



CENTRE FOR DISRUPTIVE PHOTONIC TECHNOLOGIES



서울대학교

SEOUL NATIONAL UNIVERSITY

2nd International Workshop on
**Quantum and Topological
Nanophotonics (QTN)**

5-7 April 2018

Nanyang Technological University, Singapore

Supported By:

Institute of Advanced Studies, NTU (Co-organizer)
College of Science, NTU
School of Physical and Mathematical Sciences, NTU



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Thursday 5 Apr 2018	
08:45	Registration Auditorium - Nanyang Executive Centre, NTU
09:00	Opening remarks
09:05	Prof Dennis Polla, A*STAR <i>The Singapore AME Quantum Technologies Programme</i>
TN1. Topological Nanophotonics 1 - Chair: Prof Nikolay Zheludev	
09:15	Prof Moti Segev (TECHNION, Israel) <i>Topological Insulator Lasers</i>
09:45	Prof Baile Zhang (Nanyang Technological University, Singapore) <i>Spin-valley locking and topological phase transition in photonic crystals</i>
10:05	Prof Nicholas Fang (MIT, USA) <i>2D Topological Magnetoplasmon</i>
QTN group photo	
10:50	Coffee & Tea Break
QN1. Quantum Nanophotonics 1 - Chair: Prof Harry Atwater	
11:20	Prof Javier García de Abajo (ICFO, Spain) <i>Quantum Effects in Atomic-Scale Plasmons</i>
11:50	Prof Ranjan Singh (Nanyang Technological University, Singapore) <i>Meissner' effect in quantum superconductor metamaterials</i>
12:20	Prof Q-Han Park (Korea University, South Korea) <i>Universal Impedance Matching and Metamaterials</i>
12:50	Lunch Break & Poster Session 1 (PS1)
MN1. Metamaterials and Nanophotonics 1 - Chair: Prof Jinghua Teng	
14:00	Prof Jennifer Dionne (Stanford University, USA) <i>Nanophotonic approaches to observe and control atomic and molecular processes</i>
14:30	Prof Byoungho Lee (Seoul National University, South Korea) <i>Complex Modulation for On- and Off-Axis Metasurface Holograms</i>
15:00	Prof Che Ting Chan (Hong Kong University of Science and Technology) <i>Quantum effects associated with nano-corrugation in plasmonic surface</i>
15:30	Prof Bumki Min (KAIST, South Korea) <i>Time-variant metasurfaces as a frequency converting platform</i>
16:00	End of day 1

Friday 6 Apr 2018

08:45

Registration
Auditorium - Nanyang Executive Centre, NTU

TN2. Topological Nanophotonics 2 - Chair: Prof ByoungHo Lee

09:00

Prof Yuri Kivshar (Australian National University, Australia)
Topological structures made of dielectric resonant nanoparticles

09:30

Prof Yidong Chong (Nanyang Technological University, Singapore)
Magneto-optical Dirac cones

09:50

Prof Gennady Shvets (Cornell University, USA)
Bringing topological photonics to nanoscale

10:20

Coffee & Tea Break

MN2. Metamaterials and Nanophotonics 2 - Chair: Prof Cesare Soci

10:50

Prof Jonghwa Shin (KAIST, South Korea)
Giant broadband enhancement of linear and nonlinear susceptibility tensors in mesoscopic crystals

11:20

Prof Daniele Faccio (Heriot-Watt University, UK)
Metasurfaces for the control of quantum imaging and optical nonlinearities

11:50

Prof Namkyoo Park (Seoul National University, South Korea)
k-space imaging of quantum mechanical nonlinear polarization sources in second harmonic generation

12:20

Prof Junsuk Rho (Postech, South Korea)
Peptide encoded gigantic chirality evolution in three-dimensional plasmonic helicoids

12:50

Lunch Break & Poster Session 2 (PS2)

TN3. Topological Nanophotonics 3 - Chair: Prof Yuri Kivshar

14:00

Prof Nikolay Zheludev (NTU, Singapore & University of Southampton, UK)
"Plasmonics" in free space

14:20

Dr Hannah Price (Birmingham University, UK)
Advances in geometrical and topological pumping

14:50

Prof Janne Ruostekoski (Lancaster University)
Some topological states of light and matter

15:20

Coffee & Tea Break

TN4. Topological Nanophotonics 4 - Chair: Prof Moti Segev

15:50

Prof Justin Song (Nanyang Technological University, Singapore)
Hidden plasmon geometric phase

16:10

Prof Igor Aharonovich (University of Technology Sydney, Australia)
Nanophotonics with hexagonal boron nitride

16:40

Prof Frank Koppens (ICFO, Spain)
Probing quantum plasmonics and the ultimate limits of light compression with Van der Waals heterostructures

17:10

End of day 2

Saturday 7 Apr 2018

08:45	Registration Auditorium - Nanyang Executive Centre, NTU
	QN2. Quantum Nanophotonics 2 – Chair: Prof Ze Xiang Shen
09:00	Prof Harry Atwater (CALTECH, USA) <i>Topological Photonics in 2D Dirac Lattices and 3D Gyroid Photonic Crystals</i>
09:30	Prof Weibo Gao (Nanyang Technological University, Singapore) <i>Single photon emitter in GaN in telecom range</i>
09:50	Dr Leonid Krivitsky (A*STAR, Singapore) <i>Infrared metrology with visible photons</i>
10:10	Prof Alexander Ling Euk Jin (National University of Singapore, Singapore) <i>Quantum Optics with a Polymer Platform</i>
10:30	Coffee & Tea Break
	QN3. Electrons, Atoms and Molecules - Chair: Prof Robert Simpson
11:10	Prof Jeong Weon Wu (Ewha Womans University, South Korea) <i>Intramolecular charge transfer near hyperbolic metamaterial</i>
11:40	Dr Jinkyu So (Nanyang Technological University, Singapore) <i>Cathodoluminescence of quantum materials</i>
12:00	Prof David Wilkowski (Nanyang Technological University, Singapore) <i>Atom with surface plasmon: tuning Casimir-Polder interaction and multipole transition enhancement</i>
12:30	Prof Uriel Levy (Hebrew University of Jerusalem, Israel) <i>Nanoscale light vapor interactions on a chip</i>
13:00	Closing Remarks & End of Technical Program

Abstracts

Invited Talks

TN1. Topological Nanophotonics 1 (Thursday 5 Apr, 9:30-10:50)

T1. Topological Insulator Lasers

Moti Segev, TECHNION, Israel

The fundamentals of the recently invented topological insulator lasers will be presented, along with new ideas.

