Meta-lens World Summit

December 10-11, 2022

Online Meeting via. ZOOM

Link: https://cityu.zoom.us/j/94936292645

Invited Speakers

Federico Capasso
Harvard University

John Pendry
Imperial College, London

Takuo Tanaka
RIKEN

Howard Lee
University of California, Irvine

Yuri Kivshar
Australian National University

Che Ting Chan
Hong Kong University of Science and Technology

Shuang Zhang
University of Hong Kong

Tao Li
Nanjing University

Junsuk Rho
Pohang University of Science and Technology

Jie Zhu
Tongji University / City University of Hong Kong

Jensen Li
Hong Kong University of Science and Technology

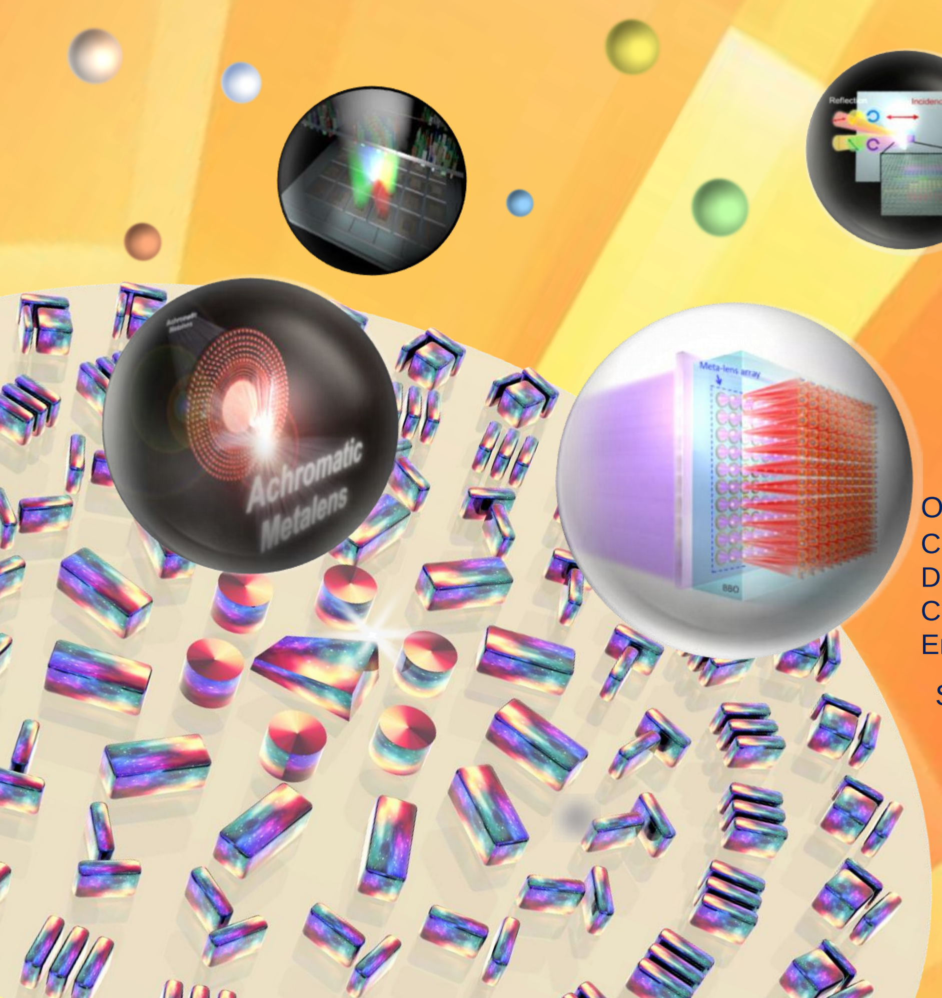
Yuan Luo
National Taiwan University

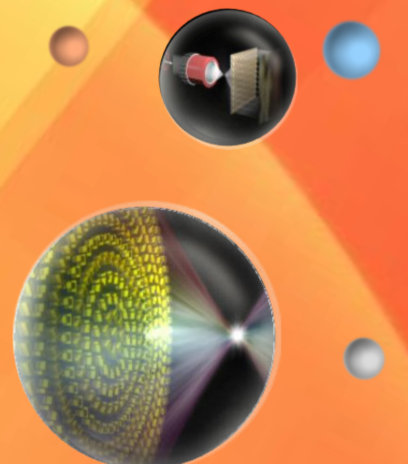
Jing Hua Teng
Agency for Science, Technology and Research

Din Ping Tsai
City University of Hong Kong

Shubo Wang
City University of Hong Kong

Mu Ku Chen
City University of Hong Kong





Organized by **Prof. Din Ping Tsai**
Chair Professor
Department of Electrical Engineering
City University of Hong Kong
Email: dptsai@cityu.edu.hk

Sponsored & co-organized by

CityU

Meta-lens World Summit

Program

10 December 2022		
9:00	Opening & Group Photo Session	Din Ping Tsai
9:10	**Flat Optics: From Metalenses and Cameras to Structured Light and Dark	Federico Capasso
9:45	*Recent Advances in Resonant Metaphotonics	Yuri Kivshar
10:15	*Perspectives of Design, Materials, and Fabrication for Metasurfaces	Junsuk Rho
10:45	*Break [10 mins]*	
10:55	*Meta-devices for Ultra-sensitive IR Spectroscopy	Takuo Tanaka
11:25	3D Varifocal Meta-lens for 6G Applications	Jingcheng Zhang
11:45	An Intelligent Meta-device Resolving Magic Stairs	Xiaoyuan Liu
12:05	Manipulating Near-field Directionality by Anisotropic Chirality	Yuqiong Cheng
12:25	*Lunch & Break*	
14:00	Imaging With an Ultra-thin Reciprocal Lens	Wenzhe Liu
14:20	Inhomogeneous Dirac Systems and Their Chiral Anomaly	Hongwei Jia
14:40	Asymmetric Acoustic Transmission with Controllable Rectification via The Combination of Metasurface and Zero-index Metamaterials	Zhongming Gu
15:00	Ultrasound Focusing Enhancement Through The Stiff Plate Without Any Openings	He Gao
15:20	Heralding Vortex Beams Using A Quantum Metasurface	Hong Liang
15:40	*Break [20 mins]*	
16:00	Time-varying OAM Beams From A Space-time-coding Digital Metasurface	Jingxin Zhang
16:20	Quantum Exceptional Points of Metasurfaces	WaiChun Wong
16:40	Observation of Non-abelian Thouless Pump in an Acoustic System	Oubo You
17:00	**Focussing Photons in Time	John Pendry
17:35	Wireless Power Transfer Inside Zero Index Media	Qingdong Yang

Note: **Keynote talk ; *Invited talk

Meta-lens World Summit

Program

11 December 2022		
9:30	*"Meta"-Optical Fibers	Howard Lee
10:00	*Metasurface for Biomedical Applications	Yuan Luo
10:30	*Break [15 mins]*	
10:45	*Nested Meta-crystals and Spin-1 Weyl Points	Che Ting Chan
11:15	*Metalenses: Forging towards Applications	Tao Li
11:45	*Tunable Metadevices Using Phase Change Materials and 2D Transition Metal Dichalcogenides	Jinghua Teng
12:15	*Lunch & Break*	
14:00	*Metasurface-based Jones-matrix Imaging with Two-Photon Interference	Jensen Li
14:30	*Anomalous Electromagnetic Tunneling with A Growing Field	Shuang Zhang
15:00	*Passive Parity-Time-Symmetric Acoustic Metamaterial	Jie Zhu
15:30	*Break [10 mins]*	
15:40	*Polarization Singularities in Optical Near Fields	Shubo Wang
16:10	*Meta-devices for Optical Imaging and Depth Sensing	Mu Ku Chen
16:40	Award and Closing	

Note: **Keynote talk ; *Invited talk

Program Chair: Din Ping Tsai (CityU)
Program Committee:
Che Ting Chan (HKUST), Ping Sheng (HKUST), Jensen Li (HKUST), Shuang Zhang (HKU), Jie Zhu (CityU/Tongji Univ.), Shubo Wang (CityU), Mu Ku Chen (CityU)

Secretary:
Tammy Hung (CityU)

Keynote Speakers' Bio & Abstracts

John PENDRY

E-mail: j.pendry@imperial.ac.uk

Professor Sir John Pendry received his Ph.D. in Solid State Theory from the University of Cambridge in 1969. He began his career in the Cavendish Laboratory, Cambridge, and later worked at Downing College, Bell Laboratories and Daresbury Laboratory. Since 1981, he has been the Chair in Theoretical Solid-State Physics in the Imperial College London where he has served as Head of Physics Department (1998-2001), and subsequently Principal of the Faculty of Physical Sciences (2001-2002).

Professor Sir Pendry is a condensed matter theorist known for his research into refractive indexes and creation of the first practical “Invisibility Cloak”. He has worked extensively on electronic and structural properties of surfaces, developing the theory of low energy diffraction and electronic surface states and transport in disordered systems.

