Denmark - Hong Kong Workshop on Metamaterials and Plasmonics

Andrei Lavrinenko, Radu Malureanu, Kresten Yvind, Xiaolong Zhu

Technical University of Denmark

Kok Wai Cheah, Jack Ng

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The Chinese University of Hong Kong

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12 Nov 2012 (Mon), 9:30 am – 5:45 pm, Room 2612A (2/F via Lifts 31-32)

Program:

09:30 - 10:15	A. Lavrinenko (DTU) – Electromagnetic Approach in the Analysis of Structured Materials
10:15 - 10:45	K. W. Cheah (HKBU) – Nonlinear Optics in Plasmonic Nanostructures
10:45 - 11:00	Break
11:00 - 11:45	R. Malureanu (DTU) – Fabrication and Characterisation Activities in the THz and NIR Ranges
11:45 - 12:15	K. H. Fung (PolyU) – Waves in Periodic Resonator Arrays in Absence of Time-reversal Symmetry
14:00 - 14:45	K. Yvind (DTU) – Slow Light Enhanced Gain in Photonic Crystal Amplifiers
14:45 - 15:15	K. S. Wong (HKUST) – Surface-Plasmon-Enhanced Light Emission from Organic Films and Molecules
15:15 - 15:30	Break
15:30 - 16:00	H. P. Ho (CUHK) – Surface Plasmon Resonance Photonic Biosensors
16:00 - 16:45	X. Zhu (DTU) – Enhance Light Emission by Use of Optical Nanostructures
16:45 - 17:15	J. Ng (HKBU) – Optical Pulling Force
17:15 - 17:45	Discussion

Electromagnetic Approach in the Analysis of Structured Materials

Andrei Lavrinenko*

Technical University of Denmark

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Abstract:

The topic of the lecture is advances in electromagnetic description of light-matter interactions in plasmonics and metamaterials. There are several directions, which will be highlighted: effective parameters restoration with the wave propagation method, plasmonic nanoantennas for fiber-slot waveguide coupling, electromagnetic approach in application to transformation optics and graphene hyperlens, analysis of existence of pulling force regime (tractor beam) and improvement of solar cell efficiency by employing photocurrent from plasmonic particles.

Nonlinear Optics in Plasmonic Nanostructures

G. X. Li, K. F. Li, S. M. Chen, K. W. Cheah*

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Abstract:

The topic of the lecture is advances in electromagnetic description of light-matter interactions in plasmonics and metamaterials. There are several directions, which will be highlighted: effective parameters restoration with the wave propagation method, plasmonic nanoantennas for fiber-slot waveguide coupling, electromagnetic approach in application to transformation optics and graphene hyperlens, analysis of existence of pulling force regime (tractor beam) and improvement of solar cell efficiency by employing photocurrent from plasmonic particles.

Waves in Periodic Resonator Arrays in Absence of Time-reversal Symmetry

Kin Hung Fung[a]*, Jin Wang[b], Ross C. H. Tang[c], C. T. Chan[c], Nicholas X. Fang[d]

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Abstract:

I will present some interesting effects on periodic resonator arrays that are associated with the broken time-reversal symmetry. These effects include the decoupling between resonators by static magnetic field and the splitting of leaky modes by absorption. In the first example, we consider periodic arrays of gyromagnetic resonators. We find that when the external static magnetic field is on, even nearly touching resonators can be decoupled. This interesting effect is explained by the splitting of states by external static magnetic field [1]. In the second example, we consider a linear array of plasmonic resonators [2,3]. When absorption exists, two leaky modes split and give two different exponential decays [2] together with an additional long-range power-law decay. Both effects are associated with broken time-reversal symmetry but they can be classified into effects of different physical origins.

[1] Wang, J., K. H. Fung, H. Y. Dong, and Nicholas X. Fang, "Zeeman Splitting of Photonic Angular Momentum States in Gyromagnetic Cylinder," Phys. Rev. B **84**, 235122 (2011).

[2] Fung, K. H., Ross C. H. Tang, and C. T. Chan, "Analytical properties of the plasmon decay profile in a periodic metal-nanoparticle chain," Opt. Lett. **36**, 2206 (2011).

[3] Fung, K. H., and C. T. Chan, "Plasmonic modes in periodic metal nanoparticle chains: A direct dynamic eigenmode analysis," Opt. Lett. **32**, 973 (2007).

Fabrication and Characterisation Activities in the THz and NIR Ranges

Radu Malureanu*

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Abstract:

In this talk the speaker will present the various experimental possibilities within his group or in collaboration with the Terahertz Technologies & Biophotonics group. The speaker will mainly concentrate on three examples that will show both the fabrication possibilities as well as the characterisation ones.