T2. Spin-valley locking and topological phase transition in photonic crystals

Baile Zhang, Nanyang Technological University, Singapore

Valley photonic crystals utilize valley as the new degree of freedom to manipulate electromagnetic waves, in much the same way as valleytronic materials steer electrons. Here we will talk about the construction of a valley photonic crystal, the realization of spin-valley locking, and the topological phase transition that is induced by the competition between spin-orbit coupling and inversion symmetry breaking.

T3. 2D Topological Magnetoplasmon

Nicholas X. Fang, Massachusetts Institute of Technology, USA.

Surface plasmons of different chirality can be excited in two dimensional materials that support transverse currents. We propose a method to optically excite and characterize the electromagnetic response and surface electromagnetic modes in a generic gapped Dirac material under pumping with circularly polarized light. The valley imbalance due to pumping leads to a net Berry curvature, giving rise to a finite transverse conductivity. Guided by our theoretical work, we argue the appearance of nonreciprocal chiral edge modes, their hybridization and wave guiding in a nanoribbon geometry, and giant polarization rotation in nanoribbon arrays.

QN1. Quantum Nanophotonics 1 (Thursday 5 Apr, 11:20-12:50)

T4. Quantum Effects in Atomic-Scale Plasmons

Javier García de Abajo, ICFO, Spain

Plasmons in atomic-scale structures exhibit intrinsic quantum phenomena related to both the finite confinement that they undergo and the small number of electrons on which they are supported. I will illustrate this concept in the plasmons of graphene and ultrathin metal nanostructures, with emphasis on ultrafast, nonlinear, and quantum effects.

T5. Meissner's effect in quantum superconductor metamaterials

Ranjan Singh, Nanyang Technological University, Singapore

Superconductors are one of the astonishments in the field of condensed matter physics and

characterized by simultaneous existence of the zero DC resistance and perfect diamagnetization below a certain critical temperature (T_c). The unique and dramatic properties of the superconductors are attributed to the presence of Cooper pairs, which are bound pair of electrons with the binding energy of few meV. More interestingly, upon irradiation with an optical field of energy greater than the binding energy of the Cooper pairs, high- T_c superconductors show ultrafast switching between macroscopic quantum superconducting phase and the resistive phase which can be exploited for high-performance quantum-photonics devices. In this work, we demonstrate all-optical dual-channel ultrafast switching of sharp Fano resonances excited in superconducting terahertz asymmetric split ring resonators. Upon irradiation with optical pump, the ultrasensitive Cooper pairs in cuprate

superconductor undergo dual dissociation-relaxation dynamics within a single superconductivity restoration cycle and lead to dual switching windows at picosecond timescale. The high sensitivity of Cooper pairs to external perturbations combined with the strong field confinement in Fano resonators enables access to such unique dual switching features. Our results manifest new ways to realize ultrafast dual channel switchable devices. We also report a phenomenological approach to demonstrate Meissner effect at terahertz frequencies in coupled metamaterial system. We exploited the perfect diamagnetism property of the superconductor to achieve the quantum level switching between flux exclusion and flux penetration in the coupled all-superconductor resonators as well as hybrid quantum superconductor and classical metallic resonator based metamaterial system. The observed dynamic switching behavior is attributed to the reconfiguration of the total inductance of the system due to magnetic flux exclusion and penetration. Most importantly, upon irradiation with the external optical pump, the quantum metamaterial undergoes ultrafast switching

between the flux penetration and flux exclusion states at very low pump fluences and thereby lead to low-loss, ultrasensitive, frequency agile, switchable quantum metaphotonics devices.

T6. Universal Impedance Matching and Metamaterials

Q-Han Park, Korea University, South Korea

Light is reflected at the interface between heterogeneous media due to the mismatch of impedance. Since the early works of Brewster and Rayleigh, much effort has been made to achieve anti-reflection, i.e. removing reflection with additional materials or structures. The anti-reflection of white light, which requires the simultaneous matching of impedance over extremely wide angular and spectral ranges, has until now been considered impossible. Here, we develop a theory of universal impedance matching and introduce a matching layer that enables the perfect transmission of white light. We explain the feasibility of a universal matching layer using metamaterials and present experimental confirmations.

MN1. Metamaterials and Nanophotonics 1 (Thursday 5 Apr, 14:00-16:00)

T7. Nanophotonic approaches to observe and control atomic and molecular processes

Jennifer Dionne, Stanford University, USA

We present methods to visualize and utilize light-induced chemical transformations with deeply subwavelength (~2nm) resolution. Our goal is to help unravel how photons control the local chemistry within and near plasmonic and high-index-dielectric resonators, and use that knowledge to for improved photocatalysts, nonreciprocal nanophotonics, and dynamic, few-molecule circular dichroism spectroscopy. First, we study the photocatalytic dehydrogenation of individual antenna-reactor systems with sub-2nm spatial resolution, using an environmental transmission electron microscope combined with light excitation. We find that plasmons control the photochemistry in three distinct ways: 1) Plasmons modify the rate of distinct reaction steps differently, increasing the overall rate more than ten-fold; 2) Plasmons open a new reaction pathway that is not observed without illumination; and 3) Reaction nucleation occurs

more often at electromagnetic hot-spots. Next, we study the dynamic response of chiral nanostructures and molecules in plasmonic cavities using an environmental atomic force microscope coupled with plasmonic tweezers. Illumination of the plasmonic tweezers with left- and right- circularly polarized light (CPL) results in distinct forces on a chiral nanostructure. In particular, the transverse optical forces on a chiral nanostructure are attractive with left-CPL, but repulsive with right-CPL. We use the AFM tip to map such chiral optical forces over the plasmonic tweezers with 2 nm lateral spatial resolution, and show how the technique can be applied to measure the dynamic conformational changes of DNA and proteins in real time. Finally, we show how power-independent nanoscale nonreciprocity can be achieved by controlling photon-phonon interactions. By pumping a 4-fold rotationally symmetric metasurface with circularly polarized light, detuned from a high Q resonance, stimulated Raman scattering is shown to occur only when a circularly polarized probe beam is

incident from one direction. Subsequently, a nonreciprocal electromagnetic-induced transparency dip is observed in the resonant transmission spectrum. Unlike previous demonstrations of phonon-mediated optical biasing, here we exploit atomic scale vibrations and so this mechanism has, in principle, no lower bound on the size of a device. Highly subwavelength nonreciprocity should therefore be possible.

