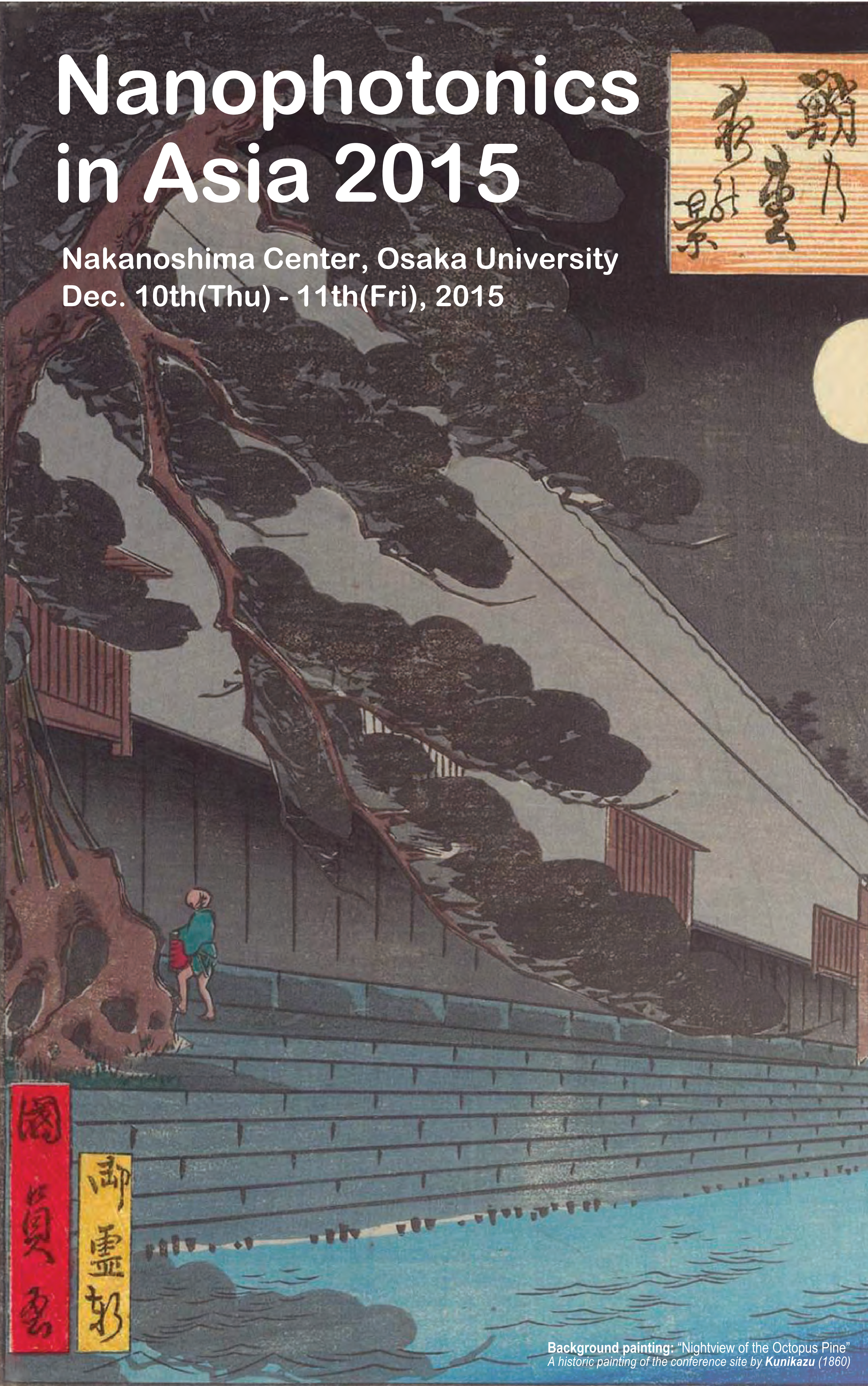
Nanophotonics in Asia 2015

Nakanoshima Center, Osaka University

Dec. 10th(Thu) - 11th(Fri), 2015



Background painting: "Nightview of the Octopus Pine"
*A historic painting of the conference site by **Kunikazu** (1860)*

photonics CENTER

OSAKA UNIVERSITY

cdpt

INTERNATIONAL YEAR OF LIGHT 2015

Nanophotonics in Asia 2015

Nakanoshima Center, Osaka University
Dec. 10 (Thu) – 11 (Fri), 2015

Organizer:
Photonics Center, Osaka University

Sponsoring organizations:

・JSPS, Asian CORE Program, Japan
・Osaka University, Japan
・MOST and NSFC, China
・Academia Sinica and MOST, Taiwan
・Nanyang Technological University, Singapore

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Committee

Co- Chairs:

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Distinguished Professor, Photonics Center, Osaka University, Japan

Prof. Prabhat Verma

Vice-Chair, Asian Core Program, Photonics Center, Japan

Professor, Department of Applied Physics, Osaka University, Japan

Prof. Xuan-Ming Duan

Professor, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, China

Prof. Din Ping Tsai

Director and Distinguished Research Fellow, Research Center for Applied Sciences, Academia Sinica, Taiwan

Distinguished Professor, Department of Physics, National Taiwan University, Taiwan

Prof. Nikolay Zheludev

Director, Centre for Disruptive Photonic Technologies, Nanyang Technological University

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Lecturer, Photonics Center, Osaka University, Japan

Dr. Kyoko Masui

Research Staff, Photonics Center, Osaka University, Japan

General Information

Registration

The registration desk will be open from 08:30 to 09:00 on Dec. 10.

Lunch & Coffee (incl. tea & juice)

Lunch will be served to all participants.

Coffee, tea and juice will be served during Coffee Break in Room #703 on Floor 7. For the last Coffee Break (16:15 ~16:30, Dec. 11), the location will be changed to Floor 10.

Internet Service

SSID:	AsiaCORE
PW:	nanophotonics

Presentation Guideline

Oral Presentation

The presentation time will be 25 minutes followed by a 5 minutes Q & A.
Please check your presentation by hooking up your laptop to the projector before your session.

Poster Session

12:45 to 14:45 (during Lunch time) on Dec. 10, in Room #703 on Floor 7
- Please put your posters during 10:40 to 11:00 on Dec. 10 (Coffee Break).
- Please take off your posters before 15:00 on Dec. 11.

Map of the Venue

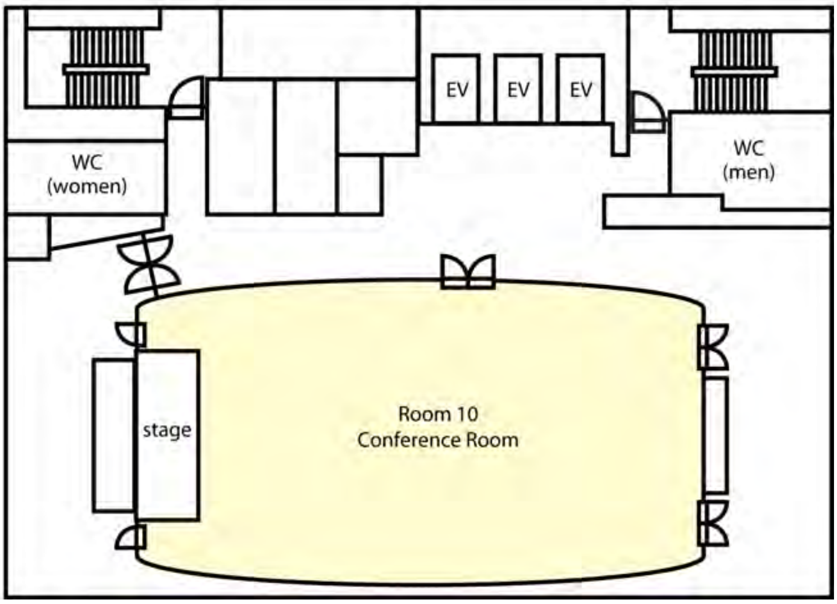
The conference will be held at the Nakanoshima Center, Osaka University in Osaka, JAPAN.
Address: 4-3-53 Nakanoshima, Kita-ku, Osaka city TEL: +81- 6 - 6444 - 2100

Opening/ Closing Session:	Floor 10
Presentation session:	Floor 10
Poster Session:	Floor 7, Room #703

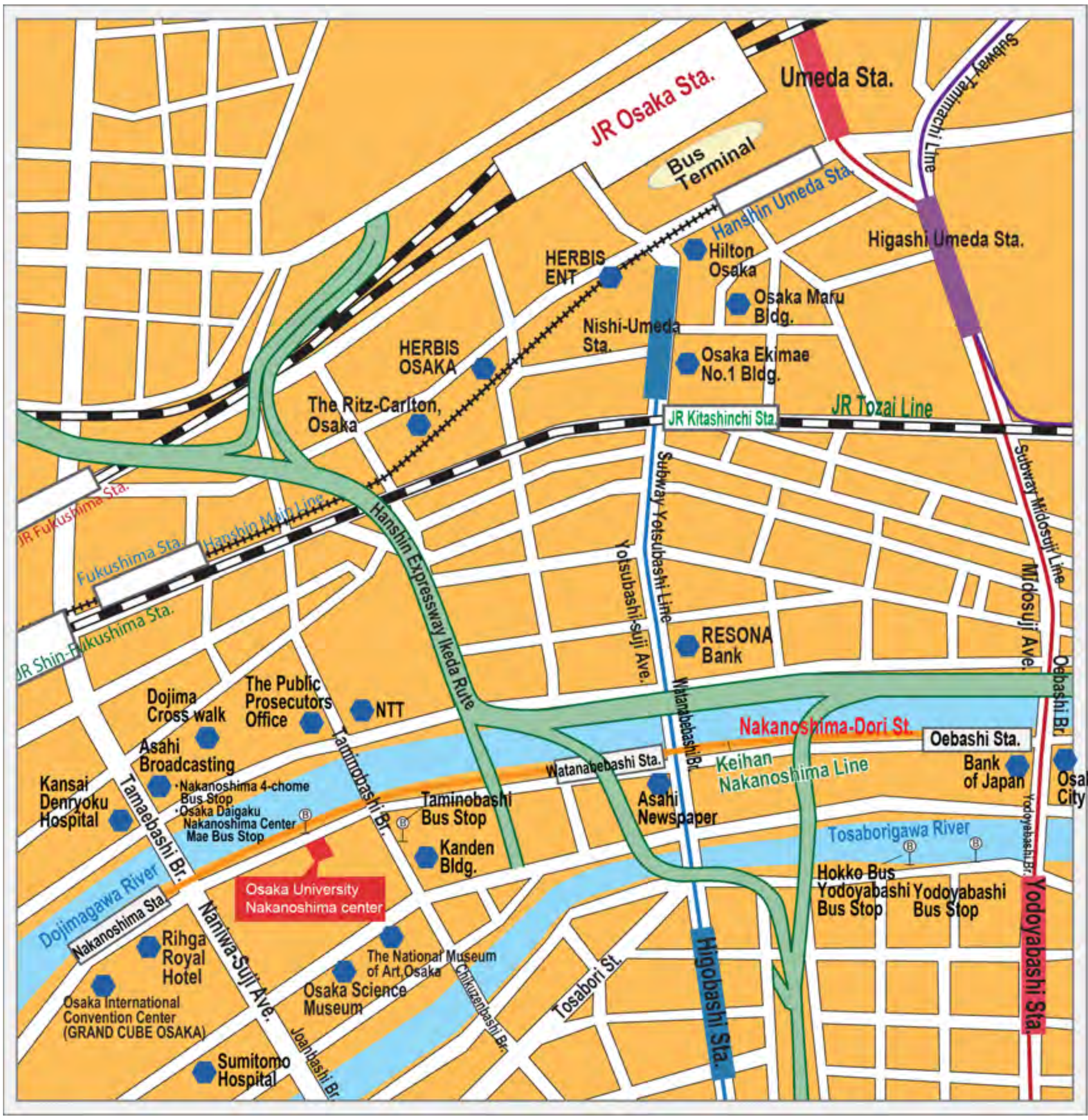
Floor map

Floor 7

Floor 10



Location Map



Nakanoshima Center, Osaka University

4-3-53 Nakanoshima, Kita-ku, Osaka City, Osaka, Japan

Nearby Train Stations:

JR Fukushima station (JR loop line), about 12 min on foot

JR Shin Fukushima station (JR Tozai line), about 8 min on foot

Fukushima station (Hanshin train), about 9 min on foot

Nakanoshima station (Keihan Nakanoshima line), about 5 min on foot

Higobashi station (Subway Yotsubashi line), about 10 min on foot

Program

【DAY 1】 Thursday, December 10, 2015

Time	Speakers	Titles	Affiliation	Page
09: 00 ~ 09: 10	Opening Remark (Chair : Satoshi Kawata) by Executive Vice President Toshiya Hoshino (Osaka Univ.)			
	Session 1 (Chair : Prabhat Verma)			
09: 10 ~ 09: 40	Satoshi Kawata	Welcome Remarks and Introduction	Osaka Univ.	
09: 40 ~ 10: 10	Nikolay Zheludev	Intriguing Properties of Localized and Propagating Toroidal Excitations	NTU, Singapore	1
10: 10 ~ 10: 40	Din Ping Tsai	Light Manipulation and Sensing Using Vertical Split-ring Resonators (VSRR)	Academia Sinica	2
10: 40 ~ 11: 00	Coffee Break			
	Session 2 (Chair : Din Ping Tsai)			
11: 00 ~ 11: 30	Xing Zhu	Plasmonic Circular Polarization Analyzer Formed by Unidirectionally Controlling Surface Plasmon Propagation	Peking Univ.	3
11: 30 ~ 12: 00	Keisuke Goda	Extreme Imaging and Beyond	Univ. of Tokyo	4
12: 00 ~ 12: 15	Photo Session			
12: 15 ~ 14: 45	Lunch & Poster Session (@ Room #703)			
	Session 3 (Chair : Xing Zhu)			
14: 45 ~ 15: 15	Yusuke Mori	Functional Crystals for and by Photonics	Osaka Univ.	5
15: 15 ~ 15: 45	Jing Hua Teng	Aperiodic Nanostructures for Wavefront Manipulation	A-STAR	6
15: 45 ~ 16: 15	Xiangang Luo	Catenary Optics for Nano-structured Optical Devices	CAS	7
16: 15 ~ 16: 30	Coffee Break			
	Session 4 (Chair : Jing Hua Teng)			
16: 30 ~ 17: 00	Toshio Yanagida	Single Molecule Nano-science: Noise and Function of Life	Osaka Univ. / RIKEN	8
17: 00 ~ 17: 30	Nicholas Smith	Label-free Raman and Phase Imaging for Diagnosis of Disease	Osaka Univ.	9
17: 30 ~ 18: 15	Break / Committee Meeting (Floor 9)			
18: 30 ~ 20: 30	Banquet Opening Speech by Toshihiro Tanaka			

【DAY 2】 Friday, December 11, 2015

Time	Speakers	Titles	Chair	Page
	Session 5 (Chair : Gong-Ru Lin)			
08: 30 ~ 09: 00	Takashige Omatsu	Optical Vortices 'Twist' Materials to Form Chiral Nanostructures	Chiba Univ.	10
09: 00 ~ 09: 30	Jian Zi	Coloration of Amorphous Photonic Crystals	Fudan Univ.	11
09: 30 ~ 10: 00	Ta-Jen Yen	Enhanced Vibrational Spectroscopic, Intracellular Refractive Indexing for Label-free Biosensing and Bioimaging by Multi-band Plasmonic-Antenna Array	National Tsing Hua Univ.	12
10: 00 ~ 10: 20	Coffee Break			
	Session 6 (Chair : Cesare Soci)			
10: 20 ~ 10: 50	Zexiang Shen	Inter-layer Coupling in 2D Materials	NTU, Singapore	13
10: 50 ~ 11: 20	Zheyu Fang	Plasmonic Hot Electrons Doping of 2D Materials	Peking Univ.	14
11: 20 ~ 11: 50	Xinzheng Zhang	Different Coupling Effects in Graphene Plasmons	Nankai Univ.	15
11: 50 ~ 13: 00	Lunch			
	Session 7 (Chair : Nicholas Smith)			
13: 00 ~ 13: 30	Qihuang Gong	Micro/Nano-scale Light Manipulation	Peking Univ.	16
13: 30 ~ 14: 00	Cesare Soci	Plasmonic Topological Insulators: an Emerging Platform for Broadband Tunable Metamaterials	NTU, Singapore	17
14: 00 ~ 14: 30	Jer-Shing Huang	Plasmonic Doppler Grating as Azimuthal Angle-dependent Platform for Index Sensing and Color Sorting	National Tsing Hua Univ.	18
14: 30 ~ 14: 50	Coffee Break			
	Session 8 (Chair : Zheyu Fang)			
14: 50 ~ 15: 20	Yidong Chong	Anomalous Phases in Topological Photonics	NTU, Singapore	19
15: 20 ~ 15: 50	Chen-Bin (Robin) Huang	Surface Plasmon Vortex: Its Creation, Shaping, and Application in Particle Manipulations	National Tsing Hua Univ.	20
15: 50 ~ 16: 20	Masanori Ozaki	3D Helix Structure based on Chiral Liquid Crystal for Photonics	Osaka Univ.	21
16: 20 ~ 16: 40	Coffee Break			
	Session 9 (Chair : Yidong Chong)			
16: 40 ~ 17: 10	Gong-Ru Lin	All-Optical Data Processing in SiN_x:Si-QD Ring Waveguide Modulator Based on Free Carrier Absorption or Nonlinear Kerr Switching	NTU, Taiwan	22
17: 10 ~ 17: 40	Weibo Gao	Coherent Manipulation, Measurement and Entanglement of Quantum Dot Spins Using Optical Fields	NTU, Singapore	23
17: 40 ~	Poster Award & Closing Remarks (By Nikolay Zheludev and Din Ping Tsai)			

Invited Talks

I-1 Intriguing properties of localized and propagating toroidal excitations

Nikolay I. Zheludev[1] & Din Ping Tsai[2]

[1] Univ. of Southampton, UK & Nanyang Technological Univ., Singapore / [2] Academia Sinica & National Taiwan Univ., Taiwan

I-2 Light manipulation and sensing using vertical split-ring resonators (VSRR)

Din Ping Tsai[1,5], Pin Chieh Wu[1], Wei-Lun Hsu[1], Wei Ting Chen[1], Chun Yen Liao[1], Pei Ru Wu[1], Jia-Wern Chen[1], Ting-Yu Chen[1], Yi-Hao Chen[1], Wei-Yi Tsai[1], Mu-Ku Chen[1], Ai Qun Liu[2], Nikolay I. Zheludev[3] & Greg Sun[4]

[1] National Taiwan Univ., Taiwan / [2] Nanyang Technological Univ., Singapore, Singapore / [3] Univ. of Southampton, UK / [4] Univ. of Massachusetts Boston, U.S.A. / [5] Academia Sinica, Taiwan

I-3 Plasmonic circular polarization analyzer formed by unidirectionally controlling surface plasmon propagation

Xing ZHU[1, 2] , Tao Huang[1], Jiaming Li[1], Jie Li[1], Feng Lin & Zhueyu FANG[1]

[1] Peking Univ. / [2] National Center for Nanoscience and Technology, China

I-4 Extreme imaging and beyond

Keisuke GODA

Univ. of Tokyo, Japan / Univ. of California, U.S.A. / Japan Science and Technology Agency, Japan

I-5 Functional Crystals for and by Photonics

Yusuke MORI

Osaka Univ., Japan

I-6 Aperiodic nanostructures for wavefront manipulation

Jinghua Teng[1*], Hong Liu[1], Kun Huang[1,2], Yanjun Liu[1], Muhammad Q. Mehmood[2] & Cheng-Wei Qiu[2]

*[1] A*STAR / [2] National Univ. of Singapore, Singapore*

I-7 Catenary Optics for Nano-structured Optical Devices

Xiangang Luo

Institute of Optics and Electronics, Chinese Academy of Science, China

I-8 Single Molecule Nano-Science: Noise and Function of Life

Toshio Yanagida

Riken Quantitative Biology Center (QBiC) / NICT Center for Information and Neuronal Networks (CiNet) / Osaka Univ., Japan

I-9 Label-free Raman and phase imaging for diagnosis of disease

Nicholas SMITH

Osaka Univ., Japan

I-10 Optical vortices 'twist' materials to form chiral nanostructures

Takashige OMATSU

Chiba Univ., Japan

I-11 Coloration of amorphous photonic crystals

Jian Zi, Yafeng Zhang, Biqin Dong, Haiwei Yin, Lei Shi, Xiaohan Liu & Eli Yabolonovitch

Fudan Univ., China

I-12 Enhanced Vibrational Spectroscopic, Intracellular Refractive Indexing for Label-free Biosensing and Bioimaging by Multi-band Plasmonic-antenna Array

Cheng-Kuang Chen[1], Hsin-Cheng Lee[1], How-Foo Chen[2] & Ta-Jen Yen[1]

[1] National Tsing Hua Univ. / [2] National Yang Ming Univ., Taiwan

I-13 Inter-layer coupling in 2D materials

Ze Xiang Shen[1,2,3], Jiaxu Yan[1], Juan Xia[1], & Zheng Liu[3]

[1] Disruptive Photonic Technologies, Nanyang Technological Univ. / [2] Division of Physics and Applied Physics, Nanyang Technological Univ. / [3] School of Materials Science and Engineering, Nanyang Technological Univ. , Singapore

I-14 Plasmonic hot electrons doping of 2D Materials

Zheyu Fang

Peking Univ., China

I-15 Different Coupling effects in Graphene Plasmons

Wei CAI[1], Lei WANG[2], Xinzheng ZHANG[1], Weiwei LUO[1], Zenghong MA[1] & Jingjun XU[1]

[1] Nankai Univ., China / [2] Xinyang Normal Univ., China

I-16 Micro/Nano-Scale light Manipulation

Qihuang Gong, Jiangjun Chen, Hong Yang, & Xiaoyong Hu

Peking Univ., China

I-17 Plasmonic Topological Insulators: an Emerging Platform for Broadband Tunable Metamaterials

Cesare SOCI,[1] Giorgio ADAMO,[1] Jun-Yu OU,[2] Jin-Kyu SO,[2] Jun YIN,[1] Zilong WANG,[1] Stefano VEZZOLI,[1] Lan WANG,[3] & Nikolay ZHELUDEV[1,2]

[1] Nanyang Technological Univ., Singapore / [2] Univ. of Southampton, UK / RMIT Univ., Australia

I-18 Plasmonic Doppler Grating as Azimuthal Angle- dependent Platform for Index Sensing and Color Sorting

Fan-Cheng Lin, See-Kel Meng & Jer-Shing Huang

National Tsing Hua Univ., Taiwan

I-19 Anomalous Phases in Topological Photonics

Yidong CHONG[1,2], Wenchao HU[1], Daniel LEYKAM[2], Michael PASEK[2], Jason PILLAY[2] & Hailong WANG[2]

[1]Centre for Disruptive Photonic Technologies, Nanyang Technological Univ. / [2]School of Physical and Mathematical Sciences, Nanyang Technological Univ., Singapore

I-20 Surface plasmon vortex: its creation, shaping, and application in particle manipulations

Wei-Yi Tsai[1,2], Chen-Ta Ku[1,2], Ching-Fu Chen[1,2], Chung-Ying Lin[1] & Chen-Bin Huang[1]

[1] National Tsing Hua Univ., [2] Academia Sinica, Taiwan

I-21 3D Helix Structure based on Chiral Liquid Crystal for Photonics

Masanori OZAKI, Konkanok ANUCHA, Yuto KAWATA, Shu TANAKA & Hiroyuki YOSHIDA

Osaka University, Japan

I-22 All-optical data processing in SiN_x:Si-QD ring waveguide modulator based on free carrier absorption or nonlinear Kerr switching

Chung-Lun Wu, Yung-Hsiang Lin, Sheng-Pin Su, Bo-Ji Huang, Cheng-Ting Tsai, Huai-Yung Wang, Yu-Chieh Chi, Chih-I Wu & Gong-Ru Lin

National Taiwan Univ., Taiwan

I-23 Coherent manipulation, measurement and entanglement of quantum dot spins using optical fields

Weibo Gao

Nanyang Technological Univ., Singapore

Posters

P-1 Metal-insulator-metal plasmonic sensor for high sensing sensitivity

Siham Refki[1,2,3,4], Shinji Hayashi[1,5], Zouheir Sekkat[1,2,4], Hidekazu Ishitobi[3,4] & Yasushi Inouye[3,4]

[1] Moroccan Foundation for Advanced Science Innovations and Research (MAScIR), Morocco / [2] Faculty of Sciences, Univ. Mohammed V, Morocco / [3] Graduate School of Frontier Biosciences, Osaka Univ., Japan / [4]Graduate School of Engineering, Osaka Univ. / [5]Graduate School of Engineering, Kobe Univ., Japan

P-2 Polymer-stabilized fluorescent platinum nanoclusters

Xin Huang[1], Kasuki Tsutsukawa[1], Hidekazu Ishitobi,[1, 2] & Yasushi Inouye[1, 2, 3]

[1] Graduate School of Frontier Biosciences, Osaka Univ. / [2] Department of Applied Physics, Osaka Univ. / [3] Photonics Advanced Research Center, Osaka Univ., Japan

