction scheme for SPN-approximation modeled fluorescence optical tomography incorporated into the regularising Levenberg-Marquardt method. Numerical studies show enhanced contrast and noise tolerance with respect to the first-order scheme.

MW4D.4 • 17:00
Characterization of Ultrasound Fields Using a Potential Optical Flow Based Synthetic Schlieren Tomography, Eero J. Koponen[1], Jarkko Leskinen[1], Tanja Tarvainen[1,2], Aki Pulkkinen[1]; [1]*Univ. of Eastern Finland, Finland;* [2]*Univ. College London, UK.* Synthetic schlieren tomography is an optical imaging method for characterization of ultrasound fields based on observing bending of light due to acousto-optic effect. In this work, potential optical flow based pressure estimation method is introduced.

Room 4 Emmett Leith	Room 5 Marie Curie	A11 Gordon Gould	A12 Max Born
Computational Optical Sensing and Imaging		Propagation Through and Characterization of Atmospheric and Oceanic Phenomena	Mathematics in Imaging

CW4A • Advances in Computational Microscopy—Continued

CW4A.5 • 17:15
Upgrading a brightfield optical microscope into a robust numerically advanced interference-based phase imager, Maciej Trusiak[1], Krzysztof Patorski[1], Piotr Zdankowski[1], Maria Cywinska[1], Vicente Mico[2], Jose-Angel Picazo-Bueno[2], Javier Garcia[2]; [1]*Politechnika Warszawska, Poland;* [2]*Univ. of Valencia, Spain.* The approach to convert a brightfield microscope into an interference-based versatile quantitative phase imaging unit is presented. It employs partially coherent illumination and diffraction grating. Enhanced interferogram bio-phase retrieval is performed by two-shot numerically-robust Hilbert–Huang method.

CW4A.6 • 17:30
Withdrawn.

CW4A.7 • 17:45
Luminescence Decay Measurement via Temporal Speckles, Jiri Junek[1,2], Karel Zidek[1]; [1]*Toptec, ASCR, Czechia;* [2]*Technical Univ. of Liberec, Czechia.* We present a method able to reconstruct luminescence decay on the microsecond timescale from measurements based on a randomly fluctuating excitation intensity. The fluctuations are attained by rapidly changing speckle patterns, i.e. temporal speckles.

PW4C • Wavefront Sensing & Optical Links—Continued

PW4C.5 • 17:15
Temporal characterization of an urban horizontal atmospheric telecom channel, Chloé Sauvage[1,2], Clélia Robert[1], Béatrice Sorrente[1], Didier Erasme[2]; [1]*ONERA - The French Aerospace Lab, France;* [2]*LTCI, Telecom ParisTech, France.* Free Space Optics (FSO) are breakable under some climatic conditions. However characterization of the propagation channel by studying wavelength transmisttance and data coming from a wavefront experiment could improve FSO's performance.

PW4C.6 • 17:30
Adaptive Detection Scheme for Free Space Optical Communication System under Atmospheric Turbulence, Youyu He[1]; [1]*College of Information and Business, Nor, China.* In order to trace the time-varying channel capacity automatically, an adaptive rate scheme based on recurrence form for computing log-likelihood ratio is proposed. The theoretical and numerical analysis shows the effectiveness of the scheme.

PW4C.7 • 17:45
Multi-Wavelength Characterization of Free-Space Optical Link Loss Dynamics Caused by Fog, Evgeny Slivinskiy[1], Markku Vainio[1,2]; [1]*Univ. of Helsinki, Finland;* [2]*Tampere Univ., Finland.* To explain interruptions in laser link operation in fog, we conducted a series of on-field and laboratory experiments. From direct extinction of multi-wavelength signal we made reverse calculation of droplet size distributions at different fog stages.

MW4D • Tomography—Continued

MW4D.5 • 17:15
Simulating Optical System Performance Using Light Fields Generated from Rendering Software, Jim Schwiegerling[1]; [1]*Univ. of Arizona, USA.* The light field describes the radiance at a point from a ray coming from a particular direction. A scene's light field is calculated with rendering software to simulate images for camera lenses with different aberrations.

17:00–18:00 Laser Systems Technical Group Meet and Greet, *Room A110*

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

Room 5 Marie Curie

Imaging Systems and Applications

A11 Gordon Gould

Imaging Systems and Applications

A12 Max Born

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

08:00–18:00 Registration, *Entrance West*

08:30–09:45 CTh1A • Computed Tomography

Presider: Oliver Cossairt; Northwestern Univ., USA

CTh1A.1 • 08:30 Invited

X-ray Scattering as a Source of Information in Computed Tomography (CT), Adam Geva[1], Yoav Y. Schechner[1], Yonatan Chernyak[1], Rajiv Gupta[2]; [1]*Technion - Israel Inst. of Technology, Israel;* [2]*Harvard Medical School, Massachusetts General Hospital, USA.* We formulate and solve computed tomography (CT) that contrary to traditional CT, intentionally includes all scattering events. This leads to estimation of chemical decomposition per voxel, and significant dose reduction per quality of recovery.

CTh1A.2 • 09:00

Learning tomography plus for highly scattering samples, Joowon Lim[1], Ahmed Ayoub[1], Elizabeth Antoine[1], Demetri Psaltis[1]; [1]*Ecole Polytechnique Federale de Lausanne, Switzerland.* We propose learning tomography plus (LT+) which outperforms learning tomography (LT) for reconstruction of 3D refractive index distributions of highly scattering samples. We validate the performance of LT+ using experimental data as well as simulations.

