CENTRE FOR DISRUPTIVE PHOTONIC TECHNOLOGIES

ICFO The Institute of Photonic Sciences

Quantum and Topological Nanophotonics (QTN) Workshop

7-9 December 2016

Nanyang Technological University, Singapore

Supported by:

NANYANG TECHNOLOGICAL UNIVERSITY
Institute of Advanced

TPI The Photonics Institute SINGAPORE

NANYANG TECHNOLOGICAL UNIVERSITY
School of Physical and Mathematical Sciences

Thursday 8 Dec 2016	
13:45	**Program for international visitors**

Thursday 8 Dec 2016	
8:45	**Registration** **Auditorium - Nanyang Executive Centre, NTU**
9:00	**Opening Address**
	TN1. *Topological Nanophotonics* - Chair: Prof Nikolay Zheludev (CDPT)
9:20	**TN1.1 Prof Yuri Kivshar (Australian National University, Australia)** *Topological photonics with all-dielectric nanostructures and metacrystals*
9:50	**TN1.2 Prof Yidong Chong (Nanyang Technological University, Singapore)** *Solitons and Weyl modes in photonic lattices*
10:10	**Coffee & Tea Break**
10:40	**TN1.3 Prof Gennady Shvets (Cornell University, USA)** *Topological phases of light: implementation, integration, and applications*
11:10	**TN1.4 Prof Baile Zhang (Nanyang Technological University, Singapore)** *Testing robustness of topological photonic states*
	QN1. *Quantum Phenomena in Graphene* - Chair: Prof Zexiang Shen (CDPT)
11:30	**QN1.1 Prof Javier Garcia de Abajo (ICFO, Spain)** *Ultrafast plasmonic processes in atomically thin materials*
12:00	**QN1.2 Prof Dimitri Basov (Columbia University, USA)** *Probing quantum phenomena in graphene by infrared nano-imaging of plasmonic waves*
12:30	**Lunch Break & Poster Session**
	TN2. *Topological Elecromagnetism* - Chair: Prof Romain Quidant (ICFO)
14:00	**TN2.1 Prof Nikolay Zheludev (NTU, Singapore & University of Southampton, UK)** *Propagating and localized toroidal electromagnetic excitations*
14:20	**TN2.2 Prof Meir Orenstein (TECHNION, Israel)** *The topological structure of electromagnetic fields in the nanoscale*
14:50	**TN2.3 Prof Ranjan Singh (Nanyang Technological University, Singapore)** *High Q toroidal and anapole resonances in metamaterials*
15:10	**Coffee & Tea Break**
	QN2. *Quantum Optics* - Chair: Prof Yidong Chong (CDPT)
15:30	**QN2.1 Prof Dimitris Angelakis (CQT, National University of Singapore)** *From fractional Hall physics to topological pumping with interacting photons*
16:00	**QN2.2 Prof Romain Quidant (ICFO, Spain)** *Nano-optomechanics with a levitated nanoparticle*
16:30	**QN2.3 Prof Weibo Gao (Nanyang Technological University, Singapore)** *Coherent control of a strongly driven silicon vacancy in diamond*
16:50	**End of day 1**

Friday 9 Dec 2016	
8:45	**Registration** **Auditorium - Nanyang Executive Centre, NTU**
	QN3. *Quantum Nanophotonics* - Chair: Prof Valerio Pruneri (ICFO)
9:00	**QN3.1 Prof Arno Rauschenbeutel (Technical University Vienna, Austria)** *Chiral nanophotonics and quantum optics*
9:30	**QN3.2 Prof David Wilkowski (CQT, Nanyang Technological University, Singapore)** *Quantum atoms/metamaterial*
9:50	**QN3.3 Prof Janne Ruostekoski (University of Southampton)** *Electrodynamics from standard optics to correlations and to quantum*
10:20	**QN3.4 Prof Rainer Dumke (CQT, Nanyang Technological University, Singapore)** *Superconducting atom chips*
10:40	**Coffee & Tea Break**
	TN3. *Topological Materials* - Chair: Prof Javier Garcia de Abajo (ICFO)
11:10	**TN3.1 Prof Feodor Kusmartsev (Loughborough University, UK)** *Topological materials: origin, history, symmetry and future*
11:40	**TN3.2 Prof Harry Atwater (CALTECH, USA)** *Photons and plasmons in topologically structured materials*
12:10	**TN3.3 Prof Cesare Soci (Nanyang Technological University, Singapore)** *Plasmonics of topological insulators*
12:30	**TN3.4 Prof Robert Simpson (Singapore University of Technology & Design)** *Design and growth of Sb_2Te_3, Bi_2Te_3, and Bi_2Se_3 heterostructure superlattices*
12:50	**Lunch Break & Poster Session**
	MD1. *Optical Materials and Devices* - Chair: Prof Cesare Soci (CDPT)
14:30	**MD1.1 Prof Valerio Pruneri (ICFO, Spain)** *Multifunctional optical surfaces for industrial applications using ultrathin materials and nano-structuring*
15:00	**MD1.2 Prof Harald Giessen (Stuttgart University, Germany)** *Short-range surface plasmonics on atomically flat gold surfaces*
15:30	**MD1.3 Prof Niek van Hulst (ICFO, Spain)** *Nanophotonics: coherent control, strong coupling, bright photon emitters*
16:00	**Coffee & Tea Break**
	QN4. *Quantum @ Epsilon Near Zero* - Chair: Prof Niek Van Hulst (ICFO)
16:30	**QN4.1 Prof Daniele Faccio (Heriot-Watt University, UK)** *Quantum optics in ENZ and absorbing metamaterials*
17:00	**QN4.2 Prof Nader Engheta (University of Pennsylvania, USA)** *Quantum features of near-zero photonics*
17:30	**Closing Remarks & End of Technical Program**