T8. Complex Modulation for On- and Off-Axis Metasurface Holograms

ByoungHo Lee, Seoul National University, South Korea

We report the methods of modulating both amplitude and phase of light or plasmonic waves using subwavelength nanostructures. These metasurfaces can independently modulate amplitude and phase of the waves and hence, provide arbitrary patterns or holograms.

T9. Quantum effects associated with nano-corrugation in plasmonic surface

Che Ting Chan, HKUST, Hong Kong

There is a kind of nano-scale force, which can be attractive or repulsive, that exists between electrically neutral nano-corrugated or nano-patterned surfaces due to the electronic charge profile. Due to the quantum nature of the force, it cannot be calculated using the standard classical electrodynamics methods.

T10. Time-variant metasurfaces as a frequency converting platform

Bumki Min, KAIST, South Korea

We propose rapidly time - variant metasurfaces as a frequency - conversion platform and experimentally demonstrate their efficacy at THz frequencies. The proposed metasurface is designed for the sudden merging of two distinct resonances into a single resonance upon ultrafast optical excitation. From this spectrally-engineered temporal boundary onward, the merged-resonance frequency component is radiated.

TN2. Topological Nanophotonics 2 (Friday 6 Apr, 9:00-10:20)

T11. Topological structures made of dielectric resonant nanoparticles

Yuri Kivshar, Australian National University, Australia

We will introduce the field of all-dielectric resonant meta-optics and discuss several problems involving topological edge states. In particular, we generate a third-harmonic field from topological photonic edge states in zigzag arrays of silicon nanoparticles. The effect is unidirectional due to the interplay of nonlinearity and bianisotropic coupling between electric and magnetic Mie resonances.

T12. Nano-optomechanics with a levitated nanoparticle

Yidong Chong, Nanyang Technological University, Singapore

Photonic systems with tunable topological transitions have many interesting properties.

I discuss (i) a magneto-optical photonic crystal that behaves as a strongly magneto-optical effective medium, revealing a novel connection to magneto-optical surface waves, and (ii) a design for an optical resonator lattice with switchable topological edge states.

T13. Bringing topological photonics to nanoscale

Gennady Shvets, Cornell University, USA

We demonstrate how graphene surface plasmon polaritons (GSPPs) can be used as a reconfigurable platform for creating topological photonic phases on the nanoscale. By applying voltage between the metagate and graphene, one can induce a strongly non-uniform distribution of chemical potential that endows GSPPs with non-trivial valley-Chern numbers.

MN2. Metamaterials and Nanophotonics 2 (Friday 6 Apr, 10:50-12:50)

T14. Giant broadband enhancement of linear and nonlinear susceptibility tensors in mesoscopic crystals

Jonghwa Shin, KAIST, South Korea

We show that it is possible to enhance the linear and nonlinear susceptibilities by several orders of magnitudes over broad frequency ranges by introducing mesoscopic composites of conductors and insulators. On top of electric field localization, the manipulation of the effective electric displacement field is the key towards this.

T15. Metasurfaces for the control of quantum imaging and optical nonlinearities

Daniele Faccio, Heriot-Watt University, UK

We will present recent work with epsilon-near-zero films based on transparent conductive oxides (e.g. ITO, AZO). These show remarkable nonlinear effects that are many orders of magnitude higher than in any other optical material (even if the nonlinearity itself is not significantly larger than e.g. metals). We will also show results of strong polariton coupling between ENZ films and metallic nano-antennas.

T16. k-space imaging of quantum mechanical nonlinear polarization sources in second harmonic generation

Namkyoo Park, Seoul National University, South Korea

The lack of an experimentally supported theoretical model composes a current bottleneck in the application of SHG. Here, we show the angle-resolved SHG radiation from 82 antennas with varying widths, to reveal that the use of quantum-feature modelling is critical, in the correct description of microscopic origins of SHG.

T17. Peptide encoded gigantic chirality evolution in three-dimensional plasmonic helicoïds

Junsuk Rho, Postech, South Korea

In this talk, we will discuss recent progress in 3D chiral metamaterials. Especially, bottom-up based chiral nanoparticles which are encoded by amino acid and peptides, and show the gigantic chiroptical properties will be discussed.

TN3. Topological Nanophotonics 3 (Friday 6 Apr, 14:00-15:20)

T18. "Plasmonics" in free space

Nikolay Zheludev, NTU, Singapore & University of Southampton, UK

We show that electromagnetic field near the superoscillatory hotspot has many features similar to those found near resonant plasmonic nanoparticles or nanoholes: the hotspots are surrounded by nanoscale phase singularities ($\sim \lambda/50$ in size) and zones where the phase of the wave changes more than tenfold faster than in a standing wave. These areas with high local wavevectors are pinned to zones of energy backflow ($\sim \lambda/20$ in size) that narrow light's channel in the forward direction thus focusing it beyond the Abbe-Rayleigh limit. Our observations reveal the analogy between plasmonic nano-focusing of evanescent waves and superoscillatory nano-focusing of free-space waves.

T19. Advances in geometrical and topological pumping

Hannah Price, Birmingham University, UK

The geometrical and topological properties of energy bands underlie many fascinating phenomena, such as the robust and precise quantization of electrical conductance observed in the quantum Hall effect. In a "topological pump", this physics manifests in a lower-dimensional system as the quantisation of particle transport across a band insulator, when that system is periodically and adiabatically "pumped" over time. In a "geometrical pump", on the other hand, a wave-packet moves by an unquantized amount after each pump period, but in such a way that depends on local geometrical properties, such as the Berry curvature of a band. In this talk, I will first present our implementation of such a one-dimensional geometrical pump in two coupled fibre loops and then show how we have

used this approach to experimentally map out the Berry curvature in an optical system. Secondly, I will review how topological pumps can be extended into higher dimensions, allowing us to probe exotic physics, such as the four-dimensional quantum Hall effect for the first time.