CTh1A.3 • 09:15

Optical-CT with Incomplete Data for Applications to Radiation Dosimetry, Matthew Faulkner[1], lucia Florescu[1]; [1]*Univ. of Surrey, UK.* Numerical experiments were performed to analyse the effect of data loss at the edges of the sample on the accuracy of optical-CT reconstruction, in the context of applications to radiation dosimetry.

CTh1A.4 • 09:30

Nonreciprocal Broken-Ray Tomography: Applications to Fluorescence Optical Imaging, Lucia Florescu[1], Matthew Faulkner[1], Vadim Markel[2], John C. Schotland[3]; [1]*Univ. of Surrey, UK;* [2]*Univ. of Pennsylvania, USA;* [3]*Univ. of Michigan, USA.* We present a novel tomographic imaging technique based on inverting a non-reciprocal broken-ray Radon transform and enabling for the first time simultaneous reconstruction of the attenuation coefficient at two energies and of the contrast-agent concentration.

CTh1A.5 • 09:45

Withdrawn.

08:30–10:00 ITh1B • 3D Image Acquisition and Display: Technology, Perception and Applications III

Presider: Maitreyee Roy; Univ. of New South Wales, Australia

ITh1B.1 • 08:30 Invited

Recent Advances on 3D Imaging with Single Pixel Detectors, Enrique Tajahuerce[1]; [1]*Universitat Jaume I, Spain.* We review recent 3D computational imaging techniques based on structured illumination and single-pixel detection. In particular, we describe a method where the light patterns are generated with a color LED array and several advances in single-pixel digital holography.

ITh1B.2 • 09:00 Invited

Optical Challenges for Scaling AR/VR Displays, Hong Hua[1]; [1]*Univ. of Arizona, USA.* Developing AR/VR displays confronts many technical and non-technical challenges. In this presentation, I will present a few examples of optical challenges we need to overcome when attempting to scaling up or down several key performance specifications of VR/AR displays.

ITh1B.3 • 09:30 Invited

A 1mm Thin-Film Short-Distance Optical Sensor, Oliver Bimber[1], Indrajit Kurmi[1]; [1]*Johannes Kepler Universität Linz, Austria.* A sandwich of three 300µm PMMA layers enables large and flexible short-distance optical sensors. While two layers are wavelength selective luminescent concentrators, the third layer is an optical Söller collimator realized by X-ray lithography.

08:30–10:00 ITh1C • Microscopy

Presider: Seung-Whan Bahk; University of Rochester, USA

ITh1C.1 • 08:30 Invited

Multicolour wavefront shaping for imaging applications, Monika A. Ritsch-Marte[1]; [1]*Innsbruck Medical Univ., Austria.* Synthetic holography with wavefront shapers can turn an imaging system into a programmable and sample-customizable tool. In this talk it will be shown how multicolor-operation of LC-SLMs can significantly expand the wealth of options.

ITh1C.2 • 09:00

Diffractive Oblique Plane Microscopy, Maximilian Hoffmann[1,2], Benjamin Judkewitz[1,2]; [1]*Charité Universitätsmedizin, Germany;* [2]*Einstein Center for Neuroscience, NeuroCure Cluster of Excellence, Germany.* Oblique plane microscopy circumvents the geometric contraints of light sheet microscopy by exciting oblique planes and detecting the image through the same microscope objective. So far this technique relies on the use of high numerical aperture (NA) detection objectives, which limits their field of view. Diffractive oblique plane microscopy introduces a new solution for the central re-imaging geometry in OPM and extends the family of these techniques to larger field of views.

ITh1C.3 • 09:15

Extended Focused Image in White Light Scanning Interference Microscopy, Hernando Altamar-Mercado[1], Alberto Patiño-Vanegas[1], Andrés G Marrugo[1]; [1]*Universidad Tecnologica de Bolivar, Colombia.* We propose a method to obtain a fringe-free extended focused image in white light scanning interference microscopy based on processing the stack of images over a range within the coherence length of the source.

ITh1C.4 • 09:30

Quasi-noise-free stimulated emission depletion microscopy imaging of thick samples using adaptive optics and block-matching 3D filtering, Piotr Zdankowski[1,2], Maciej Trusiak[1], David McGloin[3], Jason R. Swedlow[2]; [1]*Warsaw Univ. of Technology, Poland;* [2]*Univ. of Dundee, UK;* [3]*Univ. of Technology Sydney, Australia.* We present a novel-method of increasing signal-to-noise-ratio and effective-resolution of STED microscope by combining aberration-correction and image-processing. We imaged 15µm thick mitotic cell and observed in-plane resolution of 118nm without filtering and 70nm with filtering.

ITh1C.5 • 09:45

DDS Nanoparticle Imaging with Polarization Interferometric Nonlinear Confocal Microscope, Chikara Egami[1]; [1]*Shizuoka University, Japan.* We demonstrate three-dimensional imaging with a polarization-interferometric nonlinear confocal microscope targeted on Drug Delivery System (DDS) spectroscopy. The microscope successfully measured fine structure of a single DDS nanoparticle through the third-order nonlinear dielectric polarization photoinduced.

08:30–10:00 PTh1D • Turbulence Characterization I

Presider: Daniel LeMaster; US Air Force Research Laboratory, USA

PTh1D.1 • 08:30 Invited

Turbulence Characterization through Anisoplanatic Passive Imaging, Matthew R. Whiteley[1]; [1]*MZA Associates Corporation, USA.* MZA's "DELTA" Imaging Path Atmospheric Turbulence Monitor passively measures the Cn2 profile over a propagation path by tracking multiple target features. We illustrate effects impacting measurement sensitivity over the path and present example test data.