Focussing Photons In Time

John PENDRY

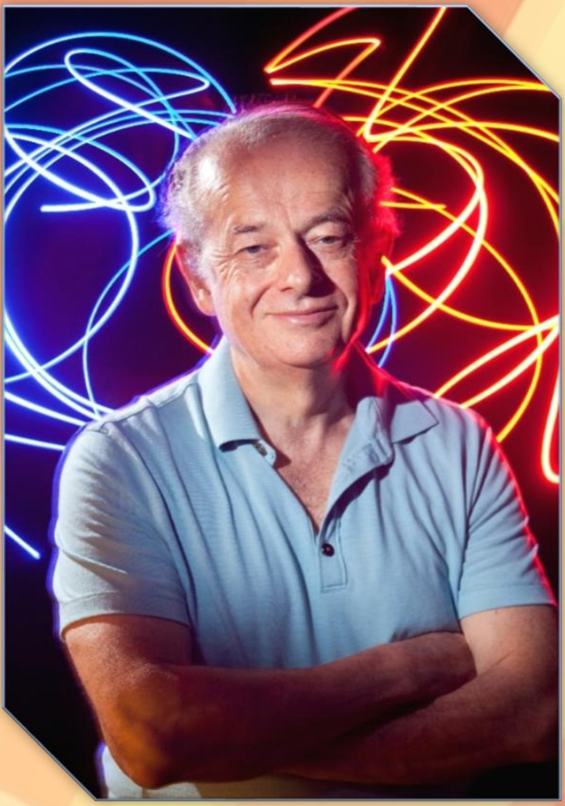
Faculty of Natural Sciences, Department of Physics, Imperial College London

Abstract

Metamaterials exploit the spatial structure of matter to produce new properties. Now we are beginning to explore materials which vary in time, on a scale comparable to the period of radiation. Time dependent systems do not in general conserve energy invalidating much of the theory developed for static systems and turning our intuition on its head. This is particularly acute in luminal space time crystals where the structure moves at or close to the velocity of light. Conventional Bloch wave theory no longer applies, energy grows exponentially with time, and a new perspective is required to understand the phenomenology. In this talk we identify a new mechanism for amplification: the focusing of lines of force that are nevertheless conserved in number.

Federico CAPASSO

E-mail: capasso@seas.harvard.edu



Federico Capasso is the Robert Wallace Professor of Applied Physics at Harvard University, which he joined in 2003 after 27 years at Bell Labs where his career advanced from postdoctoral fellow to Vice President for Physical Research. His contributions include band structure engineering technique leading to his invention of the quantum cascade laser, MEMS based on the Casimir effect and the first measurement of the repulsive Casimir force, metasurfaces including the generalized laws of refraction and reflection, "flat optics" such a high performance metalenses and Matrix Fourier optics used to demonstrate single shot ultracompact polarization sensitive cameras. He is cofounder and a board member of Metalenz (https://www.metalenz.com/), which he cofounded in 2016 and is focused on commercializing metaoptics for high volume markets.

His awards include the Yves Medal of Optica (formerly Optical Society), the Balzan Prize in Applied Photonics, the King Faisal Prize, the IEEE Edison Medal, the American Physical Society Arthur Schawlow Prize in Laser Science, the AAAS Rumford Prize, the Enrico Fermi Prize, the European Physical Society Quantum Electronics Prize, the Wetherill Medal of the Franklin Institute, the Materials Research Society Medal, the Jan Czochralski Award for lifetime achievements in Materials Science, the Rob Wood Prize of Optica. He is a member of the National Academy of Sciences, the National Academy of Engineering, and a fellow of the American Academy of Arts and Sciences (AAAS).

Flat Optics: From Metalenses And Cameras To Structured Light And Dark

Federico CAPASSO

John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138

Abstract

Metasurfaces are sub-wavelength spaced arrays of nanostructures that enable the design of ultrathin optical components with superior aberration control and ease of optical alignment compared to refractive optics, leading to a major reduction in complexity and footprint and to functions not available in standard optics [1]. Flat optics will lead to the unification of semiconductor manufacturing and lens making, where the planar technology to manufacture ICs will be used to make CMOS compatible lenses for high volume markets like cell phones [2] [3]. Metasurfaces have led to polarization optics that does not rely on birefringent materials and to the realization of ultracompact single-shot polarization sensitive cameras [4]. Metasurfaces can be designed to perform multiple and independent optical functions, depending on the incident polarization, angle or wavelength and provide unique opportunities to design optical wavefronts at will in the transverse plane as well along the propagation direction. Finally, the demonstration of 2D phase and polarization singularities ("structured dark") and the applications they will lead to will be discussed [5].

References:

[1] W. T. Chen, A. Y. Zhu, and F. Capasso Nature Reviews Materials 5, 604 (2020)
[2] F. Capasso Nanophotonics 7, 6953 (2018)
[3] J-S. Park, S. Zhang, A.She, W-T Chen, P. Lin, K.M. A. Yousef, J-X Chen and F. Capasso, Nano Letters 19, 8673 (2019)
[4] N. A. Rubin, G. D'Aversa, P. Chevalier, Z. Shi, W-T Chen, and F. Capasso Science 365, 6448 (2019)
[5] S.W.D Lim, J-S. Park, M. L. Meretska, A.H. Dorrah and F. Capasso Nature Communications 12, 4190 (2021)

Invited Speakers' Bio & Abstracts

Yuri KIVSHAR

E-mail: yuri.kivshar@anu.edu.au

Professor Yuri Kivshar is Distinguished Professor of the Australian National University in Canberra, Australia. He received PhD degree in 1984 in Kharkov (Ukraine). From 1989 to 1993 he worked at several research centers in USA and Europe, and in 1993 he moved to Australia where he established Nonlinear Physics Center at the Australian National University. His research interests include nonlinear physics, metamaterials, and nanophotonics. He is Fellow of the Australian Academy of Science, OSA, APS, SPIE, and IOP. He received many awards for his research including Lyle Medal (Australia), Lebedev Medal (Russia), The State Prize in Science and Technology (Ukraine), Harrie Massey Medal (UK), Humboldt Research Award (Germany), 2020 SPIE Mozi Award (USA), and more recently 2022 Max Born Award (Optica, former OSA).

Recent Advances in Resonant Metaphotonics

Yuri Kivshar

Nonlinear Physics Center, Research School of Physics,
Australian National University, Canberra ACT 2601, Australia

Abstract

For many years, plasmonics was considered as the only available platform for subwavelength optics and nanophotonics, but the recently emerged field of Mie resonant metaphotonics provides practical alternatives for nanoscale optics by employing resonances in high-index dielectric nanoparticles and metasurfaces. In this talk we aim to discuss the physics of dielectric Mie-resonant metamaterials for efficient spatial and temporal control of light by employing multipolar resonances and bound states in the continuum to achieve high values of the Q factor, with applications of these concepts to nonlinear photonics, nonlinear meta-lensing, and sensing. In addition, we will discuss linear and nonlinear circular dichroism in dielectric metastructures empowered by optically induced electric and magnetic Mie resonances and bound states in the continuum, including the demonstration of second- and third-harmonic generation and chiral lasing.

Che Ting CHAN

E-mail: phchan@ust.hk

C.T. Chan received his PhD degree from the University of California at Berkeley in 1985. He is currently serving as the Associate Vice-President for Research & Development at HKUST. He is also concurrently the Daniel C K Yu Professor of Science, Chair Professor of Physics, and the Director of Research Office of HKUST. He has been elected a Fellow of the American Physical Society and the Physical Society of Hong Kong and a member of the Hong Kong Academy of Sciences.

Nested Meta-crystals And Spin-1 Weyl Points

C. T. CHAN[1]

[1] *Department of Physics, The Hong Kong University of Science and Technology, Hong Kong*

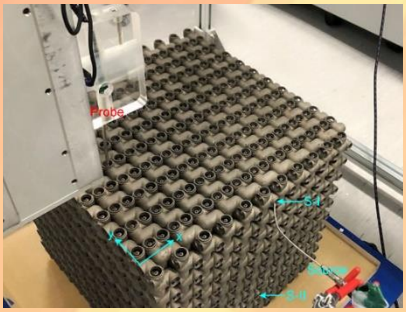


Fig. 1: A nested meta-crystal

Abstract

It is well-known that the electromagnetic modes in 3D photonic crystals must be solved explicitly as vector waves, and the scalar wave approximation is not applicable. This is fundamentally different from condensed matter physics in which the scalar approach (ignoring spin) usually gives a good approximation, as the incorporation of the spin degree of freedom can be regarded as a perturbation to the scalar wave band dispersion. However, for EM waves, there is no “scalar” analogue of Maxwell's equations (except in 2D where the TE and TM modes can be separately mapped to a scalar wave equation in some special high symmetry systems).

It would be highly desirable if there is a way to realize “scalar photonic topological phases” in 3D. While the mission sounds impossible, we show here that it is achievable if we construct nested crystal structures. The band structure of these crystals shows strong resemblance to s-orbital hopping (scalar wave) in condensed matter physics. We experimentally demonstrated the scheme by constructing a meta-crystal (see Fig. 1) carrying spin-1 Weyl points simply from space group considerations.

We will also show that the zero-frequency k=0 point of some chiral photonic crystals is effectively a spin-1 Weyl point and we will demonstrate the robust transport properties of surface state arcs emerging from those nodal points.

Work done in collaboration with B. Yang, Q.H Guo, D.Y. Wang, R.Y. Zhang and Z.Q. Zhang with funding support from RGC.

Shuang ZHANG

E-mail: shuzhang@hku.hk

Shuang Zhang is a chair Professor in the Department of Physics and the Department of Electronic & Electrical Engineering at the University of Hong Kong. He obtained his PhD in Electrical Engineering from the University of New Mexico. Thereafter he worked as postdoc at UIUC and UC Berkeley. He joined the University of Birmingham, UK as a Reader in 2010 and was promoted to professor in 2013. Prof. Zhang joined the University of Hong Kong as a Chair Professor in 2020. He was the recipient of IUPAP award in Optics (2010), ERC consolidator grant (2015-2020), Royal Society Wolfson Research Award (2016-2021), and was elected OSA fellow in 2016, APS fellow in 2022, and has been on the list of highly cited researchers (by Clarviate) since 2018.

