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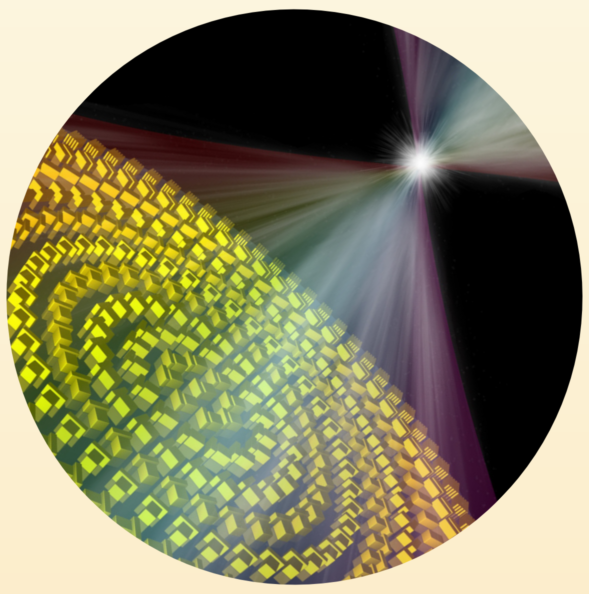
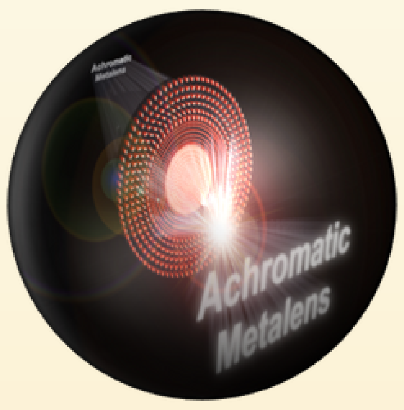
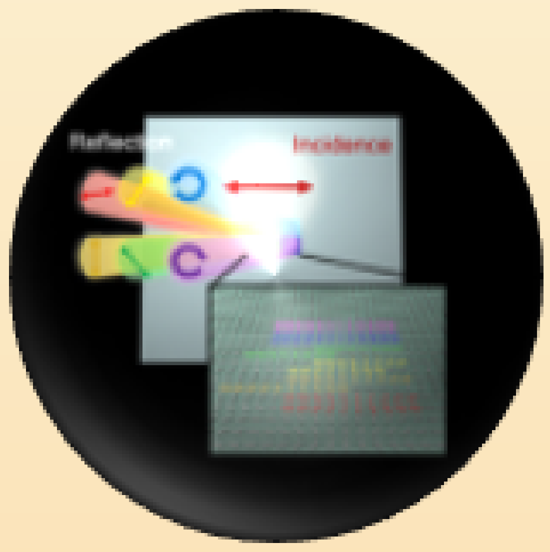
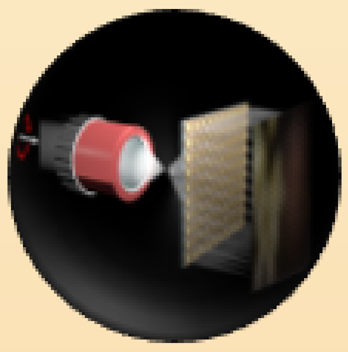
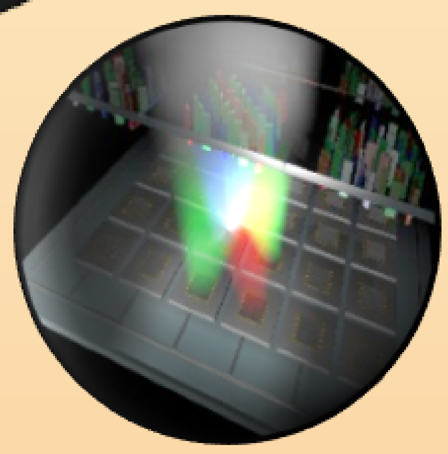