PTh1D.2 • 09:00

Multiplexed Digital Holography for Atmospheric Characterization, Matthias T. Banet[1], Mark F. Spencer[2]; [1]*The Inst. of Optics, Univ. of Rochester, USA;* [2]*Directed Energy Directorate, Air Force Research Laboratory, USA.* Provided a coherently-illuminated object and a point-source beacon, multiplexed digital holography enables atmospheric characterization via complex-valued data. In this paper, we study two off-axis recording geometries which enable multiplexed digital holography and show that both perform well with respect to the field-estimated Strehl ratio.

PTh1D.3 • 09:15

Atmospheric Turbulence Outer Scale Estimation Using Laser Light Backscattered off Moving Target, Victor A. Kulikov[1], Svetlana L. Lachinova[2], Mikhail A. Vorontsov[1,2]; [1]*Univ. of Dayton, USA;* [2]*II-VI Optical Systems Optonicus, USA.* A new technique for estimation of atmospheric turbulence outer scale using laser light back-reflected off a moving unresolved target or a moving target with glint is considered and analyzed through wave-optics numerical simulations.

PTh1D.4 • 09:30 Invited

Range-resolved turbulence profiling with a wavefront sensor and cooperative source, Jason D. Schmidt[1]; [1]*MZA Associates Corporation, USA.* MZA's "PROPS" turbulence sensor uses a cooperative source and wavefront sensor to measure the Cn2 profile over a propagation path by calculating subaperture tilt differences. We describe the theory and present example test data.

10:00–10:30
Coffee Break,
A1 Foyer

Room 4 Emmett Leith

Computational Optical Sensing and Imaging

10:30–12:30
CTh2A • Advances in Macroscopic 3D Sensing (including LiDAR)
Presider: Florian Willomitzer; Northwestern Univ., USA

CTh2A.1 • 10:30 Invited
Discover better optical sensors - by exploring and exploiting nature's limits, Gerd Häusler[1]; *[1]Universität Erlangen-Nürnberg, Germany.* Nature's limits are precious: they often reveal uncertainty products connecting coherence, resolution, precision, channel capacity... So we can bargain with nature for "optimal" 3D sensors with novel features - or just better precision, resolution, speed.

CTh2A.2 • 11:00
Mega-pixel time-of-flight imager with GHz modulation frequencies, Fengqiang Li[1], Florian Willomitzer[1], Prasanna V. Rangarajan[2], Oliver S. Cossairt[1]; *[1]Northwestern Univ., USA; [2]Southern Methodist Univ., USA.* We propose a novel time-of-flight imaging technique with GHz modulation frequencies using a regular CCD/CMOS sensor as the detector. Our proposed system can provide sub-mm depth resolution and megapixel level lateral resolution.

CTh2A.3 • 11:15
EMCCD-SPAD Camera data fusion for high spatial resolution time-of-flight imaging., Ashley Lyons[1], Clara Callenberg[2], Dennis den Brok[2], Robert Henderson[3], Matthias B. Hullin[2], Daniele Faccio[1]; *[1]Univ. of Glasgow, UK; [2]Inst. of Computer Science II, Univ. of Bonn, Germany; [3]Inst. for Micro and Nano Systems, Univ. of Edinburgh, UK.* High temporal resolution SPAD imagers are currently limited by their pixel count. Here we show that data can be combined with a higher spatial resolution EMCCD camera to achieve the advantages of both.

CTh2A.4 • 11:30
Photon-efficient 3D imaging up to 21.6 km, Zheng-Ping Li[1,2], Xin Huang[1,2]; *[1]Hefei National Laboratory for Physical Sciences at Microscale Univ. of Science and Tech. of China, China; [2]Synergetic Innovation Center of Quantum Information & Quantum Physics, Univ. of Science and Tech. of China, China.* We demonstrate active single-photon 3D imaging at a range of up to 21.6 km by implementing a high-efficiency and low-noise single-photon LiDAR system and designing a long-range-tailored computational algorithm.

Room 5 Marie Curie

Imaging Systems and Applications

10:30–12:30
ITh2B • Optical Coherence Tomography
Presider: Kristina Irsch; Johns Hopkins Univ. & Sorbonne Univ., USA

ITh2B.1 • 10:30 Invited
High-resolution optical coherence tomography. Application in dermatology, Arnaud Dubois[1]; *[1]Institut d'Optique Graduate School, France.* Advances in optical coherence tomography (OCT) for application in dermatology are reported. Full-field OCT and line-field OCT are compared in terms of spatial resolution, penetration and acquisition rate. In vivo imaging of various skin lesions is demonstrated with good similarity to histology.

ITh2B.2 • 11:00
Analysis of OCT Images to Optimize Glaucoma Diagnosis, Nahida Akter[1], Jack Fu[1,2], Stuart Perry[3], John Fletcher[4], Michael Kalloniatis[1,2], Maitreyee Roy[1]; *[1]UNSW Sydney, Australia; [2]Center for Eye Health, Australia; [3]Univ. of Technology Sydney, Australia; [4]UNSW Sydney, Australia.* In this paper, the data from OCT images are extracted, statistically analyzed and further an image processing task has been performed on optic nerve head image to optimize the features in the diagnosis of glaucoma.

ITh2B.3 • 11:15
Matrix approach of Full-Field OCT for volumetric imaging of an opaque human cornea, Paul Balondrade[1], Victor Barolle[1], Laura A. Cobus[1], Kristina Irsch[2], Claude Boccara[1], Mathias Fink[1], Alexandre Aubry[1]; *[1]Institut Langevin, ESPCI, France; [2]Institut de la vision, France.* We report on a matrix approach of optical imaging that allows to overcome aberration and multiple scattering issues in microscopy. This allows in-depth diffraction-limited imaging of biological media over a wide field-of-view.