Anomalous Electromagnetic Tunneling with A Growing Field

Shuang ZHANG

Department of Physics, The University of Hong Kong, Pokfulam, Hong Kong

Abstract

Quantum tunnelling, one of the most celebrated effects arising from the wave nature of matters, describes the partial penetration of an incident propagating wave through a potential barrier in the form of an evanescent field that exponentially decays from the incident interface. Similar tunnelling effect has also been observed in classical systems, such as the frustrated total internal reflection. In this talk I will describe an unexplored form of tunnelling for electromagnetic waves which features opposite behaviors for the electric and magnetic fields, with one turning into a growing field, and the other a decaying field, in a medium that exhibits both ε-μ-zero and bianisotropy. Our work provides a new mechanism for manipulating electromagnetic waves for novel device applications.

Jinghua TENG

E-mail: jh-teng@imre.a-star.edu.sg

Dr. Jinghua Teng is a Principal Scientist in the Institute of Materials Research and Engineering (IMRE), Agency for Science, Technology and Research (A*STAR), Singapore, and an Adjunct Professor in the Nanyang Technological University and the National University of Singapore. He has extensive experiences in both use-inspired basic research and technology translation through industry collaborations. He has edited/authored 5 book/book chapters, filed 30 primary patents, and published over 240 journal papers. He is an editorial board member of the Journal of Optics, Opto-Electronic Advances, PhotoniX, Advanced Photonics Nexus, Journal of Molecular and Engineering Materials, and A*STAR Research Publication. He is a Fellow of SPIE and OPTICA.

Tunable Metadevices Using Phase Change Materials And 2D Transition Metal Dichalcogenides

Jinghua TENG

*Institute of Materials Research and Engineering (IMRE), Agency for Science, Technology and Research (A*STAR), Singapore*

Abstract

Beyond the static metadevices with the fixed functionality, tunable and reconfigurable metadevices have practical and fundamental significances in applications such as autonomous vehicles, robots, display, augmented and virtual reality, consumer electronics and telecommunications, and could lead to the alluring on-demand optics and photonics1. To achieve the objective of tunable metadevices, many technologies have been proposed in the past years. In this talk, I will introduce several of our recent works on tunable metadevices including wide-angle tunable perfect absorption and polarization insensitive large-angle high-directivity beam switching using phase change materials2,3, electrostatically tunable plasmonic response in near infrared range in NbSe24, ultra-thin flat lens for sub-diffraction limit focusing and imaging by engaging the strong excitonic absorption in MoS25, and the high electrical tunability of refractive index in WS2 for potentially tunable atomically thin metadevices.

References:
[1] Chunqi Zheng, Robert E Simpson, Kechao Tang, Yujie Ke, Arash Nemati, Qing Zhang, Guangwei Hu, Chengkuo Lee, Jinghua Teng, Joel K.W. Yang, Junqiao Wu, Cheng-Wei Qiu, “Enabling Active Nanotechnologies by Phase Transition From Electronics, Photonics to Thermotics,” Chemical Reviews 122, 15450 (2022)
[2] Kandammathe Valiyaveedu Sreekanth, Patinharekandy Prabhathan, Apoorva Chaturvedi, Yulia Lekina, Shen Zexiang, Jinghua Teng and Ranjan Singh “Wide-angle tunable critical coupling in nanophotonic optical coatings with low-loss phase change material,” Small 10.1002/smll.202202005 (2022)
[3] Arash Nemati, Guanghui Yuan, Jie Deng, Aihong Huang, Weide Wang, Toh Yeow Teck, Jinghua Teng and Qian Wang, “Controllable polarization insensitive and large-angle beam switching with phase-change metasurfaces,” Advanced Optical Materials 10, 2101847, (2022)
[4] M. Zhao, J. Li, Matej Sebek, Yanjun Liu, Michel Bosman, Qian Wang, Xinting Zheng, Le Yang, Jiong Lu, Jinghua Teng, “Electrostatically Tunable Near-Infrared Plasmonic Resonance in Solution Processed Atomically Thin NbSe2,” Advanced Materials 33, 2101950 (2021)
[5] Zeng Wang, Guanghui Yuan, Ming Yang, Jianwei Chai, Qing Yang Wu Steve, Tao Wang, Shijie Wang, Dongzhi Chi, Giorgio Adamo, Cesare Soci, Handong Sun, Kun Huang, Jinghua Teng, “Exciton Enabled Meta-Optics in Two-Dimensional Transition Metal Dichalcogenides,” Nano Letters 20, 7964 (2020)

Takuo TANAKA

E-mail: t-tanaka@riken.jp

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.

Meta-devices for Ultra-sensitive IR Spectroscopy

Takuo TANAKA

Metamaterials Laboratory, RIKEN Cluster for Pioneering Research, Saitama JAPAN

Innovative Photon Manipulation Research Team, RIKEN Center for Advanced Photonics, Saitama JAPAN

Institute of Post-LED Photonics, Tokushima University, Tokushima JAPAN

Abstract

Label-free detections and recognitions of molecules are highly demanded in bioanalysis applications. IR spectroscopy is one of the label-free techniques and gives us chemical information of molecules. However, application of IR spectroscopy in bioanalysis is still limited due to its low sensitivity. To improve the sensitivity of IR spectroscopy, we propose a broadband metamaterial absorber that suppress the unwanted background as well as enhancement of molecular signals by the use of plasmonic hot spots and attomole-level molecular sensitivity was obtained [1].

To full utilize the enhancement property of metamaterial absorber, introducing analyte molecules into the hot-spots is crucial. To solve this problem, we proposed metamaterial and nanofluidic hybrid devices that can introduce analytes into the hot-spots of metamaterials, consequently an ultra-high sensitivity of IR absorption detection can be achieved. The structure consists of metal square-disks array and metal mirror separated by a nano fluidic channel. When the molecule whose absorption is overlapped with this mode is introduced, strong interaction between molecules and metamaterials is excited and it creates the reflection light within the absorption band of the metamaterial. The sensitivity was achieved at molecule density of ~10-4 molecules/Å2, which is improved by 2 orders compared to reported plasmonic induced IR detection methods [2]. Moreover, using this device, we could confirm that strong H-bonded network water confined in 10-100 nm regime existed [3].

Signal strength from molecules also depends on the density of the hot spots. In order to increase the density of hot spots, we designed and fabricated the vertically aligned MIM (v-MIM) structure with a nano-gap of 25 nm channel [4]. This meta-device was applied to carbon dioxide and butane detection designing to exhibit a resonance at 4033 cm-1 and 2945 cm-1 which spectral overlap with the C=O and –CH2 vibration mode, respectively. Owing to the small footprint of v-MIM, the density of the MIM structure is substantially increased and its sensing performance was also improved.

References:

[1] A. Ishikawa and T. Tanaka, Scientific Reports 5, 12570 (2015).

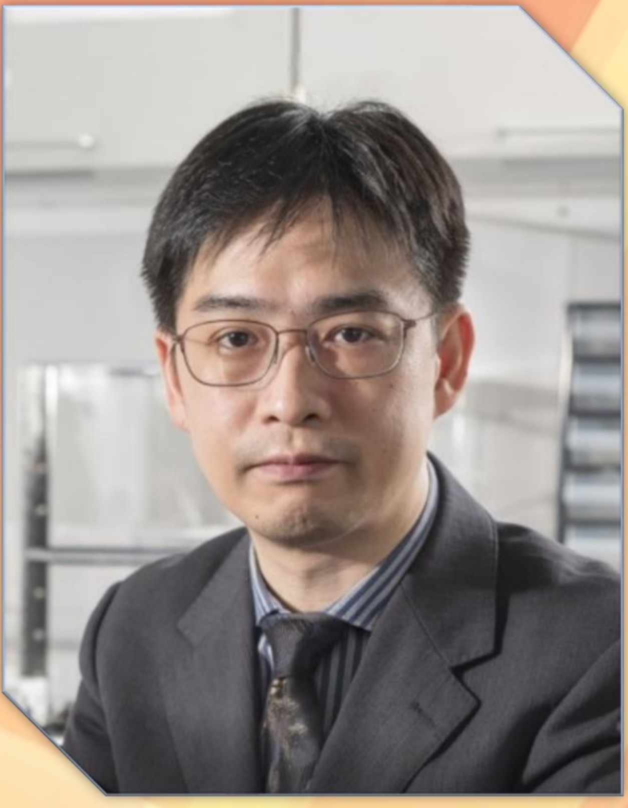
[2] T. Le and T. Tanaka, ACS Nano 11, 9780 (2017).

[3] T. Le, A. Morita, K. Mawatari, T. Kitamori, and T. Tanaka, ACS Photonics 5, 3179 (2018).

[4] D.-S. Su, D. P. Tsai, T.-J. Yen, and T. Tanaka, ACS Sensors 4, 2900 (2019).

Jensen LI

E-mail: jensenli@ust.hk



Professor Jensen Li is a professor in the Department of Physics at Hong Kong University of Science and Technology. He is working on optical metasurfaces, non-Hermitian systems, transformation optics and acoustic metamaterials. He has published more than one hundred peer-reviewed articles. His research group in Hong Kong and previously in UK has been supported by research grants from Hong Kong RGC and EU. He has led a collaborative research project on “Non-Hermitian Systems in Optics and Acoustics” across several local universities in Hong Kong. Professor Li is an elected member of Hong Kong Young Academy of Sciences and received Croucher Senior Research Fellowship in 2022.