T20. Some topological states of light and matter

Janne Ruostekoski, University of Southampton

Topologically non-trivial states of matter have attracted considerable interest already for quite

some time. Light as well as combinations of light and matter can also form topologically non-trivial configurations that exhibit topological winding numbers and charges. These include simple vortex lines in physical space, vortices in configuration space, and more complex particle-like charges.

One of the major challenges is the development of techniques for controlled preparation and engineering of such states.

TN4. Topological Nanophotonics 4 (Friday 6 Apr, 15:50-17:10)

T21. Hidden plasmon geometric phase

Justin Song, Nanyang Technological University, Singapore

Deep sub-wavelength plasmons (e.g., in 2D materials) as longitudinal-electric modes are conventionally thought to be vanilla objects with a featureless structure. We will discuss how these plasmons can acquire an internal non-trivial structure composed of the free charge current density in Hall metals, allowing them to pick up non-trivial geometric phases and exhibit unconventional dynamics.

T22. Nanophotonics with hexagonal boron nitride

Igor Aharonovich, University of Technology Sydney, Australia

Engineering solid state quantum systems is amongst grand challenges in engineering quantum information processing systems. While several 3D systems (such as diamond, silicon carbide, zinc oxide) have been thoroughly studied, solid state emitters in two dimensional (2D) materials have not been observed. 2D materials are becoming major players in modern nanophotonics technologies and engineering quantum emitters in these systems is a vital goal. In this talk I will discuss the recently discovered single photon emitters in 2D hexagonal boron nitride (hBN). I will present several avenues to engineer these emitters in large exfoliated sheets using ion and electron beam techniques. I will also show our recent experiments including strain tuning, two photon absorption and stability at high temperatures. Those properties make these

emitters extremely attractive for their integration with optical resonators and waveguides. Finally, I will discuss several challenges and promising directions in the field of quantum emitters and nanophotonics with 2D materials and other wide band gap materials.

T23. Probing quantum plasmonics and the ultimate limits of light compression with Van der Waals heterostructures

Frank Koppens, ICFO, Spain

Van der Waals materials have emerged as a toolbox for in-situ control of a wide range of collective excitations coupled to light: polaritons. In this talk, we will show several examples of novel ways of exciting, controlling and detecting polaritons. Plasmon modes propagating almost as slow as the electron Fermi velocity show a strong quantum non-local response, which can be further exploited to study many-body effects. We further show that a graphene-insulator-metal heterostructure can overcome the trade-off of optical confinement and loss, and we demonstrate plasmon confinement down to the ultimate limit of the lengthscale of one atom. Record strong normalized mode volume confinement of the range 10^9 - 10^{10} was achieved by far-field excitation of plasmon modes squeezed into an atomically thin h-BN spacer between graphene and metal rods. These ultra-confined plasmonic modes, addressed with far-field light excitation, enables a route to new regimes of ultra-strong light-matter interactions.

QN2. Quantum Nanophotonics 2 (Saturday 7 Apr, 9:00-10:20)

T24. Topological Photonics in 2D Dirac Lattices and 3D Gyroid Photonic Crystals

Harry Atwater, CALTECH, USA

The interaction between light and matter can give rise to novel topological states. We report on the flow of light in two topological nanophotonic systems: two-dimensional Dirac lattices and three-dimensional gyroid photonic crystals. The photonic band and light dispersion characteristics in two-dimensional hexagonal Dirac lattices of cylindrical Si nanoparticles are probed using angle-resolved optical extinction and angle-resolved cathodoluminescence measurements, revealing clear evidence of strong interparticle optical coupling and also changes in the lattice photonic band structure, suggesting appearance of edge states within photonic bandgaps that emerge upon lattice deformation. Three dimensional gyroid photonic crystals synthesized by two-photon lithography show evidence of photonic bandgaps at mid-infrared wavelengths induced by inclusion of gyroid lattice distortions. Mid-infrared scattering measurements indicate surface states within the gyroid photonic crystal bandgap.

T25. Single photon emitter in GaN in telecom range

Weibo Gao, Nanyang Technological University, Singapore

On demand single photon emitters (SPEs) play a key role across a broad range of quantum technologies, including quantum computation, quantum simulation quantum metrology and quantum communications. In quantum networks and quantum key distribution protocols, where photons are employed as flying qubits, telecom wavelength operation is preferred due to the reduced fibre loss. However, despite the tremendous efforts to develop various triggered SPE platforms¹, a robust source of triggered SPEs operating at room temperature and the telecom wavelength is still missing. Here we report a triggered, optically stable, room temperature solid state SPE operating at telecom wavelengths. The emitters exhibit high photon purity (~5% multiphoton events) and a record-high brightness of ~1.5 MHz. The emission is attributed to

localized defects in a gallium nitride (GaN) crystal. The high performance SPEs embedded in a technologically mature semiconductor are promising for on-chip quantum simulators and practical quantum communication technologies.

T26. Infrared metrology with visible photons

Leonid Krivitsky, A*STAR, Singapore

Infrared (IR) optical range is a vital fingerprint region where a variety of media has distinctive absorption lines. That is why it is widely used for material characterization and analysis in pharma, bio-medical and petrochemical industries. Although conventional methods of IR measurements are well developed, there are remaining challenges associated with high cost and low efficiency of IR light sources and detectors. Here we show that by exploiting effects of nonlinear and quantum optics it is possible to overcome this challenge and retrieve properties of the materials in the IR range from measurements of visible range photons.

Our approach is based on the nonclassical interference of frequency correlated photons produced via spontaneous parametric down conversion (SPDC). Within this process, one of the photons is generated in the detection-friendly visible range, and its correlated counterpart in the IR range is used to probe properties of the medium. The interference fringes observed for the visible photon depend on the properties of the IR photon, traveling through the sample. We build a nonlinear analog of a Michelson interferometer and demonstrate the absorption spectroscopy, optical coherence tomography (OCT) and imaging in the IR range when the actual measurements are performed in the visible range. Our method contributes to further development of metrology techniques based on nonlinear optical phenomena, where information about sample properties in IR range can be inferred from measurements in a much more user-friendly visible band.