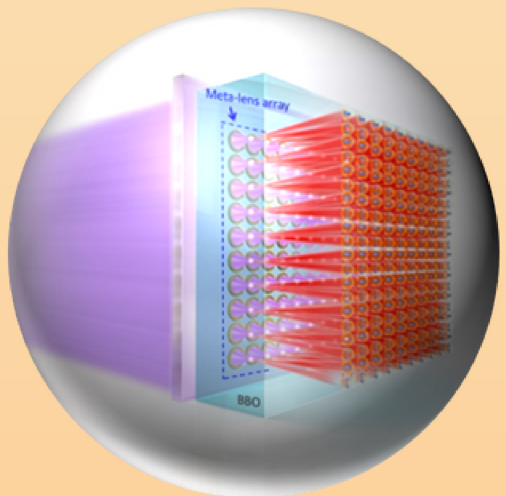


META-LENS WORLD SUMMIT 2023









Date: 20 December 2023 (Wed)

Time: 9:30am - 5:30pm

Venue: LT401,

Bank of China (HK) Complex,

City University of Hong Kong

Online Participation via. Zoom
Meeting ID: 511 222 6666
Pw: 2023

Program & Abstract


Takuo TANAKA
RIKEN, Japan


Nicholas Xuanlai FANG
University of Hong Kong


Wakana KUBO
Tokyo University of Agriculture and Technology


Yuanmu YANG
Tsinghua University


Ting XU
Nanjing University


Wolfgang FRITZSCHE
Leibniz-Institute of Photonic Technology


Guixin LI
Southern University of Science and Technology


Yuan LUO
National Taiwan University


Shuming WANG
Nanjing University


Muku Chen
City University of Hong Kong

Sponsored and co-organized by

Organized by **Prof. Din Ping Tsai**
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Editor-in-Chief: Stefan Maier

META-LENS WORLD SUMMIT 2023 PROGRAM

Time	Title	Speaker
09:30-09:40	Opening	Kwai Man LUK/ Din Ping TSAI
09:40-10:10	2.5 Dimensional Metasurfaces	Takuo TANAKA
10:10-10:40	New Horizons Beyond Optical Metadevices	Nicholas Xuanlai FANG
10:40-11:00	Break (20 mins)	
11:00-11:30	Metamaterial for Energy Harvesting	Wakana KUBO
11:30-12:00	Monocular metasurface camera for multi-dimensional light field sensing	Yuanmu YANG
12:00-12:30	Multi-dimensional imaging enabled by optical metasurface	Ting XU
12:30-14:30	Lunch (2 hr)	
14:30-15:00	Bioanalytics using plasmonic nanostructures	Wolfgang FRITZSCHE
15:00-15:30	Large Area Fabrication of Metasurface Diffractive Optical Elements	Guixin LI
15:30-16:00	Optical Metasurface for Biomedical Applications	Yuan LUO
16:00-16:20	Break (20 mins)	
16:20-16:50	Optical imaging based on metasurfaces	Shuming WANG
16:50-17:20	Varifocal Meta-devices from 1D to 3D for Bio-imaging and Future 6G Communication	Mu Ku CHEN
17:20-17:30	Award Ceremony and Closing	Din Ping TSAI

Prof. Takuo TANAKA
RIKEN, Japan

Takuo Tanaka is a chief scientist of RIKEN. He received his PhD degree in 1996 from Osaka University. After that, he joined faculty of Engineering Science, Osaka University as an assistant professor. In 2003, he moved to RIKEN as a research scientist in Nanophotonics Laboratory. He was promoted to associate chief scientist in 2008 and to chief scientist in 2017. His research background is three-dimensional microscopy such as confocal microscope and two-photon microscope. Recently, he is studying about nanophotonics, plasmonics, and metamaterials fields with developing many new nanofabrication techniques. He has also experimental and theoretical experiences about high precision optical measurements and spectroscopy.