The first example regards the fabrication and characterisation of a 3D photonic crystal structure. The fabrication procedure implies the use of two-photon polymerisation technique and electroless deposition of metal in order to obtain a metal-covered woodpile structure. The speaker and his group characterise its properties by using a free-space optical setup. Its main measuring possibilities will be described within the talk.

The second one describes the fabrication and characterisation of waveguides. For fabricating the waveguides we can use either standard UV lithography, in the case of plasmonic ones, or electron-beam one in the dielectric case. Both fabrication processes will be described as well as the waveguides characterisation setup.

The third example is dedicated to the THz samples. The fabrication procedure for obtaining THz metamaterial membranes will be presented. The characterisation setups, for both low (0.1-1.2THz) and well as high (0.8-10THz) THz ranges will be described.

Optical Pulling Force

Jack Ng[a,b]*, Jun Chen[c], Zhifang Lin[c], C. T. Chan[a]

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[b]Hong Kong Baptist University

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Abstract:

Can the scattering force of a forward propagating beam pull a particle backward? A photon carries a momentum of $\hbar k$, so one may expect light will push against any object standing in its path. However, light can indeed "attract" in some cases. For example, if light is focused to a spot, small particles will be attracted towards it due to the gradient force. But it is probably more appropriate to say that the gradient force "grabs" rather than "pulls", as the particle will remain stable in the trap after being drawn to the focus. Here, we discuss another possibility — a backward scattering force which is always opposite to the propagation direction of the beam so that the beam keeps on pulling an object towards the source without an equilibrium point.

In the absence of intensity gradient, using a light beam to pull a particle backwards is counter intuitive. The underlining physics is the maximization of forward scattering via interference of the radiation multipoles. We show explicitly that the necessary condition to realize a pulling force is the simultaneous excitation of multipoles in the particle and if the projection of the total photon momentum along the propagation direction is small, attractive optical force is possible.

Nonlinear Optics in Plasmonic Nanostructures

Kresten Yvind*, Elizaveta S. Semenova, Nadezda Kuznetsova, Martin Schubert, Luisa Ottaviano, Sara Ek, Yaohui Chen, Per Lunnemann Hansen, and Jesper Mørk

Technical University of Denmark

***Email of Presenting Author: kryv@fotonik.dtu.dk**

Abstract:

High index contrast semiconductor photonic structures, like photonic crystals, are powerful in enhancing light-matter interaction. We experimentally demonstrate enhanced gain in the slow-light regime of InP based quantum well photonic crystal amplifiers. A strong gain enhancement is observed with the increase of the group refractive index, due to light slow-down. The slow light enhancement is shown in an amplified spontaneous emission study of a 1 QW photonic crystal amplifier. Devices with uniform QWs, Qdots and selective grown QWs are also investigated in photonic crystal micro cavities. These results are promising for short and efficient semiconductor optical amplifiers. This effect will also benefit other devices, such as mode-locked lasers.

The work is done in the Villum Kann Rasmussen Center of Excellence: Nanophotonics for Terabit communication. www.natec.dtu.dk.

Surface-plasmon-enhanced Light Emission from Organic Films and Molecules

Huimin Su[a], Hoi Sing Kwok[a], Xiao-Yuan Li[a], Jianfang Wang[b], Kam Sing Wong[a]*

[a]The Hong Kong University of Science and Technology

[b]The Chinese University of Hong Kong

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Abstract:

Our recent work on surface plasmon resonance from metal films, 2-dimensional networks and nanorods demonstrated strong enhancement in spontaneous emission rate and Raman scattering effect for molecules at close proximity of these metal nanostructures. We have shown that an organic film (Alq_3) simply coated on metal layer separated by a thin spacer layer can enhance the external emission efficiency by two to six times [1]. More sophisticated structures such as metal nano-networks or nanorods embedded with dye molecules observed strong surface-enhanced Raman scattering with enhancement factor of 10^6 and extraordinary surface plasmon coupled emission at the long wavelength fluorescence spectral region of the fluorophore respectively [2, 3]. The ability to control and enhance emission/scattering at desired wavelength by surface plasmon coupling via engineered metal nanostructures can fundamentally change the capabilities of fluorescence/Raman based technology and creates potential applications of new plasmonic devices.