Metasurface-based Jones-matrix Imaging With Two-photon Interference

Tsz Kit Yung[1], Hong Liang[1], Jiawei Xi[1], Wing Yim Tam[1] and Jensen Li[1,2]

1 Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong

2 IAS Center for Quantum Technologies, The Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong, China

Abstract

Here, we combine metasurface's polarization-selection capability with two-photon interference for imaging Jones-matrix profiles. Using a metasurface with reference panels of known polarization responses and an object of unknown polarization responses, an image of Jones matrix elements of the object can be extracted from the pairwise coincidence signals probed by a polarization analyzer and a single-photon camera. When two photons of orthogonal polarizations pass through the metasurface simultaneously, quantum interference occurs between two processes, in which one photon passes the reference panels while another passes the object and vice versa. Dictated by the Jones matrix elements, quantum interference can be destructive to constructive. Therefore, the coincidence signals between a particular object pixel and the different reference pixels reveal the Jones matrix elements of each object pixel in a parallel fashion. The adoption of different reference panels in our imaging scheme effectively parallelizes the preparation of input (polarization) states, prevalent in any quantum algorithms, showing an advantage of using two-photon interference in Jones matrix imaging.

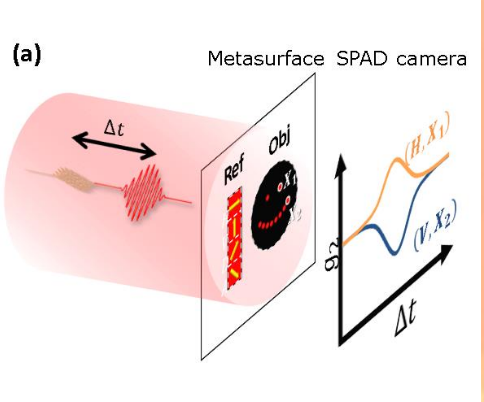


Fig. 1: Two-photon Imaging scheme. Two photons with orthogonal polarizations, with controllable time delay Δt, are shone on the metasurface, which consists of two regions: reference panels of known polarization responses and an unknown region of object to be imaged. A SPAD camera is used to image the metasurface with time-arrival signal at each pixel and coincidence signal is extracted between any pair of pixels of the two regions.

References:

[1] Yung, Z. K., Xi, J., Liang, H., Lau, K. M., Wong, W. C., Tanuwijaya, R. S., Zhong, F., Liu, H., Tam, W. Y., Li, J. Polarization coincidence images from metasurfaces with HOM-type interference. iScience. 25, 104155 (2022)

[2] Yung, Z. K., Liang, H., Xi, J., Tam, W. Y., Li, J. Jones-matrix imaging based on two-photon interference. Nanophotonics. (in press, https://doi.org/10.1515/nanoph-2022-0499)

Junsuk RHO

E-mail: jsrho@postech.ac.kr

Prof. Rho is a Mu-Eun-Jae (无垠斋) Endowed Chair Professor and Young Distinguished Professor at Pohang University of Science and Technology (POSTECH), Korea, with a double appointment in the Department of Chemical Engineering and the Department of Mechanical Engineering. He received his Ph.D. at the University of California, Berkeley (2013), M.S. at the University of Illinois, Urbana-Champaign (2008), and B.S. at Seoul National University, Korea (2007) all in Mechanical Engineering. Prior to joining POSTECH, he conducted postdoctoral research in Materials Sciences Division & Molecular Foundry at Lawrence Berkeley National Laboratory, and also worked as a principal investigator (Ugo Fano Fellow) in Nanoscience and Technology Division & the Center for Nanoscale Materials at Argonne National Laboratory.

Prof. Rho has authored and co-authored more than 250 high-impact journal papers including Science, Nature, Nature Nanotechnology, Nature Materials, Nature Photonics, and Chemical Reviews. He is also the recipients of several notable honors and awards such as Samsung Lee Kun-Hee fellowship (2008-2013), US Department of Energy Argonne Named fellowship (2013-2016), Edmund Optics Award (2015), SPIE Rising Researcher Award (2017), OSA IMCO Young Scientist Award (2019), Korean Presidential Early Career Award for Scientists and Engineers (2019), Springer-Nature MINE Young Scientist Award (2020), Elsevier MEE/MNE Young Investigator Award and Lectureship (2020), MDPI Micromachines Young Investigator Award (2020), Member of the Young Korean Academy of Science and Technology (2020), Associate Member of the National Academy of Engineering of Korea (2022), NAEK Young Engineers Award (2022), Hong Jin-Ki Creator Award (2022). He serves 13 editorial positions including Light: Science and Applications (Springer-Nature), Microsystems and Nanoengineering (Springer-Nature), and Nanophotonics (De Gruyter).

Perspectives Of Design, Materials, And Fabrication For Metasurfaces

Junsuk Rho [1,2,3]

1 Department of Mechanical Engineering, Pohang University of Science and Technology (POSTECH), Pohang 37673, Republic of Korea

2 Department of Chemical Engineering, Pohang University of Science and Technology (POSTECH), Pohang 37673, Republic of Korea

3 POSCO-POSTECH-RIST Convergence Research Center for Flat Optics and Metaphotonics, Pohang 37673, Republic of Korea

Abstract

We represent AI-designed metasurfaces [1, 2] and three low-cost manufacturing: 1) nanoimprinting with high-refractive-index dielectric particle embedding resin (PER)[2-5], 2) bandgap engineering of hydrogenated amorphous silicon (a-Si:H)[6], and 3) atomic-layer coating on imprinted resin[7]. a-Si[3], TiO_2[2, 4], and ZrO_2 PERs[5] are used for metasurfaces at infrared (940 nm), visible (532 nm), and ultraviolet (325 and 248 nm), respectively; measured efficiencies reach 47% (940 nm), 91% (532 nm), 72% (325 nm), and 49% (248 nm). PER metasurfaces with an inverse design provide 3D, full-color holography at visible[2]. The bandgap of a-Si:H is engineered to suppress optical losses, realizing metasurface efficiencies of 42% (450 nm), 65% (532 nm), and 75% (635 nm)[6]. We deposit an atomic layer on resin for 12-inch metasurfaces, achieving measured efficiencies of 61% (450 nm), 78% (532 nm), and 65% (635 nm)[7].

References:

1. G. Yoon, and J. Rho, “MAXIM: Metasurfaces-oriented electromagnetic wave simulation software with intuitive graphical user interfaces,” Computer Physics Communications 264, 107846, (2021).

2. S. So, J. Kim, T. Badloe, C. Lee, Y. Yang, H. Kang, and J. Rho, “Breaking the information capacity limits of single-celled metasurfaces using inverse design,” Advanced Materials (In review).

3. G. Yoon, K. Kim, S.-U. Kim, S. Han, H. Lee, and J. Rho, “Printable nanocomposite metalens for high-contrast near-infrared imaging,” ACS Nano, 15, 698-706, (2021).

4. J. Kim, D. K. Oh, H. Kim, G. Yoon, C. Jung, J. Kim, T. Badloe, H. Kang, S. Kim, Y. Yang, J. Lee, B. Ko, J. G. Ok, and J. Rho, “Metasurface holography reaching the highest efficiency limit in the visible via one-step nanoparticle-embedded-resin printing,” Laser & Photonics Reviews, 16, 2200098, (2022).

5. J. Kim, W. Kim, D. K. Oh, H. Kang, H. Kim, T. Badloe, S. Kim, C. Park, H. Choi, H. Lee, and J. Rho, “One-step printable platform for high-efficiency metasurfaces down to the deep ultraviolet region,” Light Science and Applications, (In revision).

6. Y. Yang, G. Yoon, S. Park, S. D. Namgung, T. Badloe, K. T. Nam, and J. Rho, “Revealing structural disorder in hydrogenated amorphous silicon for a low-loss photonic platform at visible frequencies,” Advanced Materials 33, 2005893, (2021).

7. J. Kim, J. Seong, W. Kim, G.-Y. Lee, H. Kim, S.-W. Moon, B. Lee, H. Lee, and J. Rho, “Mass-production of visible metalenses,” Nature Materials (In revision).

Tao LI

E-mail: taoli@nju.edu.cn

Prof. Tao LI, Professor of Nanjing University (NJU), received his PhD degree at NJU in 2005, joined NJU as a faculty in 2008. He worked as a visiting scholar in Nanyang Technology University, Singapore (2012), and Hong Kong Baptist University under the support of “K.C. Wong Education Foundation” scholarship (2013). He was selected as the "Dengfeng Talent Program B" from NJU (2012), "National Funds for Outstanding Young Scientists" (2013), and "Young and middle-aged leading scientists" from MOST (2018), honored with the "VEBLEO SCIENTIST AWARD" (2021). His research interest is about the metamaterials, plasmonics, and photonic integration. Till now, he has published >110 papers with citation over 5500 and a recent H index of 38, presented >50 invited talks in international conferences and seminars. He is currently working as the Topical Editor of Chinese Optical Letters, Executive Board Member of Science Bulletin, and Editorial Committee of Chinese Laser Express, Frontier of Optoelectronics, and Advanced Devices & Instrumentation.