ITh2B.4 • 11:30
Mid-infrared optical coherent tomography: non-destructive testing of ceramics and plastics, Niels M. Israelsen[1,2], Christian R. Petersen[1,2], Ajanta Barh[3], Günther Hannesschläger[4], Louise Bierregaard[5], Peter Tidemand-Lichtenberg[3,6], Christian Pedersen[3,6], Adrian Podoleanu[7], Ole Bang[1,8]; *[1]DTU Fotonik, Technical Univ. of Denmark, Denmark; [2]NORBLIS, Denmark; [3]DTU Fotonik, Technical Univ. of Denmark, Denmark; [4]RECENDT, Austria; [5]Meggitt A/S, Denmark; [6]NLIR, Denmark; [7]Univ. of Kent, UK; [8]NKT Photonics, Denmark.* We investigate the potential of mid-infrared (mid-IR) optical coherence tomography (OCT) by imaging a number of industrially applied ceramics and plastics and by imaging the same materials with a state-of-the-art near-infrared OCT system.

A11 Gordon Gould

Computational Optical Sensing and Imaging

10:45–11:45
CTh2C • Holography / Phase Retrieval
Presider: Tatiana Alieva; Universidad Complutense de Madrid, Spain

CTh2C.1 • 10:30
Withdrawn.

CTh2C.2 • 10:45
Merging optical and numerical methods for denoising in digital holography, Pasquale Memmolo[1], Vittorio Bianco[1], Melania Paturzo[1], Pietro Ferraro[1]; *[1]CNR-ISASI, Italy.* The possibility to merge different denoising strategies, by considering optical and numerical methods, permits to sensitively reduce the speckle noise in digital holography. Some examples are made to quantify the performance of these hybrid methods.

CTh2C.3 • 11:00
Fast Transmission Matrix Measurement System for Multimode Optical Networks, Stefan Rothe[1], Hannes Radner[1], Nektarios Koukourakis[1], Jürgen W. Czarske[1]; *[1]TU Dresden, Germany.* The information security of multimode optical networks can be characterized by their transmission matrix (TM). A fast TM measuring system will be introduced using selective mode excitation and a holographic decomposition technique.

CTh2C.4 • 11:15
Phase Retrieval Using Gaussian Basis Functions, Seung-Whan Bahk[1]; *[1]University. of Rochester, USA.* It is shown that an arbitrary wavefront can be represented using the superposition of Gaussian functions. Phase retrieval is demonstrated using nonlinear optimization based on Gaussian basis functions. It performs well for high-frequency modes.

CTh2C.5 • 11:30
Deep Learning-Based Hybrid Approach for Phase Retrieval, Cagatay Isil[1,2], Figen S. Oktem[2], Aykut Koc[1]; *[1]Aselsan Research Center, Turkey; [2]Electrical and Electronics Engineering, Middle East Technical Univ., Turkey.* We develop a phase retrieval algorithm that utilizes the hybrid-input-output (HIO) algorithm with a deep neural network (DNN). The DNN architecture, which is trained to remove the artifacts of HIO, is used iteratively with HIO to improve the reconstructions. The results demonstrate the effectiveness of the approach with little additional cost.

A12 Max Born

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

10:30–12:30
PTh2D • Beam Propagation
Presider: Karin Stein; Fraunhofer IOSB, Germany

PTh2D.1 • 10:30 Invited
Laser and Turbulence: How our Researches on Atmospheric Propagation Started and Where They Arrived, Anna Consortini[1]; *[1]Universita degli Studi di Firenze, Italy.* An overview is made of our research on laser propagation through atmospheric turbulence, first to find the turbulence effects on systems, then to utilize laser deterioration to derive information on turbulence model and its parameters.

PTh2D.2 • 11:00
Considering Power Law, Optical Refractivity, and Anisotropy Using Gaussian Beam Statistics, Melissa K. Beason[1], Frank Sanzone[1], Bruce Berry[1], Joseph Coffaro[1], Jonathon Spychalski[1], Franklin Titus[1], Robert Crabbs[1], Larry Andrews[1], Ronald Phillips[1]; *[1]CREOL, Univ. of Central Florida, USA.* The Rytov approximation is used with different initial beam radius of curvature in orthogonal directions to approximate optical refractivity with an anisotropic nonKolmogorov spectrum in weak turbulence. Results are compared to experimental data.

PTh2D.3 • 11:15
High Energy Laser Propagation: Scintillation Effects, Dana Morrill[1]; *[1]Air Force Inst. of Technology, USA.* The environmental effects of high energy laser propagation are numerically simulated in a wave optics model coupled with direct simulation of the background fluid flow. The roles of fluid boundary conditions and scintillation are discussed.

PTh2D.4 • 11:30
Beaming Through Turbulence, Josselin Garnier[2], Knut Solna[1]; *[1]Univ. of California Irvine, USA; [2]CMAP, Ecole Polytechnique, France.* When (laser) beams propagate through atmospheric turbulence in the scintillation regime the beam exhibits anomalous spreading and gradually becomes incoherent due to scattering and eventually forms a speckle pattern. We characterize here the scintillation scaling regime for beams and describe the beam transformation via a moment theory.