[1] Surface-plasmon-enhanced photoluminescence from metal-capped Alq3 thin films; Man Chun Tam, Huimin Su, Kam Sing Wong, Xiuling Zhu and Hoi Sing Kwok, Appl. Phys. Lett. **2009**, 95, 051503

[2] Surface-enhanced Raman spectroscopy on two-dimensional networks of gold nanoparticle-nanocavity dual structures supported on dielectric nanosieves; Yingshun Li, Humin Su, Kam Sing Wong, Xiao-Yuan Li, J. Phys. Chem. C **2010**, 114, 10463

[3] Extraordinary plasmon-coupled fluorescence on gold nanorods with core/shell configuration. Huimin Su, Yongchun Zhong, Tian Ming, Jianfang Wang and Kam Sing Wong, J. Phys. Chem. C **2012**, 116, 9259

(This article was selected by the editor for **Top Cover** of the April 26, 2012 issue of J. Phys. Chem. C)

Surface Plasmon Resonance Photonic Biosensors

Aaron H. P. Ho*

The Chinese University of Hong Kong

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Abstract:

Surface plasmon resonance (SPR) has been known to be a sensitive tool for assessing binding of molecules. The detection mechanism is based on resonant charge oscillations in the surface of nano-sized metallic objects upon receiving incident photons. Recent advancement of nanophotonics has prompted much progress in the field of SPR biosensing. This presentation aims to report some of the new ideas we have been exploring to improve sensor performance over the years. We started our SPR work with the demonstration of a robust inverted-prism SPR sensor design based on differential phase interferometry using a laser beam. More recently a while-light interferometer has been incorporated to address dynamic range issues. The SPR sensing figure-of-merit of several other phase detection techniques including plasmon-enhanced ellipsometry and mixed polarization analysis has also been investigated. Studies on hybrid systems that combines localized surface plasmon resonance (LSPR) in isolated metallic nanoparticles and surface plasmon polaritons (SPPs) also reveals much enhanced phase sensitivity performance. Finally, we report a phase-sensitive SPR imaging system for the implementation of high-through 2-dimensional biosensor site arrays.

Enhance Light Emission by Use of Optical Nanostructures

Sanshui Xiao and Xiaolong Zhu*

Technical University of Denmark

***Email of Presenting Author: xizhu@fotonik.dtu.dk**

Abstract:

In this talk, we will present our recent results about how to enhance light emission/ extraction by use of optical nanostructures. The optical nanostructures are realized by a simple and inexpensive method based on a self-assembly technology.

In the first part, we will discuss the spontaneous light emission by fluorescent materials with host/guest system composed of 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP) and tris(1-phenylisoquinolinolato-C^2,N)iridium(III) [$Ir(piq)_3$, 1 wt% concentration]. Fluorescent materials are deposited on the structure consisting of a gold capped monolayer array of polystyrene (PS) spheres. The measured photoluminescence spectrum is strongly enhanced with a factor of 30, see Fig. 1(a), when placing a photonic-plasmonic structure on the top of the fluorescent materials.

Then we will discuss how to increase light extraction for the photoluminescence spectrum by SiC, used for the white LED application. We will present a light-extraction approach by using a whispering gallery resonators array. The wavelength-scale resonant dielectric nanospheres array supports whispering gallery modes, used to couple with the confined waveguide modes inside the bulk material, thus dramatically improves light extraction, see Fig. 1(b).

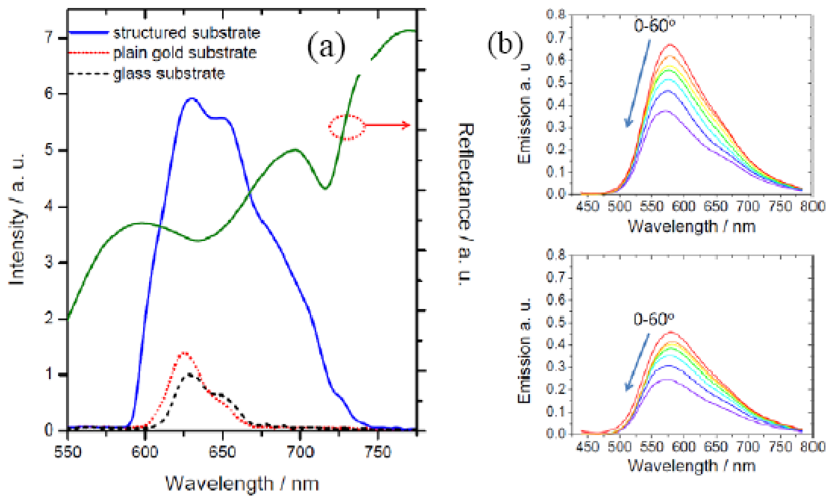

Fig. 1: (a) Normal-incidence reflection and emission spectra from the sample with photonic plasmonic structure. The emission spectra from the samples with bare and gold coated plain glass substrates are also plotted for comparison. (b) Angle-resolved photoluminescence spectra from 0, 10, 20, 30, 40, 50, to 60 degrees for the SiC samples (upper-right) with and (down-right) without the whispering gallery resonators array.

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