Metalenses: Forging Towards Applications

Chen Chen, Xin Ye, Ji Chen, Beibei Xu, Hanmeng Li, Yuxin Chen, Shining Zhu, Tao Li

National Laboratory of Solid State Microstructures, School of Physics, College of Engineering and Applied Sciences, Nanjing University

Abstract

In recent years, the ultrathin and ultralight metalens becomes a hot topic both in academia and industry for its potential revolutionary applications. Towards this ultimate goal, in this talk, I would like to share our recent efforts in the designs and implementations of the compact metalens devices that is high expected for convenient applications. First, a mini meta-microscope with large field-of-view (FOV) will be interpreted, which takes good uses of polarization multiplexing of metalens array to fulfill a large FOV that breaks the conventional Space-bandwidth product (SBP)[1,2]. Second, such a lens-array design is extended to a wide-angle flat fish-eye camera, in which multiple metalenses are design with respect to different viewing angles and gives rise to a super wide-angle imaging [3]. As a third approach, we would like to show an interesting pancake metalens camera, which can efficiently fold the imaging space to further reduce the device column [4]. It is implemented by a bifacial metalens that can transmit and focus the light for a certain circular polarization, but reflect the other orthogonal polarized light. By incorporating with a mirror, the reflected light with polarization flip will be trapped inside the "cavity" and gives rise to a folded imaging optical path. It significantly reduces the space to 1/3 and even more. All of these progresses definitely show uniqueness of metalenses for ultra-compact imaging devices that might possibly revolutionize the current technology.

References:

[1] Beibei Xu, Hanmeng Li, Shenglun Gao, Xia Hua, Cheng Yang, Chen Chen, Feng Yan, Shining Zhu, and Tao Li*, "Metalens-integrated compact imaging devices for wide-field microscopy", Advanced Photonics 2, 066004 (2020)
[2] Xin Ye, Xiao Qian, Yuxin Chen, Rui Yuan, Xingjian Xiao, Chen Chen, Wei Hu, Chunyu Huang, Shining Zhu, and Tao Li*, "Chip-scale metalens microscope for wide-field and depth-of-field imaging", Advanced Photonics 4 046006 (2022).
[3] Ji Chen, Xin Ye, Shenglun Gao, Yuxin Chen, Yunwei Zhao, Chunyu Huang, Kai Qiu, Shining Zhu, and Tao Li*, "Planar wide-angle-imaging camera enabled by metalens array", Optica 9, 431 (2022).
[4] Chen Chen*, Xin Ye, Jiacheng Sun, Yuxin Chen, Chunyu Huang, Xingjian Xiao,Wange Song, Shining Zhu, and Tao Li*, "Bifacial-metasurface-enabled pancake metalens with polarized space folding", Optica 9, xxx (2022) in press.

Jie ZHU

E-mail: jiezhu@tongji.edu.cn

Professor Jie Zhu is currently a Professor in the school of physics science and engineering, Tongji University, China. After obtaining doctoral degrees from the Pennsylvania State University, he served as a postdoctoral researcher at the University of California, Berkeley, then assistant professor and associate professor at the Hong Kong Polytechnic University. Prof. Zhu's research mainly focus on the basic and applied research in acoustic metamaterials, metasurface and the cutting-edge interdisciplinary fields. He has published multiple papers in Nature Physics, Physical Review Letters, and Nature Communications, etc. Currently Prof. Zhu serves as an editorial board member of Ultrasonics and Advanced Devices & Instrumentation. He has led a number of research projects funded by the National Natural Science Foundation of China and the UGC Research Grants Council of the Hong Kong Special Administrative Region Government.

Passive Parity-Time-Symmetric Acoustic Metamaterial

Tuo Liu[1], Xuefeng Zhu[2], Renmin Ma[3], Guancong Ma[4], Jie Zhu[5]

[1] Key Laboratory of Noise and Vibration Research, Institute of Acoustics, Chinese Academy of Sciences, China

[2] School of Physics, Huazhong University of Science and Technology, China

[3] State Key Lab for Mesoscopic Physics and School of Physics, Peking University, China

[4] Department of Physics, Hong Kong Baptist University, Hong Kong, China

[5] Institute of Acoustics, School of Physics Science and Engineering, Tongji University, China

Abstract

Classical wave systems provide fertile ground for a new concept of Parity-Time (PT) Symmetry. A growing number of related studies not only revealed rich physical connotations, but also showed a series of novel phenomena and potential applications. However, the exploration of acoustic PT symmetry systems is still in the early stage. The main constraint comes from the lack of natural acoustic gain materials. Passive PT symmetric systems without gain are a viable solution to overcome this problem in specific application scenarios. In view of this, this report will report how we managed to design and arrange artificial metamaterials within waveguides to construct passive acoustic PT symmetric metamaterial crystals, and how we conducted related research to utilize such material in exploring other functionalities and possibility.

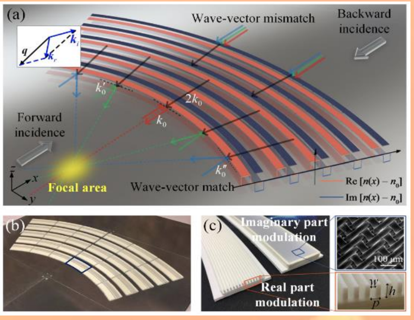


Fig. 1: All passive acoustic PT-symmetric metamaterials crystal.

References:
[1] T. Liu, X. F. Zhu, F. Chen, S. Liang and J. Zhu, “Parity-time symmetry beyond one dimension with all passive acoustic metamaterials crystal”, Physical Review Letters, 120 (12), 124502, (2018).
[2] H. Z. Chen, T. Liu, H. Y. Luan, R. J. Liu, X. Y. Wang, X. F. Zhu, Y. B. Li, Z. M. Gu, S. Liang, H. Gao, L. Lu, L. Ge, S. Zhang, J. Zhu and R. M. Ma, “Revealing the missing dimension at an exceptional point”, Nature Physics, 16 (5), 571-578, (2020).
[3] T. Liu, S. An, Z. Gu, S. Liang, H. Gao, G. Ma and J. Zhu, “Chirality-switchable acoustic vortex emission via non-Hermitian selective excitation at an exceptional point”, Science Bulletin, 67 (11), 1131-1136, (2022).

Yuan LUO

E-mail: yuanluo@ntu.edu.tw

Professor Yuan Luo received the MSc and PhD degrees in College of Optical Sciences in 2007 and 2008, respectively, from the University of Arizona. After post-doctoral work at Massachusetts Institute of Technology (MIT, 2009-2011), he joined the faculty at National Taiwan University (NTU) in 2011, where he is now Director/Professor of Institute of Medical Device and Imaging. He serves Associate Dean in NTU YongLin Institute of Health. His research interests are three-dimensional (3D) and spectral imaging; shift-invariant optics theory and implementation with 3D active structured light. He is a Fellow of International Society for Optical Engineering (SPIE).

Metasurface for Biomedical Applications

Cheng Hung Chu[1], Sunil Vyas[2] and Yuan Luo[1,2,3]

[1]*YongLin Institute of Health, National Taiwan University, Taipei 10672, Taiwan*

[2]*Institute of Medical Device and Imaging, National Taiwan University, Taipei 10051, Taiwan*

[3]*Institute of Biomedical Engineering, National Taiwan University, Taipei 10051, Taiwan*

Abstract

Fluorescence microscopy is a typical technique for observing the structural characteristics of biological specimens. To obtain fluorescence optical sectioning images, conventional tunable lenses are usually employed to axially scan volumetric materials. However, they have issues with distortion and spherical aberration. Microscopy optical systems can benefit greatly from the use of metasurfaces due to their extreme thinness (down to several hundred nanometers) and extraordinary optical properties. In this paper, we propose a compact imaging system with optical sectioning capacity based on Moiré metalens for fluorescent bio-imaging in visible regions[1]. The Moiré metalens consists of two phase complementary metasurfaces. By adjusting the mutual angles between two metasurfaces, the focal length of the system can be varied from 10 mm to 125 mm at a wavelength of 532 nm. The HiLo speckle illumination microscopy is also used to reduce the background light scattering. The labeled beads and ex vivo mice intestinal tissue samples are imaged to demonstrate our system's optical sectioning capacity. The described varifocal metalens design is expected to realize significant applications in fluorescence microscopy and endoscopy. In addition, recent works on implementing metasurface for biomedical optical instrument research are also discussed[2,3].

References:

[1] Luo, Yuan, et al. "Varifocal metalens for optical sectioning fluorescence microscopy." Nano Letters 21, 5133-5142 (2021).

[2] Luo, Yuan, et al. "Meta-lens light-sheet fluorescence microscopy for in vivo imaging." Nanophotonics 11, 1949-1959 (2022).

[3] Luo, Yuan, et al. "Metasurface-Based Abrupt Autofocusing Beam for Biomedical Applications." Small Methods 6, 2101228 (2022).

Howard LEE

E-mail: Howardhw.lee@uci.edu

Howard Lee is currently an Associate Professor in the Department of Physics and Astronomy at UC Irvine. Before joining UCI, he was an Associated Professor in the Department of Physics at Baylor University and IQSE Fellow and visiting professor in the Institute for Quantum Science and Engineering (IQSE) at TexasA&M. He was a Postdoctoral Fellow at the Caltech, working with Prof. Harry Atwater in active plasmonics/metasurfaces. He received his PhD in Physics from the Max Planck Institute for the Science of Light in Germany in 2012 under the supervision of Prof. Philip Russell. His work on nano-optics, plasmonics, and specialty optical fibers has led to 45 journal publications in various journals, such as Science, Nano Letters, Advanced Materials, ACS Photonics, and Laser & Photonics Reviews as well as 80 invited talks and 150 conference papers. Dr. Lee is a recipient of a 2022 Finalist of Moore Inventor Fellow, a 2021 iCANX Young Scientist Award, 2021 Finalist of Rising Stars of Light, 2020 SPIE Rising Researcher, a 2020 Baylor Outstanding Professor Award, a 2019 DARPA Director's Fellowship, a 2019 IEEE OGC Young Scientist Award, a 2018 NSF CAREER Award, a 2017 DARPA Young Faculty Award, a 2018 OSA Ambassador, and a 2017 APS Robert S. Hyer Award.