P-3 Helical metasurface based optical devices

Shengtao Mei[1, 2] & Jinghua Teng[1]

[1] Agency for Science Technology and Research / [2] National Univ. of Singapore, Singapore

P-4 Optical Tunable Graphene Plasmonic Terahertz Modulator

H. W. Hou[1,2], Z. H. Liu[1], S. J. Chua [1, 2] & J. H. Teng[3]

[1] Singapore-MIT Alliance for Research and Technology Center / [2] National Univ. of Singapore / [3] Agency for Science, Technology and Research, Singapore

P-5 Helicity Light Analysis Based on Meta-detector

Pei Ru Wu[1], Wei-Yi Tsai[1], Wei Ting Chen[1], Chun Yen Liao[1], Greg Sun[2], Peter Török[3] & Din Ping Tsai[1,4]

[1] National Taiwan Univ., Taiwan / [2] Univ. of Massachusetts Boston, USA / [3] Imperial College London, UK / [4] Academia Sinica, Taiwan

P-6 Plasmonic Sensor Using VSRR Structure

Jia-Wern Chen[1] , Pin Chieh Wu[1], Greg Sun[2], Wei Ting Chen[1], Yao-Wei Huang[1], Hsiang Lin Huang[3], Hai Pang Chiang[3,4,5] & Din Ping Tsai[1,4]

[1] National Taiwan Univ., Taiwan / [2] Univ. of Mas-sachusetts Boston, USA / [3] National Taiwan Ocean Univ., Taiwan / [4] Academia Sinica, Taiwan

P-7 Colorful Meta-hologram based on Aluminum

Wei-Yi Tsai[1], Yi-Hao Chen[1], Yao-Wei Huang[1], Wei Ting Chen[1], Pin Chieh Wu[1], Chih-Ming Wang[2], Greg Sun[3] & Din Ping Tsai[1,4]

[1]National Taiwan Univ., Taiwan / [2] National Dong Hwa Univ., Taiwan / [3] Univ. of Massachusetts Boston, USA / [4] Academia Sinica, Taiwan

P-8 Selective imaging by high efficiency meta-hologram

Yi-Hao Chen[1], Wei-Yi Tsai[1], Wei Ting Chen[1], Kuang-Yu Yang[2], Chih-Ming Wang[3], Yao-Wei Huang[1], Greg Sun[4], Shulin Sun[5], Lei Zhou[6], Ai Qun Liu[7] & Din Ping Tsai[1,2]

[1] National Taiwan Univ., Taiwan / [2] Academia Sinica, Taiwan / [3] National Dong Hwa Univ., Taiwan / [4] Univ. of Massachusetts Boston, USA / [5] Department of Optical Science and Engineering, Fudan Univ., China / [6] State Key Laboratory of Surface Physics and Key Laboratory of Micro and Nano Photonic Structures, Fudan Univ., China / [7] Nanyang Technological Univ., Singapore

P-9 Unidirectional propagation of surface plasmons through spin-orbit coupling

Wei Liu & Feng Lin

Peking Univ., China

P-10 Nanomechanics of polymer nanocoil springs

Shota Ushiba[1], Kyoko Masui[1], Natsuo Taguchi[1], Satoru Shoji[2] & Satoshi Kawata[1]

[1] Department of Applied Physics, Osaka Univ. / [2] Department of Engineering Science, The Univ. of Electro-Communications, Japan

P-11 Transfer matrix method for optical calculations of multilayered topological insulators

Ang Chen[1], Lixin Ge[1], Yunyun Dai[1], Lei Shi[1], Xiaohan Liu[1], Dezhuan Han[2] & Jian Zi[1]

[1] Fudan Univ. / [2] Chongqing Univ., China

P-12 Symmetry-breaking induced excitations of anti-symmetric modes in graphene nanoribbons

Yunyun Dai[1], Ang Chen[1], Yuyu Xia[1], Dezhuan Han[2], Xiaohan Liu[1], Lei Shi[1] & Jian Zi[1]

[1] Fudan Univ. / [2] Chongqing Univ., China

P-13 Coherent fluorescence emission by using a 2D photonic–plasmonic crystal slab structure

Lei Shi, Xiaohan Liu & Jian Zi

Fudan Univ., China

P-14 Realization of maximum optical absorption cross section via active gain medium

Jie Wang, Xiaohan Liu, Lei Shi & Jian Zi

Fudan Univ., China

P-15 Watching dying retinal ganglion cells induced by high concentration of glutamate by using Raman microscopy

Takeshi Morimoto[1], Liang-da Chiu[2], Katsumasa Fujita[2], Hiroyuki Kanda[1] & Takashi Fujikado[1]

[1] Graduate School of Medicine, Osaka Univ. / [2] Graduate School of Engineering, Osaka Univ., Japan

P-16 Controlling of Graphene Plasmons in Mid-infrared Regime

Lei WANG[1,2], Xinzheng ZHANG[2], Wei CAI, Zenghong MA[2], Weiwei LUO[2] & Jingjun XU[2]

[1] Xinyang Normal Univ. / [2] Nankai Univ., China

P-17 Tunable Photonic Response of Lead Iodide Perovskites metamaterials

Behrad GHOLIPOUR,[1,2] Giorgio ADAMO,[1,2] Daniele CORTECCHIA,[1,3] Harish Krishnamoorthy,[1,2] Jun YIN[1,2], Annalisa BRUNO,[2,3] & Cesare SOCI,[1,2]

[1] Centre for Disruptive Photonic Technologies, Nanyang Technological Univ. / [2] Division of Physics and Applied Physics, Nanyang Technological Univ. / [3] Energy Research Institute @ NTU, Singapore

P-18 Electronic and Optical Properties of Topological Insulators for Plasmonics and Metamaterials

Jun Yin[1,2], Giogio Adamo[2], Nikolay I. Zheludev[2,3] & Cesare Soci[1,2]

[1] Division of Physics and Applied Physics, Nanyang Technological Univ., Singapore / [2] Centre for Disruptive Photonic Technologies, Nanyang Technological Univ., Singapore / [3] Univ. of Southampton, UK

P-19 Development of a stimuli-responsive nanocarrier based on the core-shell assembly of a self-immolative polymer embedded in amphiphilic dendrons

Yuko KAMIKAWA,[2] Yuki SAKASHITA,[1] Shohei IKEDA[1] & Kazuya KIKUCHI[1,2]

[1] Graduate School of Engineering, Osaka Univ. / [2] IFReC, Osaka Univ., Japan

P-20 Toward achieving super-resolution in linear and nonlinear Raman microscopy

Almar F. Palonpon[1], Kozue Watanabe[1], Yasuo Yonemaru[1], Nicholas I. Smith[2], Liang-da Chiu[1], Shogo Kawano[1], Atsushi Kasai[3], Hitoshi Hashimoto[3], Satoshi Kawata[1] & Katsumasa Fujita[1]

[1]Department of Applied Physics, Osaka Univ. / [2]Immunology Frontier Research Center, Osaka Univ. / [3]Laboratory of Molecular Neuropharmacology, Osaka Univ., Japan

P-21 In Situ Generation of Active Ni Species within an Acidic Resin for H_2 Evolution under Visible-light Irradiation

Hiroki Kakudo,[1] Kohsuke Mori,[1,2] & Hiromi Yamashita[1,2]

[1] Division of Materials and Manufacturing Science, Osaka Univ. / [2] ESICB, Kyoto Univ., Japan

P-22 Wastewater Treatment By Plasmonic Enhanced Optical Disk Reactor

Mu Ku Chen[1], Wen Ting Hsieh[1], Yu Lim Chen[1], I Da Chiang[1], Cheng Hung Chu[2] & Din Ping Tsai[1,2]

[1] National Taiwan Univ. / [2] Academia Sinica, Taiwan

P-23 Multiple Polarization State Generator Based on Aluminum Metasurface

Ting-Yu Chen[1], Wei Ting Chen[1], Wei-Yi Tsai[1], Ching-Fu Chen[1], Yao-Wei Huang[1] & Din Ping Tsai[1,2]

[1] National Taiwan Univ. / [2] Academia Sinica, Taiwan

P-24 Controlling the fraction of luminescent sites in Eu-doped GaN by compressive strain

Tomohiro Inaba, Atsushi Koizumi & Yasufumi Fujiwara

Osaka Univ., Japan

P-25 Enhanced nonlinear refractive index and absorption of C-rich Si_xC_{1-x} saturable absorber for passively mode-locked fiber laser application

Chih-Hsien Cheng & Gong-Ru Lin

National Taiwan Univ., Taiwan

P-26 Numerical demonstration of reconfigurable metal-air -metal plasmonic slow light structures

Tianji LIU[1] & Junichi TAKAHARA[1, 2]

[1] Graduate School of Engineering, Osaka Univ. / [2] Photonics Advanced Research Center, Osaka Univ., Japan

P-27 Nano-electromechanically tunable plasmonic resonator

Akira Kaijima[1], Masashi Miyata[1], Yusuke Nagasaki[1] & Junichi Takahara[1, 2]

[1] Graduate School of Eng., Osaka Univ. / [2] Photonics Advanced Research Center, Osaka Univ., Japan

P-28 Plasmon-based CQED: From weak to strong coupling

Ying Gu, Hang Lian, Dongxing Zhao, Juanjuan Ren, Fan Zhang & Qihuang Gong

Peking Univ., China

P-29 Polarization-independent directional launchers of surface plasmon polaritons

Chengwei Sun[1,2], Jianjun Chen[1,2], Kexiu Rong[1,2], Hongyun Li[1] & Qihuang Gong[1,2]

[1] Peking Univ. / [2]Collaborative Innovation Center of Quantum Matter, China

P-30 On-chip Plasmon-Induced Transparency by a Single Composite Nanocavity side-coupled with Plasmonic Waveguide

Zhen Chai[1], Xiaoyong Hu[1,2], Hong Yang[1] & Qihuang Gong[1,2]

[1] Peking Univ. / [2] Collaborative Innovation Center of Quantum Matter, China

P-31 Control of Caesium Atomic Spectrum with a 2D Plasmono-Atomic Metamaterial

Eng Aik CHAN[1], Syed Abdullah ALJUNID[1], Giorgio ADAMO[1], Martial DUCLOY[1,2], David WILKOWSKI[1,3,4] & Nikolay ZHELUDEV[1,5]

[1] Nanyang Technological Univ., Singapore / [2] Université Paris, France / [3] National Univ. of Singapore, Singapore / [4] CNRS-UNS-NUS-NTU, Singapore / [5] Univ. of Southampton, UK

P-32 Localization and propagation of visible range plasmons in $Bi_{1.5}Sb_{0.5}Te_{1.8}Se_{1.2}$ topological insulator

Alexander M. DUBROVKIN[1], Giorgio ADAMO[1], Azat SULAEV[2], Qi Jie WANG[1,3], Lan WANG[4] & Nikolay I. ZHELUDEV[1,5]

[1] Centre for Disruptive Photonic Technologies, Nanyang Technological Univ., Singapore / [2] School of Physical and Mathematical Sciences, Nanyang Technological Univ., Singapore / [3] Centre for OptoElectronics and Biophotonics, Nanyang Technological Univ., Singapore / [4] RMIT Univ., Australia / [5] Univ. of Southampton, UK

P-33 Sub-diffraction Localization of a Single Photon

Guanghui YUAN[1], Stefano Vezzoli[1], Charles Altuzarra[1], Edward T. F. Rogers[2], Christophe Couteau[1], Cesare Soci[1] & Nikolay I. Zheludev[1,2]

[1] Nanyang Technological Univ., Singapore / [2] Univ. of Southampton, UK

P-34 Quantum Coherent Absorption of Plasmons With Entangled Photons

Charles ALTUZARRA[1,4], Stefano VEZZOLI[3], Joao VALENTE[2], Cesare SOCI[1], Daniele FACCIO[3], Christophe COUTEAU[1,4,5] & Nikolay I.ZHELUDEV[1,2]

[1] Nanyang Technological Univ., Singapore / [2] Univ. of Southampton, UK / [3] Heriot-Watt Univ., UK / [4] CINTRA CNRS-NTU-Thales, Singapore / [5] Univ. of Technology of Troyes, France

P-35 Study on effect of dielectric environment on grapheme plasmon properties

Xiangdong Guo[1,2]

[1] National Center for Nanoscience and technology / [2] Peking Univ., China

P-36 Plasmonic Optical Trapping by Elliptical Nanohole for Chiral Analysis Using Raman Optical Activity

Zi-Huan Huang, Fan-Cheng Lin & Jer-Shing Huang

National Tsing Hua Univ., Taiwan

P-37 Unidirectional Beaming of Photoluminescence from Gold Yagi-Uda Nanoantenna

Kel-Meng See, Tzu-Yu Chen, Fan-Cheng Lin & Jer-Shing Huang

National Tsing Hua Univ., Taiwan

P-38 Imaging method for nanomagnet with magnetic multi-layer with magnetic force microscopy

Ryouki Wakasa, Hikaru Nomura & Ryoichi Nakatani

Osaka Univ., JAPAN

P-39 Shift register based on magnetic quantum cellular automata

Naomichi YOSHIOKA, Hikaru NOMURA & Ryoichi NAKATANI

Osaka Univ., Japan

P-40 Tunable optical deflector based on a Fresnel-type liquid crystal device

Giichi SHIBUYA, Shohei YAMANO, Junji KOBASHI, Hiroyuki YOSHIDA & Masanori OZAKI

Osaka Univ., Japan

P-41 3D hydrogels with high resolution fabricated by two photon polymerization

Mei-Ling ZHENG[1], Jin-Feng XING[3], Xian-Zi DONG[1], Feng JIN[1] & Xuan-Ming DUAN[1,2]

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P-42 Nonreciprocal transmission effect in 30° wedged shape photonic crystals made by two photon polymerization

Xian-Zi Dong[1], Ling-Jing Chen[1],Mei-Ling Zheng[1], Zhen-Sheng Zhao[1] & Xuan-Ming Duan[1,2]

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P-43 The application of Inverse opals in lasing oscillation and chemical sensors

Feng JIN[1], Meiling ZHENG[1], Xianzi DONG[1], Zhensheng ZHAO[1] & Xuanming DUAN[1,2]

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P-44 Raman imaging of living cells and tissues by analytical spectroscopy

Jie Liu[1], Mei-Ling Zheng[1] & Xuan-Ming Duan[1,2]

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P-45 Enhancement of SHG from Ge-doped SiO_2 by metal-insulator-metal structure

Byungjun Kang, Akihiro Kitao, Kenji Imakita & Minoru Fujii

Kobe Univ., Japan.

P-46 Upconversion Luminescence of Rare-Earth-Doped Y_2O_3 Nanoparticle with Metal Nano-Cap

Kaoru Yamamoto, Hiroyuki Takashina, Kenji Imakita, Kanna Aoki & Minoru Fujii

Kobe Univ., Japan

P-47 Anomalous Photoluminescence of Gold Nanoparticles Induced by Ultrafast Collective Free Electron Relaxation

Tingting Yin[1], Zhaogang Dong[2], Liyong Jiang[1], Lei Zhang[3], Cheng-Wei Qiu[3], Joel Kwang Wei Yang[2] & Ze Xiang Shen[1]

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P-48 Effect of V/III ratio on polarity inversion on −*c*-GaN growth by OVPE

Y. Taniyama[1], Y. Yamaguchi[1], H. Takatsu[1], A. Kitamoto[1], M. Imade[1], M. Yoshimura[1], M. Isemura[2] & Y. Mori[1]

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P-49 Ultraviolet laser-induced degradation of $CsLiB_6O_{10}$

Yuichi OEKI[1], Masashi YOSHIMURA[1,2], Yoshinori TAKAHASHI[1,2], Hiroaki ADACHI[1,2] & Yusuke MORI[1,2]

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P-50 Switchable surface plasmon subwavelength focusing and bi-directional vortex creation in a metasurface

Chung-Ying Lin, and Chen-Bin Huang

National Tsing Hua Univ., Taiwan

P-51 Effect of dispersive layers thicknesses on graphene-based SPR biosensor

Hamid Toloue[1,2], Masato Saito[2], Hiroyuki Yoshikawa[2], Anthony Centeno[1], Noriyuki Kuwano[1] & Eiichi Tamiya[2,3]

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P-52 Gold nanostructure fabrication by focused UV laser annealing for surface enhanced Raman spectroscopy

Ryo NAKAGAWA, Hiroyuki YOSHIKAWA & Eiichi TAMIYA

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P-53 Fabrication of chiral plasmonic oligomers using cysteine-modified gold nanorods

Zhijian HU[1], Shuai HOU[1] & Xiaochun WU[1]

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P-54 Label free imaging using nonlinear optical phenomena

Shuichiro FUKUSHIMA[1], Taichi FURUKAWA[2] & Mamoru Hashimoto[1]

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P-55 Correlative imaging nanoprobes for near-infrared and cathodoluminescence microscopy

H. Niioka[1], S. Fukushima[1], T. Furukawa[2], M. Ichimiya[3], M. Ashida[1], J. Miyake[1] & M. Hashimoto[1]

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P-56 Metadevice for tunable dispersion-free polarization control

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P-57 Demonstration of an ultrasensitive refractive-index plasmonic sensor by enabling its quadrupole resonance in phase interrogation

Hsin-Cheng Lee[1], How-Foo Chen[2] & Ta-Jen Yen[1]

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P-58 Development of key components for integrated plasmonic circuits

Masanobu Haraguchi, Koji Okuda, Shun Kamata, Kota Tanikawa & Toshihiro Okamoto

Tokushima Univ.

P-59 Fabrication of multilayer graphene nanoribbons with the turbostratic structure by graphene over-layer growth on unzipped carbon nanotube

K. Yamamoto[1], R. Negishi[1], H. Tanaka[2], M. Fukumori[3], T. Ogawa[3], K. Matsumoto[4], Y. Kobayashi

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P-60 Photonics Innovation for Human Friendly Society

Yuichi NAGANO, Jumpei TAKEGATA, Tae OTONO, Kazunari KIMINO, Kinya SAKAI & Hiroshi IWASAKI

Photonics Center, Osaka University

Invited Talks

Intriguing properties of localized and propagating toroidal excitations

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Abstract

In this talk we review progress in toroidal electrodynamics and implications of recent discoveries in this field for nanophotonics. The toroidal dipole is a localized electromagnetic excitation independent from the familiar magnetic and electric dipoles. While the electric dipole can be understood as separated opposite charges and the magnetic dipole as a current loop, the toroidal dipole introduced by Y.B. Zaldovich in 1958 it corresponds to currents flowing on the surface of a torus. Resonant interactions of induced toroidal dipoles with electromagnetic waves have recently been observed at microwave, terahertz and optical frequencies. They provide distinct and physically significant contributions to the basic characteristics of matter including absorption, dispersion, and optical activity, the origin of which cannot be comprehensively interpreted in the context of standard multipoles alone. Interference of radiating induced toroidal and electric dipoles leads to transparency windows in artificial materials as a manifestation of the dynamic anapole. Toroidal excitations also exist in free-space as spatially and temporally localized electromagnetic pulses propagating at the speed of light and interacting with matter.

Light manipulation and sensing using vertical split-ring resonators (VSRR)

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Abstract

Plasmonic metamaterials composed of artificial structures in subwavelength scale exhibit many unconventional properties for light manipulation photonic devices and high-sensitivity optical sensor. We design and fabricate vertical split-ring resonators (VSRRs) to investigate the fundamental plasmon properties and potential applications. Tuning the configuration of VSRR unit cells is able to generate various novel coupling phenomena in VSRRs, such as plasmon hybridization [Fig. 1(a)] and Fano resonance [Fig. 1(b)]. The VSRR-based refractive-index sensor will be demonstrated, as shown in Figs. 1(c). Due to the unique structural configuration, the enhanced plasmon fields localized in VSRR gaps can be lifted off from the dielectric substrate, allowing for the increase of sensing volume and enhancing the sensitivity. We perform a VSRR based metasurface for light manipulation in optical communication frequency, as shown in 1(d) as well. Because the phase shift dominate by the upright configuration rather than the one parallel to the substrate, it can be used for high areal density integration of metal nanostructures and opto-electronic devices.

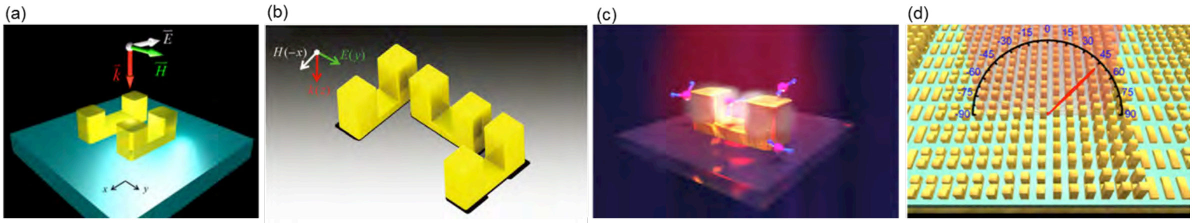

Fig. 1. Schematic diagrams for VSRR based (a) plasmon coupling, (b) Fano resonance, (c) nanoplasmonic sensor and (d) metasurface

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Plasmonic circular polarization analyzer formed by unidirectionally controlling surface plasmon propagation

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Abstract

Analyzing the polarization of a circular illuminated light is a critical issue. We have fabricated a spiral nano-structure on the Au film by using focused ion beam etching technique. The fabricated structure can be used as a plasmonic circular polarization analyzer. By designing the relative orientation of two nano-apertures in the spiral structural unit, the propagation direction of the surface plasmon polaritons excited by circularly polarized light of opposite handedness can be controlled. Therefore, the spiral structure could be used to accurately determine the helicity of the excited circularly polarized light. Based on the results of scanning near-field optical microscopy, the obtained circular polarization extinction ratio of this structure was above 500. This structure can be used to for a flexible detecting size and a very wide spectrum.

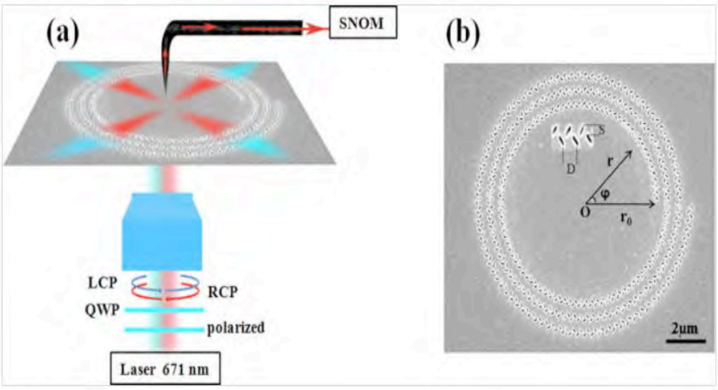

FIG. 1.

(a) Schematic of the experimental setup imaged by using scanning near-field optical microscopy. (b) SEM image of the Au-spiral plasmonic nano-aperture structure with three turns.

Acknowledgements

This work was supported by the National Natural Science Foundation of China, Grant Nos. 61176120, 61378059; The National Basic Research Program of China (973 Program), Grant No. 2007CB936800, No. 2015CB932403.

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Extreme imaging and beyond

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Abstract

High-speed optical imaging is an indispensable tool for blur-free observation of fast transient dynamics in virtually all fields including science, industry, defense, energy, and medicine. High temporal resolution is particularly important for microscopic imaging as even slow events appear to occur "fast" in a small field of view and can be found in a diverse range of areas such as photochemistry, plasma physics, microfluidic biotechnology, semiconductor physics, shockwave therapy, and neuroscience. Unfortunately, the speed of conventional cameras based on electronic image sensors is significantly constrained by their electrical operation and limited storage. Over the recent years, several unique and unconventional approaches to high-speed optical imaging have been reported to circumvent the technical challenges and reach a frame rate and shutter speed far beyond what can be reached with the conventional image sensors. In this talk, I review the unique concepts and principles of such ultrafast optical imaging methods, compare their advantages and disadvantages, and discuss an entirely new class of applications they can bring to us.

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Functional Crystals for and by Photonics

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Abstract

Functional crystals, such as nonlinear optical (NLO) materials and semiconductors, are important for generation of photons. In 1990's, the blue LED and LD have been realized by group III nitride semiconductors. Researches on the growth of high-quality bulk GaN crystals are accelerated in order to improve the performance of blue LED and LD devices. For the generation of shorter wavelength like ultraviolet (UV) laser light, frequency conversion process is indispensable because of difficulty in electrical doping for wide-bandgap semiconductors. NLO borate crystals are found to be promising for UV generation because of their wide-bandgap and adequate optical non-linearity. Barium borate (BBO), lithium triborate (LBO) have been developed by Chen's group in China in 1980's. In 1993, another new borate crystal, $CsLiB_6O_{10}$ (CLBO), has been discovered and developed by the author's group. CLBO crystals can generate the shorter wavelength below 200 nm with high efficiency. Recently, vacuum UV laser light (>200 nm) became important in the field of lithography mask inspection technology. Therefore, high-quality CLBO crystal is requested to realize high power VUV light source.