Abstracts

Invited Talks

TN1. Topological Nanophotonics

TN1.1. *Topological photonics with all-dielectric nanostructures and metacrystals*
Yuri Kivshar, Australian National University, Australia

We suggest several all-dielectric photonic structures for realising topological edge states including zigzag arrays of dielectric nanoparticles based on optically induced magnetic Mie resonances and all-dielectric metacrystals. We demonstrate experimentally the ability to control the subwavelength topologically protected optical edge modes by changing the polarization of the incident wave.

TN1.2. *Solitons and Weyl modes in photonic lattices*
Yidong Chong, Nanyang Technological University, Singapore

This talk describes novel phenomena in specially-designed arrays of helical waveguides. In the nonlinear regime we predict the existence of "topological solitons" that move along the edge, similar to linear topological edge states. Furthermore, the 3D photonic bandstructure exhibits type-II Weyl points, which we have now experimentally observed.

TN1.3. *Topological phases of light: implementation, integration, and applications*
Gennady Shvets, Cornell University, USA

Topological photonics is one of the emerging areas in optics. In this talk I will demonstrate how a wide range of concepts from condensed matter physics such as quantum spin-Hall and valley-Hall effects, can be utilized to develop novel photonics devices such as ultra-compact cavities, circulators, and delay lines. New photonic topological phases based on periodically biased graphene will also be described.

TN1.4. *Testing robustness of topological photonic states*
Baile Zhang, Nanyang Technological University, Singapore

Because of the intrinsic difference between electrons and photons, topological photonic states should not share the same robustness as their counterparts in electronic topological insulators. On a designer surface plasmon platform consisting of tunable metallic sub-wavelength structures, we probe the robustness of topological photonic states with common time-reversal-invariant photonic defects.

QN1. Quantum Phenomena in Graphene

QN1.1. *Ultrafast plasmonic processes in atomically thin materials*

Javier Garcia de Abajo, ICFO, Spain

Atomically thin materials such as graphene and other 2D crystals exhibits unique electrical, optical, and thermal properties that are a continuous source of unexpected phenomena. In this colloquim, I will review recent advances in the field of graphene nanophotonics, including the following results obtained by my group: the design and realistic description of a new class of random metamaterials incorporating optical gain and displaying a varied photonic behaviour ranging from stable lasing to chaotic regimes; a new strategy for molecular sensing that relies on the strong plasmon-driven nonlinearity of nanographenes; a scenario in which radiative heat transfer is the fastest cooling mechanism, even beating relaxation to phonons; and the generation of intense high harmonics from graphene, assisted by its plasmons. These results constitute examples that extend ultrafast optical phenomena in new directions with strong potential for technological applications

QN1.2. *Probing quantum phenomena in graphene by infrared nano-imaging of plasmonic waves*

Dimitri Basov, Columbia University, USA

Images of surfaces plasmon polaritons and other forms of hybrid light-matter polaritons provide insights into fundamental physics of materials supporting these polaritonic waves. I will discuss this emerging experimental technique with several examples from graphene physics: i) ultrafast dynamics of hot photo-excited electrons; and ii) topological defects in bilayers.