Room 4 Emmett Leith	Room 5 Marie Curie	A11 Gordon Gould	A12 Max Born
Computational Optical Sensing and Imaging	Imaging Systems and Applications	Computational Optical Sensing and Imaging	Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

Room 4 Emmett Leith — Computational Optical Sensing and Imaging

CTh2A • Advances in Macroscopic 3D Sensing (including LiDAR)—Continued

CTh2A.5 • 11:45
SCALABLE: Self-Calibrated Adaptive LIDAR Aperture Beamsteering Light Engine, Kelvin H. Wagner[1], Nathan Dostart[1,2], Bohan Zhang[2], Michael Brand[1], Daniel Feldkhun[1], Milos Popovic[2]; [1]*Univ. of Colorado at Boulder, USA;* [2]*Photonics Center, Boston Univ., USA.* We present a SCALABLE (Self-Calibrated Adaptive Lidar Aperture Beamsteering Light Engine) multibeam transmitting and receiving aperture for rapid 2-D beamsteering from an array of Si-photonic tiles and perform computational interferometric image synthesis within each beam.

CTh2A.6 • 12:00 Invited
How to Exploit Prior Knowledge in Industrial 3D-Metrology, Christian Faber[1], Michael Strohmeier[2], Hanning Liang[1]; [1]*Univ. of Applied Sciences Landshut, Germany;* [2]*BMW Group Plant Dingolfing, Germany.* The goal of every measurement is to obtain new information about the specimen – preferably with as little effort as possible. We will discuss different ways of exploiting prior knowledge to accomplish this goal in industrial environments.

Room 5 Marie Curie — Imaging Systems and Applications

ITh2B • Optical Coherence Tomography—Continued

ITh2B.5 • 11:45
Quantitative Measures of Corneal Transparency, Derived from Objective Analysis of Stromal Light Backscattering with Full-Field Optical Coherence Tomography, Romain Bocheux[1,2], Pascal Pernot[3], Vincent Borderie[2], Karsten Plamann[1], Kristina Irsch[2]; [1]*Laboratoire d'Optique et Biosciences (LOB) – École polytechnique, CNRS UMR 7645, INSERM U 1182, and LOA – ENSTA ParisTech, École polytechnique, CNRS UMR 7639, France;* [2]*Vision Inst. / Quinze-Vingts National Eye Hospital – Sorbonne Univ., CNRS UMR 7210, INSERM U 968, France;* [3]*Laboratoire de Chimie Physique – Université Paris-Sud, CNRS UMR 8000, France.* We demonstrate the feasibility of deriving quantitative measures of corneal transparency from objective analysis of stromal light backscattering with full-field optical coherence tomography (FF-OCT), addressing an unmet need in ophthalmology.

ITh2B.6 • 12:00
Observation of the Fujiwhara effect in optical coherence function by using coherence holography, Juan Zhao[1,2], Baixin Chen[3], Mitsuo Takeda[4], Wei Wang[3]; [1]*Shenzhen Inst. of Advanced Tech., Chinese Academy of Sciences, China;* [2]*The Chinese Univ. of Hong Kong, China;* [3]*School of Engineering and Physical Sciences, Heriot-Watt Univ., UK;* [4]*Center for Optical Research and Education (CORE), Utsunomiya Univ., Japan.* By using coherence holography technique, we have observed the fluid-like rotation of a pair of coherence vortices with the same topological charge in optical coherence function as they propagate through the free space.

ITh2B.7 • 12:15
Supercontinuum sources for multimodal MIR-OCT imaging, Ivan Zorin[1], Jakob Kilgus[1], Markus Brandstetter[1], Rong Su[2], Bettina Heise[1]; [1]*RECENDT, Austria;* [2]*Univ. of Nottingham, UK.* In this paper we present a multimodal OCT imaging system operating in the NIR and MIR spectral region. NIR/MIR Supercontinuum source based multimodal OCT provides new insights in scattering .materials. The system combines the modality of OCT and spectroscopy and enables a structural and specific characterization of different ceramics, polymers or composites.

A11 Gordon Gould — Computational Optical Sensing and Imaging

CTh2C • Holography / Phase Retrieval—Continued

A12 Max Born — Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

PTh2D • Beam Propagation—Continued

PTh2D.5 • 11:45
Experimental Investigation of Gaussian and Vortex Beam Propagation in an Extremely Calm In-Door Atmospere, Vladimir Y. Venediktov[1,2]; [1]*Saint-Petersburg Electrotechnical Univ, Russian Federation;* [2]*St.-Petersburg State Univ., Russian Federation.* The paper overviews the results of several seasons of investigation of optical beams propagation along the in-door (artificial) beam path with the length of several hundred meters. Special attention was paid to investigation of evolution of optical vortices with the large (up to 10) topological charge.

PTh2D.6 • 12:00
OAM of beams and waves and atmospheric turbulence, Mikhail Charnotskii[1]; [1]*none, USA.* We present a review of the recently developed theory of the total beam OAM fluctuations and fluctuations of the OAM intercepted by a finite aperture both for weak and strong scintillations in the incident wave.

PTh2D.7 • 12:15
Propagation of I_0-Bessel correlated beams carrying orbital angular momentum in weak atmospheric turbulence, Svetlana Avramov-Zamurovic[1], Charles Nelson[1], Olga Korotkova[2], Milo Hyde[3]; [1]*US Naval Academy, USA;* [2]*Univ. of Miami, USA;* [3]*Air force Inst. of Technology, USA.* Scintillation index of I0-Bessel correlated beams generated as temporally incoherent superposition of Laguerre-Gaussian modes is shown experimentally to reduce with increase of the OAM index on propagation in weak atmospheric turbulence over a 168m link.