Author's group found that photons can induce crystallization of protein molecules. Protein crystallization can be induced by using the femto-second laser irradiation. This method is useful for producing high quality protein crystals in short nucleation times. The forced nucleation in a low supersaturation solution followed with crystal growth in stirred solution is very effective to produce crystals with high X-ray diffraction (XRD) resolution. The precise structural information of membrane proteins is important for designing and developing novel drugs. With this new technology, we have succeeded to crystallize various proteins with high XRD resolution, such as, membrane protein AcrB, orotidine 5'-monophosphate decarboxylase, the translocon-associated membrane protein (SecDF), the tRNA thiolation enzyme MnmA from Escherichia coli complexed with tRNA Glu, SHPS-1(receptor-type transmembrane protein). Based on this technology, we have established protein crystallization company SOSHO Inc..

In this report, I will present the solution growth of CLBO, GaN and protein crystals and show the following results: (1) high quality CLBO crystals for high power VUV generation, (2) high quality bulk GaN crystal by Na flux method for high efficient LED, and (3) high quality protein crystal growth by means of forced nucleation induced by laser irradiation and solution stirring method.

Aperiodic nanostructures for wavefront manipulation

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Abstract

Periodic or quasi-periodic structures are widely studied and developed. Breaking such a symmetry and periodicity by engineering aperiodic micro-nano-optics to govern complex optical responses, we can go for more technical innovations and get more interesting flat optics. It imposes challenges on the accurate design, simulation, handling and fabrication of the large amount of unit nano-elements in the miniaturized devices. In this talk, I will introduce several of our recent works on aperiodic flat optics using photon sieves, fractal structure and logarithmic spiral lens.

Ultrahigh capacity photon-sieve structures have been designed with the help of new analytical model in different structural orders of randomness and aperiodicity. They showed uniform optical hologram with high diffraction efficiency and free from twin-images as well as sub-diffraction limit focusing beyond evanescent region in air. A fractal holey metal microlens based on finite areas of two-dimensional arrays of circular nanoholes is used to suppress the side lobes and high order diffractions in a FZP to achieve better focusing performance. A logarithmic spiral lens is demonstrated capable of generating as well as focusing optical vortex beam twisting around its beam-axis to follow a conical trajectory with the unique feature of a crescent-shaped intensity cross section. It also works as a compact broadband circular polarization analyzer by focusing light of different handedness into a sub-wavelength confined spot or a ring-shaped intensity profile.

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Catenary Optics for Nano-structured Optical Devices

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Abstract

The catenary is the curve that free-hanging chain assumes under its own weight, and thought to be a "true mathematical and mechanical form" in architecture by Robert Hooke in 1670s, with nevertheless no significant phenomena observed in optics. Here we show that optical catenary can serve as a unique building block of metamaterials with continuous and linear phase shift covering [0, 2π], a mission which is extremely difficult if not impossible with state-of-the-art technology [1, 2]. We present a methodology that, making use of metallic structures inspired by natural catenaries, to generate geometrical phase with spatially continuous and spectrally achromatic distribution, as shown in Fig. 1. Based on the unique features of single element, catenary arrays were used to generate optical angular momentum (OAM) beams and high-order Bessel beam (HOBB) with both linear and nonlinear radial phase distribution. The simultaneously phase control over the azimuthal and radial directions suggest that our strategy is universal for almost arbitrary two-dimensional phase profile. These devices provide ultra-broadband operation since the anisotropic modes associated with the spin-orbit interaction are almost independent on the incident light frequency. By combing the optical and topological characteristics, our approach would allow the complete control of photonics and optomechanics within a single nanometric layer.

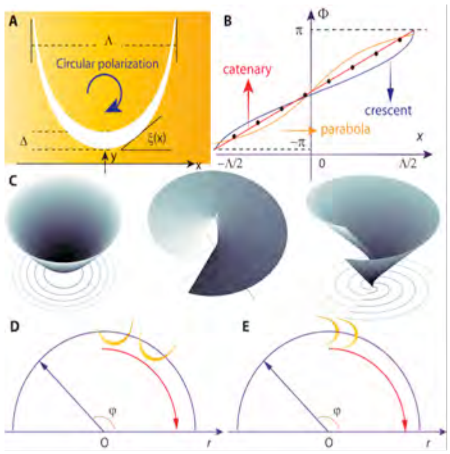

Fig. 1: Schematic representation of the geometric phase in metallic catenaries. (A) Sketch map of a catenary aperture illuminated at normal incidence by circularly polarized wave. **(B)** Phase distributions of catenary (red), parabola (green), crescent (purple) and discrete antennas (black dot) for LCP illumination (σ = 1). **(C)** Three typical kinds of phase profile for focus (left), generation of OAM (middle) and HOBB (right). (D and E) Sketch map of the arrangement of catenaries to obtain ordinary OAM (D) and HOBB (E).

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Single Molecule Nano-Science: Noise and Function of Life

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Abstract

Since biological molecular machines such as molecular motors, cell signal processors, DNA transcription processors and protein synthesizers are only nanometers in size and have a flexible structure, they are very prone to thermal agitation. Furthermore, the input energy level is not much different from that of average thermal energy, k_BT. Molecular machines can use this thermal noise with a high efficiency of energy conversion for their functions. This is in sharp contrast to man-made machines that operate at energies much higher than thermal noise. In recent years, single molecule imaging and nano-technologies have rapidly been expanding to include a wide range of life science applications. The dynamic properties of biomolecules and the unique operations of molecular machines, which were previously hidden in averaged ensemble measurements, are now being unveiled. The aim of our research is to approach the engineering principle of adaptive biological systems by uncovering the unique operation of biological molecular machines. Here, I review our single molecule experiments designed to investigate molecular motors, enzyme reactions, protein dynamics and cell signaling, and discuss how thermal fluctuations (noise) play a positive role in the unique operation of biological molecular machines allowing for flexible and adaptive biological systems including cell and brain.

http://www.fbs.osaka-u.ac.jp/labs/yanagida/

Label-free Raman and phase imaging for diagnosis of disease

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Abstract

The development of high-speed Raman imaging[1] has allowed new possibilities in diagnosis and understanding of disease. The ability to measure and interpret small biochemical changes in living samples without resorting to fluorescent labels leads towards applications in recognizing key chemical signatures that correspond to a disease, or to look at the effects of a disease on an individual cell level. In our laboratory we are pursuing both of these aspects, and in this presentation I will introduce some of the techniques we have developed, in terms of the implementation of optical methods to extract the maximum amount of information while staying label-free[2]. I will also cover some of the findings we observed when applying these analytic techniques to living cell samples.

One important disease that label-free imaging can help elucidate is malaria. The World Health Organization (WHO) and Center for Disease Control (CDC, USA), estimate that half the world’s population is at risk of malaria and that in 2013 it was responsible for half a million deaths worldwide. One of our uses of Raman analysis is to identify key molecular components that indicate malaria infection as early as one day post-infection, thereby allowing effective early treatment. We also use the analysis of chemical changes in the cell to greater understand the process of malaria sickness in macrophage cells[3].

For other diseases such as the process of inflammation, these label-free techniques can provide a window into the chemical and structural rearrangements. By combining quantitative phase imaging and simultaneously imaging immune cells, such as macrophages, we can gain understanding of the “first-defender” response of macrophages when they recognize foreign objects. We can also identify new information that can only be observed using a combination of imaging modes, rather than a single or sequential imaging analysis.

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Optical vortices 'twist' materials to form chiral nanostructures

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Abstract

'Twisted' nanostructures have the potential to be widely utilized in many fields such as spintronics, metasurfaces, and so on. In principle, laser material processing, in which basically breaks a target material down into its compositional elements by high intense laser pulse illumination, is ill suitable to gather coherently compositional elements so as to form structured nanomaterials. Thus, a 'twisted structured material by laser processing' has never been established so far even by utilizing advanced femtosecond lasers.

Optical vortices carry an annular intensity profile and an orbital angular momentum, $m\hbar$, (m is an integer known as the topological charge) arising from a helical wavefront, and they have provided us a variety of research opportunities, such as advanced optical trappings and manipulations, space division multiplexing optical telecommunications, and super resolution microscopy beyond the diffraction limit. In recent years, we discovered that optical vortices 'twist' directly a material to form various structured materials, including chiral (or achiral) metallic nanoneedes, chiral surface reliefs, and submicronscale crystalline needles owing to orbital angular momentum transfer effects. Circularly polarized light carries a spin angular momentum arising from a helical electric field. We also discover that the spin angular momentum constructively or destructively couples with the orbital angular momentum to shape further the nanostructures.

In this presentation, we report on nanostructures formation based on optical vortices illumination, in which the orbital angular momentum transfer effects 'twist' materials (metal, semiconductor, and organic materials) to form chiral (or achiral) nanostructures. We also address spin–orbital angular momentum coupling effects in the nanostructures formation.

Such material processing technique based on optical vortex illumination will allow us to develop advanced photonic elements and devices, *e.g.*, plasmonic metasurfaces with chiral selectivity, at high time and cost efficiencies. It will also enable us to pioneer novel photonic devices, such as an optical polarization rotator in the mid-IR or terahertz region.

Coloration of amorphous photonic crystals

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Abstract

In addition to pigmentation, structural coloration is another way of color production in the biological world, resulting from the interaction of natural light with photonic structures with featured sizes comparable to the visible wavelength via optical effects [1]. Structural colors are widely spread in the biological world found, for example, in birds, insects and even in plants. Natural photonic structures and their interesting ways of light steering always offer invaluable inspirations.

Photonic structures that can produce structural coloration include thin films, multilayers, diffraction gratings and photonic crystals. Ordered photonic crystals possess both short- and long-range order and can produce structural colors with iridescence. On the other side, amorphous photonic crystals that possess only short-range order lead to non-iridescent structural colors [2-4]. Optically, amorphous photonic crystals are very special with many unique and interesting optical properties [5].

With structural characterizations, we found a few interesting amorphous photonic structures, namely, an amorphous diamond-structured photonic crystal in the feather barbs of the scarlet macaw [4], a photonic crystal consisting of random-close-packed nanoparticles [2] and a spinodal-decomposition photonic crystal [3] in the scales of long horn beetles. From numerical simulations, we revealed that photonic pseudo-gaps in the photon density of states of these amorphous crystals are the ultimate origin of non-iridescent structural coloration.

Inspired by nature, we fabricated artificially amorphous photonic crystals consisting of monodisperse polystyrene spheres and cuttlefish-ink nanoparticles based on a self-assembly method [6]. Fabricated structures show vivid non-iridescent structural colors with high color visibility.

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Enhanced Vibrational Spectroscopic, Intracellular Refractive Indexing for Label-free Biosensing and Bioimaging by Multi-band Plasmonic-antenna Array

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Abstract

We demonstrated a multi-functional plasmonic-antenna array enables molecular characterization, label-free bio-detection, and imaging simultaneously. For molecular characterization, the enhancement of vibrational signature reaches three orders by the resonating plasmonic antennas. This enhancement can be selective, which means, a tailored plasmonic antenna can be designed to fit the specific vibrational signatures of analytes. This characteristic validates an accurate qualitative analysis and also promotes the signal-to-noise ratio. For bio-detection, we showed a label-free process in detecting the refractive index shift of analytes. An empirical formula is provided to predict the sensitivity of variety of plasmonic antenna. This refractive index dependency promises a reliable sensor design for refractive index sensing and film thickness measurement. For imaging, we observed the vibrational signature image (VSi) and refractive index image (RIi) of HeLa cells (human cervical epithelioid carcinoma cell). In VSi, we defined the distribution of lipid signal, and can be further integrated with other vibrational signature distribution; on the other side, in RIi, we provided intracellular images with different detection length, which can observe the cell image at different cross-section. Both imaging characteristics can not only provide abundant information of intracellular components, but also provides a non-invasive observation method.

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Inter-layer coupling in 2D materials

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Abstract

Following the extensive research work on graphene, a lot of attention has now been focused on two dimensional transition metal dichalcogenide (2D TMD) materials which can in principle compensate some of the disadvantages of graphene, such as lack of a energy bandgap. 2D TMD often show very strong layer-dependent properties. For example, their properties can be strongly influenced by the stacking of the layers, the relative orientation of the layers and the number of layers. Detailed understanding of the inter-layer interaction will help greatly in tailoring the properties of 2D TMD materials for applications. Raman/Photoluminescence (PL) spectroscopy and imaging have been extensively used in the study of nano-materials and nano-devices. They provide critical information for the characterization of the materials such as electronic structure, optical property, phonon structure, defects, doping and stacking sequence.

In this talk, we use Raman and PL techniques to study few-layer MoS_2 samples. The Raman and PL spectra show clear correlation with layer-thickness and stacking sequence. Our *ab initio* calculations reveal that difference in the electronic structures mainly arises from competition between spin-orbit coupling and interlayer coupling in different structural configurations.

Plasmonic hot electrons doping of 2D Materials

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Abstract

Plasmonics deals with the phenomena of collective vibration of electrons in the interface between metallic and dielectric media. With the advanced nanofabrication techniques, a broad variety of nanostructures can be designed and fabricated for plasmonic investigations at nanoscale. In this presentation, we will demonstrate our latest results of the design of new plasmonic nanostructures and the characterization of surface plasmon nanostructures with 2D materials by using Scanning Near-field Optical Microscopy (SNOM), which is one of the unique characterization tools for nano-optical detection, and other techniques, and discuss some fundamental properties for both localized surface plasmons and surface plasmon polaritons arise a new insight and understanding for the electro-optical devices, such as plasmonic PL control, active plasmonic modulator and detectors for energy harvesting.

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Different Coupling effects in Graphene Plasmons

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Abstract

Graphene is well suited for a number of photonic applications due to its interesting optical and electronic properties. The intrinsic collective excitation in graphene has attracted much attention. Specifically, surface plasmons in graphene are believed to be potential ingredients for infrared and terahertz applications. Different coupling effects including the mode coupling, phonon-photon coupling, and etc. are utilized for intentional purposes.

The coupled modes between graphene plasmons and surface phonons of a semiconductor substrate are investigated, which can be efficiently controlled by carrier injection of the substrate. The properties of surface plasmons localized at the interface between graphene and Kerr-type nonlinear substrates are investigated analytically[1]. The dispersion of graphene plasmons may be affected much by the inevitable nonlinear effect of substrates.

The spatial switching of mid-infrared light near-fields is proposed in coupled graphene heterogeneous ribbon pairs[2]. By using the coupled plasmon modes in graphene ribbon pairs, the electric near-field enhancement can be spatially controlled in graphene ribbons as the tuning of the external bias voltage difference. Furthermore, plasmon induced transparency (PIT) effect is demonstrated in such graphene ribbon pairs[3]. The transparency effect is understood by the mode coupling between dipolar and quadrupole plasmons modes in graphene ribbons. A typical Fano resonance for a metallic symmetry-breaking structure is simulated for graphene[4]. Although a Fano-like extinction spectrum emerges, our analysis proves that the asymmetry is due to the intensity superposition of three plasmon modes instead of interference. The difference be-tween graphene and metal plasmons comes from different contributions to the extinction, where the former is absorption instead of scattering.

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Micro/Nano-Scale light Manipulation

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Abstract

Micro/nano photonic structures permit remarkable control of the propagation of light. A selection of recent results will be presented.

Using two-dimensional photonic crystal made of the composite materials with large and fast third-order optical nonlinearity, ultrafast and low threshold all-optical switching was demonstrated. Based on tunable Fano resonance or PIT of metallic nanostructures, ultrafast modulations on light transmission were also demonstrated. Moreover, ultracompact plasmonic devices including SPP unidirectional generator, splitter and others were experimentally demonstrated.

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Plasmonic Topological Insulators: an Emerging Platform for Broadband Tunable Metamaterials

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Abstract

New plasmonic materials are needed to overcome limitations of noble metals, particularly their high ohmic losses, to develop metamaterial-based devices for nanophotonics, data processing circuits, sensors, etc. Recently, topological insulators were identified as a potential platform for broadband plasmonics [1]. Here we study a topological insulator compound, BSTS, which supports broadband plasmonic response and has appealing photonic properties in the mid-IR to UV spectral range.

BSTS dielectric constants derived by ellipsometric measurements are in excellent agreement with first principle DFT calculations. Unlike common direct or indirect bandgap semiconductors, the anomalous dispersion region falls in the visible part of the spectrum, leading to negative values of the permittivity. This behavior of the optical response is attributed to a combination of bulk interband transitions and surface contribution of the topologically protected states.

To prove the plasmonic behavior of BSTS, we fabricated metamaterials and gratings on crystal flakes and obtained strong plasmonic response from UV to NIR. The coexistence of plasmonic response of the topological surface with dielectric properties of the semiconducting bulk enables broadband (up to to mid-IR) [2] and ultrafast (t >100 fs) photo-modulation of the optical response, which shows a two-fold enhancement by metamaterial structuring of the BSTS surface (Fig. 1).

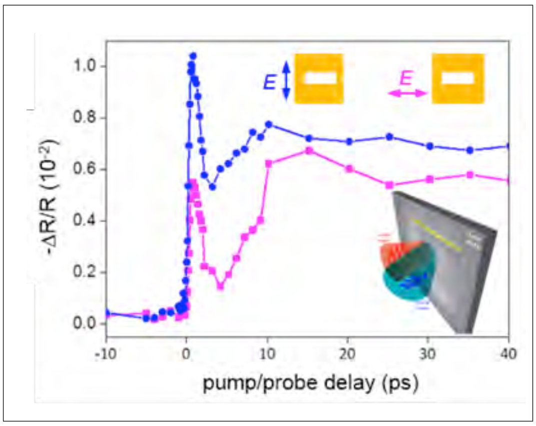

Fig. 1:. Ultrafast (t=100 fs) plasmonic response of nano-slit array metamaterial fabricated on topological insulator semiconductor BSTS.

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Plasmonic Doppler Grating as Azimuthal Angle-dependent Platform for Index Sensing and Color Sorting

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Abstract

We present a new design of two dimensional plasmonic grating with continuous and azimuthal angle-dependent periodicity. As shown in Fig.1, our design consists of a set of non-concentric circular rings mimicking the wavefronts from a moving point source and, therefore, is termed a Plasmonic Doppler Grating (PDG). We use a hybrid nanofabrication technique to fabricate the designed PDG so that the structure is single-crystalline, well-defined and has atomically flat surface [1]. We detail the design, fabrication and optical characterization of the PDG and show an example of many possible applications as an index odometer, where the variation of environmental index of refraction is revealed in the change of angle distribution of color. The sensitivity of the PDG index odometer has a unit of angle per index unit and can be optimally designed for specific applications by choosing the radius increment and ring center displacement. With our recent single-crystalline aluminum platform [2], applications in angle-dependent fluorescence enhancement in the UV regime is anticipated. We demonstrate the applications of PDG in color sorting and index sensing. It may also serve as an ideal platform for the study of surface-enhanced Raman spectroscopy (SERS). Other applications, such as hydrogen sensing, surface plasmon-enhanced spectroscopy and non-linear wave-mixing are anticipated.

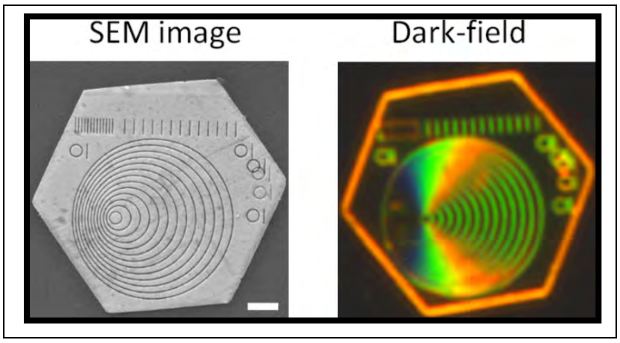

Fig. 1: SEM image and the corresponding dark-field scattering image of a single-crystalline gold PDG showing the azimuthal angle resolved surface plasmon resonance.

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Anomalous Phases in Topological Photonics

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Abstract

Topological insulators–phases of matter whose bandstructures are "topologically distinct" from conventional insulators–exhibit striking properties such as edge states that are protected against backscattering. First discovered in condensed matter physics, the concept can be applied to photonics, using electromagnetic fields in place of electronic wavefunctions. Topological photonics has now been realized in magnetic photonic crystals [1], waveguide lattices [2], and on-chip resonator lattices [3]. We present experimental and theoretical studies showing how topological photonics can probe fundamental and previously-unexplored aspects of topological bandstructure physics, including anomalous 2D phases with zero "Chern number" band invariants despite being topologically invariant [4]; anomalous 3D Weyl semi-metal phases; realizations of topological pumping in actual experiments [5]; and "single-cone" 2D Dirac modes that are immune to inter-valley scattering. Implications for switchable topological photonics and other applications are also discussed.

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Surface plasmon vortex: its creation, shaping, and application in particle manipulations

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Abstract

Optical vortices are waves carrying orbital angular momentum and exhibit helical phase fronts. Helical phase front leads to discontinuous azimuthal phase jumps and the number of phase discontinuities (abrupt phase jumps from $-\pi$ to π) within a 2π range is referred to as the topological charge of an optical vortex. Optical vortices have been applied in trapping and spinning of microparticles, and recently in free-space data transmission. Generation of optical beams carrying orbital angular momentum has received increasing attentions recently, both in the far-field and in the near-field. Near-field vortices are typically generated through the excitation of surface plasmons (SP). However, the intensity patterns of the SP vortices generated thus far, just like the free-space vortex beams, are all azimuthally symmetrical (annular) since mathematically they conform to the Bessel function.

In this talk, I will first introduce our recent progress on applying surface plasmon vortex for selectable particle trapping and rotation. In the second part, spatial shaping the near-field spatial patterns of surface plasmon vortices will be discussed. Moreover, in all past studies, SP vortices were excited by far-field circularly polarized light. This means the functionality of the SP devices were merely converting the far-field spin angular momentum to orbital angular momentum in the near-field. In the last part, I will focus on the creation of surface plasmon vortex using non-angular momentum excitation.

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3D Helix Structure based on Chiral Liquid Crystal for Photonics

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Abstract

Liquid crystals are mesophases in which anisotropic molecules spontaneously form ordered structures. Liquid crystalline cholesteric blue phases typically appear between the cholesteric and the isotropic liquid phases, and form three-dimensional helix structure. The cubic orientational order exhibited by BPs I and II make them interesting both as subjects of soft matter physics and as candidate materials for next generation electro-optic applications. The invention of the polymer-stabilization technology has allowed blue phases to be applied to various devices such as displays, tunable lenses, filters and lasers.

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All-optical data processing in SiNx:Si-QD ring waveguide modulator based on free carrier absorption or nonlinear Kerr switching

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Abstract

The Si-based all-optical modulators have been demonstrated by using ring resonator or Mach-Zander interferometer. However, the modulation bandwidth is typically limited by the free-carrier lifetime of few nanoseconds in bulk Si, which can be enhanced by introducing the p-i-n structures with complex transmission line design for carrier transport acceleration. Another approach to achieve the ultrafast all-optical modulation is to utilize the nonlinear optical properties of the semiconductor. Recently, the nonlinear optical effects, including four-wave-mixing (FWM), two-photon absorption (TPA) [1], and nonlinear Kerr effect [2-3], have been demonstrated by using Si nano-waveguide, Si quantum dot (Si-QD) based slot waveguide and Si_3N_4 based channel waveguide. These nonlinear optical effects are originated from the high third-order susceptibility of Si. FWM can be utilized to demonstrate the wavelength generation, and the multi-wavelength oscillator has been fabricated by using the low-loss Si_3N_4 based ring resonator in 2009. This multi-wavelength generating component with narrow-linewidth properties can be served as a key element in the integrated photonic network for high-bandwidth WDM communication systems. In this talk, the SiO_x:Si-QD waveguide modulated by the FCA effect and the SiN_x:Si-QD waveguide modulated by the Kerr switching effect are demonstrated for all-optical data processing.

By shrinking the Si-QD size to 1.7 nm in SiO_x:Si-QD waveguide to enlarge the electron/hole effective masses, decrease the FCA cross section, shorten the PL and Auger lifetime, the all-optical return-to-zero on-off keying (RZ-OOK) modulation is performed by using the SiO_x:Si-QD waveguides, providing the transmission bit rate of 2 Mbit/s. To greatly improve the data transmission capacity, the Si-rich SiN_x micro-ring based optical Kerr switch is performed. The field-resonant nonlinear Kerr effect enhances the transient refractive index change so as to induce a spectral red-shift by 100 pm on the transmission dip. The enlarged refractive index of $\Delta n = 1.6\times10^{-4}$ with increasing nonlinear refractive index to $n_2 = 1.6\times10^{-13}$ cm^2/W at 1550 nm is observed in the Si-rich SiN_x film. The cross-wavelength all-optical data conversion/inversion processing is presented to enable 12-Gbit/s all-optical cross-wavelength switching of the pulsed RZ-OOK data with converted or inverted format. The photon lifetime of ~19 ps in the Si-rich SiN_x microring resonator cavity can support the Si-rich SiN_x all-optical Kerr switch with a maximal bandwidth of up to 50 GHz effectively.