2.5 Dimensional Metasurfaces

Metasurfaces are defined as two-dimensional counterparts to metamaterials. Recently they attracts significant attentions due to their capacity to control light waves within flat and thin two-dimensional structures. They have already been applied for various optical functional components including lenses, polarizers, waveplates, holograms, and more. Despite the "two-dimensional" label, it's important to note that the unit elements in metasurfaces can sometimes possess a high aspect ratio and substantial thickness. Furthermore, when we introduce complex or thicker three-dimensional (3D) structures into metasurfaces, it opens up the possibility of new optical functionalities; we refer to them as “2.5 dimensional (2.5D) metasurfaces”. In my presentation, we will delve into the three-dimensional nanofabrication techniques that we have developed and explore their optical capabilities.

We developed a metal-stress driven self-folding method, enabling mass production 3D metallic nanostructures. The key advantage is the direct formation of 3D structures from 2D templates, driven by bilayer metal stress. Since the folding force were entirely programmed by the deposition condition and structure design, the fabricated structures were quite uniform over a sample area. Using this technique, we fabricate large-scale 2.5D metamaterials and demonstrated that the real part of the refractive index of the structure swings from 0.35 to 1.86 at its resonant frequency[1].

Fabrication of metamaterial and nanofluidic hybrid structures enables us to introduce analyte molecules into the hot-spots region of the MIM metamaterial absorber and consequently realizes an ultra-high sensitivity of IR absorption detection. The fabricated device creates the strong molecular signals within the absorption band of the metamaterial resulting in 2 orders improvement in molecular sensitivity compared to the reported plasmonic IR detection methods[2,3].

Three-dimensional vertically aligned MIM (v-MIM) structure with a nano-gap channel was applied to gas molecular sensing. Owing to the small footprint of v-MIM, the density of the MIM structure is substantially increased, and fabricated device could sense the vibrational signals of C=O and –CH2 of carbon dioxide and butane gasses[4].

References:
[1] C.-C. Chen, A. Ishikawa, Y.-H. Tang, M.-H. Shiao, D. P. Tsai, and T. Tanaka, Adv. Opt. Mater. 3, 44-48 (2015).
[2] A. Ishikawa and T. Tanaka, Scientific Reports 5, 12570 (2015).
[3] T. Le and T. Tanaka, ACS Nano 11, 9780 (2017).
[4] D.-S. Su, D. P. Tsai, T.-J. Yen, and T. Tanaka, ACS Sensors 4, 2900 (2019).

Prof. Nicholas Xuanlai FANG

University of Hong Kong

Professor Fang joined the University of Hong Kong in 2022 as Professor of Mechanical Engineering. He was full professor with tenure Mechanical Engineering at MIT. His research programs have focused on the scalable manufacturing processes for wave functional materials. Professor Fang earned his B.S. and M.S. degrees in Physics from Nanjing University, China; and Ph.D. degree in Mechanical Engineering from the University of California at Los Angeles. Professor Fang's His research on nanoarchitectured metamaterials was highlighted among the top 10 Emerging breakthrough technologies of the year 2015. His recognitions also include the OSA Fellow (2021); ASME Chao and Trigger Young Manufacturing Engineer Award (2013); the ICO prize from the International Commission of Optics (2011); the NSF CAREER Award (2009) and MIT Technology Review Magazine's 35 Young Innovators Award (2008).

New Horizons Beyond Optical Metadevices

In recent years, nanostructured metasurfaces have emerged as powerful research tools for controlling light-material energy transfer at unprecedented dimensions. From manipulating electrons and atoms to enhancing photon-phonon interactions, significant progress has been made in unlocking the full potential of metamaterial-based devices beyond the optical realm. In this talk, I will present our recent exploration of metasurfaces for acoustic waves enabled by advanced design and micro/nanofabrication techniques. By integrating features of soft materials, metamaterials, and gradient refractive index, the acoustic metalenses opens new avenues for developing next-generation ultrasound imaging devices such as underwater sonar detection, non-destructive evaluation, and high-resolution medical ultrasound imaging.