12:30–14:00 Lunch Break

14:00–15:30 Post Deadline Presentations, *Room A12*

Room 4
Emmett Leith

Computational Optical Sensing and Imaging

14:00–15:15
CTh3A • Computational Micro and Nano-Optics
Presider: Figen Oktem; Middle East Technical Univ., Turkey

CTh3A.1 • 14:00 Invited
Computational Optics and Microoptics - a Mutual Benefit, Jürgen Jahns[1], Armin Grasnick[1], Ulrich Lohmann[1]; [1]*Fernuniversität in Hagen, Germany.* Microoptics offers novel and compact implementations for imaging and sensing, however, usually with a reduced space-bandwidth product (resolution). Computational techniques can compensate for this drawback and yield high quality performance.

CTh3A.2 • 14:30
Polarimetric and interferometric measurement of orbital angular momentum imparted by single plasmon nano-antennas, Ruslan Rohrich[1,2], Chris Hoekmeijer[1], Clara I. Osorio[1], A. Femius Koenderink[1]; [1]*AMOLF, Netherlands;* [2]*ARCNL, Netherlands.* We report an experimental technique for quantitative analysis of amplitude, phase, directivity and polarization of wavefronts scattered by single nano-objects. As a demonstration we quantify the spin and orbital angular momentum imposed by plasmonic spiral nano-antennas.

CTh3A.3 • 14:45
Fast Computational Spectral Imaging with a Programmable Diffractive Lens, Oguzhan Fatih Kar[1], Figen S. Oktem[1]; [1]*Middle East Technical Univ., Turkey.* We develop a fast computational spectral imaging modality that utilizes a single programmable diffractive lens. The proposed optical configuration is simple and provides promising reconstruction performance for the three-dimensional spectral data cube.

CTh3A.4 • 15:00
Two cross patterns with the golden mean generated by a square Fibonacci zone plate, Tian Xia[1], Shubo Cheng[2], Shaohua Tao[1]; [1]*Central South Univ.,, China;* [2]*Yangtze Univ., China.* A square Fibonacci zone plate (SFiZP) is proposed to generate two cross patterns at the positions with the golden mean. Twin vortices with the same topological charge for the spiral- phase SFiZP are found to follow the modulo-4 transmutation rule.

Room 5
Marie Curie

Imaging Systems and Applications

14:00–15:30
ITh3B • Biophotonics
Presider: Maitreyee Roy; Univ. of New South Wales, Australia

ITh3B.1 • 14:00 Invited
Optogenetics and Optical Brain Imaging and Manipulation, Nicolo Accantro[1]; [1]*Universite Paris Descartes, France.* Abstract not Provided.

ITh3B.2 • 14:30
Label-Free Biosensing by Ultrasensitive Supercritical Angle Refractometry, Lucien E. Weiss[1], Boris Ferdman[1,2], Onit Alalouf[1], Yoav Shechtman[1]; [1]*Biomedical Engineering, Technion, Israel Inst. of Technology, Israel;* [2]*Russell Berrie Nanotechnology Inst., Technion, Israel Inst. of Tech., Israel.* By imaging the back focal plane of a fluorescence microscope, we demonstrate precise determination of a sample's refractive index in a fluorophore-laden microfluidic device. We apply the technique to biosensing by detecting unlabeled bacteria.

ITh3B.3 • 14:45
Intraoperative Monitoring of Cerebral Hemodynamics by Camera-Based Photoplethysmography, Alexei A. Kamshilin[1], Oleg Mamontov[2,1], Anton Shcherbinin[2]; [1]*ITMO Univ., Finland;* [2]*Almazov National Medical Research Centre,, Russian Federation.* Monitoring cortical hemodynamics during open brain surgery is important but hitherto unresolved problem. Here we demonstrate that changes in cerebral microcirculation caused by surgical intervention are clearly revealed by camera-based photoplethysmography at green illumination.

ITh3B.4 • 15:00
Monitoring Changes in Capillary Blood Flow due to Thermal Impact Using Imaging Photoplethysmography, Maxim A. Volynsky[1], Nikita B. Margaryants[1], Alexei A. Kamshilin[1]; [1]*ITMO Univ., Russian Federation.* Imaging photoplethysmography was applied to study local thermal impact on facial microcirculation. We found that skin heating by five degrees leads to significant increase in blood pulsations with their subsequent decrease despite constant skin temperature.

ITh3B.5 • 15:15
uC2 – An Open-Source Optical Toolbox for Multi-Modal Imaging in the Incubator, Benedict Diederich[1,4], René Richter[1], Swen Carlstedt[2], Xavier Uwurukundo[3,1], Haoran Wang[1], Alexander Mosig[2], Rainer Heintzmann[1,4]; [1]*Microscopy, Leibniz Inst. of Photonic Tech., Germany;* [2]*Cellbiology, Univ. Clinic of Jena, Germany;* [3]*Optical Tech., Ernst Abbe Fachhochschule Jena, Germany;* [4]*Chemistry, Friedrich-Schiller Univ., Germany.* We present a novel open-source modular electro-optical toolbox to be used for many different optical setups. Based on off-the-shelf components we show a live-cell imaging device and an optical super-resolution microscope using Image-Scanning-Microscopy (ISM) techniques.

A11
Gordon Gould

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

14:00–15:30
PTh3C • Turbulence Characterization II
Presider: Melissa Beason; UCF/TISTEF/CREOL, USA

PTh3C.1 • 14:00 Invited
Aero-Optical Turbulence: Measurement, Simulation and Analysis, Donald Wittich[1]; [1]*AFRL, USA.* "Aero-optics" is the study of optical distortions induced by compressible or weakly-compressible flow. This presentation summarizes some of the current research in aero-optic turbulence with a focus on measurement, simulation and data analysis techniques.