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Coherent manipulation, measurement and entanglement of quantum dot spins using optical fields

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Abstract

Quantum Realization of a quantum interface between stationary and flying qubits is a requirement for long-distance quantum communication and distributed quantum computation. The prospects for integrating many qubits on a single chip render solid-state spins promising candidates for stationary qubits. Quantum dots exhibit spin-state-dependent optical transitions, allowing for fast initialization, manipulation and measurement of the spins using laser excitation. Recent progress has brought spin photonics research into the quantum realm, allowing the demonstration of spin–photon entanglement, which in turn has enabled distant spin entanglement as well as quantum teleportation. In this talk, I will talk about the recent progress in this direction.

Posters

Metal-insulator-metal plasmonic sensor for high sensing sensitivity

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Abstract

Optical biosensors based on surface plasmon resonance (SPR) have attracted increasing attention over the past three decades. In SPR sensors, a single metal layer is commonly used, but the resolution is limited because of broad resonances.[1)] in metal-insulator-metal (MIM) structures, coupling between surface plasmon polaritons (SPPs) can be achieved and a sharp resonance can be expected.

In the present work, we propose a MIM structure consisting of a thick insulator layer sandwiched with metal layers. Theoretical results of the angle-scan ATR spectrum show two resonances: the first one is a sharp resonance corresponding to a SPP propagating along the Au/sensing medium interface modified by the MIM structures. The second one is a broad resonance which corresponds to a symmetric SPP arising from coupling between two SPP modes in the MIM structure.

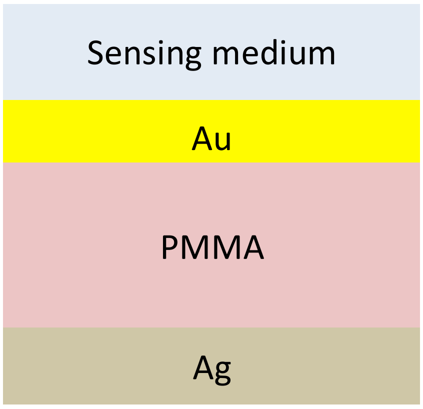

Fig. 1: Metal-insulator-metal SPR sensor.

Estimation of the sensitivity with intensity modulation indicates that the Figure of Merit of the MIM structure is six times larger than that of conventional SPR.

References:

[1] S. Hayashi; D. V. Nesterenko, and Z.Sekkat, "Fano resonance and plasmon-induced transparency in waveguide-coupled surface plasmon resonance sensors" *Physics Express*, 8, 022201 (2015).

Polymer-stabilized fluorescent platinum nanoclusters

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Abstract

Recently, fluorescent gold and silver nanoclusters have been already prepared and used for labeling the living cells as probes due to their molecule-like behaviors such as size-dependent fluorescence of which the emission wavelengths can be adjusted by controlling the number of atoms. Platinum, another noble metal, has widely catalytic applications, however, their fluorescence properties were rarely investigated.

In this presentation, three kinds of aqueous fluorescent platinum nanoclusters (Pt NCs) with different emission wavelengths will be reported. Blue[1] and green[2] fluorescent Pt NCs were produced using four-generation poly(amidoamine) dendrimers (PAMAM(G4-OH)) as a template and yellow[2] fluorescent Pt NCs were synthesized employing hyperbranched polyethyleneimine (PEI) as a stabilizer. Through binding to antibodies, these multi-colored fluorescent Pt NCs were successfully applied for bio-imaging of chemokine receptors in the living HeLa cells. On the other hand, the yellow fluorescent Pt NCs have the ability of sensitive and quantitative detection for Co^{2+} ions as a sensing probe and the limit of detection reaches to 500 nM. Compared to common fluorophores, Pt NCs have plenty of advantages, such as water solubility, ultrafine size, and low cytotoxicity, demonstrating the enormous potential in the fields of tracking, imaging, and sensing as an alternative fluorescent probe.

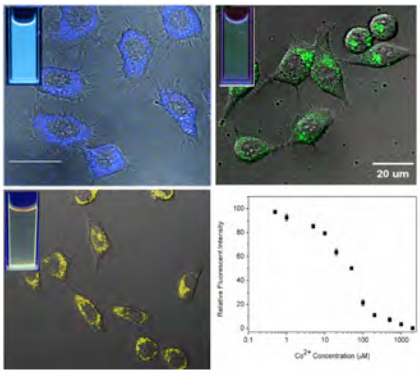

Fig. 1: Three kinds of fluorescent Pt NCs and their applications.

References:

[1] S.-I. Tanaka, J. Miyazaki, D. K. Tiwari, et al. "Fluorescent Platinum Nanoclusters: Synthesis, Purification, Characterization, and Application to Bioimaging." *Angew. Chem. Int. Ed.*, **50**, 431-435 (2011).

[2] S.-I. Tanaka, K. Aoki, A. Muratsugu, et al. "Synthesis of Green-Emitting Pt_8 Nanoclusters for Biomedical Imaging by Pre-Equilibrated Pt/PAMAM (G4-OH) and Mild Reduction." *Opt. Mater. Express*, **3**, 157-165 (2013).

[3] X. Huang, K. Aoki, H. Ishitobi, and Y. Inouye, "Preparation of Pt Nanoclusters with Different Emission Wavelengths and Their Application in Co^{2+} Detection." *ChemPhysChem*, **15**, 642-646 (2014).

Helical metasurface based optical devices

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Abstract

Compact and miniaturized devices with flexible functionalities are always highly demanded in optical integrated systems. Metasurface has been successfully harnessed as an ultrathin flat platform for complex manipulation of light, including holography, vortex generation and non-linear processes [1]. Multi-functional metasurface elements might find novel applications across nano-photonics, optics and nanotechnology. Here, we experimentally demonstrate a promising roadmap for transmission-type Babinet metasurface based helical devices, which achieves full manipulations of optical vortices, including its generation, hybridization, spatial multiplexing, focusing and non-diffraction propagation etc. as shown in Fig. 1, by controlling the geometric phase of spin light via over 121 thousands of spatially-rotated nano-voids.

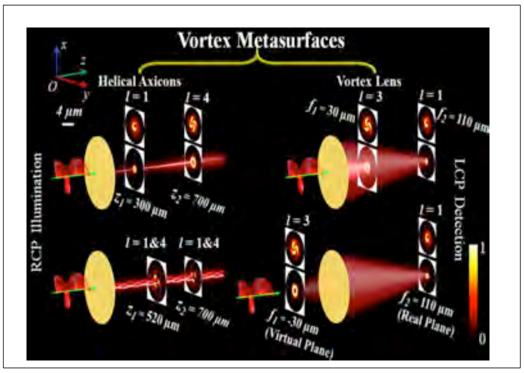

Fig. 1: Illumination of different functional (hybridizing and multiplexing) flat helical devices (Helical Axicons and Vortex Lens) with simulated intensity profiles and the corresponding interference patterns.

References:
[1] N. Yu, *Science* **334**, 333(2011)

Optical Tunable Graphene Plasmonic Terahertz Modulator

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Abstract

A room temperature optical tunable terahertz modulator based on graphene/semiconductor was fabricated to manipulate terahertz wave. By utilizing graphene localized plasmon and optical gating method, efficient modulation of terahertz wave can be realized. We experimentally achieved 10.4% modulation depth and modulation bandwidth up to 3.184 kHz. This progress suggests potential utility of graphene-based terahertz modulator in the terahertz technologies.

The active device consists of graphene disk arrays coupled with a semiconductor substrate (see figure 1 (a)). The graphene disks can support the localized graphene plasmon when it's excited by the terahertz electromagnetic wave. Localized graphene plasmon will absorb the terahertz signal[1]. By optically gating the localized graphene plasmon frequency and amplitude, the modulation of THz signal transmission can be achieved within a certain bandwidth.

At the interface of graphene and semiconductor, a Schottky electric field is typically established due to the work function misalignment (see figure 1 (b)). When a graphene/semiconductor system is illuminated by photons with energy larger than the semiconductor bandgap, the Schottky electric field at the interface can further split the photo-excited electron-hole pairs, and drive the one kind of the charge carriers to accumulate in the graphene [2]. Carrier doping in the graphene by such non-contact optical gating is very effective.

As a result, terahertz beam absorption by single-layer graphene disks in the experiment is tuned from 4% to 14% under the illumination.

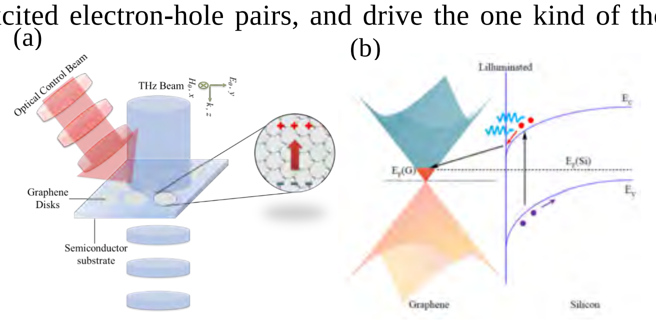

Fig. 1: (a) Schematic of optical tunable graphene plasmonic modulator. (b) Electron doping by photo excited electrons injected from Si under illumination

References:

[1] Yan, Hugen, et al. "Tunable infrared plasmonic devices using graphene/insulator stacks." *Nature Nanotechnology*, **7.5**, 330-334 (2012).

[2] Qi, Ji, et al. "Controlled Ambipolar Tuning and Electronic Superlattice Fabrication of Graphene via Optical Gating." *Advanced Materials*, **26.22**, 3735-3740 (2014).

Helicity Light Analysis Based on Meta-detector

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Abstract

The polarization state is an important feature for characterizing the electromagnetic wave. The s- and p-polarization can be distinguished by natural material such as sapphire and quartz while the right-and left-handed circular polarization can't. [1]

The metasurfaces, an array of subwavelength antenna with varying sizes, show the abilities to manipulate the phase of incident light [2-4]. The gradient phase distribution is achieved by solely rotating the nanorod, and the working frequency of metasurface is tunable by adjusting the parameters of the nanorods.

In this paper, we present a metasurface which integrates optical functionalities of grating, mirror and circular polarized light analyzer into a tiny device. It can split the different handed circular polarization and its efficiency is higher than that of the transmittance type as shows in figure 1. The broadband light can be separated into space with different wavelength as well. This device as a potential candidate can be applied to helicity analyzer and plasmon-enhanced circular dichroism spectroscopy.

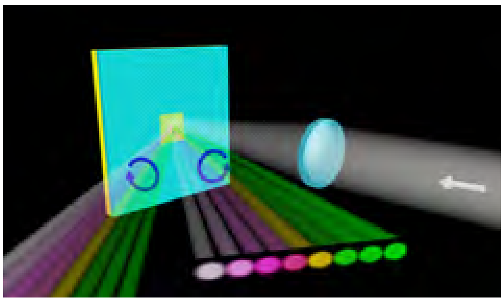

Fig. 1: The multifunctional metasurface separates right-handed and left-handed polarization light into two regions with pre-determined angle and separates light into space with different wavelength.

References:

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[3] S. Sun et al., "High-Efficiency Broadband Anomalous Reflection by Gradient Meta-Surfaces," *Nano Letters*, **12**, 6223–6229 (2012).

[4] W. T. Chen et al., "High-Efficiency Broadband Meta-Hologram with Polarization-Controlled Dual Images," *Nano Letters*, **14**, 225-230 (2014).

Plasmonic Sensor Using VSRR Structure

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Abstract

The split-ring resonator (SRR) is such a metal structure that is typically used as a building block for metamaterials because of its strong magnetic resonance accompanied with strong field enhancement within the SRR gap [1]. One important measure of a metamaterial sensor is its sensitivity to the refractive index change of nearby sensing medium (δλ/δn). Unfortunately, a majority of the metamaterials reported so far are with planar SRRs, resulting in a rather appreciable fraction of the plasmon energy distributed in the dielectric substrate which limits the effective sensing volume as well as the sensing performance [2]. In this work, we report the fabrication of vertical SRRs (VSRRs) capable of lifting essentially all of the localized fields above the supporting substrate they stand on as illustrated in Fig. 1(a). This upright configuration strongly confines an electromagnetic field within the gap as the magnetic plasmon is excited, suspending the enhanced field entirely in the free space away from the dielectric substrate and thus increasing the sensing volume. To demonstrate and examine the sensing performance of the VSRR structure, we have performed the sensitivity analysis by experiment and simulation. According to the linear fitting, the simulation has predicted a sensitivity of about δλ/δn = 797 nm/RIU, while our measurement has produced a less value of 603 nm/RIU, as shown in Fig. 1(b).

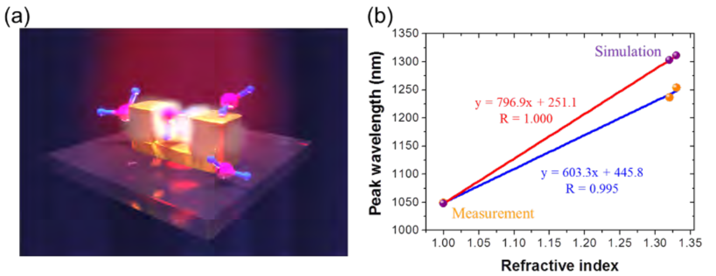

Figure 1. (a) Illustration of the field distribution in the VSRR gap and its advantage for increasing sensing volume. (b) The resonance wavelength associated with magnetic resonance of experimental (orange dots) and simulation (purple dots) results as a function of the surrounding refractive index.

References:

[1] P. C. Wu, et al.," Magnetic plasmon induced transparency in three-dimensional metamolecules," *Nanophotonics* **1**, 131(2012).

[2] A. Dmitriev et al.,"Enhanced Nanoplasmonic Optical Sensors with Reduced Substrate Effect," *Nano Letters* **8**, 3893(2008)

Colorful Meta-hologram based on Aluminum

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Abstract

Traditional full-color holograms with scalar diffraction patterns renders polarization uncontrolled and have rather thick photoresists. In recent years, metasurface has won a lot of popularity because of its complete modulation of polarization, phase1 and amplitude of electromagnetic waves and its subwavelength nature. So here we present a phase-modulated multicolor meta-hologram (MCMH) that is polarization-dependent and capable of producing images in three primary colors.2 Its structure is made of aluminum nanorods which are arranged in a two-dimensional array of pixels with surface plasmon resonances in red, green, and blue. Aluminum is used here for it has high plasma frequency causing plasmonic resonance into visible or UV region. The fabrication of MCMH is the patterning of aluminum nanorod array on a 30 nm thick SiO2 spacer layer sputtered on top of a 130 nm thick aluminum mirror. With proper design of the structure, we obtain resonances of narrow bandwidths to allow for implementation of the multicolor scheme. Also with proper phase distribution of MCMH from computer-generated hologram method, a specified image can be reconstructed. Taking into account of the wavelength dependence of the diffraction angle, we can project images to specific locations with predetermined size and order. By tuning the size of aluminum nanorods, we demonstrate that the image color can be continuously varied across the visible spectrum.

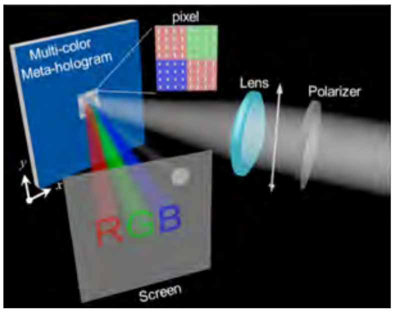

Fig. 1: Designed multi-color meta-hologram under linearly polarized light containing red, green and blue.

References:

[1] Chen, W. T. *et al.*, "High-Efficiency Broadband Meta-Hologram with Polarization-Controlled Dual Images", *Nano Lett.*, **14**, 225-230 (2014).

[2] Huang, Y. W. *et al.*, "Aluminum Plasmonic Multicolor Meta-Hologram", *Nano Lett.*, **15**, 3122-3127 (2015).

Selective imaging by high efficiency meta-hologram

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Abstract

Holograms are the optical devices which can reconstruct designed images, although widely used but with limited applications because of the constituent materials and the narrow working range of the electromagnetic region. Recently, metasurfaces, composed of arrays of subwavelength nanoantennae with varying sizes, are capable of manipulating the phase of an incident electromagnetic wave from visible to microwave frequencies[1,2]. Here, we present a reflective-type and high-efficiency meta-hologram for visible wavelength in the principle of metasurfaces as shown in Fig. 1. Using subwavelength gold cross-nanoantennae as building blocks to construct our meta-hologram with also a subwavelength thickness, the reconstructed images of the meta-hologram show polarization-controlled dual images with high contrast, functioning for both coherent and incoherent light sources within a broad spectral range and under a wide range of incidence angles. The flexibility demonstrated here for our meta-hologram paves the way to a wide range of holography-related applications at regions of arbitrary electromagnetic frequencies.

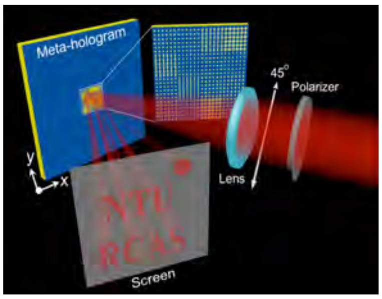

Fig. 1: Our designed meta-hologram under 45°-linearly polarized light.

References:
[1] S. L. Sun *et al.*, "Gradient-index meta-surfaces as a bridge linking propagating waves and surface waves", *Nat. Mater.*, **11**, 426−431 (2012).
[2] W. T. Chen *et al.*, "High-Efficiency Broadband Meta-Hologram with Polarization-Controlled Dual Images," *Nano Lett.*, **14**, 225-230 (2014).

Unidirectional propagation of surface plasmons through spin-orbit coupling

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Abstract

Photos with the left or right circular polarization could be defined as opposite optical spins in analogy with electron spins. While in evanescent light field, the surface plasmon processes transverse spin with spin vector normal to the wavevector, in contrast to conventional light. The excited electric field vector of a gold nano-plate irradiated vertically by a beam of circular polarized light keeps the same direction with the polarization of the light. By placing a gold nano-plate near a gold nano-rod, the spatial inversion symmetry is broken, which causes the spin-orbit coupling interaction of the excited surface plasmons between the plate and rod. By means of this interaction, we can control the propagating directionality of the surface plasmons on the nano-rod. This spin-orbit coupling effect provide us new approach for manipulating the direction of propagation of surface plasmons.

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[1] Jan Petersen, Jürgen Volz,* Arno Rauschenbeutel*, Chiral nanophotonic waveguide interface based on spin-orbit interaction of light, *Science*, **346**(6205), 67-71 (2014).
[2] D. O' Connor1 et al. Spin‑orbit coupling in surface plasmon scattering by nanostructures, *Nature communications*. **5**, 5327(2014)

Nanomechanics of polymer nanocoil springs

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Abstract

We present nanomechanics of polymer nanocoil springs. The polymer springs were fabricated by the direct laser writing via two-photon polymerization. Figure 1(a) shows a SEM image of a polymer spring, of which the wire width is 200 nm. The springs, whose wire radius ranges from 350 to 550 nm, were characterized through compression tests using AFM, as shown in the inset (b). We found that even the nanocoil springs followed a linear-response against applied forces, following Hooke's law. Furthermore, the shear modulus of the polymer was increased as the wire radius was decreased from 550 to 350 nm. Our polarized Raman study implied the polymer chains were aligned in the nanowire along the axis. Our findings provide insight into the nanomechanics of polymer materials.

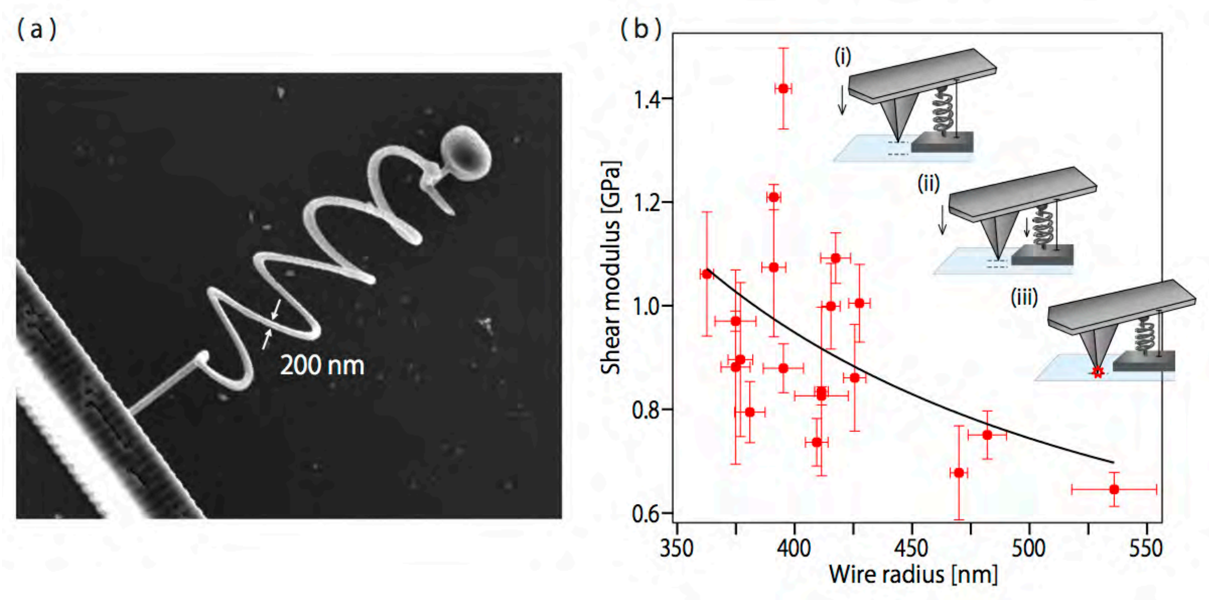

Fig.1: (a) SEM image of a polymer nanocoil spring, of which the wire width is 200 nm. (b) The shear modulus of polymer nanowires as a function of the wire radius. Inset to (b) the process showing compression tests using AFM.

References:

[1] S. Ushiba et al., "Size dependent nanomechanics of coil spring shaped polymer nanowires," *Scientific Reports* (2015) (*in press*).

Transfer matrix method for optical calculations of multilayered topological insulators

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Abstract

Owing to a topological magneto-electric effect, topological insulators (TIs) show unusual electromagnetic response. As a result, TI films and multilayers possess many interesting and unique optical properties which could offer many important potential applications in designing new functional devices. An efficient method for optical calculations on TI multilayers is thus highly desired. Here, a 4×4 transfer matrix method is developed for optical calculations in layered media consisting of TIs. With the framework of this method, optical properties such as reflection and transmission, and magneto-optical effects such as Kerr and Faraday rotations for different TI-layers are calculated. Unusual photonic band structures and band gaps in TI photonic crystals are also revealed.

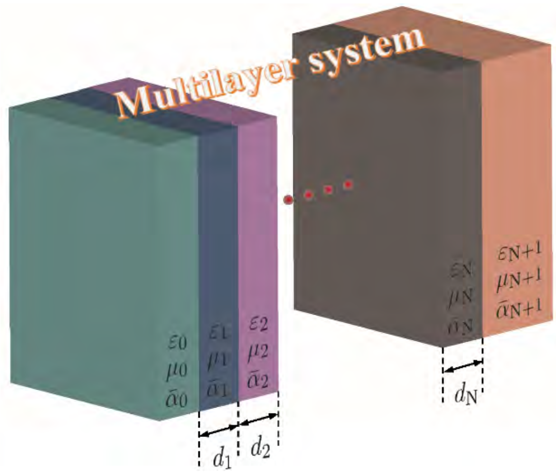

Fig. 1: A stack of *N* layers with different optical parameters $\varepsilon_j, \mu_j, \bar{\alpha}_j$ and thicknesses d_j $(j = 1, 2, 3, \cdots, N)$. The leftmost and rightmost media are denoted by 0 and *N*+1, respectively.

References:

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[2] X. L. Qi, T. L. Hughes, and S. C. Zhang, "Topological field theory of time-reversal invariant insulators", *Phys. Rev. B*, **78**, 195424 (2008).

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Symmetry-breaking induced excitations of anti-symmetric modes in graphene nanoribbons

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Abstract

Graphene nanostructures, such as ribbons and disks, can support localized plasmonic modes in the mid-infrared range, and show many interesting properties including tunability and high confinements of optical near fields [1]. It has been suggested that multi-layer graphene can realize more functionalities for photonic applications over single-layer graphene. For symmetric multi-layer graphene nanoribbons, only symmetric plasmonic resonances can be excited by normally incident light [2]. Here, the effect of structural asymmetry in multi-layer graphene nanoribbons is numerically studied. By introducing structural asymmetry, the anti-symmetric modes can be directly excited by normally incident light as well, as shown in Fig. 1. Our calculations show that the resonant modes with different symmetries possess different features of electric or magnetic dipole resonances. Moreover, we design a structure consisting of multi-layer graphene nanoribbons. With this structure, broadband absorption can be achieved. Our results suggest that asymmetric multi-layer graphene nanoribbons could be potentially used as building blocks for constructing graphene-based metamaterials.

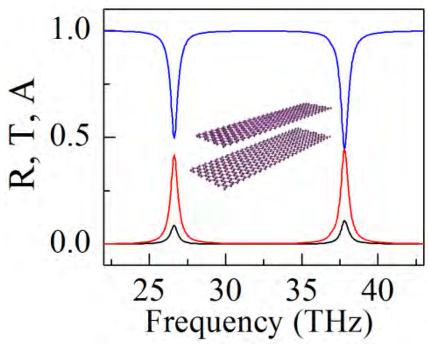

Fig. 1: Calculated spectra for an asymmetric graphene ribbon pair.