“Meta”-Optical Fibers

Andrew Palmer,[1,2] Leon Zhang,[1,2] Stuart Love,[1,2] Zoey Liu,[1,2] Ho Wai Howard Lee[1,2,*]

[1] Department of Physics & Astronomy, University of California, Irvine, United States

[2] Beckman Laser Institute and Medical Clinic, University of California, Irvine, United States

Abstract

Optical fiber is a well-established and efficient light-guiding medium. Although optical fiber is efficient for transmitting light, its functionality is limited by the dielectric material of the core, which has poor optoelectronic, magneto-optical, and nonlinear-optical responses and has a dielectric diffraction limit. Therefore, the optical properties of the optical fiber such as phase, amplitude, polarization, and mode profile, cannot be altered after the fiber drawing fabrication, thus limiting the development of novel in-fiber devices. Integration of new materials and nanostructures into fiber will enhance processing/transmission capabilities and novel functionalities.

In this talk, I will present our recent development of “Meta”-optical fiber, an advanced optical fiber integrated with emerging nanophotonic concepts such as optical metasurfaces, plasmonic nanowires, and zero-index photonics. I will present the development of ultrathin optical metalens which is cascaded on the facet of a photonic crystal fiber that enables light focusing. I will also discuss the first experimental demonstration of zero-index resonance excitation in an optical fiber coated with AZO nanolayer and excitation of plasmonic resonances on holey optical fiber for advanced optical sensing and tip-enhanced Raman spectroscopy. These advanced “meta”-optical fibers open a pathway to revolutionary in-fiber lasers/spectroscopies, optical imaging/sensing, and optical communication devices

Shubo WANG

E-mail: shubwang@cityu.edu.hk

Dr Shubo Wang is an Assistant Professor in the Department of Physics at City University of Hong Kong. He received BSc degree from Shandong University and PhD degree from the Hong Kong University of Science and Technology. His research interests include chiral light-matter interactions, singular optics, non-Hermitian optics, metamaterials, and optical forces. He has published ~50 papers in peer reviewed journals including Nature Communications, Science Advances, and Physical Review Letters, among which some are selected as "Editors' Suggestion", highlighted in Nature Photonics, and received media coverage by EurekAlert, Phys.org, Science Daily, etc. He delivered 20 invited/keynote talks at international conferences and received William Mong Outstanding Paper Award in 2012.

Polarization Singularities in Optical Near Fields

Jie Peng[1], Shiqi Jia[1], Ruo-Yang Zhang[2], Wei Liu[3], and Shubo Wang[1,4]

1Department of Physics, City University of Hong Kong, Hong Kong, China

2Department of Physics, The Hong Kong University of Science and Technology, Hong Kong, China

3College for Advanced Interdisciplinary Studies, National University of Defense Technology, Hunan, China

4City University of Hong Kong Shenzhen Research Institute, Guangdong, China

Abstract

We investigate the real-space polarization singularities (PSs) emerged in the optical near fields of meta-atoms under external excitations. These singularities carry intrinsic topological properties characterized by integer/half-integer topological indices. We discover a subtle relationship between the topological properties of the PSs and the topology associated with the geometry of meta-atoms. For meta-atoms made of metal and having smooth surfaces, the genus (number of “holes”) of their geometry decides the total topological index of the PSs born on the surface. Varying the meta-atoms’ geometry will not change the global topological properties of the PSs. In addition, we find that the integration of topology and spatial symmetries (mirror symmetry or rotational symmetry) can give rise to higher-order PSs with nontrivial polarization Möbius strips. We apply the near-field PSs to achieve chiral discrimination and optical manipulations of small particles. The results can find further applications in chiral sensing, chiral quantum optics, and beyond photonics in other wave systems.

References:
[1] J. Peng, R.-Y. Zhang, S. Jia, W. Liu, S. Wang, "Topological near fields generated by topological structures", Science Advances 8, eabq0910 (2022).
[2] J. Peng, S. Jia, C. Zhang, and S. Wang, "Optical force and torque on small particles induced by polarization singularities", Optics Express 30, 16489 (2022).
[3] S. Jia, J. Peng, Y. Cheng, and S. Wang, "Chiral discrimination by polarization singularities of a metal sphere", Physical Review A, 105, 033513 (2022).
[4] J. Peng, W. Liu, and S. Wang, "Polarization singularities in light scattering by small particles", Physical Review A 103, 023520 (2021).

Mu Ku CHEN

E-mail: mkchen@cityu.edu.hk

Dr. 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.

Meta-devices for Optical Imaging and Depth Sensing

Mu Ku Chen[1,2,3,*], Xiaoyuan Liu[1], Jing-Cheng Zhang[1], Jin Yao[1], Yubin Fan[1], Yao Liang[1], and Din Ping Tsai[1,2,3]

[1]Department of Electrical Engineering, City University of Hong Kong, Kowloon, Hong Kong SAR, China
[2]Centre for Biosystems, Neuroscience, and Nanotechnology, City University of Hong Kong, Kowloon, Hong Kong SAR, China
[3]The State Key Laboratory of Terahertz and Millimeter Waves, City University of Hong Kong, Kowloon, Hong Kong SAR, China

Abstract

Meta-lens is an emerging optical device which composed of artificial nanostructures can freely manipulate the phase and amplitude of light. Meta-lenses show excellent performance and novel applications to meet the optical demands. The fascinating advantages of meta-lenses 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. We demonstrate an intelligent depth-sensing system prototype applicable for diverse scenes, a switchable stereo vision system that adopts a 60 $\times$ 60 achromatic meta-lens array to measure depth over a 30-cm range with the support of deep learning. This system combines a light field camera and a structured light system to adapt to all light levels. The design, application, and experimental verification of the intelligent depth-sensing meta-device are reported in this talk [1-5].

References:
[1] M. K. Chen, X. Liu, Y. Sun, and D. P. Tsai, Artificial Intelligence in Meta-optics. Chemical Reviews, (2022).
[2] M. K. Chen, X. Liu, Y. Wu, J. Zhang, J. Yuan, Z. Zhang, and D. P. Tsai, A Meta-Device for Intelligent Depth Perception. Advanced Materials n/a, n/a, 2107465, (2022).
[3] M. K. Chen, Y. Yan, X. Liu, Y. Wu, J. Zhang, J. Yuan, Z. Zhang, and D. P. Tsai, Edge detection with meta-lens: from one dimension to three dimensions. Nanophotonics 10, 14, 3709, (2021).
[4] R. J. Lin, V.-C. Su, S. Wang, M. K. Chen, T. L. Chung, Y. H. Chen, H. Y. Kuo, J.-W. Chen, J. Chen, and Y.-T. Huang, Achromatic metalens array for full-colour light-field imaging. Nature nanotechnology 14, 3, 227, (2019).
[5] M. K. Chen, C. H. Chu, X. Liu, J. Zhang, L. Sun, J. Yao, Y. Fan, Y. Liang, T. Yamaguchi, and T. Tanaka, Meta-Lens in the Sky. IEEE Access 10, 46552, (2022).

Oral Presentations' Abstracts

3D Varifocal Meta-lens for 6G Applications

Jing Cheng ZHANG[1,2], Geng-Bo WU[1,2], Mu Ku CHEN[1,2], Chi Hou CHAN[1,2], and Din Ping TSAI[1,2]

1 Department of Electrical Engineering, City University of Hong Kong, Kowloon, Hong Kong SAR, China

2 The State Key Laboratory of Terahertz and Millimeter Waves, City University of Hong Kong, Kowloon, Hong Kong SAR, China

E-mail: jzhang2442-c@my.cityu.edu.hk

Abstract

Meta-lenses are highly potential for the future applications of the sixth-generation (6G) communication network [1,2]. Meta-lenses could help enhance the transfer directivity and the concentration strength of signal which are key points of the 6G generation technology. As traditional terahertz communication system usually has bulky and complex setups, especially the dielectric lenses and the reflectors. They are the elements to guide the terahertz waves into transmitters or focus the incident beams to the detector [3]. However, these elements lose the flexibility and can only guide the waves to a transmitter or a receiver in a fixed location or covering a limited area hindering the future development of the 6G applications [4].

Here we report a novel terahertz meta-lens to manipulate the focal spots with a fully tunable range. The different setups for the meta-lens guide the focal spot to various transmitters or detectors, providing a huge promotion for a flexible, high directivity, high signal concentration, and secure 6G communication system in the future. Besides the free regulation of the varifocal characteristics, the diffraction-free, self-healing, self-accelerating properties of Airy beams can also improve stability and security of the signal in future 6G communication systems. This meta-lens technology avoids the high costs related to numerous use of components like pin diodes and varactor diodes. It will benefit their large-scale deployments in the 6G communication systems, wireless power transfer, zoom imaging, and remote sensing.

References:
[1] S. Dang, O. Amin, B. Shihada, M.-S. Alouini, " What should 6g be?" Nature Electronics, 3, 20-29 (2020).
[2] S. Zhu; G.B. Wu, and S.W. Pang, and C.H. Chan "Compact terahertz dielectric folded metasurface," Advanced Optical Materials, 3, 2101663 (2022).
[3] X.-Y. Peng, R. Jung, T. Toncian, O. Willi, J.-H. Teng, " Distortion of the intense terahertz signal measured by spectral-encoding technique," Applied Physics Letters, 94, 221107 (2009).
[4] H. J. Song and N. Lee, " Terahertz communications: Challenges in the next decade," IEEE Transactions on Terahertz Science and Technology, 12, 105-117 (2022).