PTh3C.2 • 14:30
Overcoming four limitations of the 5/3 structure function, Mikhail Charnotskii[1]; [1]*None, USA.* Four major assumptions used to derive the commonly used $r^{5/3}$ phase structure function are: perturbation theory, Markov approximation, neglecting diffraction and use of inertial interval. We present alternative models that avoid some of associated limitations.

PTh3C.3 • 14:45
Probability densities of atmospheric optical scintillation observed with large apertures, Andreas Muschinski[1,2], David G. Voelz[3]; [1]*NorthWest Research Associates, USA;* [2]*Ann and H. J. Smead Aerospace Engineering Sciences, Univ. of Colorado Boulder, USA;* [3]*Klipsch School of Computer and Electrical Engineering, New Mexico State Univ., USA.* We present and discuss probability densities of optical scintillation observed with large apertures in the atmosphere. We interpret the observations on the basis of theoretical models and compare them with scintillation statistics obtained from computer simulations.

PTh3C.4 • 15:00
An Electro-Optical Detection and Recognition Trial in a Desert-Like Environment: First Results, Christian Eisele[1], Dirk Seiffer[1], Erik Sucher[1], Detlev Sprung[1]; [1]*Fraunhofer IOSB, Germany.* We report on first findings of a field trial, which has been carried out in a desert-like shrub land environment in New Mexico (USA) to acquire data for the improvement of electro-optical tactical decisions aids.

PTh3C.5 • 15:15
A Single Pixel Infrared Camera for Atmospheric Extinction Measurements, Bruce Berry[1]; [1]*UCF/TISTEF, USA.* A single pixel infrared camera is developed utilizing digital micromirror technology. The imager is applied to determination of atmospheric extinction and other meteorological parameters. Experimental evidence demonstrates agreement with forward-scatter based visibility measurements.

15:30–16:00 Coffee Break, *A1 Foyer*

Room 4
Emmett Leith

Computational Optical Sensing and Imaging

16:00–18:00
CTh4A • Circumventing Traditional Imaging Limits
Presider: Figen Oktem; Middle East Technical Univ., Turkey

CTh4A.1 • 16:00 Invited
Depth from Differential Defocus, Emma Alexander[1]; [1]*Harvard University, USA.* Inspired by the jumping spider, a provably unique and practically robust class of computational cameras observe differential changes in defocus and extract depth and velocity information with high computational efficiency.

CTh4A.2 • 16:30
Depth tracking using a multi-aperture microscope, Ling Zhong[1], Pavan Chandra Konda[1], Mark Harfouche[2,1], Roarke Horstmeyer[1,2]; [1]*Duke University, USA;* [2]*Ramona Optics, USA.* We present a multi-aperture gigapixel microscope that is capable of imaging a 600cm^2 area at 10 micrometer resolution and can simultaneously track the depth of objects within the scene. We demonstrate this capability by tracking freely swimming zebrafish larvae in a large petri dish.

CTh4A.3 • 16:45
Spatio-Temporal Coded Imaging for Motion Deblurring, Shay Elmalem[1], Raja Giryes[1], Emanuel Marom[1]; [1]*Tel-Aviv University, Israel.* Motion deblurring solution based on spatio-temporal coding is proposed. Using aperture coding and focus variations during exposure, a joint spatio-temporal coding is achieved, which is in-turn utilized for motion deblurring in the post processing step.

CTh4A.4 • 17:00
Single-Molecule Super-Resolution Imaging of Molecular Orientation using a Tri-Spot Point Spread Function, Hesam Mazidi[1], Eshan S. King[1], Oumeng Zhang[1], Arye Nehorai[1], Matthew D. Lew[1]; [1]*Electrical and Systems Engineering, Washington Univ. in St. Louis, USA.* We demonstrate the use of an engineered Tri-spot point-spread function and a joint sparse deconvolution algorithm for imaging the positions and 3D orientations of single molecules. Our images reveal nanoscale order and disorder in DNA strands.

CTh4A.5 • 17:15
Resolution Enhancement of imaging systems using a phase-only SLM, Mani R. Rai[1], A. Vijayakumar[1], Joseph Rosen[1]; [1]*Ben Gurion University, Israel.* A superresolution technique for imaging beyond the diffraction limit is demonstrated using a phase-only spatial light modulator (SLM) inserted between the object and the entrance of an ordinary imaging system.

CTh4A.6 • 17:30
Speckle based Extended Depth-of-Field for Macroscopic Imaging: First results, Florian Schiffers[1], Florian Willomitzer[1], Pablo Ruiz[1], Aggelos K. Katsaggelos[1], Oliver S. Cossairt[1]; [1]*Northwestern University., USA.* Optical imagers experience a fundamental trade-off between spatial resolution and Depth-of-Field (DoF). This work discusses the possibility of speckle projection to achieve super-resolution within a large DoF. Preliminary results for planar objects are presented.

CTh4A.7 • 17:45
Experimental Demonstration of Superresolution Exploiting Zeros of the Point Spread Function, Martin Paur[1], Bohumil Stoklasa[1], Dominik Koutny[1], Jaroslav Rehacek[1], Zdenek Hradil[1], Jai Grover[2], Andrej Krzic[2], Luis L. Sanchez-Soto[3,4]; [1]*Optics, Palacky Univ. Olomouc, Czechia;* [2]*European Space Research and Technology Centre (ESTEC), Netherlands;* [3]*Universidad Complutense, Spain;* [4]*Max-Planck-Institit fur die Physik des Lichts, Germany.* We present superresolution concept which exploits isolated zeros of PSF, where the information of two-point separation scales linearly and dominantly contribute from these regions. This is experimentally demonstrated by resolving natural and artificial spectral doublets.