As an example, we demonstrated the concept of acoustic subwavelength imaging system based on wave vector conversion. The combination of resonator arrays that enhance the waves with specific wave vectors, and binary phase gratings that add or subtract wave vectors by first-order diffraction, establishes a one-to-one relationship between the subwavelength and propagating wave components. Our experimental data using airborne sound confirmed the feasibility of our experimental model of 2D acoustic system with the edge detection of acoustic scattering objects with a resolution of quarter wavelength. I will also discuss our recent effort of ultrasonic metalenses over broadband frequencies, ranging from 38 kHz to 0.5 MHz. Through simulations and experimental validation, we show that ultrasonic metalens offer remarkable advantages in intensity transmission and enhancement in spatial resolution. I will also discuss the promise of ultrasonic metalens in focusing and collimating ultrasound in AUV ranging applications and transcranial medical imaging and diagnosis.

Prof. Wakana KUBO
Tokyo University of Agriculture and Technology

Wakana Kubo received her Ph.D. in Applied Chemistry from the University of Tokyo in 2006, with her graduate research focusing on the mechanisms of TiO_2 photocatalysts and their applications. In 2007, she joined RIKEN, the national institute for basic science, as a postdoctoral researcher, focusing her research primarily on nanofabrication. Subsequently, in 2010, she transitioned her research focus to plasmonics and metamaterials.
In 2016, Wakana joined the Division of Advanced Electrical and Electronics Engineering at the Tokyo University of Agriculture and Technology (TUAT) as an associate professor. Her current research interests lie in the field of plasmonic energy conversion.

Metamaterial for Energy Harvesting

To increase the efficiency of energy harvesting, technologies that can utilize weak thermal energies existing in environments are in demand; however, conventional technologies fail to realize this objective because energy accumulation does not occur in them. Herein we propose a metamaterial for energy harvesting by which thermal energy can be accumulated from the surrounding environment and can be converted into electricity.

Metasurfaces are artificial thin materials that achieve optical thickness through thin geometrical structure. This feature of metasurface results in unprecedented benefits for enhancing the performance of optoelectronic devices. In this study, we report that this metasurface feature facilitates photo-thermoelectric conversion by enabling the accumulation of thermal energy and effective heat conduction. For example, a metasurface-attached thermoelectric device placed in an environment with uniform thermal radiation generates an output voltage by gathering the thermal energy existing in the environment and creating an additional thermal gradient across the thermoelectric element.1-3) Here, metasurfaces functions as a lens-like element that gathers thermal energy existing in the vicinity.
Figure 1(a) presents a schematic of metasurface thermoelectric device which creates electricity in an environment with uniform thermal radiation. The metasurface absorber (MA), consisting of a silver mirror layer and silver microdisk arrays sandwiching a transparent calcium fluoride layer (Fig. 1(b)), is attached on one end of a thermoelectric element. The MA functions as a lens to collect thermal energy existing in the surrounding medium, resulting in local heat generation owing to absorption loss. The local heating propagates to the thermoelectric device, creating an additional thermal gradient and driving thermoelectric conversion.

In fact, we observed output voltage generation on the MA device as shown in Fig. 1(b). This graph presents the dependence of the output voltages generated on the MA device and a control device on the measured environmental temperature. The output voltages generated across the MA thermoelectric device showed significant temperature dependence, whereas those generated on the control device did not show temperature dependence at all. These output voltage generation is enabled by metamaterial thermal management, which effectively controls thermal distribution across an object or space in the vicinity of the MA. Unlike conventional thermoelectric devices, the metamaterial thermoelectric device can collect and extract thermal energies from the surrounding medium, leading to an example of metamaterial thermal management.

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Prof. Yuanmu Yang

Tsinghua University

Yuanmu Yang is an Associate Professor in the Department of Precision Instrument at Tsinghua University. Before joining Tsinghua, he obtained his B.Eng. in Optoelectronics from Tianjin University in 2011, and his Ph.D. in Interdisciplinary Materials Science from Vanderbilt University in 2015. He was a postdoctoral researcher at Sandia National Laboratories from 2015 to 2017, and was a research scientist at Intellectual Ventures from 2017 to 2018, where he was a founding team member of Lumotive, a startup company developing metasurface-based solid-state lidar. His research focuses on the area of meta-optics. He has published more than 40 journal articles, including 2 in Nature Photonics and 1 in Nature Physics, received over 5000 citations according to Google Scholar, and was selected as a "Highly-cited Researcher in China" by Elsevier in 2023. He has been granted over 10 China and US patents. His recognitions include the Jin-Guofan Young Scientist Award given by the China Instrument and Control Society as well as the Forbes China “30 under 30” in 2018.