An Intelligent Meta-device Resolving Magic Stairs

Xiaoyuan LIU[1], Mu Ku CHEN[1], Yubin FAN[1], Jin YAO[1], Yao LIANG[1], Jingcheng ZHANG[1] and Din Ping TSAI

[1]*Department of Electrical Engineering, City University of Hong Kong, Hong Kong, China*

E-mail: xliu499-c@my.cityu.edu.hk

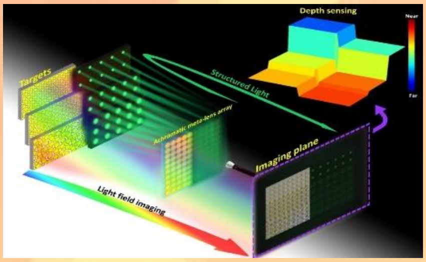


Fig. 1: The 60 by 60 achromatic meta-lens array for intelligent imaging and sensing.

Abstract

Meta-lens is an emerging optical device developed in recent years. Meta-lenses composed of artificial nanostructures can freely manipulate the phase and amplitude of light. Successful applications of optical meta-devices have been demonstrated in imaging [1, 2] and light-field sensing [4]. The meta-lens array can collect three-dimensional (3D) light field information. Placed in front of the laser, the metalens array can project a uniformly arranged array of structured light. We develop a depth-sensing and imaging system that integrates light-field imaging and actively structured light by using an achromatic meta-lens array optical device. Fig. 1 is the schematic of our intelligent imaging and depth-sensing system based on the meta-lens array. The meta-lens array is used in two ways, one acts as a core imaging optical component of the light-field imaging system, and another is to generate structured light.

Magic stairs (impossible stairs) is a stair loop in which we can always find a higher stair. It is a kind of geometric paradox caused by limited and specific light field information. For this demand, we developed the meta-lens array for intelligent imaging and sensing. A 60 $\times$ 60 broadband achromatic optical meta-lens array is designed and fabricated for working in the whole visible range. We developed two sets of convolutional neural networks for light field imaging and structured light data processing. This work provides a meta-device solution for optical illusions like magic stairs and can be widely applied to applications demanding depth information such as three-dimensional (3D) reconstruction, face recognition, and autonomous driving.

References:

[1] S. M. Wang, P. C. Wu, V. C. Su, et al., "A broadband achromatic metalens in the visible," Nature Nanotechnology, 13, 227-232 (2018).

[2] R. J. Lin, V. C. Su, S. M. Wang, M. K. Chen, et al., "Achromatic metalens array for full-colour light-field imaging," Nature Nanotechnology, 14, 227-231 (2019).

[3] M. K. Chen, Y. Yan, X. Liu, et al., "Edge detection with meta-lens: from one dimension to three dimensions," Nanophotonics, 10, 3709-3715 (2021).

Manipulating Near-field Directionality by Anisotropic Chirality

Yuqiong Cheng[1], Kayode Adedotun Oyesina[2], Bo Xue[2], Dangyuan Lei[3], Alex M. H. Wong[2,4], and Shubo Wang[1,5]

1 Department of Physics, City University of Hong Kong, Hong Kong, China
2 Department of Electrical Engineering, City University of Hong Kong, Hong Kong, China
3 Department of Materials Science and Engineering, City University of Hong Kong, Hong Kong, China
4 State Key Laboratory of Terahertz and Millimeter Waves, City University of Hong Kong, Hong Kong, China
5 City University of Hong Kong Shenzhen Research Institute, Guangdong, China

E-mail: yqcheng3-c@my.cityu.edu.hk

Abstract

We theoretically and experimentally demonstrate the flexible manipulation of near-field directionality by the synergy of chirality and anisotropy. A simple helix particle can be applied to construct a complete directionality space, achieving all types of directional dipoles via different “faces” of the particle, which is attributed to the selective excitations of the resonance modes in the helix. We employ it to realize the face-multiplexed unidirectional excitation of guided waves in orthogonal directions, with the directionality determined by the spin, the power flow, and the reactive power, respectively. This unified realization and control of the near-field directionality greatly increases the degrees of freedom for light routing, which can be applied to construct high-dimensional and multifunctional directional sources. The results can find promising applications in photonic integrated circuits, quantum information processing, and subwavelength-resolution imaging.

Imaging With an Ultra-thin Reciprocal Lens

Wenzhe LIU[1], Jingguang CHEN[2], Tongyu LI[2], Zhe ZHANG[2], Fang GUAN[2], Lei SHI[2], Jian ZI[2], and C. T. CHAN[1]

1 Department of Physics, The Hong Kong University of Science and Technology

2 State Key Laboratory of Surface Physics, Key Laboratory of Micro- and Nano-Photonic Structures (Ministry of Education), and Department of Physics, Fudan University

E-mail: wliubh@connect.ust.hk

Abstract

Lenses are very important for their uses in everyday life and various fields of modern technology. Conventional and modern metamaterial-based lenses all function based on a “ray-bending” mechanism: rays emitted from an object are bent differently at different positions of the lens to produce an image. The “ray-bending” mechanism brings some fundamental limitations to the imaging process.

Here, we discuss the limitations of conventional lenses and introduce another class of imaging elements that we call “reciprocal lenses” that mitigates such limitations. These lenses image by shifting rays with different incident angles. We design and realize an ultra-thin reciprocal lens based on a photonic crystal slab of which the thickness is only a tenth of the wavelength. The angle-dependent ray-shifting behavior of the reciprocal lens is characterized experimentally, and we directly demonstrate imaging by the realized reciprocal lens. Our work demonstrates a new mechanism for focusing and imaging and may inspire a new generation of optical elements based on beam-shifting.

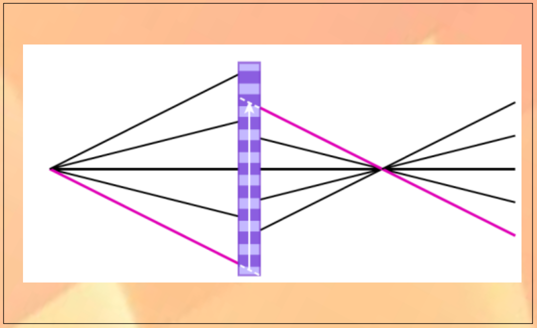


Fig. 1: Reciprocal lens: a beam-shifting-based imaging element.

Inhomogeneous Dirac Systems and Their Chiral Anomaly

Hongwei JIA[1], Mudi WANG[1] and C. T. CHAN[1]

1 Department of Physics and Institute for Advanced Study, The Hong Kong University of Science and Technology
E-mail: jiahongwei@ust.hk

Abstract

Chiral anomaly, which is characterized by the non-conservation of chiral current under chiral symmetry breaking, plays an important role in high energy physics. A typical way for realizing chiral anomaly is the chiral Landau levels, which is conventionally believed to arise when an axial magnetic field is applied to a three-dimensional system with Weyl degeneracies.

Here, we propose that the chiral Landau levels can also appear in two-dimensional systems with Dirac cones. By inhomogeneously engineering each unit cell structure of a photonic honeycomb lattice, the gap side at the K (or K') point in band structure depends linearly with respect space, meaning that an inhomogeneous effective mass is introduced to the system. As a result, an artificial in-plane magnetic is generated, which couples with the Dirac quasi-particles. Consequently, the energy levels are quantized, and the zeroth modes have unidirectional group velocity depending on the chirality of the Dirac degeneracy. The zeroth chiral Landau levels are experimentally characterized. Our work extends the chiral Landau levels from three-dimensional systems to two-dimensional system, which facilitates its realization, and is thus more promising for future applications.

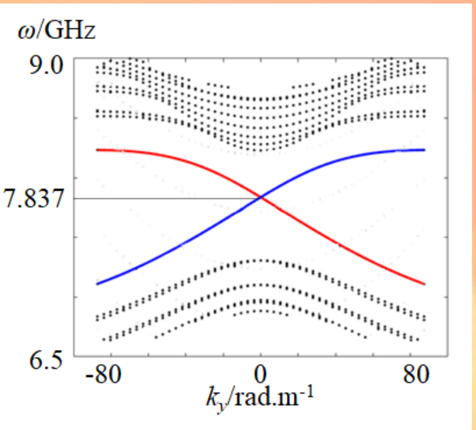


Fig. 1: Dispersion of chiral Landau levels.

Asymmetric Acoustic Transmission With Controllable Rectification via The Combination of Metasurface and Zero-index Metamaterials

Zhongming Gu[1,2], Xinsheng Fang[3], Tuo Liu[1,2], He Gao[1,2], Shanjun Liang[1,2], Yong Li[3], Bin Liang[4], Jianchun Cheng[4], Jie Zhu[1,2]

1 The Hong Kong Polytechnic University Shenzhen Research Institute, Shenzhen 518057, P.R. China.

2 Research Center for Fluid-Structure Interactions, Department of Mechanical Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong SAR, P.R. China.

3 Institute of Acoustics, Tongji University, Shanghai 200092, P.R. China.

4 Key Laboratory of Modern Acoustics, MOE, Institute of Acoustics, Department of Physics, Nanjing University, Nanjing 210093, P.R. China.

E-mail: zhmgu@tongji.edu.cn

Abstract

The asymmetric acoustic transmission can enrich the abilities of wave manipulation and provide more solutions in many areas of acoustic engineering. However, the tunable asymmetric transmission is still an obstacle since many previous approaches are based on the bulk materials or complex schemes. Here, we proposed a design to break this barrier that can realize the tunable asymmetric transmission via the combination of zero-index metamaterials and binary metasurface. The zero-index metamaterial can provide the effective extremely large speed to shrink the infinite domain into a spot acoustically and the binary metasurface can be used to tune the specific phase difference. Numerical simulations and experimental measurements have good agreements and show that the acoustic waves impinged from the side of metasurface will be manipulated to have controllable transmission while the acoustic waves impinged from the side of zero-index metamaterials will keep a high transmission. We think the proposed design is full of physical significance, which may find potential applications in many fields, like noise cancellation, acoustic imaging, and ultrasound therapy[1].