Room 5
Marie Curie

Imaging Systems and Applications

16:00–18:00
ITh4B • Biophotonics
Presider: Kristina Irsch; Johns Hopkins Univ. & Sorbonne Univ., USA

ITh4B.1 • 16:00 Invited
Ultrasound-assisted optical imaging, Emmanuel Bossy[1]; [1]*LIPhy, Univ. Grenoble Alpes - CNRS, France.* This presentation will illustrate how optical imaging of biological tissue at depth can benefit from the interaction of light and sound to palliate the loss of optical resolution caused by the multiple scattering of light.

ITh4B.2 • 16:30 Invited
Defying the Raleigh range - Hyperparallel Optical Coherence Tomography in-vivo metrology and imaging, Steve Fisken[1]; [1]*Cylite, Australia.* A highly parallelized snap-shot OCT provides high-sensitivity volume acquisition with relative phase preservation in-vivo. Micron-accuracy in metrology and holoscopic high-resolution imaging with numerical aberration correction and refocusing are enabled. Applications include Ophthalmic biometry and imaging.

ITh4B.3 • 17:00
Development of skin chromophore mapping device using five spectral line illumination, Edgars Kviesis-Kipge[1]; [1]*Univ. of Latvia, Latvia.* A portable diagnostic imaging device able to capture five monochromatic spectral line images for distribution mapping of up to five skin chromophores is being developed. The device is intended for routine patient examination in dermatology. © 2019 Edgars Kviesis-Kipge.

ITh4B.4 • 17:15
Withdrawn.

ITh4B.5 • 17:30
Diffuse Reflectance Based Tissue Characterization Using Spatial Frequency Domain Imaging, Omnia H. Abd El-Rahman Nematallah[1], Mahmoud Hassan[2], Jala El-Azab[1], Nahed Solouma[3,1]; [1]*Engineering Applications of Laser, Cairo Univ., Egypt;* [2]*Benha Univ., Egypt;* [3]*Dept. Biomedical Engineering, King Faisal Univ., Saudi Arabia.* In this work, an experimental setup of a spatial frequency domain imaging system was implemented and investigated to provide a rapid and scan-free method for tissue characterization based on the modulated diffuse reflectance images.

ITh4B.6 • 17:45
Spatial-frequency domain imaging for maturation determination of Elstar apples, Stefan A. Lohner[1], Steffen Nothelfer[1], Ansgar Hohmann[1], Florian Foschum[1], Konni Biegert[2], Cécile Prunier[2], Roy McCormick[2], Alwin Kienle[1]; [1]*Institut für Lasertechnologien, Germany;* [2]*Stiftung Kompetenzzentrum Obstbau-Bodensee, Germany.* Spatial-frequency domain imaging is used to determine the optical properties of Elstar apples during the maturation process. A high correlation with Streif index is shown as well as further options of fruit monitoring.

A11
Gordon Gould

Propagation Through and Characterization of Atmospheric and Oceanic Phenomena

16:00–17:45
PTh4C • Underwater and Marine Environment
Presider: Olga Korotkova; University of Miami, USA

PTh4C.1 • 16:00 Invited
Spatially and temporally multiplexed Orbital Angular Momentum beams for underwater sensing and communications, Eric G. Johnson[1]; [1]*Clemson University, USA.* This presentation provides an overview of Orbital Angular Momentum and its application to underwater sensing and communications in a highly turbid environment. Specifically, different multiplexing and modulation schemes are compared using incoherent and coherent OAM multiplexing techniques.

PTh4C.2 • 16:30 Invited
Exploring an Underwater Hybrid Scattering Environment with the Compressive Line Sensing System, Bing Ouyang[1]; [1]*Florida Atlantic University, USA.* This work will explore the imaging system in a hybrid scattering environment where light propagation will be impacted by both turbulence and turbidity. In particular, the compress line sensing imaging system will be investigated.

PTh4C.3 • 17:00
Measurements of Temperature and Image Motion Structure Functions in a Rayleigh-Bénard Water Tank, José P. Montoya[1], Max Segel[1], Szymon Gladysz[1], Michael Kremer[1], Karin Stein[1]; [1]*Fraunhofer Inst. of Optronics, System Technologies and Image Exploitation IOSB, Germany.* We carried out differential measurements of temperature and image motion in a convective Rayleigh-Bénard water tank to test the assumption of Kolmogorov turbulence. Careful selection of the experimental methodology is required to arrive at the agreement between theory and experiment.

PTh4C.4 • 17:15
Phase correction by adaptive optics for oceanic turbulence-affected laser beams, Italo Toselli[1], Szymon Gladysz[1]; [1]*Fraunhofer IOSB, Germany.* We theoretically investigate the effectiveness of adaptive optics to correct phase aberrations for laser beams affected by oceanic turbulence. Action of adaptive optics is modeled as removal of a certain number of Zernike modes from the distorted wavefront.

PTh4C.5 • 17:30
Sensitivity of C_n^2 in the Marine Environment to Different Empirical Refractive Index Equations, Benjamin J. Wauer[1], Qing Wang[1]; [1]*Naval Postgraduate School, USA.* The refractive structure parameter (C_n^2) are sensitive to the various formulations of the refractive index (n). The small differences in C_n^2 may result in measurable difference in the high energy laser weapon performance.

Key to Authors and Presiders

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