T27. Quantum Optics with a Polymer Platform

Alexander Ling Euk Jin, National University of Singapore, Singapore

Mapping the random walk of a single photon traversing a complex photonic array is conceptually and mathematically trivial, but quite

challenging to implement. In this talk, I will present a novel polymer photonics platform that will enable us to achieve this challenging implementation. I will discuss the outlook for these devices in the context of quantum and nonlinear optics.

QN3. Electrons, Atoms and Molecules (Saturday 7 Apr, 11:10-13:00)

T28. Intramolecular charge transfer near hyperbolic metamaterial

Jeong Weon Wu, Ewha Womans University, South Korea

Blue-shifting intramolecular charge transfer emission takes place owing to nonlocal effect of hyperbolic metamaterials, differently from π - π^* emission. Also charge-transfer dynamics can be controlled by nonlocal dielectric permittivity tuned with metamaterial structures as solvent analogues.

T29. Cathodoluminescence of quantum materials

Jinkyu So, Nanyang Technological University, Singapore

Optical characterization of quantum materials often requires spatial resolution below diffraction limit and this can be resolved by creating optical excitations with subwavelength probes such as scanning probes or focused electron beams. We will discuss how cathodoluminescence can contribute to the understanding of quantum materials such as perovskites, 2D transition metal dichalcogenides, and gallium nitrides.

T30. Atom with surface plasmon: tuning Casimir-Polder interaction and multiple transition enhancement

David Wilkowski, Nanyang Technological University, Singapore

At the vicinity of a surface (metallic or dielectric) atomic resonances are shifted by the

Casimir-Polder interaction. The spatial dependency of this interaction ($1/z^3$, in the non retarded regime) can be a crucial limitation for the development of compact sensors at the micrometre size scale. To address this issue, we explore the tunability property of the Casimir-Polder interaction with resonant surface plasmon modes. These latter are generated using nano-structured metallic layers. We found that the atomic resonance shift can be almost suppressed and the Purcell factor enhanced. More recently, we investigate quadrupole atomic transitions in surface plasmon. Those transitions are extremely weak in vacuum (~ 1 Hz) but can be enhanced if the spatial variation of the electromagnetic field become stronger as expected with localized surface plasmons. In this context, we will present our results, obtained with a caesium vapour, and discuss the potential application of creating new excitation channels in atomic spectrum.

T31. Nanoscale light vapor interactions on a chip

Uriel Levy, Hebrew University of Jerusalem, Israel

In this talk we describe our work on quantum nanophotonics devices based on the integration of hot vapors with nanoscale photonic structures. We describe the platform and present recent experimental results.

Posters

PS1. Quantum & Topological Nanophotonics (Thursday 5 Apr, 12:50-14:00)

P1. Zeeman splitting via spin-valley-layer coupling in bilayer MoTe₂

Chongyun Jiang et al., SPMS, Nanyang Technological University, Singapore

Atomically thin monolayer transition metal dichalcogenides possess coupling of spin and valley degrees of freedom. The chirality is locked to identical valleys as a consequence of spin-orbit coupling and inversion symmetry breaking, leading to a valley analog of the Zeeman Effect in presence of an out-of-plane magnetic field. Owing to the inversion symmetry in bilayers, the photoluminescence helicity should no longer be locked to the valleys. Here we show that the Zeeman splitting, however, persists in 2H-MoTe₂ bilayers, as a result of an additional degree of freedom, namely the layer pseudospin, and spin-valley-layer locking. Unlike monolayers, the Zeeman splitting in bilayers occurs without lifting valley degeneracy. The degree of circularly polarized photoluminescence is tuned with magnetic field from -37% to 37%. Our results demonstrate the control of degree of freedom in bilayer with magnetic field, which makes bilayer a promising platform for spin-valley quantum gates based on magnetoelectric effects.

P2. Metamaterial with non-radiating anapole mode

Tsung Lin Chung et al., National Taiwan University, Taiwan

Natural toroidal molecules, such as biomolecules and proteins, possess toroidal dipole moments that are hard to be detected, which leads to extensive studies of artificial toroidal materials. Metamaterials are sub-wavelength artificial structures that can be carefully designed to manipulate the intensity of induced electric and magnetic dipoles. Recently, toroidal metamaterials have been widely investigated to enhance toroidal dipole moments while the other multipoles are eliminated due to the spatial symmetry. However, to effectively excite a toroidal dipole, a specific excitation method is necessary since a closed-loop of induced magnetic

dipoles in a toroidal metamaterial weakly interact with the external wave. This is a key issue that has to be carefully taken into account in existing toroidal experiments. Moreover, most of generated toroidal dipole moments are either aligned vertically to the substrate surface or embedded in a dielectric, which is another constraint for further applications.

P3. Topological Insulator Metamaterials

Harish N S Krishnamoorthy et al., Centre for Disruptive Photonic Technologies, TPI, SPMS, Nanyang Technological University, Singapore

We investigate the composition-dependent optical response of nanostructured Bi-based topological insulator crystalline films and show that an increased concentration of Te results in stronger resonances that persist over a large spectral range. By means of ellipsometry and FTIR absorption measurements, we establish that the materials show composition-dependent bandgap in the mid-infrared region and resulting absorption in the visible and near-infrared part of the spectrum. In addition, they also show plasmonic behavior in the visible region with figure of merits that compare well with that of noble metals in certain parts of the spectrum. Nanoslit metamaterial arrays were fabricated in exfoliated films of these crystals by means of focused ion-beam milling. They exhibit strong optical resonances over a wide spectral range from the visible to the mid-infrared region that persist well outside of the plasmonic regime. We observe that the rate at which the resonances red-shift with the length of the nanoslit varies depending on whether it lies in the plasmonic or dielectric regime of the dielectric function and that a larger Te concentration makes this effect more pronounced.