References:

[1] Zhong-ming Gu, Xinsheng Fang, Tuo Liu, He Gao, Shanjun Liang, Yong Li, Bin Liang, Jianchun Cheng and Jie Zhu. Tunable asymmetric acoustic transmission via zero-index metamaterials-based interference effect. Applied Physics Letter 118, 113501 (2021).

Ultrasound Focusing Enhancement Through The Stiff Plate Without Any Openings

He Gao[1], Zhongming Gu[1], Shanjun Liang[2], Tuo Liu[1], Jie Zhu[3] and Zhongqing Su[1]

[1] Department of Mechanical Engineering, The Hong Kong Polytechnic University, Kowloon, Hong Kong SAR, China
[2] Division of Science, Engineering and Health Studies, College of Professional and Continuing Education, Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong SAR, China
[3] Institute of Acoustics, School of Physics Science and Engineering, Tongji University, Shanghai 200092, PR China
E-mail: h.e.gao@connect.polyu.hk

Abstract

Conventional ultrasound focusing implementations in water generally rely on steering the transmitted ultrasound wave through the openings in the designed lenses, which are ineffective in many practical situations that contain dense layers. Here, we pro- posed an inversely designed metamaterial lens to enhance ultrasound focusing through a stiff plate without any openings. The inverse strategy based on genetic algorithm contributes to finding the suitable structure with only one-sided lumps, which can enhance the power transmission, and at the same time focus the transmitted power well. The optimized ultrasound focusing enhancement lens is experimentally demonstrated, consistent with the numerical predictions by considering acoustic-solid inter- action. Moreover, the designed lens has simple structures that can be fabricated easily with commonly used materials, which shows great application prospects in medical imaging and disease treatment[1].

References:
[1] H. Gao, Z. Gu, S. Liang, T. Liu, J. Zhu, and Z. Su, Enhancing ultrasound transmission and focusing through a stiff plate with inversely optimized auxiliary meta-lens, Appl. Phys. Lett. 120, 111701 (2022).

Heralding Vortex Beams Using A Quantum Metasurface

Hong Liang[1], Hammad Ahmed[2], Wing Yim Tam[1], Xianzhong Chen[2] and Jensen Li[1]

[1] Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China

[2] School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh EH144AS, UK

E-mail: x.chen@hw.ac.uk

Abstract

Recently, multifunctional metasurfaces have been extended into the quantum optical regime, giving rise to new opportunities for tailor-made manipulation of the photon quantum state. Here, based on a geometric-phase metasurface with spin-orbit interaction (SOI), we explore the remote control of the photon vortex structure with polarization-entangled photon pairs: heralding and signal photons. While the SOI from the metasurface translates to hybridization between orbital angular momentum and polarization degrees of freedom of the signal photon, the heralding technique reveals the entanglement of the heralding photon polarization with the vortex structure of the signal photon through an illustration of orbital rotation remotely controlled by the different polarization projections of the heralding photon. The experimental demonstration of the heralding scheme to control vortex structure further extends the applications of the quantum metasurfaces towards quantum communication. We also demonstrate an increase in signal-to-noise ratio in the vortex beam control compared to the classical approaches through the measured images of orbitals.

Time-varying OAM Beams from A Space-time-coding Digital Metasurface

Jingxin Zhang[1], Peixing Li[2], Ray C. C. Cheung[2], Alex M. H. Wong[2] and Jensen Li[1]

1 Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China

2 Department of Electrical Engineering, City University of Hong Kong, Hong Kong

E-mail: jensenli@ust.hk

Abstract

The orbital angular momentum (OAM) is the component of the angular momentum of electromagnetic waves, which is associated with a helical wavefront. The helical modes are characterized by their topological charges. The recent demonstration of extreme-ultraviolet beams with time-varying OAM realized by high harmonic generation has opened new opportunities for quantum excitation control and particle manipulation [1]. However, such an approach is not easily scalable to other frequency regimes and needs to be more flexible for exploring other time-varying OAM modes. Here, we design a space-time-coding digital metasurface operating in the microwave regime to experimentally generate different modes of time-varying OAM beams with a periodic modulation of the topological charge of the beam. With the flexibility of the metasurface's spatial and time-varying capability, we introduce a concept of superhelicity of time-varying OAM as a higher-order twist of the wavefront structure [2], which can be further realized by reflection phase profiles varying nonlinearly with time. These demonstrations become feasible by combining the programmability of the space-time-coding digital metasurface and the time-domain field pattern measurement enabled by a two-probe field mapping technique. Our investigations are potentially useful for OAM multiplexing communications and Floquet topological studies.

References:

[1] Rego, L. et al. Generation of extreme-ultraviolet beams with time-varying orbital angular momentum. Science 364, eaaw9486 (2019).

[2] J. Zhang, P. Li, A. H. H. Wong and J. Li Generation of superhelical time-varying OAM beam with space-time-coding digital metasurfaces. arXiv:2210.06941 (2022)

Quantum Exceptional Points of Metasurfaces

Wai Chun Wong, Hong Liang, Kai Ming Lau, Tsz Kit Yung, Bei Zeng and Jensen Li

Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China
E-mail: jensenli@ust.hk

Abstract

Modelling a multiport system in quantum optics involves a mathematical description of the input-output relationship on the photon density matrix. On the other hand, an open quantum system evolving in time is usually described by the Lindblad master equation. Understanding the recent non-Hermitian metasurfaces in terms of an open quantum system is necessary to exploit the meaning of quantum exceptional points. Here, we unify the two pictures by mapping the quantum optical scattering of a linear dissipative metasurface to an equivalent Liouvillian dynamics with respect to the effective Hamiltonian of the metasurface propagating in fictitious time.

Starting from the classical scattering matrix of a lossy metasurface, our formulation allows the modelling of the quantum optical scattering of the metasurface solely within the radiation mode subspace. It facilitates further numerical and analytic developments of quantum metasurfaces. First, we can monitor the flow of the input state from the photon density or moment matrix to the output density or moment matrix using a complete basis of the semi-classical Liouvillian superoperator for a linear bianisotropic lossy metasurface. The process can be applied to metasurfaces whether they capture exceptional points. Second, in terms of two-photon scattering, we show that an exceptional point of the scattering matrix of a lossy metasurface allows an effect of one-sided destructive quantum interference. When two identical photons enter both sides of the lossy metasurface with an exceptional point, quantum interference only occurs for the single-photon output state towards one side but not the other, as one-sided quantum interference, which can be further manipulated to be totally destructive.

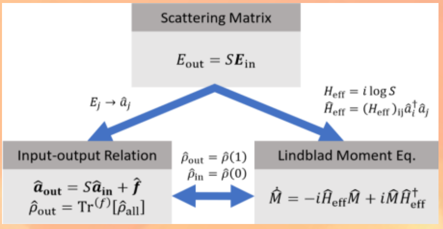


Fig. 1: The left route is the standard dilation approach with ancilla modes added to represent absorption channels. The right route is the mapped Lindblad moment equation propagating photon moment matrix from fictitious time $\tau = 0$ to 1.

[1] Wong, W.C. , Lau, K.M., Liang, H., Yung, T.K., Zeng, B. and Li, J., 2022. Quantum optics of lossy metasurfaces: Propagating the photon-moment matrix by the semiclassical Liouvillian. Physical Review A, 106(1), p.013503..

[2] Liang, H., et.al., 2021. One-sided destructive quantum interference from an exceptional-point-based metasurface. Physical Review A, 104(6), p.063710.

Observation of Non-abelian Thouless Pump in An Acoustic System

Oubo You, Shanjun Liang, Biye Xie, Wenlong Gao, Weimin Ye, Jie Zhu, and Shuang Zhang

Department of Physics, The University of Hong Kong, Pokfulam, Hong Kong

Abstract

Berry phase has attracted tremendous attention due to its geometric nature in math. It underlies many interesting phenomena, such as polarization, quantun Hall effect and quantum charge pumping. Different from the Abelian counterpart, the non-Abelian Berry phase shows more interesting properties due to the band transition, i.e. its matrix form. Most experimental works have focused on the non-Abelian Gauge field to achieve non-Abelian Berry phase, and the evolution loop is deliberately designed to avoid the singularities in the band structure of the system. On the contrary, in this talk, we will introduce a new way to achieve non-Abelian Berry phase by changing the angles of evolution loops across the singularities. As an example, we achieved non-Abelian Thouless pump between three different bands in acoustic waveguide system, and the singularities in our system is achieved by blocking the coupling between different p modes in rectangular subwaveguides.

Wireless Power Transfer Inside Zero Index Media

Qingdong Yang and Shuang Zhang

Department of Physics, The University of Hong Kong, Pokfulam, Hong Kong

Abstract

Efficient power distribution to multiple receivers with controlled amount is of paramount significance for wireless communication systems. Many efforts have been made to improve the power transfer efficiency via strong coupling and PT symmetry, which provides attractive opportunities for flexible control of the flow of energy. By utilizing unique properties of epsilon near-zero index (ENZ) materials, we theoretically propose and numerically demonstrate a new method to realize arbitrary power distribution. In epsilon near-zero media, the power from single source can be transferred to multiple receivers with negligible loss, by modification of optical properties of receivers instead of the introduction of sophisticated control modules. In this talk, I will introduce the application of (ENZ) materials in the power transfer, and discuss a realizable system to confirms the high efficiency of energy transfer. This work proposes a unique doping approach for advanced perfect power transfer with versatile control functionalities.