Monocular metasurface camera for multi-dimensional light field sensing

Conventional camera systems can only detect light intensity while losing important information about the target scene, including depth, polarization, and spectrum. In order to further obtain the multi-dimensional light-field information of the target object, it is often required to use bulky and expensive instruments. Metasurface is composed of an array of optical antennas that can manipulate the amplitude, phase, polarization, and spectrum of light at the subwavelength scale. By replacing conventional diffractive of refractive elements with metasurfaces in imaging systems, one may be able to build optical sensors for high-performance multidimensional light sensing with low size, weight, power, and cost. Here, I will present our group’s recent effort to replace conventional camera lenses with metalenses. By leveraging the unique capability of metasurface to tailor the vectorial field of light, in combination with an advanced image retrieval algorithm, we aim to build compact camera systems that can capture multi-dimensional light field information of a target scene in a single shot under ambient illumination conditions. Specifically, I will show how we use a polarization-multiplexed metalens for imaging through turbid. Recently, we further extended such a concept to build a monocular camera that can capture a 4D image, including 2D all-in-focus intensity, depth, and polarization of a target scene in a single shot. I would also like to present our effort to leverage meta-optics towards real-world applications in consumer electronics and smart home devices.

Prof. Ting XU
Nanjing University

Prof. Xu obtained his Ph.D. in Optical Engineering from the Institute of Optics and Electronics, Chinese Academy of Sciences, and was recognized with the Chinese Academy of Sciences' Outstanding Doctoral Thesis award. After graduating, he joined the National Institute of Standards and Technology (NIST) in the United States as a postdoctoral research fellow and was then promoted to research scientist in 2014. In 2015, he joined College of Engineering and Applied Science, Nanjing University as a professor. Dr. Xu currently serves as the Deputy Director of the Optical Manufacturing Committee of the Chinese Optical Society. Dr. Xu's research primarily focuses on multi-dimensional light-field manipulation technology based on optical metamaterials and their applications. He has led the publication of over a hundred research papers, including in journals such as Nature, Nature Nanotechnology, Nature Communications, Science Advances and Physical Review Letters.

Multi-dimensional imaging enabled by optical metasurface

An optical metasurface is a two-dimensional array of subwavelength-structured elements that interact with light to control its properties. These surfaces are engineered to have precise control over the phase, amplitude, and polarization of light, allowing for the manipulation of light waves in highly customizable ways. In this talk, I will introduce several metasurface-based multi-dimensional imaging technologies from my research group, including spiral phase contrast imaging, light-field imaging with extreme depth-of-field and full-Stokes polarization imaging. Combined with the advantages of planar architecture and ultrathin thickness of the metasurface, these multi-dimensional imaging technologies are expected to provide support in the fields of microscopy, biomedicine, and materials science.

Prof. Wolfgang FRITZSCHE

Leibniz-Institute of Photonic Technology (Leibniz-IPHT)

Wolfgang Fritzsche studied chemistry in Jena and received his doctorate in 1994 on high-resolution microscopy of DNA-protein complexes at the Max Planck Institute for Biophysical Chemistry and the Georg August University in Göttingen. After a research stay at Iowa State University in the USA, W. Fritzsche returned to Jena in 1996 and established the "Molecular Nanotechnology" working group, before 2001 he took over the management of the "Nanobiophotonics" department at the IPHT. He was President of the German Society for Cytometry (DGfZ) 2016-2018 and organizes annual conferences Molecular Plasmonics and DNA Nanotechnology.