P4. Plasmon geometric phase and plasmon Hall shift

Li-kun Shi et al., A*STAR, Singapore

The collective plasmonic modes of a metal comprise a simple pattern of oscillating charge density that yields enhanced light-matter interaction. Here we unveil that beneath this familiar façade, plasmons possess a hidden internal structure that fundamentally alters its dynamics. In particular, we find that metals with non-zero Hall conductivity host plasmons with an intricate current density configuration that sharply departs from that of ordinary zero Hall conductivity metals. This non-trivial internal structure dramatically enriches the dynamics of plasmon propagation, enabling plasmon wavepackets to acquire geometric phases as they scatter. At boundaries these phases accumulate allowing plasmon waves that reflect off to experience a non-reciprocal parallel shift along the boundary. This plasmon Hall shift, tunable by Hall conductivity as well as plasmon wavelength, displaces the incident and reflected plasmon trajectories and can be readily probed by near field photonics techniques. Anomalous plasmon geometric phases dramatically enriches the Nanophotonics toolbox, and yield radical new means for directing plasmonic beams.

P5. Directional thermal infrared absorption and emission of zero refractive index dielectric metamaterials

Byungsoo Kang et al., KAIST, South Korea

The zero refractive index metamaterial is numerically simulated and experimented, proven to exhibit abrupt change in transmittance with respect to the incident angle from the surface normal direction and highly directional infrared absorption and thermal emission.

P6. Electromagnetic spontaneous emission enhancement outside hyperbolic metamaterials

Jongwoo Hong et al., Seoul National University, South Korea

An electromagnetic spontaneous emission is enhanced outside hyperbolic metamaterial by bowtie pattern for electric spontaneous emission enhancement and tapered pattern for magnetic spontaneous emission enhancement, which is

numerically demonstrated in FDTD solutions. Contrary to spontaneous emission enhancement inside hyperbolic metamaterial, it is possible to inject dye molecule after fabrication.

P7. Ultra-confined surface phonon polaritons in molecular layers of van der Waals dielectrics

Alexander M. Dubrovkin et al., Centre for Disruptive Photonic Technologies, TPI, SPMS, Nanyang Technological University, Singapore

Improvements in device density in photonic circuits can only be achieved with interconnects exploiting highly confined states of light. Recently this brought interests to highly confined plasmon and phonon polaritons. While plasmonic structures have been extensively studied, the ultimate limits of phonon polaritons squeezing, in particular enabling the confinement (the ratio between the excitation and polariton wavelengths) exceeding 102 is yet to be explored. Here, exploiting unique structure of 2D materials, we report for the first time that atomically-thin van der Waals dielectrics (e.g. transition metal dichalcogenides) on silicon carbide substrate demonstrate experimentally record-breaking propagating phonon polaritons confinement resulting in 190-times squeezed surface waves. The strongly dispersive confinement can be potentially tuned to greater than 103 near the phonon resonance of the substrate, and it scales with number of van der Waals layers. We argue that our findings are a substantial step towards infrared ultra-compact phonon polaritonic circuits and would stimulate further investigations on nanophotonics in non-plasmonic atomically-thin interface platform.

P8. Fully fiberized dissipative single photon switch

Anton N. Vetlugin et al., Centre for Disruptive Photonic Technologies, TPI, SPMS, Nanyang Technological University, Singapore

In this report we provide the first demonstration of a fully fiberized dissipative single photon switch with a fiber-integrated metamaterial. To control the single photon absorption and realize the switching we use the phenomenon of coherent absorption in plasmonic metamaterials. Splitting a single photon and forming a standing wave can significantly change the interaction with

absorptive metamaterial allowing to achieve both deterministic absorption and transmission, while the absorption of photons from a travelling wave is significantly probabilistic. Here we demonstrate manipulation of light at a single photon level in an all-fiber-optic quantum network based on Sagnac-like interferometer with a fiber-integrated plasmonic absorber. First, we achieve continuous control of the single photon (heralded down-converted single photon source is used) absorption probability with visibility of 80% by altering phase retardation in one arm of the interferometer. Finally, we demonstrate single photon switching regime with active phase modulation, showing the ability of driving the quantum network in time-domain between coherent single photon transmission and absorption regimes.

Our results demonstrate that stabilized and free-running fiber networks can be robustly used in dissipative single photon switching, thereby presenting powerful opportunities for novel coherent optical data processing architectures.

P9. 2D Monte Carlo simulation of CMOS-compatible waveguide-based single-photon avalanche diode for visible wavelengths

Salih Yanikgonul et al., DSI, A*STAR, Singapore

Integrated photonics platforms are a potential key factor in enabling the scalable implementation of photonic quantum technologies, but many such applications still rely on external bulk photodetectors. We report the design and simulation of a waveguide-based single-photon avalanche diode (SPAD) for visible wavelengths. The SPAD consists of a PN junction implemented in a doped silicon waveguide, which is end-fire coupled to an input silicon nitride waveguide. We develop a 2D Monte Carlo model to simulate the avalanche multiplication process of charge carriers following the absorption of an input photon, and calculate the photon detection efficiency η and timing jitter Δt_j of the SPAD. We investigate the SPAD performance at 640 nm for different device dimensions and device doping configurations. For our simulated parameters, we obtain a maximum efficiency of $\eta = 0.45\%$ with a breakdown voltage of 25V, and typical timing jitter values of $\Delta t_j < 10$ ps.

P10. Realization of microscopic dipole trap for cesium atoms using structured superoscillating light beams

Hubert Souquet-Basiège et al., Centre for Disruptive Photonic Technologies, TPI, SPMS, Nanyang Technological University, Singapore

It is commonly admitted that the resolution for the imaging of a point in far field regime is fundamentally limited by the diffraction of the light going through the lens of a finite size. However, a method to reach subdiffraction resolution was proposed in 1952. A spot with an arbitrary small size can be generated by modulating the amplitude of an incoming beam. It can be achieved by using a binary mask of concentric annulars called super oscillatory lens. The transmitted light is referred as super oscillating because it locally oscillates faster than its fastest Fourier component. These super oscillatory lenses were initially introduced for super resolution microscopy. Lately, they were used to trap nanoparticles with high localization accuracy in optical tweezers. In a future experiment, we plan to trap a single cesium atom in a microscopic dipole trap generated by focusing a far red detuned laser beam with a super oscillatory lens. It should lead to a very accurate spatial localization of this atom. We present in this poster some properties of this kind of microscopic dipole trap and discuss some way to load an atom in such tiny trap.