TN2. Topological Elecromagnetism

TN2.1. *Propagating and localized toroidal electromagnetic excitations*

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

The toroidal dipole is a localized electromagnetic excitation, distinct from the magnetic and electric dipoles. While the electric dipole can be understood as a pair of opposite charges and the magnetic dipole as a current loop, the toroidal dipole corresponds to currents flowing on the surface of a torus. Toroidal dipoles provide physically significant contributions to the basic characteristics of matter including absorption, dispersion and optical activity. Toroidal excitations also exist in free space as spatially and temporally localized electromagnetic pulses propagating at the speed of light and interacting with matter. We review recent experimental observations of resonant toroidal dipole excitations in metamaterials and the discovery of anapoles, non-radiating charge-current configurations involving toroidal dipoles. While certain fundamental and practical aspects of toroidal electrodynamics remain open for the moment, we envision that exploitation of toroidal excitations can have important implications for the fields of photonics, sensing, energy and information.

TN2.2. *The topological structure of electromagnetic fields in the nanoscale*

Meir Orenstein, TECHNION, Israel

When exploring the nanoscale – the topological characteristics of Maxwell fields become more prominent in determining the physical observations. We recently showed the relations between this topology to perfect imaging, and to the fact that SPR (surface plasmon resonance) is not plasmonic at all. Here we present mainly the angular momentum features of plasmons: conversion of light "spin" to plasmon angular momentum, vortex plasmonic fields and their formation dynamics, generation of C point singularities and peculiar transverse plasmonic spin. The relations of the topological structure of plasmons to light matter interactions will be exemplified by nonlinear plasmonic "spin"- orbit coupling and the potential excitation of topological insulators by plasmonic C point singularities

TN2.3. *High Q toroidal and anapole resonances in metamaterials*

Ranjan Singh, Nanyang Technological University, Singapore

Recently, the attention of metamaterial community has been attracted by the virtually unknown third family of electromagnetic multipoles, the toroidal multipoles, which along with the familiar electric and magnetic multipoles is necessary for the complete multipole representation of an arbitrary radiating source. The interaction energy of toroidal dipole depends on the time derivatives of electromagnetic fields, rather than on field themselves. Recently, toroidal dipolar response was demonstrated in three dimensional metamaterials. However, as the size of metamolecules approaches micro and nanoscale, due to limitations of fabrication, the realization of a true 3D structure becomes quite challenging. Here, we would show a high Q toroidal dipole and anapole excitation in a 2D terahertz metamaterial which is fabricated in a single-step lithography cycle.

QN2. Quantum Optics

QN2.1. *From fractional Hall physics to topological pumping with interacting photons*

Dimitris Angelakis, CQT - National University of Singapore

Progress in quantum nonlinear optics in a variety of platforms, has motivated the use of light to explore many-body physics. I will briefly review some of the developments in this area and analyze how to implement topological pumping of photonic Fock states in nonlinear photonic lattices.

QN2.1. *Nano-optomechanics with a levitated nanoparticle*

Romain Quidant, ICFO, Spain

Optomechanics holds great promises to push the limits of experimental physics, opening new opportunities in ultra-weak force sensing, thermodynamics and shining light on the transition between the quantum and classical worlds. Most of optomechanical systems are directly connected to their thermal environment, which imposes limits to thermalization and decoherence. A laser-trapped particle in (ultra-)high vacuum, by contrast, has no physical contact to the environment, which makes it a promising optomechanical system. In this talk, we introduce the use of a levitated nanoparticle in vacuum as a nano-optomechanical system with unprecedented performances.

We first describe its unique linear and nonlinear mechanical properties including its outstanding sensing capability (sub-zeptonewton force sensitivity) and fully controllable bi-stable dynamics. Subsequently, we present our efforts in cooling its motion towards mechanical ground state at room temperature. In particular, we report on an experiment that combines active parametric feedback cooling with passive resolved side band cooling in a macroscopic high finesse optical cavity.

QN2.2. *Coherent control of a strongly driven silicon vacancy in diamond*

Weibo Gao, Nanyang Technological University, Singapore

The ability to prepare, optically read out and coherently control single quantum states is a key requirement for quantum information processing. Optically active solid state qubits have emerged as promising candidates with their prospects for spin-photon interface and chip-level integration. To realize true quantum register, a system must be coherently driven and exhibit Rabi oscillations. Under strongly driving resonant laser field, such quantum emitter can exhibit quantum behavior such as Autler-Townes splitting and Mollow triplet spectrum. Here we demonstrate coherent manipulation of a strongly driven optical transition in silicon vacancy (SiV) center in diamond. Rapid optical detection of photons enabled the observation of time resolved coherent Rabi oscillations and the Mollow triplet from an optical transition of a single SiV defect. Detection with a probing transition further confirmed Autler-Townes splitting generated by strong laser field. Coherence time of the emitted photons is shown to be comparable to its lifetime and more importantly, robust even under very strong driving laser field. These results indicate the feasibility of the SiV as a promising solid state qubit for quantum information processing, including quantum networks and quantum logic gates.