References:

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Coherent fluorescence emission by using a 2D photonic–plasmonic crystal slab structure

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Abstract

Emission of a fluorescent dye is strongly influenced by optical environments and can be significantly enhanced through coupling to optical resonances with important technological impacts, e.g., on light emitting devices, medical diagnostics, and biotechnology. Here, we have investigated experimentally the coherence properties of the fluorescence emission assisted by a 2D photonic–plasmonic crystal slab structure. Due to the periodic structure, the leaky hybrid photonic-plasmonic modes with strong optical resonances are supported. With the help of those leaky modes, intense fluorescence emission with high spatial and temporal degree of coherence is achieved. The spectral coherence length, which turned out to be around 10 times longer than the emission wavelength, was directly measured by the classical Young's double-slit interference experiment (Figure 1). The temporal coherence with around 4 times longer coherence time than that of the normal fluorescence emission is also achieved. Our findings provide a new degree of freedom in steering the light beam in applications, such as imaging and sensing.

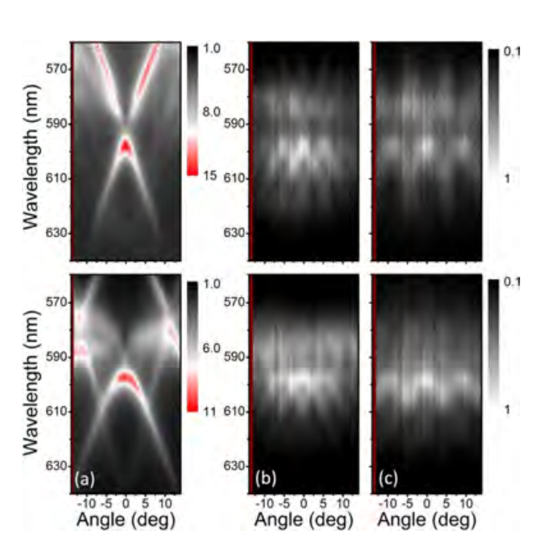

Fig. 1: The experimental results of the emission enhancement (a) and Young's double-slits (b) for the fluorescent molecules on top of the structure as a function of the wavelength and the emission angle.

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Realization of maximum optical absorption cross section via active gain medium

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Abstract

Using an optical nanoresonator, such as a nano-particle, to concentrate and absorb light at the deep subwavelength scale is of both fundamental and practical significance. To quantify the ability of absorption, the absorption efficiency, i.e., the ratio of the absorption cross section of a local resonator to its geometric cross section, is always used. For a deep subwavelength particle, normally, the absorption efficiency is only about 3. To further increase the absorption efficiency of a deep subwavelength particle is challenging. In this work, a general method to control and maximize the absorption cross section of a deep subwavelength particle by using gain material is proposed and verified theoretically. The maximum absorption cross section, $3\lambda^2/8\pi n^2$, is demonstrated in the visible frequency region with a modest gain coefficient of the order of 10^4. Moreover, the method has been further applied to boost the absorption and the local field enhancement of a single graphene nano-ribbon in the mid-infrared region. It would be emphasized that, the proposed method to increase the absorption of a deep subwavelength particle can be straightforwardly applied to other optical materials with great potential applications, such as coherent perfect absorber and optical-to-thermal converter.

Watching dying retinal ganglion cells induced by high concentration of glutamate by using Raman microscopy.

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Abstract

Purpose: Label-free imaging is desirable for elucidating morphological and biochemical changes of neurons in vitro and in vivo. Raman microscopy provides high chemical contrast without requiring preprocessing or fluorescence staining of samples. In the present study, we demonstrated dynamic imaging of molecular distribution in unstained RGC-5 cells during the glutamine-induced death process using Raman microscopy.

Methods: Our originally developed slit-scanning Raman microscopy was used in this study. All the hyperspectral Raman scattering images were obtained with 532 nm excitation from a frequency-doubled Nd: YVO4 laser. Immortalized retinal ganglion cells (RGC-5) were used as a sample in all experiments. Prior to Raman imaging, the cells were seeded on a crystal and cultured. For Raman imaging, the culture was maintained in a Hepes-buffered Tyrode's solution and then was exposed to 400 mM glutamate. Raman scattering images were taken before and after administration of glutamate at 0, 30, 60, 120 minutes. The distribution of cytochrome c was reconstructed from the intensity distribution of the Raman peak at 753 cm-1 at each time points. Other cultures were also stained with Mitotracker or anti-cytochrome c antibody to compare the Raman images of cytochrome c.

Results: We imaged the dynamic molecular distributions of cytochrome c in unstained RGC-5 cells. After the administration of glutamate, the intensity of cytochrome c Raman peak decreased, and the Raman signal distribution was seen to diffuse into the cell body and the nuclear. Raman images resembled the image of immunostaining of Mitotracker and cytochrome c.

Conclusions: We revealed time-resolved distributions of cytochrome c in RGC-5 cells in the process of glutamate-induced cell death without the need for fluorescent labels or markers. Raman microscopy enabled dynamic imaging of molecular distributions in living cells with high temporal and spatial resolution.

Controlling of Graphene Plasmons in Mid-infrared Regime

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Abstract

Recently, graphene plasmons (GPs) have been focused much attention for their extremely large field enhancement and relatively long propagation length. Specifically, surface plasmons in graphene are believed to be a good choice for infrared and terahertz applications. Controlling of GPs in Mid-infrared regime has been a rising open problem.

The properties of surface plasmons localized at the interface between graphene and Kerr-type nonlinear substrates are investigated analytically[1]. The dispersion of GPs can be tuned by Kerr nonlinear effect of the substrate, which open a new route to actively control the GPs in Mid-infrared and terahertz regime.

The spatial switching of near-fields and controllable plasmon induced transparency (PIT) effect of far-fields in mid-infrared regime are proposed in coupled graphene heterogeneous ribbon pairs[2,3]. By using the coupled plasmon modes in graphene ribbon pairs, the electric near-field enhancement and far-field extinction cross section can be actively controlled in graphene ribbon pair as the tuning of the external bias voltage. The tuning of spatial near-fields and PIT effect gives us an active way to control coherent phenomena in plasmonics, which can be learned for further coherent effect control in quantum optics.

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Tunable Photonic Response of Lead Iodide Perovskites metamaterials

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Abstract

We show that the photonic response of lead iodide perovskite films can be tuned by engineered design of metamaterials imprinted directly on the dielectric film.

Metal halide perovskites are increasingly attracting interest as solution-processable materials with outstanding optoelectronic properties[1,2] for applications beyond photovoltaic energy conversion, such as water splitting, light-emitting diodes and tunable, electrically pumped lasers.

One desirable property would certainly be the tunability of the light absorbed or emitted by the perovskite film: while the perovskite's color is tunable by bandgap enginnering and has been widely demonstrated, we here investigate the possibility of tuning via nano-structuring of the perovskite film by Focused Ion Beam milling of metamaterials arrays.

By careful characterization of the films, extrapolation of its optical constants both experimentally and by first principle calculations we are able to design, numerically model and fabricate appropriate metamaterials structures. We observe that small changes in the geometrical features of the metamolecule, its size, shape and milling depth allow us to achieve a very reach spectral response of the film that manifest itself in a very broad range of colors from violet-blue to green.

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Electronic and Optical Properties of Topological Insulators for Plasmonics and Metamaterials

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Abstract

In this work, we employ first-principles density functional theory (DFT) to study the influence of elemental composition on the electronic band structure, optical properties and plasmonic behaviour of seven different topological insulators compounds (both bulk and slab models). Optical permittivities determined from interband transitions of bulk TI materials are calculated based on many-body theory. The contribution of surface carriers to the plasmonic response of the optical permittivity is also studied by extracting the effective mass, surface carrier concentration and in-plane permittivity of slab models with the (111) orientation. Our model allows determination of the Drude and Dirac plasma frequencies, which accurately describe the long-wavelength plasmonic behavior of these materials. We show that the composition of TI compounds has significant influence on the optical and plasmonic properties: increasing the composition of tellurium results in larger negative real permittivity and low optical losses. Among this family of topological insulators with high surface carrier concentration, Bi_2Te_3 has the best Q-factor for surface plasmon polariton throughout the visible to near-infrared spectra range. This shows the potential of first-principle calculations to identify low-loss plasmonic topological insulators, for the design of next-generation broadband metamaterials that could be ultimately tuned by injection of free carriers or by manipulating the spin degree of freedom.

Development of a stimuli-responsive nanocarrier based on the core-shell assembly of a self-immolative polymer embedded in amphiphilic dendrons

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Abstract

Drug delivery system with stimuli-responsive release properties casts much attention recently in the biomedical applications. A large variety of stimuli-responsive nanocarriers have been reported which respond to light, pH, redox agents or enzyme activities. However, few carriers realized a single universal platform applicable for multiple stimuli because each stimulus is converted to different chemical reactions to induce carrier decomposition and guest release.

In this study, we developed a novel stimuli-responsive nanocapsule composed of a fluorogenic self-immolative polymer encapsulated with amphiphilic dendrons. Hydrophobic interior of the self-assembled dendrons could be used to encapsulate multiple guest molecules. The core polymer undergoes head-to-tail disassembly through sequential fragmentation in response to the head trigger elimination by specific stimuli, accompanied with the release of fluorescent reporters and guest molecules. We prepared self-immolative polymers responsive to base or enzyme activities. Self-assembly of these polymers and amphiphilic dendrons resulted in the formation of supramolecular nanocapsules with core-shell structures. Intermolecular hydrogen bonds between polymer side chains and focal head of the dendrons play crucial roles in the capsule structures. Guest loading and triggered-release properties of the nanocapsules were evaluated using nile red as an environment-sensitive fluorescent reporters. The present nanocapsules could be used as a new drug delivery agent with autonomic release properties at the targeted tissue / organs.

Toward achieving super-resolution in linear and nonlinear Raman microscopy

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Abstract

Recent developments in optical microscopy have pushed the limits of spatial resolution to unprecedented levels allowing the visualization of fine details of the sample that are unobservable using conventional optical imaging methods. A common strategy to achieve super-resolution is to exploit the excitation and emission properties of fluorescence probes. Since most of these schemes require a fluorescence probe, these super-resolution techniques could not be readily applied to label-free optical microscopies. One such example is Raman microscopy, a vibrational spectroscopic imaging technique offering high sensitivity and chemical selectivity but with a spatial resolution limited by the wave nature of light. Here, we present two approaches toward achieving super-resolution in linear and nonlinear variants of Raman microscopy.

In the linear variant given by slit-scanning Raman microscopy, a structured light pattern is introduced along the line illumination producing the Moiré effect, which effectively expands the spatial frequencies resolvable by the optics [1]. In the nonlinear variant given by coherent anti-Stokes Raman (CARS) microscopy, the saturation of the CARS signal is utilized to effectively produce a reduced point spread function at harmonic frequencies, which is extracted by a temporal modulation and demodulation scheme [2]. Therefore, both approaches result in the enhancement of the spatial resolution. The effectiveness of the above techniques is demonstrated using various samples ranging from inorganic materials to biological tissues, and thus indicates the potential benefit of super-resolution to various Raman imaging applications.

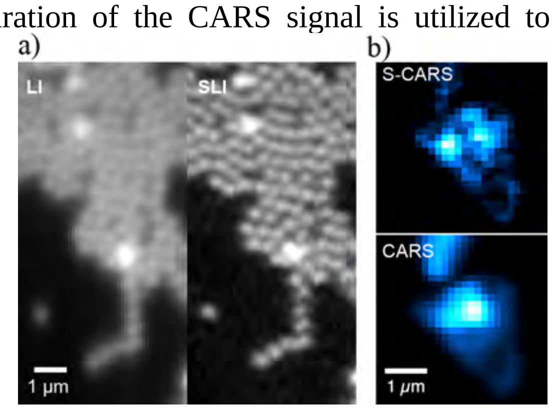

Fig. 1: a) Structured line illumination (SLI) vs LI Raman images of polystyrene beads. b) Saturated CARS (S-CARS) vs CARS images of diamond crystal.

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In Situ Generation of Active Ni Species within an Acidic Resin for H2 Evolution under Visible-light Irradiation

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Abstract

In the past decade, the development of a H_2 production system driven by heterogeneous catalysts under visible light irradiation in an aqueous medium has been desirable in the effort towards environmentally friendly artificial photosynthetic methods. In this study, we found that the acidic resin bearing $-SO_3^-$ functional groups within its macroreticular structure acts as an efficient support for *in situ* formation of a noble-metal-free Ni-based catalyst responsible for photocatalytic H_2 production from water.[1] Characterization by means of XAFS revealed that simple ion-exchange of the resin with a trinuclear Ni complex, $Ni(NiL_2)_2Cl_2$ (L=β-mercaptoethylamine) (Fig. 1A), affords monomeric Ni(II) species involving β-mercaptoethylamine and aqua ligands in an octahedral coordination geometry (Fig. 1B), which is easily transformed into real active species containing a TEOA ligand during the initial induction period of the photocatalytic reaction (Fig. 1C). Such *in situ*-generated Ni species offer a simple and efficient photocatalytic system whose activity is five times greater than that of its homogeneous counterpart, enabling efficient H_2 production when xanthene dye is employed as a visible-light-responsive photosensitizer. Moreover, leaching and agglomeration of the active Ni species were not observed, and the recovered catalyst could be recycled without significant loss of activity.

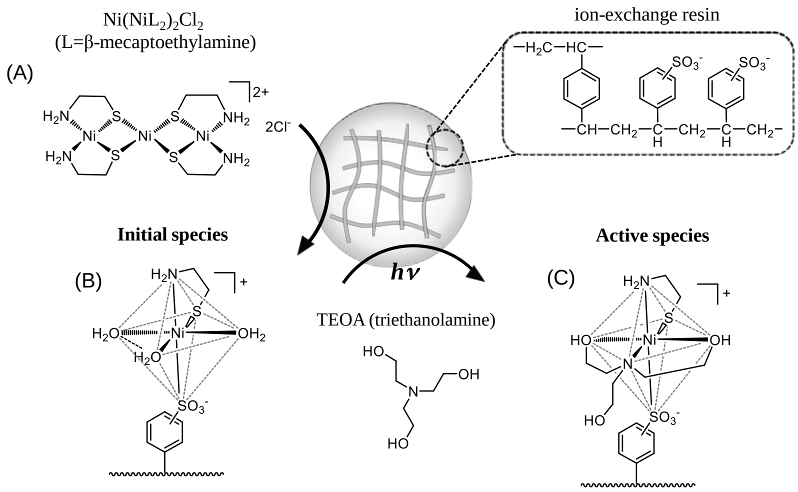

Fig. 1 Schematic illustration of (**A**) $Ni(NiL_2)_2Cl_2$ (L=β-mecaptoethylamine) into (**B**) proposed structure of fresh $Ni_{complex}$/resin and (**C**) in-situ generated active species during the photocatalytic reaction.

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Wastewater Treatment By Plasmonic Enhanced Optical Disk Reactor

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Abstract

A process of growing large-area plasmonic-nano-particles-decorated ZnO nanorods on the polycarbonate optical disk substrate was developed, while a corresponding photocatalytic rotational reactor was fabricated. Hydrothermal process was adapted to grow ZnO nanorods perpendicular to the optical disk substrate at relatively lower temperature [1]. The optical disk substrate has advantages of durable property in fast rotation and high impact-resistance. The plasmonic nano-particles, in this case, silver nano-particles, were deposed on the ZnO nanorods by direct sputtering. The morphology of ZnO nanorods and plasmonic nano-particles was investigated by Scanning Electron Microscope (SEM). The photocatalytic activity of the sample was evaluated by the degradation of methyl orange (MO) as a model compound in aqueous solution, and the decomposition rate of MO molecules is monitored by the optical spectroscopy measurements. In the optimized condition, less than 10% of the MO remained in the aqueous solution after a 20-minute treatment in the rotational reactor with our sample [2].

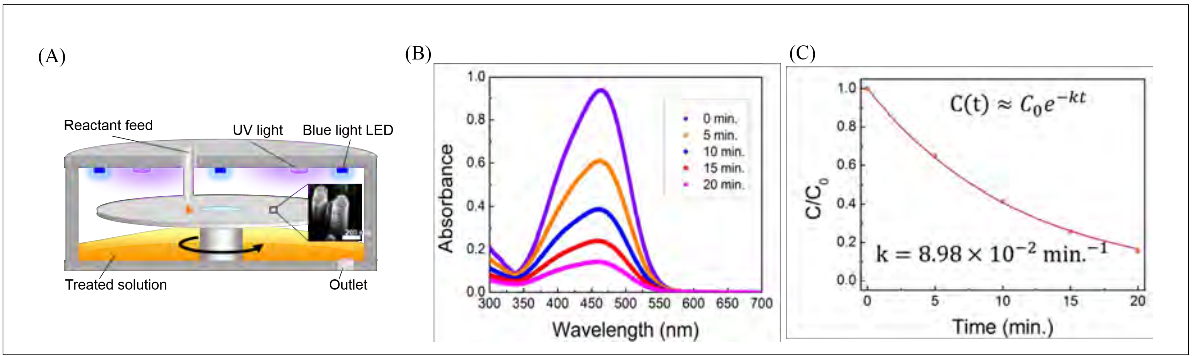

Fig. 1: (A) The schematic of the reactor structure and insert image is the SEM image of the ZnO nanorod coated Ag nanoparticles. (B) Optical absorbance spectra of MO solution at different treated time. (C) Decomposition rate curve of MO solution treated by optical disk reactor.

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Multiple Polarization State Generator Based on Aluminum Metasurface

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Abstract

Metasurfaces show the abilities to manipulate the phase and polarization of electromagnetic waves. Its optical properties are related to their geometrical structures instead of their constituent material. These advances have led to flat optical devices such as quarter waveplate, half waveplate [1]. In addition, the majority of previous works about polarization conversion are employed mostly in near-infrared because phase modulation is difficult to be realized in visible spectrum for gold and silver. Interestingly, aluminum with higher plasma frequency has recently been studied to yield surface plasmon resonances across a broader range of the spectrum spanning from visible to UV [2]. Here, we present both numerically and experimentally an aluminum-based reflective polarization state generator to produce six kinds of polarizations with high efficiency in the visible spectrum as shown in figure 1.

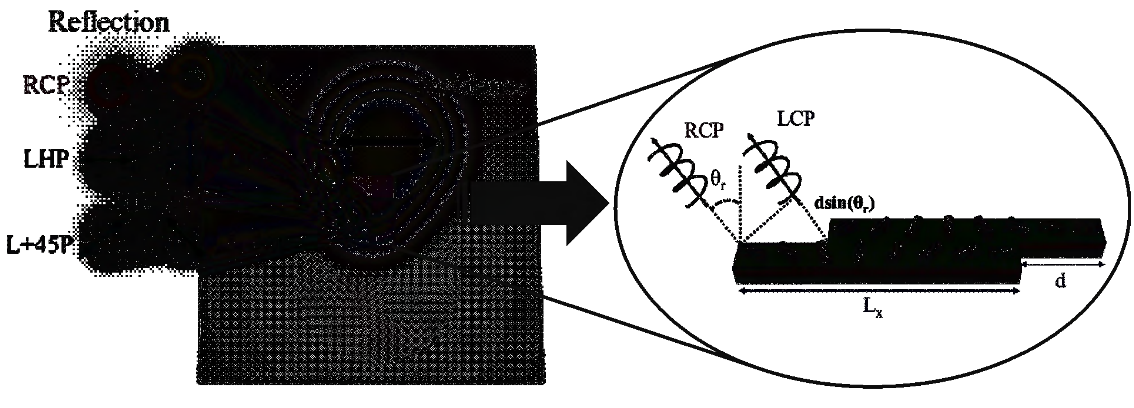

Fig. 1: Schematic of the polarization state generator.

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Controlling the fraction of luminescent sites in Eu-doped GaN by compressive strain

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Abstract

We have reported the first demonstration of a Eu-doped GaN (GaN:Eu)-based red light-emitting diode (LED) [1]. To obtain higher light output, it is necessary to increase the emission from a specular luminescent site, referred to as OMVPE 7, with highly efficient energy transfer. Recently, in comparing GaN:Eu grown on a GaN bulk substrate with that on a sapphire substrate, we found that the photoluminescence (PL) spectrum in GaN:Eu was affected by compressive strain [2]. In this contribution, we investigated effects of the compressive strain on the PL properties using AlGaN/AlN superlattices (SLs).

The samples were grown by organometallic vapor phase epitaxy on sapphire substrates. The growth sequence of the samples was initiated by the growth of an undoped GaN layer, which was followed by 10 pairs of AlGaN/AlN SLs, a 300-nm-thick Eu,O-codoped GaN (GaN:Eu,O) layer, and a 20-nm-thick GaN . The compressive strain was controlled by Al composition in AlGaN. Three samples were prepared as follows; GaN:Eu,O without SLs and GaN:Eu,O grown on SLs with Al compositions of 10 and 25% (hereafter referred to as sample A, B and C, respectively).

The in-plane compressive strains estimated by Raman spectroscopy were −0.18, −0.36, and −0.72% for samples A, B, and C, respectively. Eu-related PL spectra of the samples with different in-plane strains were shown in Fig. 1. The emission peaks due to OMVPE 7 observed at around 1.997 eV were increased with the in-plane compressive strain. To investigate the mechanism of the enhancement of the emission intensity from OMVPE 7, PL and time-resolved PL under resonant excitation were carried out. The fraction of OMVPE 7 was estimated using the lifetime and excitation cross-section [2]. The fraction was increased with increasing compressive strain, which was one of the reasons of the enhancement of PL intensity of OMVPE 7. To investigate the change of energy transfer efficiency, the excitation power dependence of PL intensity of OMVPE 7 were measured. The PL intensity was always higher in sample C than sample A. Therefore, the PL intensity enhancement of OMVPE 7 is also owing to the improvement of energy transfer efficiency.

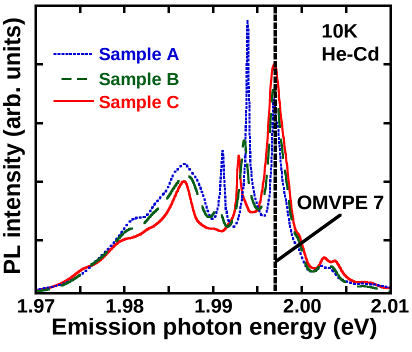

Fig. 1 PL spectra in the samples with different in-plane strains.

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Enhanced nonlinear refractive index and absorption of C-rich Si_xC_{1-x} saturable absorber for passively mode-locked fiber laser application

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Abstract

The silicon carbide (Si_xC_{1-x}) material has many advantages to employ optoelectronics devices due to its tunable bandgap by changing its composition ratio [1]. Moreover, the Si_xC_{1-x} is also used to the high-temperature and high-power electronics due to its superior thermal stabilities and chemical inertness. There are few reports emphasized on the nonlinear optical application. In recent years, the graphene as saturable absorber could be damaged under higher intra-cavity power of fiber laser to degrade the mode-locking performance because of its superior thermal stabilities. The Si_xC_{1-x} is a candidate for promoting the damage threshold of the saturable absorber. Moreover, the carbon content of Si_xC_{1-x} film could be detuned by changing the fabrication parameter to make more carbon bonds in Si_xC_{1-x} film those will contribute to the ultrafast optical nonlinearity [2]. In this work, the nonlinear optical properties of the plasma-enhanced vapor deposition (PECVD) grown carbon-rich (C-rich) Si_xC_{1-x} films as the storable absorber are characterized to passively mode-lock the Erbium-doped fiber laser (EDFL).

The PECVD grown C-rich Si_xC_{1-x} film based saturable absorber is synthesized to passively mode-lock the EDFL. When increasing the $[CH_4]/[CH_4+SiH_4]$ fluence ratio of 92%, the C/Si composition ratio of Si-rich Si_xC_{1-x} films is as high as 1.83. The higher $[CH_4]/[CH_4+SiH_4]$ fluence ratio during the PECVD process facilitates the growth of C-rich Si_xC_{1-x} films with the larger C/Si composition ratio, which provides plentful graphite-like and diamond-like C-C bonds precipitated in C-rich Si_xC_{1-x} film. The nonlinear absorption coefficient and refractive index of C-rich Si_xC_{1-x} film are -2.2×10^{-6} cm/W and 1.85×10^{-11} cm^2/W, respectively. By directly covering the C-rich Si_xC_{1-x} film on the connector end-face of the SMF patchcord, the passively mode-locked EDFL delivers a pulsewidth as short as 470 fs and a corresponding spectral linewidth of 5.13 nm to give a time-bandwidth product of 0.319 at a repetition rate of 29.89 MHz.

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Numerical demonstration of reconfigurable metal-air -metal plasmonic slow light structures

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Abstract

Slow light has various of potential applications in optical nonlinearities, switching, storage and quantum optics. However, it is very challenging for demonstrating broadband tunable single modal slow light devices experimentally and numerically at room temperature. Gan *et al.* have proposed graded metal grating for realizing broadband slow light in terahertz (THz), telecommunication and visible light domain [1-3]. However, it is very difficult for achieving wide tuning range or releasing slow light in fixed structures, which rigidly restricts potential applications in slow light optical buffer and storage.