Bioanalytics using plasmonic nanostructures

Today, innovative tools for diagnostics and bioanalytics are needed. They should be able to detect molecules of interest with sufficient sensitivity, preferably label-free and multiplexed, to be usable outside of dedicated laboratories and with less qualified personnel, at minimal costs.
Plasmonic nanostructures promise to provide sensing capabilities with the potential for ultrasensitive and robust assays in a high parallelization and miniaturization, and without the need for markers. When functionalized with certain biomolecules (such as single-stranded DNA or antibodies) which bind the target molecule of interest (e.g., a biomarker like DNA or a protein), they should capture this target molecule with high specificity. Upon binding of target molecules, the localized surface plasmon resonance (LSPR) of these structures is changed, and can be used as sensoric readout. This is possible even on a single nanostructure level, using optical darkfield detection introduced more than 100 years ago, as demonstrated for DNA detection. In contrast to SPR, LSPR senses only in a very thin layer (on the scale of the particle diameter), resulting in an efficient background suppression. Only molecules bound directly at the surface contribute significantly to the signal, but much less molecules farer away.
In order to multiplex this approach, imaging spectrometer setups, e.g. based on a Michelson interferometer or multiple LEDs have been developed, able to readout a whole array of sensors in one step. On the sensor side, microarrays of gold nanoparticle spots were fabricated using spotting of pre-synthesized gold nanoparticles. Such chemically synthesized particles allow for a cost-efficient generation of highly crystalline particles as nanosensors; by using microfluidic approaches, a higher quality and reproducibility can be achieved. Using this microarray approach, a multiplex DNA-targeting detection of fungal pathogens involved in sepsis could be demonstrated. DNA-based signal amplification, e.g. by hybridization chain reaction, improves the sensitivity. Beyond DNA detection, LSPR sensing is also applicable for the detection of protein targets, such as CRP.
In conclusion, the results demonstrate the potential of this LSPR-based array platform for molecular detection of biomolecules of interest, with possible applications in bioanalytics and diagnostics.

Acknowledgements:
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Prof. Guixin LI

Southern University of Science and Technology

Guixin Li is currently a Professor at the Department of Materials Science and Engineering & Institute for Applied Optics and Precision Engineering, College of Engineering, Southern University of Science and Technology, China. He was elected as the 2023 Optica Fellow and awarded the 2019 Qiushi Outstanding Young Scholar. Prof. Li has published over 100 papers in journals such as Nature Photonics, Nature Physics, Nature Review Materials, PNAS and so on. Total citations: > 11000. The research conducted by Prof. Li's group was highlighted by Nature Photonics, Nature Nanotechnology, Nature Physics, SPIE, etc.

Large Area Fabrication of Metasurface Diffractive Optical Elements

Two dimensional photonic metasurfaces, consisting of arrays of meta-atoms with subwavelength feature size, enable the manipulation of the multiple degrees of freedom of light field in a more powerful way. By judiciously designing the functionalities of the unit cells of metasurface, the polarization, phase and amplitude and even frequency of light can be locally manipulated. In this talk, I will share the latest progress in the large area fabrication of the metasurface diffractive optical elements by using electron beam lithography and grayscale photolithography, several applications in imaging and cold atom system will be discussed.

Prof. Yuan LUO
National Taiwan University

Yuan Luo received the MSc and PhD degrees in the College of Optical Sciences in 2007 and 2008, respectively, from the University of Arizona. After post-doctoral work at the Massachusetts Institute of Technology (MIT, 2009–2011), he joined the faculty at National Taiwan University (NTU) in 2011, where he is now Director and Professor of the Institute of Medical Device and Imaging (MDI) at NTU College of Medicine. He also serves as Program Director of Precision Health and Intelligent Medicine (PHIM) at the NTU Graduate School of Advanced Technology and holds the Associate Deanship in the NTU YongLin Institute of Health. He has worked or held visiting appointments at the Singapore-MIT Alliance for Research and Technology (SMART) Center in Singapore. His research interests are in the fields of three-dimensional (3D) and spectral imaging, shift-invariant optics theory, nanophotonics, the design of diffractive optical elements, and the implementation of 3D active structured light. He is a Fellow of the International Society for Optical Engineering (SPIE).