P11. Tailoring atom-surface Casimir-Polder interactions with Metamaterials and Integration on a fiberized platform

Chan Eng Aik et al., Centre for Disruptive Photonic Technologies, TPI, SPMS, Nanyang Technological University, Singapore

Theoretical works of atom near surface has shown interesting control of atomic internal modes such as allowing forbidden transitions on 2D surfaces, changing selection rules. Realization of such phenomena requires atoms to be positioned very close to the surface. In such regime, strong Casimir-Polder interactions come into play with strong modification of vacuum environments of the atoms, the ability to efficiently tune Casimir-Polder interactions are critical in achieving atoms localization near a surface. In this poster presentation, we report control of surface Casimir-Polder shift on Caesium energy levels, down to

near extinction by tailoring the surface metamaterials. We show that retardation effects need to be taken into account in explaining the energy shift in our experimental data. We also demonstrate experimental results on interfacing atom-metamaterial on the tip of an optical fiber, which is a stepping stone towards the realization of functionality of atoms with localized field on integrated optical network.

PS2. Nanophotonics & Metamaterials (Friday 6 Apr, 12:50-14:00)

P13. Broadband Achromatic metalens in visible
Mu-Ku Chen et al., National Taiwan University, Taiwan

Metasurfaces have shown great abilities on controlling light properties in demand at a subwavelength fashion. They therefore are very promising for the development of flat optical components. However, the building blocks of metasurfaces usual exhibit strong dispersion effect, which results in chromatic aberration apparently. For addressing this issue, we come out a design principle by incorporating integrated-resonant unit elements with geometric phase for realizing specific phase compensation as a function of spatial position. In this paper, we use a series of GaN-based integrated-resonant unit elements for a novel achromatic metalens works for the entire visible region in transmission mode. The basic building blocks of the metasurface are solid and inverse GaN nanostructures. Moreover, the waveguide-like cavity resonances in nano-pillars exhibit that the induced optical fields are highly concentrated inside the dielectric structures, resulting in the negligible interaction with their neighbours. Instead of introducing more resonators, one can also acquire large phase compensation with GaN nano-pillars by exciting higher orders of waveguide-like cavity resonances, which can be realized by directly increasing the height of the nano-pillars. The focal length of the achromatic metalens keeps unchanged in working wavelength from 400 nm to 660nm. The highest working efficiency can be up to 67%, while the average efficiency is about 40% over the whole working bandwidth. For the practical use of optical imaging, we use the resolution test chart and illuminated by a halogen light source. The resolution of the achromatic metalens is about 2.2 μm . Furthermore, full color image can be imaged

P12. Dynamics of Quantum Gas in Non-Abelian Gauge Field

Mehedi Hasan et al., SPMS, Nanyang Technological University, Singapore

We will present an experimentally a realizable way to detect the signature of nonAbelian gauge field from the expansion of an atomic wavepacket. Moreover, we will hint towards the realization of negative index media via SU (2) symmetric Hamiltonian, in the context of cold atom system.

by this achromatic metalens. This work opens a great progress for the developments of full-color imaging and display.

P14. Broadband polarizer using metallic nanowires based on impedance matching condition

Minsung Heo et al., KAIST, South Korea

This study focus on broadband polarizer using metallic nanostructures. We have theoretically investigated anisotropic impedance matching conditions through effective permittivity control based on metallic nanowire. The ratio of TM and TE transmittance of the proposed polarizer was more than 25dB in the near - infrared range from visible light.

P15. Numerical study on electrically controllable broadband absorption modulator using hyperbolic metamaterials

Yohan Lee et al., Seoul National University, South Korea

Numerical analysis on an electrically controllable broadband absorption modulator was executed. It is capable of absorbing light with 20 % of relative change at around 1550 nm. It was designed based on hyperbolic metamaterial to support high-k modes, and to operate by voltage application on the transparent conducting oxide layer. In the many-photon regime the response can be highly non-linear, and under certain circumstances the entire ensemble can behave like a single two-level system, which is only capable of absorbing and emitting a single excitation at a time. Moreover, we show that the system can be used to generate Dicke states with high fidelity, which may then be efficiently mapped back out to propagating

waveguide modes, thus giving access to multi-photon Fock states. Our results are of direct relevance to atom-PCW experiments that should soon be realizable.

P16. Broadband THz Tunable Beam Splitter Based on Electrically-controlled Graphene Metadevices
Soojeong Baek et al., KAIST, South Korea

We propose broadband THz tunable power splitters based on gated-graphene metadevices. Splitting ratio of the beam splitter can be modulated in an electrically tunable manner.

P17. Tunable Absorption with Fractal Graphene Metasurfaces
Kuan-Wei Lee et al., National Taiwan University, Taiwan

Graphene has emerged as a promising platform for THz metasurfaces supporting electrically tunable deep subwavelength plasmonic excitations. Here, we introduce a broadband graphene metasurface based on the Hilbert curve, a continuous, space-filling fractal. We demonstrate the enhancement of graphene absorption over a broad frequency band (0.5–60 THz) with an average absorption level exceeding 20%. Owing to the continuous nature of the metasurface patterns, both the absorption level and the bandwidth can be controlled electrically by varying the graphene charge-carrier concentration.

P18. Efficient visible reflection modulation using phase-change VO₂ metafilm
Sun-Je Kim et al., Seoul National University, South Korea

We demonstrate a novel phase-change ultrathin metafilm for modulation of visible light based on Mott transition of vanadium dioxide (VO₂). The proposed metafilm is designed by mixing gold and VO₂ based on effective medium theory and shows largely tunable reflection in the visible.

P19. Phase-Change Metasurfaces with Addressable Optical Functionalities
Ming Lun Tseng et al., National Taiwan University, Taiwan

Since recent years, many research efforts have been addressed on developments of novel tunable metasurface devices. This is because tunable metasurfaces as artificial subwavelength structures can show many tunable functionalities that cannot be realized by conventional photonic devices, such as tunable micro lens, color tunable surface, as well as tunable meta-hologram. One kind of material that can be conveniently applied to the development of tunable and low-loss metasurfaces is the phase change material. Phase-change materials have been widely used in commercial rewritable optical disks and as media for storage cells in electronic phase-change memories. Phase-change materials can show large optical as well as electronic contrasts between the amorphous and the crystalline states. Among all the phase change materials, Ge₂Sb₂Te₅ (GST) is known to have advantages of low optical loss in the near infrared (NIR) regime and non-volatility, high stability and quick response. Therefore, it also has also been used to be integrated into metadevices for realizing the tunable optical functionalities, such as tunable light absorber and super oscillation lens. In this paper we are going to report our recent results on the development of tunable all-dielectric metasurfaces based on GST alloy.