In this study, a graded metal-air-metal (MAM) grating is proposed (Fig. 1(a)). Depending on gradually changed thickness of air layer, effective refractive index(N_{eff}) and dispersion relation are varied gradually, resulting in trapping wide band of frequencies visible light at different position of plasmonic grating. Deriving from one-dimensional periodic layered media optical theory, N_{eff} dependence on thickness of air layer and dispersion relation are calculated by finite element methods (FEM). Then, by utilizing finite difference time domain (FDTD) method, different frequencies of trapped light are analyzed in continuous wave (CW) condition. Also, group index and field intensity are calculated in time domain with the condition of pulsed source excitation. Additionally, one of highlight in this study is reconfigurability of MAM structure. According to the electrostatic microelectromechanical systems (MEMS) actuator model, the thickness of air layer can be tuned to 2/3 of initial value with applied voltage (Pull-in phenomenon as shown in Fig. 1(b)), resulting in a great change in dispersion relation. Numerical results show the potentials for releasing trapped light, trapping frequencies tunability and wavelength selectivity.

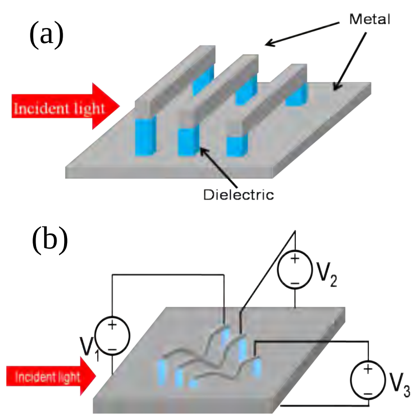

Fig. 1(a) Schematic view of silver-air- silver grating and **(b)** Pull-in phenomenon while voltage is applied.

References:
[1] Q. Gan *et al.*, *Phys. Rev. Lett.* **100**, 256803 (2008).
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Nano-electromechanically tunable plasmonic resonator

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Abstract

Nanometallic (that is, plasmonic) structures have the capability to highly confine optical fields at nanometer length scales. [1] This ability makes them attractive for use in many applications, such as ultra-compact opto-electric devices and integrated chemical/biological sensors. For these applications, it is desirable to electrically and dynamically tune optical resonant properties of plasmonic structures. Here, we demonstrate electromechanically controlled plasmonic resonances in visible wavelengths. By employing a suspended metallic nanowire (NW) over a metallic film,[2] both the electromechanical motion and the plasmonic resonance excitation can be achieved within the individual nanostructure. In this study, we show how the optical properties of such a nanostructure can be modulated by applying a voltage.

Figure 1a illustrates schematics of the electromechanically controlled plasmonic NW. A suspended gold NW is pull down by the electrostatic force, closing the metallic gap. This electromechanical response dramatically changes the resonant properties of the NW. Figure 1b shows a SEM image of a 500 nm wide and 155 nm thick gold NW suspended over a gold film coated by a 20 nm thick aluminum oxide. An initial gap size is 225 nm. This suspended NW was fabricated by a pick-and-place method[2].

To investigate the optical properties, we measured scattered light under the dark-field white light illumination while applying a voltage. Figure 2a shows scattering images of the NW at 0 V and 23.5 V. The scattering light of the NW was changed by the applied voltage. Figure 2b shows experimental scattering spectra in the NW center with varying the applied voltage. With increasing the applied voltage, a scattering peak arising from a gap plasmon resonance appears at a wavelength of 710 nm. Figure 2c shows scattering spectra simulated by COMSOL Multiphysics. Experimental scattering spectra qualitatively agree with simulated spectra. These results show clear evidence of the dynamical modulation of plasmonic resonant properties.

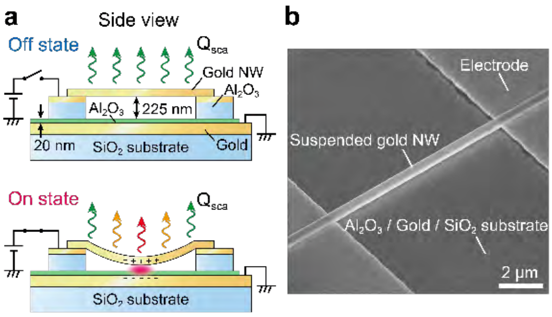

Fig 1. (a) Schematic of a nano-electromechanically tunable plasmonic resonator. (b) Oblique SEM image of a suspended gold NW.

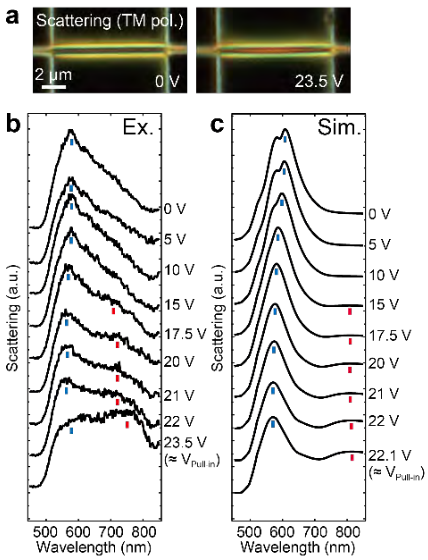

Fig 2. (a) Dark-field images of the NW for different applied voltages. (b,c) Experimental (b) and simulated (c) scattering spectra for different applied voltages.

Reference

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Plasmon-based CQED: From weak to strong coupling

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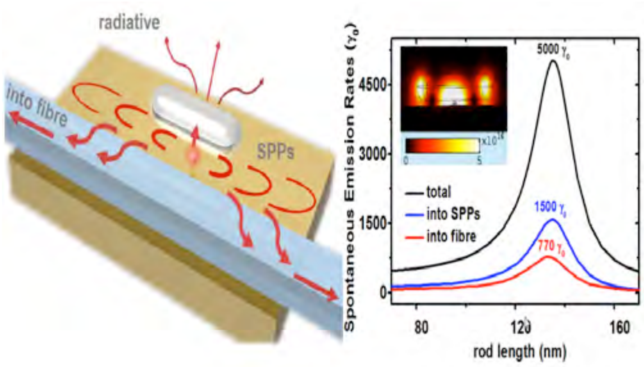
Abstract

Custom-designed plasmon nanostructures with an ultrasmall optical mode volume enable to enhance the interactions between the light and the emitter, which open the door to plasmonic cavity quantum electrodynamics. Compared with other photonic structures, plasmon nanostructures possess large and anisotropic Purcell factors, which will greatly modify the quantum interferences of coherently prepared quantum system, such as modification of spontaneous emission spectra [1].

Recently, by combining the advantages of ultrahigh emission rates in gap plasmon system with high extraction into low-loss nanofibers, we theoretically demonstrate the efficient emission and one-dimensional nanoscale guiding in metallic nanorod-coupled nanofilm structures coupled to dielectric nanofibers [2], as shown in the Fig. By placing the resonant Ag nanorod into the evanescent vacuum created by a single-mode nanofiber, we demonstrate large enhancement of coupling coefficient and efficiently nanoscale guiding of emitted photons with the Rabi splitting in spontaneous emission spectra [3]. Plasmonic nanostructures provide a quantum interface to study the CQED in nano-photonics, which will have an important impact on on-chip quantum information processing.



Schematic diagram of single quantum-emitter coupled to gap plasmon system with a designed nanofiber.

References:
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Polarization-independent directional launchers of surface plasmon polaritons

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Abstract

Surface plasmon polaritons (SPPs) are considered as one of the promising candidates of the next-generation information carries due to their remarkable capabilities of subwavelength field confinements and strong field enhancements. However, due to the inherent polarization dependence of the SPPs (TM polarization), only the p-polarized incident light can be coupled to the SPPs. The energy and information of the s-polarized incident light are completely lost. Here, we propose to fabricate a defect aperture in a subwavelength plasmonic waveguide to realize the directional launching of the SPPs from both of the p- and s-polarized incident light, as depicted in Fig. 1. The plasmonic waveguide only supports a single SPP mode. Due to the influence of the defect, hot spots emerge at the sharp corner. The radiative field from the hot spots can be coupled to the nearby plasmonic waveguides. Consequently, both of the p- and s-polarized free-space light can be directionally coupled to the single SPP mode. By adjusting the geometry parameters of the defect, both of the bidirectional and unidirectional SPP coupling from the two orthogonal linear-polarization incident beams are experimentally demonstrated. In the bidirectional launching case, the polarization-encoded information of the incident light is preserved. Therefore, the SPP coupling is independent on the polarization states of the incident light. The polarization-free coupling of the SPPs is of importance for the all-optical information processing in integrated plasmonic circuits.

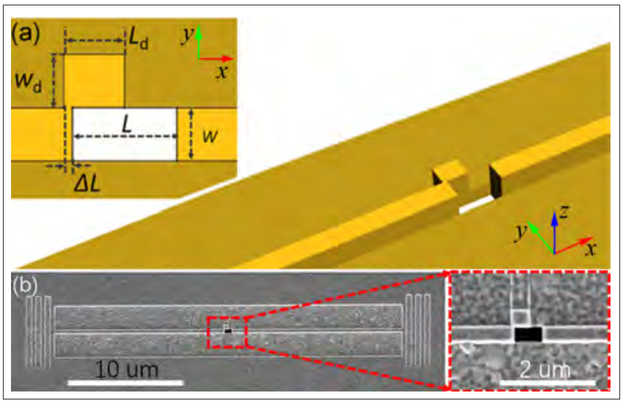

Fig. 1: Defect aperture fabricated in a subwavelength plasmonic waveguide. (a) Schematic of the defect aperture in the subwavelength plasmonic waveguide. (b) SEM images of the defect apertures fabricated in the subwavelength plasmonic waveguide.

References:

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On-chip Plasmon-Induced Transparency by a Single Composite Nanocavity side-coupled with Plasmonic Waveguide

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Abstract

Plasmon-induced transparency which can reduce the group velocity of light and confine light into subwavelength scale regions play an important role in fields of nonlinear optics and integrated photonic devices. Various configurations of plasmonic microstructure have been developed to construct plasmon-induced transparency, such as using metamaterials, plasmonic resonators, and metallic nanoparticle arrays. However, in these approaches, the light signals are illuminated in the direction perpendicular to the upper plane of plasmonic circuits, which is not suitable to directly applied in the practical integrated photonic circuits. Here, we experimentally demonstrate an ultrcompact chip-integrated PIT in a single planar plasmonic composite nanocavity in plasmonic circuits. We adopted a plasmonic composite nanocavity consisting of two crossed nanogrooves side-coupled a bus plasmonic waveguide. Small lateral dimension of 600 nm is obtained for the composite nanocavity. And dual transparency windows are obtained coated with a PMMA layer. This paves a way for the realization of chip-integrated nanoscale photonic devices.

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Control of Caesium Atomic Spectrum with a 2D Plasmono-Atomic Metamaterial

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Abstract

We present the first experimental demonstration of a 2D atomic-plasmono metamaterial interface. Using sub-Doppler reflective spectroscopy with tunable diode laser and hole-burning frequency reference, we do a surface sensitive and MHz resolution probe on the interface of the hot caesium atomic vapour and metallic metamaterials. We reports strong modification of D2 line of Caesium (62S1/2 – 62P3/2) by the atom-plasmonic coupling with metamaterials. The modification depends on the detuning between the atomic lines and the dipole plasmonic resonances of the nanostructures, which are typically a million time wider. We extract via precise analysis of the atomic line profile, a non-zero complex Van der Waals coefficients for atoms on metamaterial interface. This result provides information on the surface properties of atom-metamaterial interface and opens up the possibility of using atomic system for characterization of plasmonic behavior in MHz resolution.

Localization and propagation of visible range plasmons in $Bi_{1.5}Sb_{0.5}Te_{1.8}Se_{1.2}$ topological insulator

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Abstract

Chalcogenide topological insulators were recently identified as plasmonic materials with highly conductive surface states and negative bulk permittivity [1]. Here we report direct near-field imaging of localized and propagating visible range plasmons in $Bi_{1.5}Sb_{0.5}Te_{1.8}Se_{1.2}$ [2,3] nano and micro structures. We see a clear evidence of dipolar and higher order surface plasmon modes with well-defined field amplitude and phase profiles at optical wavelength where bulk permittivity is positive and therefore plasmonic response can only be attributed to the conductive surface states of the material. This result provides an important and independent verification of plasmonic properties of the topologically protected surface state in this chalcogenide semiconductor.

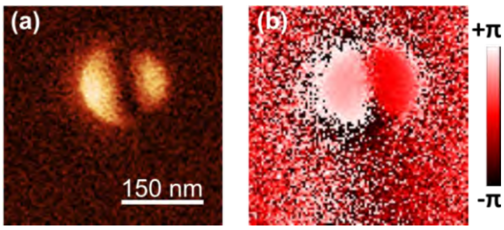

Fig. 1: Near-field amplitude (a) and phase (b) images of the topological insulator nanodisk at λ = 633 nm.

References:

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Sub-diffraction Localization of a Single Photon

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Abstract

We report the first experimental demonstration of super-oscillatory behaviors in single photon regime, where the quantum wave-function of a single photon can be localized into length scale much smaller than the smallest wave length contained in its Fourier spectrum [1,2]. Both classical and quantum measurements are carried out, where we use either a continuous laser or a single photon source from a pair of correlated photons generated by spontaneous parametric down-conversion in nonlinear crystal. We direct one channel onto a specially designed one-dimensional meta-lens consisting of multiple parallel slits, which serves as a binary mask to diffract the incoming light causing it to interfere behind the mask. In the focal plane of the lens, a hot-spot with FWHM of ~0.4λ was achieved in the super-oscillation region, undoubtedly revealing sub-wavelength localization of quantum wavefunctions of single photon.

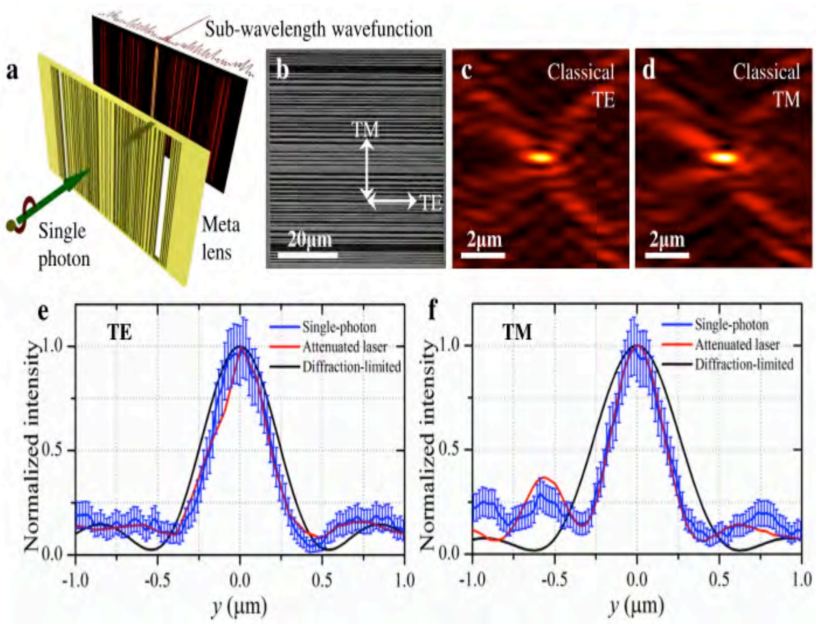

Fig. 1: (a) Schematic configuration of single photon super-oscillation; (b) SEM image of meta-lens; Classical measurement of the sub-diffraction hotspots for (c) TE and (d) TM polarizations; Normalized probability of the super-oscillatory wavefunctions for (e) TE and (f) TM, which are recorded by a single-photon detector.

References:
[1] N. I. Zheludev, "What diffraction limit?" *Nat. Mater*. **7**, 420-422 (2008).
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Quantum Coherent Absorption of Plasmons With Entangled Photons

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Abstract

The field of quantum plasmonics has been focused mostly on studying the conservation of quantum states of light in plasmons. Recent findings show that plasmons conserve superpositions of polarization states of light [1] and two photon interference [2]. These works define a plasmonic platform onto which focus can be redirected to the opposite outlook: studying the conservation of plasmonic material properties interacting with quantum states of light. Here we show nonlocal "remote control" of coherent absorption in a plasmonic metamaterial by using entangled photons. For a 'signal' photon going through a quantum eraser interferometer, we can change the state "at a distance" by making a measurement on the nonlocal correlated 'idler' photon, and as a result dictate if rather or not the single photon in the interferometer will interfere with itself. We advance from our previous work on demonstrating coherent perfect absorption in a subwavelength thin plasmonic metamaterial [3] by adding polarization entangled photons for the purpose of actively switching on/off plasmonic absorption.

References:

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[3] T. Rogers et al., "Coherent perfect absorption in deeply subwavelength films in the single photon regime", Nat. *Commun.*, 6, 7031 (2015).

Study on effect of dielectric environment on grapheme plasmon properties

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Abstract

Graphene plasmon is a collective oscillation of free carriers in graphene in accordance with the electromagnetic field in free space. Graphene plasmons have superior properties as follows: ultrahigh electromagnetic confinement, static electric tunability, very low intrinsic damping and so on. These unique properties make graphene plasmon a promising candidate for a series of plasmon devices, such as low-loss waveguides, sub-wavelength metamaterials, biological and chemical sensors. As a single-atom thick film, graphene is very sensitive to the substrate dielectric environment. In order to systematically study the effects of substrate dielectric environment on the properties of graphene plasmons, we simulate the graphene plasmons at varied substrates by using finite difference time domain. .

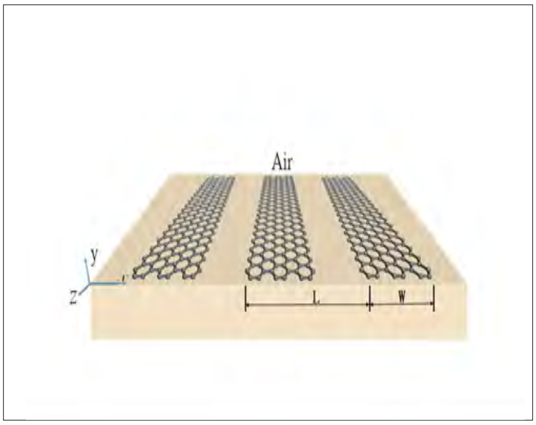

Fig. 1: Arrays of grapheme nanoribbons at varied substrates

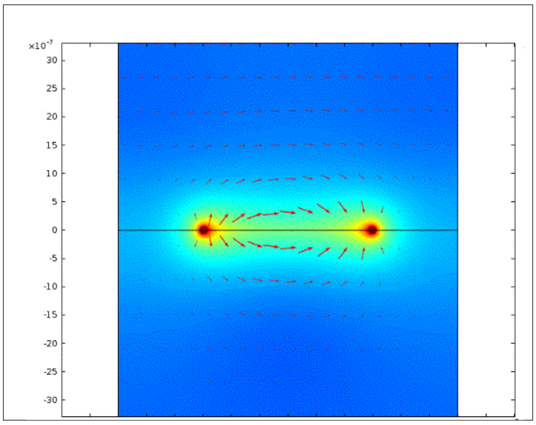

Fig. 2: FDTD simulation of grapheme nanoribbons

References:
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[2] Brar V W, Jang M S, Sherrott M et al.,*Nano Lett*.13(6): 2541-2547(2013)

Plasmonic Optical Trapping by Elliptical Nanohole for Chiral Analysis Using Raman Optical Activity

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Abstract

Chiral molecules show slightly different absorbance of left- and right-handed circularly polarized light (CPL). Such circular dichroism (CD) effect can be used for the characterization of molecular chirality. Unfortunately, CD is usually very weak due to the mismatch between the pitch of CPL helix and the size of molecular chiral domain. To overcome such problem, we have designed and fabricated plasmonic elliptical nanoholes (Left panel, Fig. 1) to create the concentrated chiral optical near field based on localized surface plasmonic resonance (LSPR). The optical near field generated in our elliptical

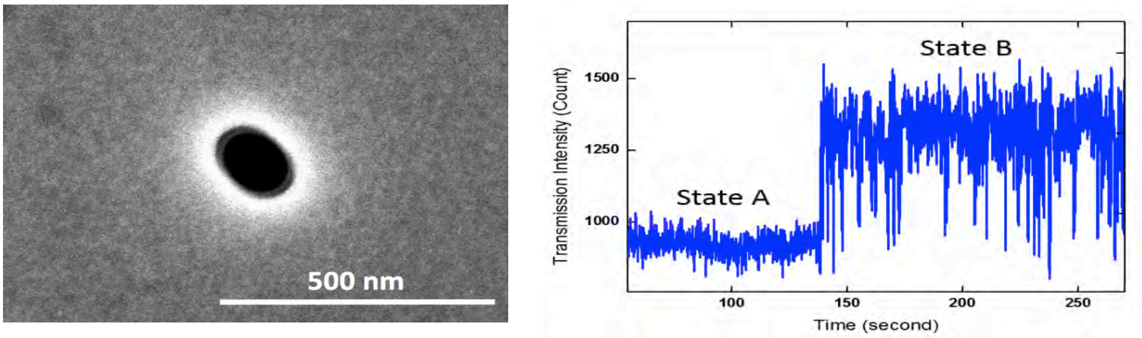

Fig. 1: (a) Scanning electron microscope (SEM) image of the elliptical nanohole on a single-crystalline gold film. (b) Time trace of transmission intensity showing the trapping of a 20 nm polystyrene sphere. State A and B are the light transmission through the hole without and with the particle trapping, respectively.

nanohole can also provide trapping force to isolate, immobilize and manipulate the target nanoparticles [1]. By controlling the polarization of the incident light, the chirality of the optical near field can be easily switched. When the object is trapped in the elliptical nanohole, the local refractive index changes dramatically, resulting in the increase of transmission intensity (Right panel, Fig. 1). By measuring the Raman scattering spectrum simultaneously, we can then obtain the information of the chemical composition of the target. Since the optical near field in the hole is circularly polarized, the Raman scattering also reveal the chirality of the target due to the Raman optical activity (ROA). Currently, we are working on the ROA of single polystyrene spheres coated with Fluorescein isothiocyanate (FITC) and bovine serum albumin (BSA). Our method has potential to achieve chiral chemical analysis on ultralow concentration. We anticipate applications in single protein analysis.

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Unidirectional Beaming of Photoluminescence from Gold Yagi-Uda Nanoantenna

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Abstract

Yagi-Uda (YU) antenna is a promising tool for highly unidirectional beaming of electromagnetic wave. The first YU nanoantenna that work in optical frequency was demonstrated by Alberto G. Curto et al. in 2010 [1], which the antenna is driven by a quantum dot that placed near the resonance feed. However, it is challenging to locate the quantum emitter to the resonance feed of YU antenna with nanoscale precision. Indeed when entering optical regime, photons with such high energy can induce the electronic transition in material which allow metallic nanostructures to emit photoluminescence (PL). The PL of metallic nanostructure is an ideal local light source to drive YU antenna itself due to the nature of broadband, non-blinking and non-bleaching.

Here, we demonstrate for the first time a gold PL driven YU nanoantenna as a localized unidirectional light source. We study the back-focal plane PL images of gold YU nanoantennas. We successfully observed unidirectional beaming of 650 nm wavelength PL from a gold YU antenna when it is excited by 532 nm laser on the resonance feed. The PL wavelength of the YU antenna is designable due to the modulation effect of PL by localized surface plasmon resonance modes. Thus, we have also design YU antenna that emitted PL of 850 nm wavelength at near IR region, as shown in Fig.1. The experimental results are confirmed by FDTD simulations and dark-field scattering spectra of each single YU element. In addition, we show a novel design of L-shape YU antenna with two working frequency that guide photoluminescence of two different wavelength toward two orthogonal direction. The PL of gold YU nanoantenna is an ideal unidirectional light source that can be applied in wide field including optical circuit and quantum photonic.

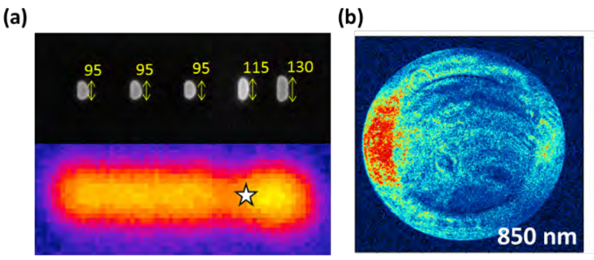

Fig 1. (a) SEM image (top) and confocal scanning PL image (bottom) of YU antenna. The star symbol indicates where the laser parked for back-focal plane PL image measurement. (b) Back-focal plane PL image of 850nm wavelength.

References:
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Imaging method for nanomagnet with magnetic multi-layer with magnetic force microscopy

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Abstract

Recently, magnetic logic devices such as a magnetic quantum cellular automata (MQCA), are gathering attention because of its low power consumption. In general, nanomagnets in MQCA are composed of single magnetic layer[1]. Therefore, the integration density of the MQCA is limited by the size of the nanomagnet. One possible approach to achieve higher integration density is using a magnetic multilayer for the MQCA. However, there is no conventional method for detecting a magnetization direction of the magnetic multilayer individually. Here, we propose and demonstrate magnetic force microscopy (MFM) technique for nanomagnet with magnetic multilayer. With a y-z scan of MFM, it is possible to detect the magnetization direction of the individual magnetic layer in nanomagnet.