Optical Metasurface for Biomedical Applications

Optical microscopic techniques are the most commonly used methods in biology and medical research. In recent years, metasurfaces, the emerging optical techniques, with unique optical capabilities to manipulate the basic characteristics of light have received a significant amount of interest in the optical microscopic field. This talk will introduce the latest studies on the biomedical use of metasurface. The following are the topics that will be covered: laser micro profiling; optical sectioning microscopy; light sheet microscopy; and optical tweezers. This talk will also discuss the technological challenges presently encountered with metasurface from the point of view of preclinical and clinical systems.

Prof. Shuming WANG
Nanjing University

Shuming Wang, professor for School of Physics, Nanjing University, specializes in nanophotonics, metasurfaces (metamaterials), plasmonics, and quantum optics. He has received the National Science Fund for Distinguished Young and the Forth Jiangsu Youth Optical Science and Technology Award. Prof. Wang has authored more than 80 research publications, with more than 3000 citations.

Optical imaging based on metasurfaces

Ideal imaging technique simultaneously requires the three-dimensional (3D) high spatial-resolution and the high spectral-resolution. To date, while compact 3D imaging technique and spectrometer have been individually developed, the combination of these techniques has only been realized in cumbersome systems, significantly limiting their practical applications. A long-standing and critical challenge is how to integrate the 3D spatial-resolution and the spectral-resolution into a single nanophotonic device. Herein, based on the precise wavefront control of metasurface and deep-leaning algorithm, we experimentally demonstrate the first ultracompact spectral light field imaging (SLIM) camera. The SLIM camera consists of TiO_2 lens array on a CMOS camera. Owing to the high dispersion of metalens, both the 3D position information and the spectrum can be re-constructed without sacrificing the light throughput. The demonstrated spectral-resolution is as high as 4nm and the spatial-resolution reaches the diffraction limit, enabling the capability of SLIM in precise 3D imaging and material discrimination. By employing an inverse-design method, we demonstrate a pixel-level metasurface-based Bayer-type colour router, with the brightness twice as high as that of a commercial camera.

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Prof. Mu Ku CHEN
City University of Hong Kong

Mu Ku Chen received his Ph.D. from the Department of Physics at the National Taiwan University in 2019. He was a Research Assistant Professor in the Department of Electronic and Information Engineering of the Hong Kong Polytechnic University and the Department of Electrical Engineering of the City University of Hong Kong. At present, he is an Assistant Professor at the Department of Electrical Engineering at the City University of Hong Kong. His research interests include photonic information, nanophotonics, nicro&nano-electronics fabrication, and artificial nano-antenna array-based meta-devices for photonic applications.

Varifocal Meta-devices from 1D to 3D for Bio-imaging and Future 6G Communication

The manipulation of focused light beams is widely used in our lives, such as camera lenses and signal transmission. Although there are traditional lenses that realize off-axis focusing, the requirements of tilting need extra space, and the tilting stage hinders its compact integration. These disadvantages hinder the development of device miniaturization or increased construction complexity. Meta-device is a new type of flat optical device that has risen in recent years. Meta-devices composed of artificial nanostructures can manipulate the incident electromagnetic wave's phase, polarization, and amplitude. Meta-devices show excellent performance and novel applications to meet optical demands. The significant advantages of meta-devices are their new properties, lighter weight, small size, high efficiency, better performance, broadband operation, lower energy consumption, data volume reduction, and CMOS compatibility for mass production. Here, we demonstrate Moiré meta-devices for focal length tuning in the z-axis (1 dimensional, 1D), focal spots manipulation in the x-y plane (2 dimensional, 2D), and x-y-z axis (3 dimensional, 3D). We developed varifocal meta-lenses to manipulate the focusing spot in 1D for bioimaging in 2D and 3D for 6G communication. The compact design of the varifocal meta-lens may find important applications in fluorescence microscopy, endoscopy for clinical purposes, communication systems, wireless power transfer, zoom imaging, and remote sensing.