P20. Frequency conversion with a highly dispersive time-varying metamaterial

Jagang Park et al., KAIST, South Korea

This work suggests an efficient frequency conversion scheme using highly dispersive time-varying metamaterials. The metamaterial with carefully designed multiple resonant structures can give steep geometric phase gradient in the frequency domain, and the active shifting of their resonant frequencies over time can lead the frequency conversion of the incident wave.

P21. Enhancing circular dichroic response of chiral molecules by utilizing nanostructures

TaeHyung Kim et al., Korea University, South Korea

The enhanced circular dichroism of chiral molecules has been achieved by using local fields of nanostructures. We study the chiroptical activity of the nanoparticle core - chiral molecule shell structure using the circular differential Mie scattering theory. We demonstrate that the circular differential extinction can be amplified through various channels.

P22. Microwave demonstration of universal impedance matching and perfect anti-reflection using metamaterials

Ku Im et al., Korea University, South Korea

We designed the universal impedance matching layer structure that allows the perfect anti-reflection in microwave region, and performed reflection and transmission measurements experimentally. This experiment demonstrates almost zero reflection up to an angle of incidence of 70 degrees and confirms the feasibility of the omnidirectional anti-reflection.

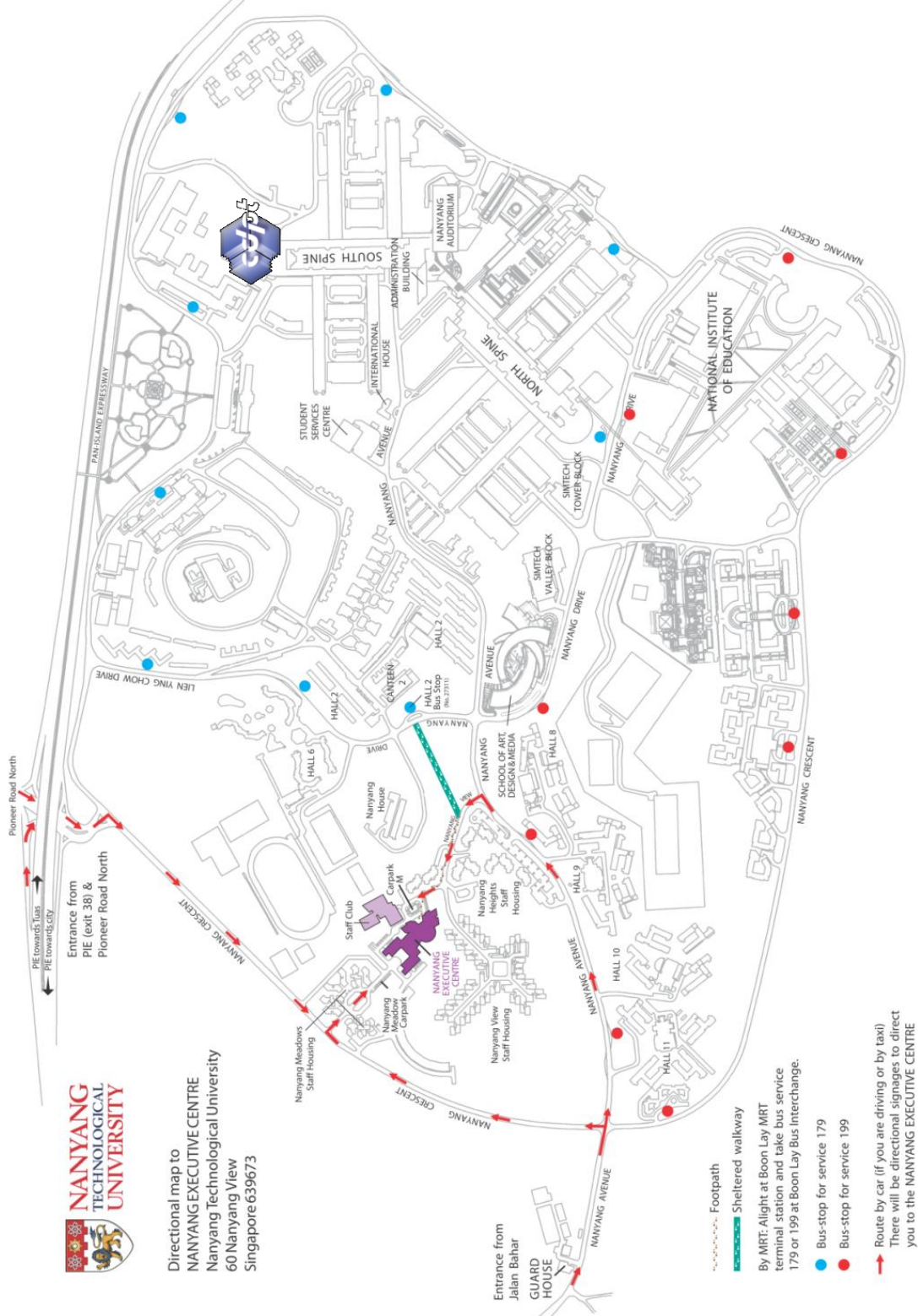
P23. Parallelization of the hybrid PSTD-FDTD method for the large-scale metamaterial simulation

Donggun Lee et al., Korea University, South Korea

Pseudo-Spectral-Time-Domain method (PSTD) has advantages against Finite-Difference-Time-Domain method (FDTD) in terms of saving memory and operation time without loss of accuracy. However, unlike FDTD, parallelization of PSTD using Fourier transform is not easy. We present a hybridized PSTD-FDTD method that has both the advantages of PSTD and allows the parallel computing simulation.



**Directional map to
NANYANG EXECUTIVE CENTRE**
Nanyang Technological University
60 Nanyang View
Singapore 639673



- Footpath
- Sheltered walkway
- By MRT: Alight at Boon Lay MRT terminal station and take bus service 179 or 199 at Boon Lay Bus Interchange.
- Bus-stop for service 179
- Bus-stop for service 199
- Route by car (if you are driving or by taxi)
- There will be directional signages to direct you to the NANYANG EXECUTIVE CENTRE