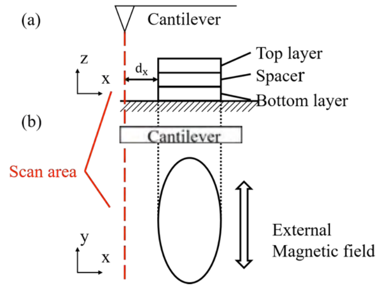

Fig. 1. Schematic illustration of nanomagnets and cantilever. (a) front view and (b) top view.

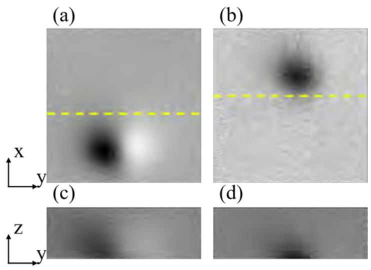

Fig. 2. MFM image of nanomagnets. (a),(b) x-y scan and (c), (d) y-z scan.

For a magnetic force microscope, we used commercially available hardware (SPA-300HV) and originally developed controller with LabVIEW FPGA/Real time OS. For MFM tip, we coated Co-17at.%Pt (80 nm) on a commercially available cantilever (SI-DL40) with ion-beam sputtering method. For a sample, cylindroid nanomagnet Au(3 nm)/Ni-20at.%Fe(20 nm)/SiO_2(20 nm)/Ni-20at.%Fe/Si-subst. is fabricated with electron-beam lithography, ion-beam sputtering method and liftoff technique (See Fig. 1). To control the magnetization of the magnetic multilayer, we use external magnetic field along the short axis of the cylindroid. Fig. 2 (a) and (b) show conventional MFM images (x-y scan MFM images) of nanomagnet under external magnetic field of 25 kA/m and 0 kA/m, respectively. Because of a difference of the magnetization of nanomagnet, the contrast of the MFM image in Fig. 2(b) becomes lower than that in Fig. 2(a). However, with x-y scan images it is difficult to determine the magnetization of each magnetic layer in nanomagnet. Fig.2 (c) and (d) show y-z scan MFM images of nanomagnet at the dashed line in Fig.2 (a) and (b), respectively. With this method, it is possible to measure an individual magnetization of magnetic multilayer in nanomagnet.

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Shift register based on magnetic quantum cellular automata

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Abstract

Recently, nanomagnet logic device such as a magnetic quantum cellular automata (MQCA)[1] has been gathering attention because of its low power consumption. For realization of MQCA circuit, it is necessary to control a data flow direction between MQCA gates. However there is no element to control the data flow direction. Here, to control a data flow direction, we experimentally demonstrate a shift register based on MQCA.

For MQCA shift register, nanomagnets Au(3 nm)/Ni-20 at.%Fe(20 nm)/Si-subst. are fabricated with electron-beam lithography, ion-beam sputtering method and lift-off technique (See Fig. 1). To read and write digital information, we use magnetic force microscopy (MFM) with originally developed controller. For MFM tip, we coated Co-17at.%Pt (80 nm) on a commercially available cantilever (SI-DL40) with ion-beam sputtering method. Initial magnetic states are created by applying an external magnetic field to the sample. After the initialization, digital information was written by the MFM tip. To execute a bit shift, external magnetic field (clock-field) was applied to the sample (See Fig. 1). After the clock field was applied, we check the operation result with constant height mode MFM. With this method, we confirmed that the shift register shown in Fig 1(a) and Fig 1(b) works correctly under the clock field with specific strength. With these shift register, an MQCA circuit with multiple gate will be demonstrated in a near future.

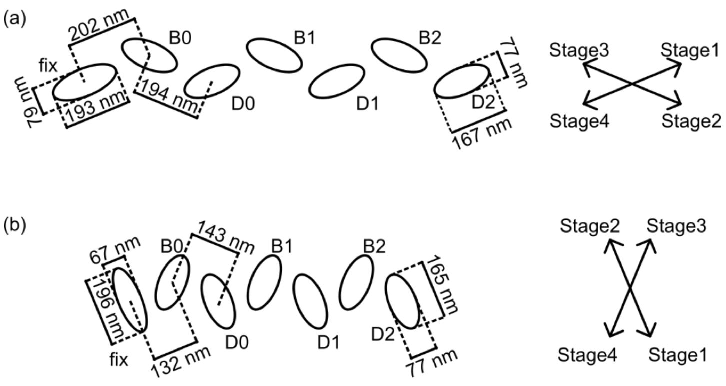

Fig. 1 Schematic illustration of MQCA shift-register with (a) feromagnetically coupled buffer dots and (b) antiferomagnetically coupled buffer dots.

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Tunable optical deflector based on a Fresnel-type liquid crystal device

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Abstract

The electric-field tunability of the refractive index of liquid crystals makes them attractive for various tunable optical devices, such as filters[1] and lenses[2,3]. One of the challenges for realizing deflectors based on liquid crystals was that the optical tilt angle, which is determined by the birefringence of the liquid crystal and the device thickness, was too small for practical use in conventional device structures. We have recently developed a Fresnel-type liquid crystal device with the potential to overcome the current limitations on the tunable deflection angle.

Figure 1 (a) depicts the proposed device structure. The device consists of two glass substrates, of which one is covered entirely with an ITO electrode. The other substrate possesses a set of interdigitated ITO electrodes, covered with an insulator (SiO_2) and a ZnO-based high-resistivity layer. When a voltage is applied between the interdigitated electrodes, a sawtooth-shaped voltage distribution is formed within the liquid crystal layer, as shown in Fig. 1 (b). This voltage distribution causes the long axis of the liquid crystal to be reoriented at different angles to the cell-normal direction, resulting in a sawtooth-shaped refractive index distribution that deflects light (Fig. 1 (c)). The new device structure enables optical tilt angles greater than ±0.6° to be achieved, making it applicable to optical image stabilizers.

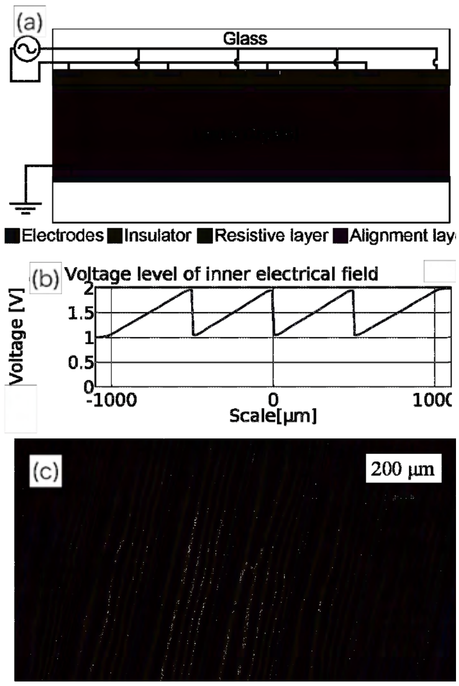

Fig. 1: Liquid crystal tunable deflector. **a,** Device structure. **b**, Simulated voltage distribution within the device. **c**, Example of interference fringes observed under a microscope.

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3D hydrogels with high resolution fabricated by two photon polymerization

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Abstract

Hydrogels with precise 3D configuration (3D hydrogels) is crucial for biomedical applications such as tissue engineering and drug delivery, which demand for the improvement of the spatial resolution on both the microscopic and the nanometric scale[1]. Two-photon polymerization (TPP) is an advanced method to fabricate 3D hydrogels. However, TPP of 3D hydrogels has been challenged by the lack of TPP initiators with high efficiency in aqueous medium. In this study, a water soluble TPP initiator (WI) with high initiating efficiency was prepared via hydrophilic-hydrophobic assembly. Both one and two-photon optical properties of WI have been investigated. In aqueous medium, WI showed a two-photon absorption cross-section of around 200 GM at the wavelength of 780 nm which was much higher compared with that of commercial initiators[2]. The threshold energy of TPP for WI was 6.29 mW. The lateral spatial resolution of 92 nm was achieved as the resolution breakthrough of 3D hydrogels[3]. Finally, the microstructure with high accuracy simulating the morphology of adenovirus was fabricated, demonstrating the ultrahigh resolution of 3D hydrogels.

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Nonreciprocal transmission effect in 30o wedged shape photonic crystals made by two photon polymerization

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Abstract

The photonic band gap effect which originates from the translational invariance of the periodic lattice of dielectrics has been widely applied in the technical applications of microwave, telecommunication and visible wavelengths. Among the various examples, polymer based three dimensional photonic crystals (PhCs) have attracted considerable interests because it is easy to fabricated by femtosecond (fs) pulsed laser direct writing (DLW) method[1] [2]. However, it is difficult to realize the complete band gap in polymer PhCs due to the low index contrast between polymer and air. Here, we report the design and experimental realization of non-reciprocal propagation of light in woodpile PhCs fabricated with DLW method. Firstly, we fabricated several woodpile PhCs on glass substrate with different crystal planes. The Fourier transform infrared spectroscopy (FTIR) measurements are in agreement with the theoretical predictions, which prove the validity and the accuracy of our DLW method. Further measurements of the transmission spectra with respect to the incident angle reveal that the crystal planes of the incident wave plays an important role in the optical response. Furthermore, we designed and fabricated a 30^o PhC wedge. We found nonreciprocal transmission effect between the forward and backward waves which comes from the nonsymmetric refraction of the light in different planes. Our results may find potential applications in future three dimensional photonic integrated circuits and pave the way for fabrication of the other photonic and optical devices with DLW method.

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The application of Inverse opals in lasing oscillation and chemical sensors

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Abstract

Photonic crystals (PhCs) are materials with periodic dielectric structure, which leads to the formation of a photonic bandgap. PhCs have attracted much interest for their promising applications in many fields, such as solar cell, laser, chemical sensor, and light-emitted diode. Polymeric inverse opals are three-dimensional PCs possess the advantages of low cost, easy processing, and stimuli response, which make them candidates for fabricating flexible laser and chemical sensors. Here, we demonstrate lasing oscillation and chemical sensing behaviors using polymeric inverse opal.[1] Lasing emission was observed in the polymeric inverse opal resonating cavity, which is constructed by sandwiching RhB/PMMA film with polymeric inverse opal PCs. Lasing oscillation emerges in the resonating cavity when the photonic stop band matches well with the photoluminescence emission band of the dye molecules.

Furthermore, we fabricated an inverse opal hydrogel (IOH) sensor which responds to the pH and mercury ions (Hg^{2+}). The diffraction wavelength of the IOH sensor was dramatically red-shifted when the pH was increased from 11 to 13. Meanwhile, carboxyl groups were used to detect Hg^{2+} as recognition groups. A low detection limit of 10 nM for Hg^{2+} was achieved in the optimized IOH sensor. The study will provide the prospect for fabricating novel devices, such as organic solid state dye lasers and chemical sensors.

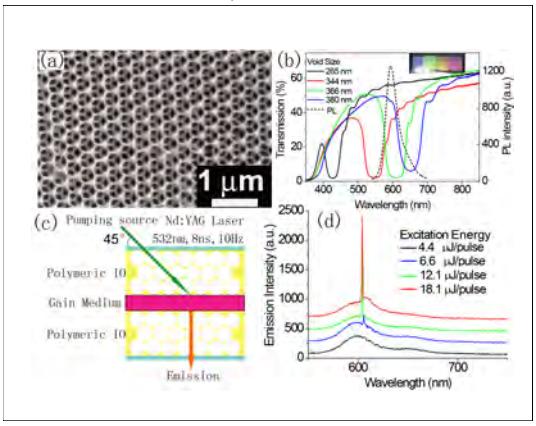

Fig. 1 Scheme of the lasing action in the polymeric inverse opal resonating cavity.

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Raman imaging of living cells and tissues by analytical spectroscopy

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Abstract

Since cells and tissues are full of large biomolecules with multiple vibrations, Raman spectroscopy technology is a powerful detective method to collect information in a non-invasive way. Several characteristic peaks can be observed in a Raman spectra measured from cells or tissues, with analyzing the variations of peak position, band width and intensity ratio, information of the molecular species and structures vibrations can be obtained, and combined with a *xy* scattering, distribution for those variations can be observed as a map.

For example, two strong peaks between 2800 cm^{-1} to 3000 cm^{-1} are always observed in Raman spectra of cells and tissues. The peak at 2853 cm^{-1} is attributed to the vibration of methylene (-CH_2-) groups, which mainly reflect lipid contents, and another peak at 2932 cm^{-1} is considered as a CH_3 vibration mode, which is abundant in proteins.[1] Therefore, the intensity ratio of these peak indicated the dominant content, lipids or proteins.

The Raman image based on the ratio of the intensities of the spectral peaks of 2853 cm^{-1} to 2932 cm^{-1} is shown in Fig.1 (a), while the typical Raman spectra, which is excited with 532 nm laser, recorded on different areas are shown in Fig. 1(b). For the bright area, it is indicates that lipids has a strong content in this area. Compared with white light image, a lot of vesicles are observed in same area, which is rich in lipids. On the contrary, proteins are dominated at the dark area, there may be a nucleus, which can't be clearly observed, since it is not in the sample focal plane with vesicles. With more *xy* plane Raman images at different depth along the *z* axis collected, a 3D Raman model of biomaterials could be constructed and the detail information about special biomolecule, especially distribution, will be displayed directly. This method will be useful to research the mechanism of cellular biology with Raman probes and provide support for medicine and diagnosis of cancer.

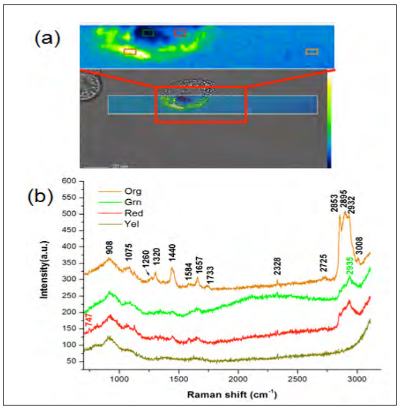

Fig. 1: (a) xy plane Raman image of a cell; (b) Typical Raman spectra for different area.

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Enhancement of SHG from Ge-doped SiO_2 by metal-insulator-metal structure

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Abstract

Recently, nonlinear optical effects play important roles in photonics, such as wavelength conversion of laser light, generation of ultrashort pulses and ultrafast switching [1]. However, nonlinear optical processes generally exhibit weak responses. The utilization of surface plasmons is a promising approach to obtain the enhancement of nonlinear optical effects [2].

In this work, we utilized the surface plasmon resonance in a metal-insulator-metal (MIM) multilayer structure to enhance a second order nonlinear optical response. The MIM multilayer structure consists of a Ge-doped SiO_2 thin film, sandwiched by two Ag thin films. The Ge-doped SiO_2 has been reported to possess a second order nonlinear optical coefficient (d33) of 5.1 pm/V [3]. We show that SHG intensity from Ge-doped SiO_2 can be significantly enhanced by the surface plasmon resonance in the MIM structure.

A Ti:Sapphire laser (800nm) and a photomultiplier tube were used as the excitation source and as the detector, respectively. Fig. 1. shows the reflectance spectrum(red) obtained by an attenuated total reflection (ATR) method and second harmonic generation (SHG) intensity (blue) with respect to the incident angle for the MIM sample. The reflectance profile shows that the surface plasmon resonance by the excitation light occurs when the incident angle is between 65 and 75 degree. The SHG profile shows that the SHG intensity from Ge-doped SiO_2 is enhanced when the reflectance drops. This suggests that the SHG intensity from Ge-doped SiO_2 is enhanced by the enhanced electric field associated by the excitation of the surface plasmon resonance in the MIM structure

In conclusions, it was found that the enhanced electric field in the MIM structure can enhance the SHG intensity from Ge-doped SiO_2 by more than 4 times.

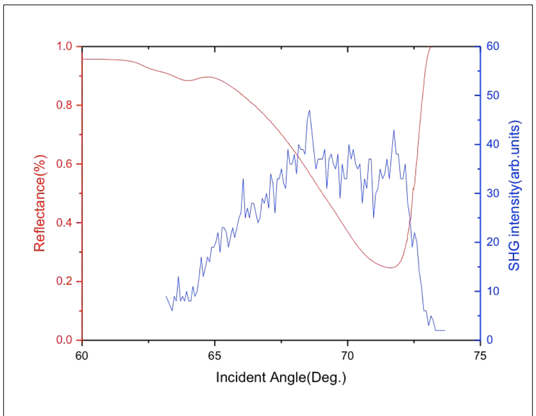

Fig. 1: Reflectance (red) and SHG intensity (blue) with respect to the incident angle for Ag-Ge doped SiO_2-Ag sample.

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Upconversion Luminescence of Rare-Earth-Doped Y_2O_3 Nanoparticle with Metal Nano-Cap

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Abstract

Rare-earth doped upconversion nanomaterials have been studied intensively because of their potential applications in biological labeling and solar cells. However, the upconversion efficiency is still not high enough for practical applications. A promising approach to enhance upconversion luminescence is utilizing localized surface plasmon resonances of metal nanostructures. In this work, as a new type of upconversion materials, we developed composite nanoparticles consisting of an upconversion nanoparticle and a metal nanocap [1].

A metal nanocap has two localized surface plasmon modes, i.e., an electric dipole mode and a magnetic dipole mode. Both modes have strongly enhanced local electric fields near a nanocap rim. The resonance wavelengths can be controlled in wide ranges by tuning the thickness and the coverage of a nanocap. The high tunability of the resonance wavelengths allows us to maximize spectral overlap between the surface plasmon resonance bands and absorption and emission peaks of rare-earth ions, and thus strong enhancement of upconversion is expected.

In this work, we developed SiO_2-coated Er- and Yb-codoped Y_2O_3 nanoparticles with Ag nanocaps. Figure 1a shows a TEM image of a nanoparticle with a Ag nanocap. In Figure 1b, the scattering spectrum of a nanoparticle with a Ag nanocap is shown. The peak around 583 nm is assigned to the electric dipole surface plasmon mode and that around 690 nm to the magnetic dipole surface plasmon mode. These peaks overlap with the green and red emission peaks, respectively, of upconversion luminescence of Er- and Yb-codoped Y_2O_3 nanoparticles.

We measured upconversion of more than 30 single nanoparticles without and with Ag nanocaps. The green and red luminescence were on average 23 and 48-fold, respectively, enhanced by the formation of Ag nanocaps.

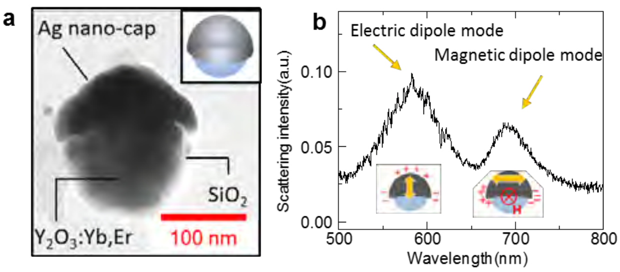

Fig. 1: (a) TEM image of a Y_2O_3:Yb,Er@SiO_2 nanoparticle with a Ag nanocap. (b) Scattering spectrum of a nanoparticle with a Ag nanocap.

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Anomalous Photoluminescence of Gold Nanoparticles Induced by Ultrafast Collective Free Electron Relaxation

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Abstract

Photoluminescence (PL), arising from the radiative recombination of electrons and holes, has an intrinsic Lorentz-like lineshape, which is always red-shifted as compared to the corresponding absorption spectra. In this letter, both the Lorentz-like lineshape PL with blue-shifted peak and Fano-like lineshape PL with almost un-shifted dip are investigated in the metallic dolmen-like nanostructures and compared to the corresponding scattering/absorption spectra. The anomalous PL is the product of the redistribution of excited collective free electrons during relaxation and density of plasmon states (DoPS) with Lorentz- or Fano-like profile. More importantly, we present an accurate model to estimate the ultrafast relaxation process of collective free electrons. It shows an ultrafast relaxation rate 47.6 THz in Lorentz-like lineshape PL and 63.1 THz in Fano-like lineshape PL. These results provide guidance for analyzing more complicated processes for the ultrafast light emission in plasmonic nanostructures.

Effect of V/III ratio on polarity inversion on –*c*-GaN growth by OVPE

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Abstract

A development of bulk growth with subsequent wafer slicing is one of the most effective ways for commercially production of GaN substrates. Oxide Vapor Phase Epitaxy (OVPE) in which Ga_2O is used as Ga source is expected to be a useful technique for bulk growth because this method allows long-term growth without solid by-product [1]. It was reported that diameter of the *c*-GaN boule generally reduced with boule length due to the appearance of inclined {10-11} facets at the edges [2]. To solve this issue, we have performed –*c*-GaN growth by OVPE for realizing large-diameter bulk crystals. In our previous study, higher Ga_2O partial pressure led to increase in growth rate, but polarity inversion occurred with increasing growth rate. In this study, we investigated an effect of V/III ratio and growth rate on polarity inversion in –*c*-GaN growth by OVPE.

A –*c*-GaN substrate prepared by HVPE was used as a seed substrate. An epitaxial growth was performed in a quartz reactor composed of source and growth zones. Ga_2O vapor generated at the source zone was transported to the growth zone and reacted with NH_3 to form GaN. V/III ratio and Growth rate were varied by changing NH_3 and Ga_2O partial pressure, respectively. Wet chemical etching in a 1.0 M NaOH solution at 80^{o}C for 5 min was performed to investigate the polarity of grown GaN crystals [3].

After NaOH etching, some regions showed no changes, indicating that polarity inversion occurred in these regions. Figures 1 shows relationships among ratio of inversion domain area to growth area, V/III ratio, and growth rate. We can see from Figs. 1 ratio of inversion domain area to growth area decreased with increasing V/III ratio and kept constant for growth rate. In conclusion, polarity inversion strongly depends on V/III ratio and can be suppressed with increasing V/III ratio.

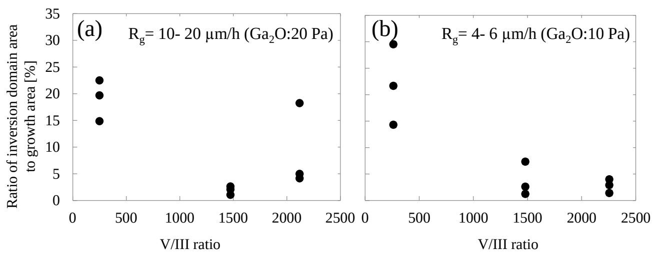

Fig. 1 Relationships between V/III ratio and ratio of inversion domain area to growth area in the samples with growth rate of (a) 10-20 μm/h and (b) 4-6 μm/h.

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Ultraviolet laser-induced degradation of $C_sLiB_6O_{10}$

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Abstract

$CsLiB_6O_{10}$ (CLBO) is the most promising candidate for generating the high-power pulsed DUV output with wavelengths below 300 nm [1]. The output degradation in the nonlinear optical crystal occurring at a lower peak power density than the bulk laser-induced damage threshold is a critical issue associated with power scaling and long-term operation.

There are several researches on a continuous motion of a nonlinear optical crystal to prolong the usage life [2-3]. In this research, we investigated the effect of continuous motion of CLBO on the UV-induced degradation.

The input fourth harmonic beam (wavelength: 266 nm; pulse width: 8.2 ns; pulse repetition frequency: 30 kHz) was generated by nonlinear crystals and a Nd:YVO_4 laser. We continuously moved the CLBO sample during the accelerated testing of the UV-induced degradation [4]. In this experiment, the beam waist was 16.6 μm in air, and its peak power density was set to be about 207 MW/cm^2. One-direction reciprocal motion of the width of 50 μm in the plane normal to the beam direction was performed by using a stepping motor. Figure 1 shows 266 nm transmitted power degradation through CLBO with/without motion and the aperture. The high intense illumination results in the short lifetime of 1-3 min for CLBO sample without motion. In contrast, the drastic improvement was observed in the same CLBO with motion. Although one experimental spot shows the lifetime of about 55 min, we have not observed degradation and damage for the other two experimental spots over 60-min illumination. The continuous reciprocal motion gives appropriate interval of UV illumination on the irradiation area. It may allow the UV-induced photorefractive damage to relax before these defects accumulate.

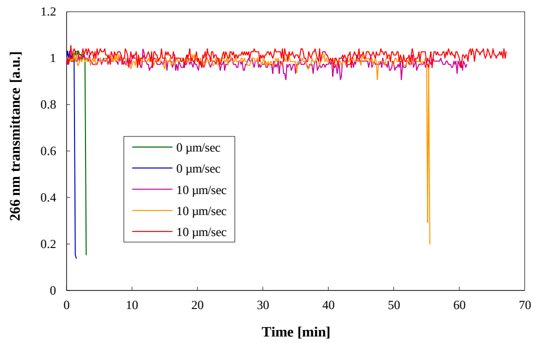

Fig. 1: 266 nm transmitted power degradation through CLBO sample.

References:

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Switchable surface plasmon subwavelength focusing and bi-directional vortex creation in a metasurface

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Abstract

Surface plasmons (SPs) are near-field waves that propagate along the metal-dielectric interface as the result of collective electrons induced by external electromagnetic waves. Optical vortices are waves carrying optical angular momentum (OAM) and exhibit abrupt azimuthal phase discontinuities. Recently, the ability to generate SP vortex or subwavelength focusing in plasmonic Archimedes spiral/slots has attracted immense research attentions [1-3]. The functionality of such plasmonic device is to allow the conversion from far-field optical spin angular momentum (SAM) to near-field OAM due to its chirality. We recently demonstrated the first controllable trapping or rotation of micro-particles using such spiral device [3]. However, this sets two major limitations: (1) SP vortices or subwavelength focusing requires circularly polarized excitations of different handedness; and (2) It would not be possible to control the rotation direction of the SP vortex in a given plasmonic spiral.

To alleviate the first limitation, we recently demonstrated a properly designed plasmonic metasurface could be used to dynamically create SP vortex or subwavelength focusing, purely through linearly polarized optical excitations [4]. In the current presentation, we extend our findings to alleviate the second limitation. We numerically demonstrate the ability not only to create SP subwavelength focusing, but also bi-directionally tunable SP vortices in a designed metasurface under linearly polarized optical excitations that carry absolutely no angular momenta. We envision major impacts in selectable motional control of nanoparticles and opto-fluidics.

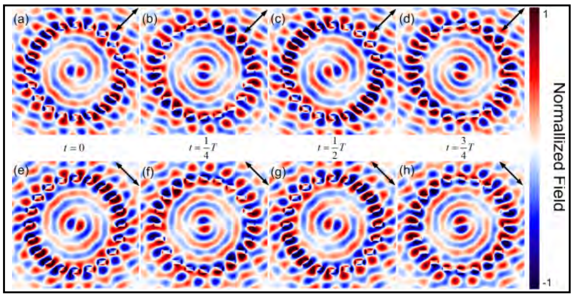

Fig 1. The instantaneous E_z fields under 45° linearly-polarized excitation (a-d) and under -45° linearly-polarized excitation (e-h).

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Effect of dispersive layers thicknesses on graphene-based SPR biosensor

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Abstract

In this paper, the effect of variation in thickness of dispersive layers on reflection curve and sensitivity of surface plasmon resonance (SPR) graphene-based biosensor is numerically presented. The change in the minimum reflection in regard to the number of extra graphene layers on varied gold films is not linear. In comparison to conventional SPR sensors, graphene based sensors give a larger local change in the refractive index near the sensor surface. The light reflection coupled into a SPR mode propagating along a gold-graphene layer is calculated and compared to a conventional SPR sensor with varied gold thicknesses. The sensitivity of this structure, Kretschmann configuration, is analyzed by changing the gold thickness, number of graphene layers and refractive index of sensing medium.

There is a linear relation among minimum reflection and graphene thickness for 50 nm thickness of gold unlike the other thicknesses such as 40 or 45 nm. The ideal thicknesses for gold and graphene should be selected based on the zero reflection at the resonance angle, at which maximum energy can be transferred to the metal surface for excitation of surface plasmons.

The SPR curve becomes wider and broader by increasing the number of graphene layers which may affect measurement [1]. Graphene holds a nonzero imaginary part for its dielectric function, so absorptive damping occurred in SPR changes.

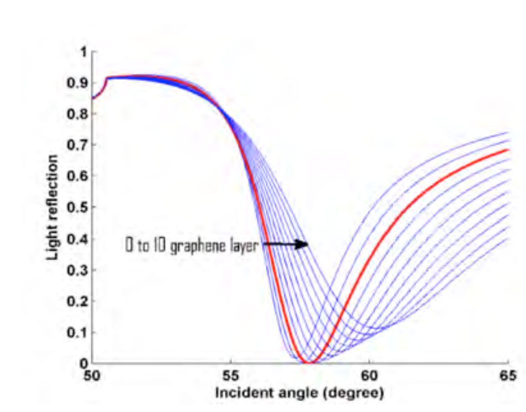

Fig. 1: SPR curves for multilayer graphene on top of 45nm thickness of gold in Kretschmann configuration.

References:

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Gold nanostructure fabrication by focused UV laser annealing for surface enhanced Raman spectroscopy

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Abstract

The biosensing with noble metal nanostructures has attracted attention as a label free and high sensitive analysis method. In order to fabricate biosensing devices, it is necessary to develop a noble metal nanofabrication technology which allows relatively simple and low-cost fabrication with high throughput and controllability. In general, techniques for fabricating nanostructures can be classified into top-down and bottom-up approaches. Top-down fabrication like a focused ion beam milling and an electron beam lithography can provide well-controlled nanoscale patterns, but production cost is high and throughput is low. On the other hand, bottom-up techniques are usually simpler and less costly. However, the resolution and reproducibility are limited. In this research, we study a focused laser annealing of metal thin-film deposited on a glass substrate to address these issues.

The 266-nm pulsed laser is focused on a few nanometer Au thin film sputtered on a glass substrate. By scanning the substrate on the x-y stage with focusing the laser, processing pattern was fabricated on the substrate. Fig. 1 show the scanning electron microscopy (SEM) images of the substrate after scanning the focused laser beam horizontally. Nanoparticles were observed in the laser irradiation area. Relatively large particles (~100nm in diameter) are formed near the edge of the laser pass, whereas small ones (~10nm) are deposited in the center area. The nanoparticle diameter and width of the fabricated line depended on laser energy density, scan speed, and deposited Au film thickness. We observed the surface-enhanced Raman scattering (SERS) of the adsorption molecules by dropping 4-aminothiophenol solution (1mM). SERS spectra were measured in the laser irradiated area as shown in Fig.1. The relationship between SERS activity and the condition of the fabrication process was investigated.

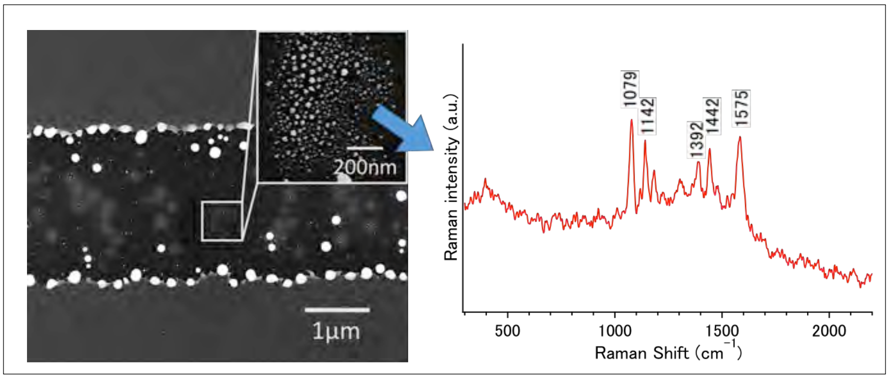

Fig. 1: SEM image of gold nanostructure produced by the laser irradiation and SERS spectra of 4-aminothiophenol adsorbed on the substrate

Fabrication of chiral plasmonic oligomers using cysteine-modified gold nanorods

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Abstract

Metal nanostructures, through Coulomb interaction with chiral molecules, exhibit plasmonic circular dichroism (PCD) around their plasmon resonance wavelength. [1] To apply this effect to chiroptical devices and bio/chemical sensing, strong and controllable PCD is desirable. [2] In this article, we report the strongly amplified PCD from the side-by-side (SS) assemblies of gold nanorod–chiral molecule complexes. Through careful manipulation of chiral molecule coverage and distribution on the nanorods as well as varying the size of the linking molecule, the location of chiral molecules and the interparticle distance are revealed to be the key factors determining the sign and magnitude of the PCD signal. Chiral molecules on the ends and sides of the nanorod induce PCD signals with opposite signs. PCD induced by chiral molecules on the ends reduces much more significantly as compared to the molecules on the sides of the rod with enlarged interparticle gaps. Moreover, the strong PCD signal around the longitudinal surface plasmon resonance is found not due to the enhancement of local electric field intensity, suggesting there are other factors beyond the electric field enhancement playing a role in the PCD signal amplification. The strongly amplified PCD effect with a rich variety of behavior as well as its unusual amplification mechanism will shed light on future PCD-based applications.

References:

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Label free imaging using nonlinear optical phenomena

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Abstract

In the medical and biological fields, staining is usually used to visualize the biomolecules in the specimen. However, since staining procedure often affects the biological activity, non-staining, label-free imaging method is desired, especially, for clinical applications.

We have constructed a multimodal microscopy system utilizing two photon excited fluorescence (TPEF), second harmonic generation (SHG), coherent anti-Stokes Raman scattering (CARS), and stimulated Raman scattering (SRS). We can observe the specimens using these 4 nonlinear optical phenomena simultaneously. CARS and SRS are nonlinear Raman scattering phenomena, visualizes the biomolecules using molecular vibrations. SHG visualizes non-centrosymmetric molecules, especially collagen in biological samples. We applied the developed system to observation of Atherosclerosis is a disease characterized by the accumulation of lipids, monocytes, fibrous components, and other inflammatory cells in the arterial wall. Therefore, imaging of lipids and fibrous components, especially collagen, is important for diagnosis of atherosclerosis. We visualized the lipid, collagen, and elastin, because the lipids have large amount of CH_2 moieties which give large Raman signal around 2845 cm^{-1}, and collagen have high efficiency for second harmonic generation (SHG), and elastic plate consists of elastin provides large autofluoresence.

Figure 1 shows the observed result of multimodal imaging of atherosclerotic plaque of spontaneously hyperlipidemic mouse. The lipid core is clearly observed by SRS. Around the lipid plaque, abnormally accumulated collagen, and fibrous cap on the lipid core are also observed by SHG. The thickness of fibrous cap might become a marker of unstable plaque.

In the symposium, applications for evaluating the quality of tissue engineered cartilage is also demonstrated.

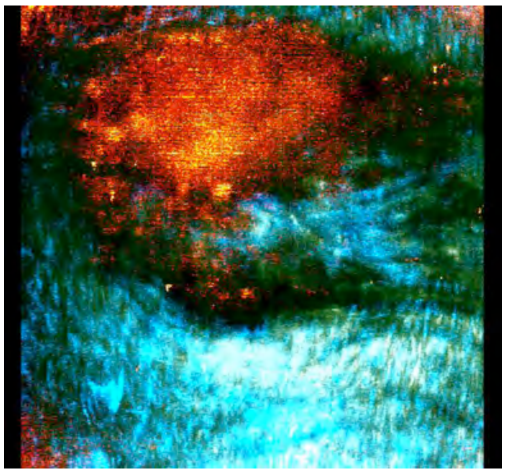

Fig. 1: multimodal imaging of atherosclerotic plaque of spontaneously hyperlipidemic mouse Red: SRS at 2845 cm^{-1}; Blue: SHG; Green TPEF

References:

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Correlative imaging nanoprobes for near-infrared and cathodoluminescence microscopy

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Abstract

Correlative light and electron microscopy (CLEM) is an emerging technique because it is possible to take advantages of both light microscopy (LM) and electron microscopy (EM) [1,2]. We propose a new correlative technique with using cathodoluminescence (CL) and near-infrared light (NIRL). By using CL, EM images are colorized as fluorescent images [3]. NIRL has advantages such as, high penetration depth in biological specimen, low photo-toxicity, low auto-fluorescence with comparing UV and visible light excitation.

To achieve correlative CL and NIR microscopy, imaging probes are key issue. We synthesized two kinds of nanoprobes (Y_2O_3: Tm, Yb and Y_2O_3: Er, Yb) which emit light under both electron beam and NIR light irradiation. Figure shows TEM images of Y_2O_3: Tm, Yb probes synthesized by homogeneous precipitation method [4]. Correlative SEM-CL and NIR imaging of both nanoprobes on silicon nitride membrane grid was performed (Fig. 1). NIR deep imaging with tissue phantom (2 % intralipid) was demonstrated. Y_2O_3:Tm, Yb nanoprobes are introduced to HeLa cells and observed through 1.5 mm tissue phantom.

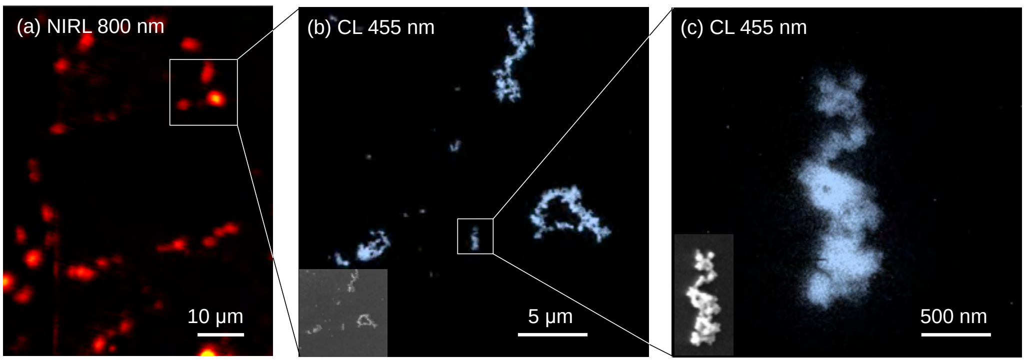

Fig. 1: Correlative (a) NIRL and (b, c) CL images of Y_2O_3: Tm 0.2 mol%, Yb 2 mol% NPs dispersed on SiN membrane grid. (a) Acquisition wavelength was around 800 nm. (b, c) Acquisition wavelength was 455 nm. Acceleration voltage was 5 kV.

References:

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Metadevice for tunable dispersion-free polarization control

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Abstract

Recent works on metasurface based phase engineered devices have witnessed novel applications in wavefront manipulation and polarization control [1]. One of the smart ways to tailor the phase discontinuity is by employing the space-variant Pancharatnam-Berry (P-B) phase in order to deflect the wave. Polarization manipulation has played a key role in achieving the wave deflection with the cross-polarized light. By applying the concept of P-B phase in polarization optics, it is possible to realize an active control of the polarization state of light by mechanically rotating the device. In polarization optics, the key ingredient to manipulate the states of polarization is to engineer the phase delay between two orthogonal optical axes that determines the polarization ellipticity in the uniaxial crystalline materials.

Here, we demonstrate P-B phase enabled phase delay modulation from 0 to 2π in ultrathin flexible metadevice. The designed metadevice allows dispersion-free operation over a broad bandwidth. An anisotropic grating configuration would lead to the birefringence between two linear eigenpolarizations oriented parallel and perpendicular to the grating vector that is regarded as ordinary (o-ray) and extraordinary (e-ray) axes. By engineering the filling factor, both the phase delay that indicates the retardation between the two eigenpolarizations and the transmission amplitude could be tailored to cover a large tuning range. In order to compensate phase dispersion, two layers of grating metasurfaces were integrated with a characteristic design criteria such that the two metasurfaces showed identical phase dispersion slope behavior but with opposite sign across the chosen frequency band [3]. Upon fulfillment of this criteria, the slope of the phase delay effectively showed a flat response when the two metasurfaces were integrated together without strong inter layer coupling.

We also demonstrate the polarization control through manipulating the phase delay using the P-B phase. In this way, the input linearly polarized light is converted into any desired output state through rotating the metadevice.

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Demonstration of an ultrasensitive refractive-index plasmonic sensor by enabling its quadrupole resonance in phase interrogation

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Abstract

We present an ultra-sensitive plasmonic sensing system, by introducing a nanostructured X-shaped plasmonic sensor (XPS) and measuring its localized optical properties in phase interrogation. Our tailored XPS exhibits two major resonant modes of a low-order dipole and a high-order quadrupole, as shown in Figure (a), between which the quadrupole resonance allows an ultra-high sensitivity, due to its higher quality factor. Furthermore, we design an in-house common-path phase-interrogation system [1], in contrast to conventional wavelength-interrogation methods, to achieve greater sensing capability. For the wavelength-interrogation method, we apply an FTIR spectrometer to examining the extinction spectra of XPS, observing a sensitivity of 303 nm/RIU. For the phase-interrogation method, we use an in-house common-path phase-interrogation system, detecting a sensitivity of 17.46 rad/RIU, shown in Figure (b). With the combination of the designed XPS and our phase-interrogation method, we obtain a remarkable sensing resolution of 1.15×10^{-6} RIU. Such result is almost two-order magnitude greater than the controlled extinction measurement (i.e. 9.90×10^{-5} RIU), and also superior to other reported LSPR sensors [2].

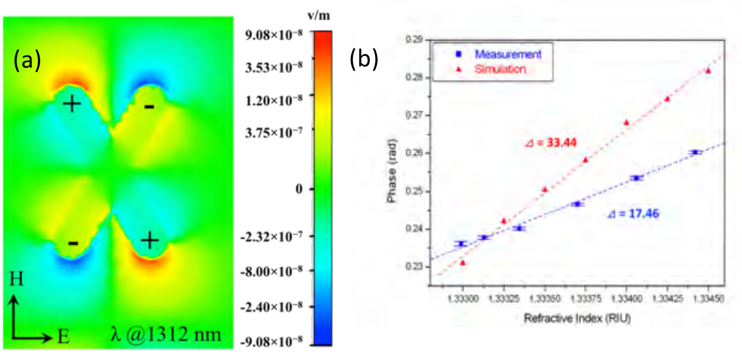

Figure. (a) E-field distribution of XPS shows a quadrupole mode resonance.
(b) Measured and simulated result of phase-interrogation sensing.

References:

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Development of key components for plasmonic integrated circuits

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Abstract

Plasmonic waveguides may provide a small mode diameter of the propagating mode, beyond the diffraction limit of the light. They, therefore, are expected to realize tiny and high-density plasmonic integrated circuits [1]. For such the integrated circuits, we are working on the development of various components. In this presentation, we present several key components, i.e., Junctions between Si wire waveguide and plasmonic waveguide (J-SiWG/PWG), a Mach-Zehnder (MZ) interferometer and split ring resonator (SRR) for near-infrared region.

These components are designed by assisting of the numerical simulation and are fabricated by the electron beam lithography and/or the focus ion beam processing. Figures 1 show typical SEM images of (a) a bird view of a J-SiWG/PWG covered with a Ag film and (b) a cross-section of a slab-type anti-symmetric MZ interferometer based on the silver plasmonic waveguide structure. For Fig. 1(a), a Si waveguide, with the height of 500 nm and the width of 400 nm, and the trench type plasmonic waveguide, with the height of 1200 nm and width of 200 nm, are successfully connected with each other. This component need for high-density and energy saving circuit because the employment of Si wire waveguide in the integrated circuit provides lower absorption loss in light energy and information transfer. From optical measurements, the coupling loss and propagation length in the plasmonic waveguide are evaluated to be 2.1 dB and 9.5 mm at l_0 = 1300 nm, respectively. For the MZ interferometer in MIM PWG shown in Fig. 1(b), the difference between optical paths of the upper and of the lower waveguides, D_{op}, is estimated to be 600 nm. This structure may provide the high ON/OFF ratio for a modulator because D_{op} can be chosen to distractive interferometer geometry. In presentation, we also show the SRR for a sensor.

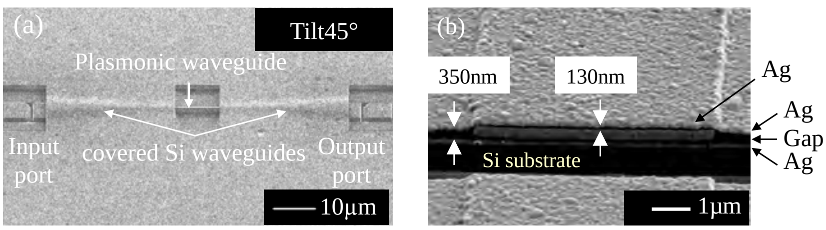

Fig. 1 Fundamental structures of integrated plasmonic circuits
(a) Junction between plasmonic waveguide and Si waveguide
(b) Slab type of Mach-Zehnder interferometer

References:
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Fabrication of multilayer graphene nanoribbons with the turbostratic structure by graphene over-layer growth on unzipped carbon nanotube

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Abstract

Since single layer graphene nanoribbons (GNRs) with narrow width (< ~10nm) have a band gap, they are one of the promising candidates as channel materials for the field effect transistor (GNR-FET). However, the electrical performance of GNR-FET is limited by a low on-state current (I_{on}) due to its narrow width and single atomic layer. It is theoretically predicted that multilayer GNRs with weak interlayer coupling like turbostratic structure overcomes this problems [1]. In order to experimentally confirm this prediction, we developed the synthesis method of multilayer GNRs with turbostratic structure. Here, graphene layers are grown on a GNR prepared by unzipping double-wall carbon nanotubes [2] as a template using chemical vapor deposition (CVD) [3]. Figure. 1 shows atomic force microscope (AFM) images observed from the GNR (a) before and (b) after CVD growth, and (c) height profiles of the GNR along L-L'. The height of the GNR increases after the CVD growth. This indicates that ~4-layer graphene is additionally formed on the pristine GNR. The structural analysis of the 2D-band profiles in Raman spectra observed from the multilayer GNRs reveals that the stacking structure in the grown graphene layers forms the turbostratic structure. We also find that the I_{on} of the multilayer GNR-FET is improved compared with the pristine GNR-FET (Fig. 2). These results are significant for the application to high performance GNR-FET.

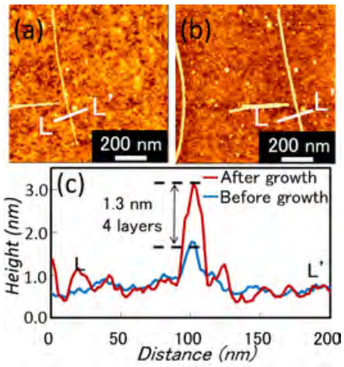

Fig. 1: AFM images of the GNR (a) before and (b) after growth.(c) Height profiles along L-L'.

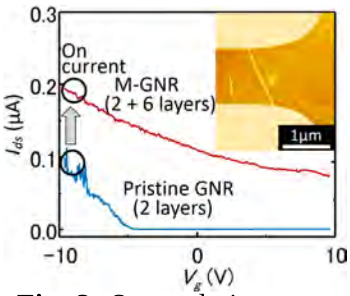

Fig. 2: Souce-drain current vs. gate voltage at V_{sd} = 0.5 V for pristine GNR (blue), M-GNR after growth (red) devices. Right inset shows an AFM image of the device.

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Photonics Innovation for Human Friendly Society

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Abstract

Over a period of 5 years, Osaka University and the Technical Institute of Physics and Chemistry, Chinese Academy of Sciences (China), Research Center for Applied Sciences, Academia Sinica (Taiwan) and, from 2014 fiscal year, the Centre for Disruptive Photonic Technologies (CDPT), Nanyang Technological University (NTU) (Singapore) have conducted a high-level joint research of nano-photonics and exchanged personnel, especially young researchers both dispatch and acceptance of students and thus founded the Nanophotonics research and education center in Asia. This is performed as part of further development of international research collaboration of Osaka University under the support of the Japan Society for the Promotion of Science. So far, we have held international symposium eight times in Japan and partner countries, and conducted14 joint researches and many researcher's exchanges. So far, the total number of dispatch of students and researchers has reached 74 people and 960 man-days and those of acceptance 131 people and 2102 man-days, in total more than 3000 man-days. This project is highly valued by Japan Society for the Promotion of Science, in the mid-term evaluation of 2013 fiscal year, has gained only the best of the S comprehensive evaluation. This time, we hold this international joint meeting for concluding our five-year project and discussing future development at Osaka University.

In the poster, we introduce our activities on advanced photonics research and development with collaborating companies by forming interpenetrating partner system, entrepreneurlal/productization project by researchersand students and promoting collaboration with SMEs by founding photonics Cannery.

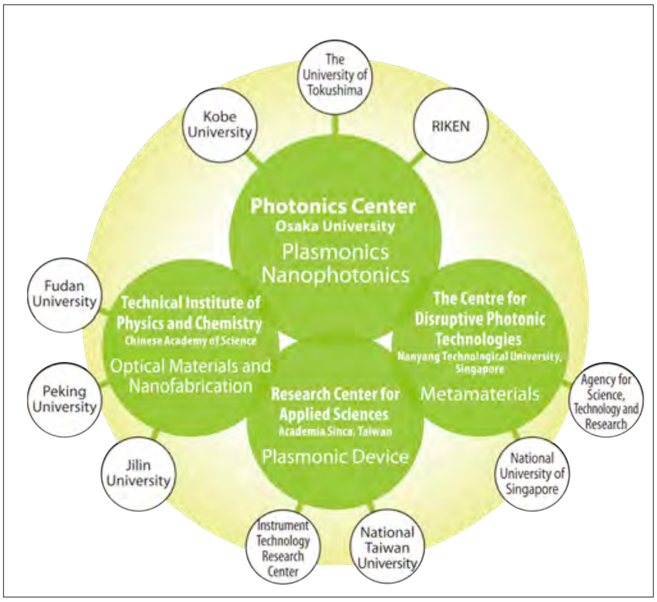

Fig. 1: Advanced Nano Photonics Research and Education Center in Asia

[1] Satoshi Kawata and Hiroshi Iwasaki, "The Photonics Center at Osaka University," *AAPPS BULLETIN*, **24**, 32-35 (2014).

AUTHOR INDEX

Notes

Notes