QN3. Quantum Nanophotonics

QN3.1. *Chiral nanophotonics and quantum optics*
Arno Rauschenbeutel, Technical University Vienna, Austria

Tightly confined light fields exhibit an inherent link between their local polarization and their propagation direction. The interaction of such light fields with emitters therefore features chiral, i.e., propagation direction-dependent, effects. The latter are interesting both conceptually and for quantum-photonic applications like chiral nanophotonic interfaces and nonreciprocal nanophotonic devices.

QN3.2. *Quantum atoms/metamaterial*
David Wilkowski, CQT - Nanyang Technological University, Singapore

We report on the coupling of a surface plasmonic mode with a thermal vapor of cesium atoms. The plasmonic resonance is created using a nano-structured metallic surface. By changing the geometrical properties of the metamaterial, we tune the plasmonic resonance wavelength with respect to the D2 line of cesium. When the two resonances are close, we observe a strong modification of the Casimir-Polder interaction accompanied by a change of the atomic lifetime. A proper tuning leads to an almost suppression of the frequency shift of the cesium transition.

QN3.3. *Electrodynamics from standard optics to correlations and to quantum*
Janne Ruostekoski, University of Southampton, UK

Coherently responding strongly coupled radiators can result in an optical response that violates standard textbook optics. The deviations result from correlations between the scatterers and can also lead to observable quantum effects. Additional light confinement enhances the coupling effects.

QN3.4. *Superconducting atom chips*
Rainer Dumke, CQT - Nanyang Technological University, Singapore

In recent years, microtraps for neutral atoms based on superconductors, i.e. ‘superconducting atom chips’ have become a subject of intensive research. Motivated by the prediction of extremely low magnetic and thermal noise compared to normal conductors, superconducting atom chips have first been implemented in the expectation of improving the coherence of atomic quantum states close to surfaces by several orders of magnitude. This boost in coherence time holds promising expectations for quantum information processing applications. In particular, superconducting atom chips are ideal candidates for the realization of hybrid quantum systems between atomic and superconducting solid state qubits, merging the fast gate operation times for superconducting qubits with the long coherence times of atomic qubits.In this talk I will discuss our work towards realizing this hybrid quantum system via coupling ultracold atoms and superconducting circuits.

TN3. Topological Materials

TN3.1. *Topological materials: origin, history, symmetry and future*
Feodor Kusmartsev, Loughborough University, UK

We describe the main ideas which led to the discovery of topological insulators and Weyl semimetals and comment on a formation of Majorana fermions in these systems. We describe some of the outstanding electronic properties originate due to the breaking of fundamental symmetries as well as an existence of the Dirac gapless spectrum. We also look forward for the futur wher topological ideas lead us.

TN3.2. *Photons and plasmons in topologically structured materials*
Harry Atwater, CALTECH, USA

Topological insulators – narrow band-gap semiconductors that exhibit both an insulating bulk and a pair of semimetallic Dirac surface states –display a remarkable range of new electronic phenomena. A fascinating feature of topological insulators is the interplay of massless Dirac electrons and massive bulk carriers. While materials in the bismuth telluride family are strong topological insulators, they are also structurally two-dimensional, layered semiconductors. The low density of states and availability of thin, gate-tunable structures enables highly tunable infrared absorption. These allow us to use gate-driven modification of bulk interband optical transitions at higher Fermi level values and modulation of intraband transitions associated with the varying topological surface states an optical probe of surface and bulk states. We have combined optical experiments with transport and angle-resolved photoemission spectroscopy to identify the origin of observed optical reflectance and transmittance features arising from bulk and surface carriers.

Gyroid photonic crystals are interesting three-dimensional triply periodic body centered cubic photonic crystals with minimal surfaces containing no straight lines. Double gyroid photonic crystals that contain parity or time reversal symmetry-breaking elements can give rise to Weyl points from the line nodes, that are degenerate energy states resulting from band crossings of linear dispersion features in three dimensional momentum space. Unlike Dirac points in two-dimensional systems, Weyl points have been shown to be stable. Phase boundaries in three-dimensional photonic crystals containing Weyl points are also expected to support fully protected surface states on either closed or open surfaces. We have synthesized and characterized the first infrared gyroid photonic crystals, including both single and double gyroid crystals with Weyl points present, in the mid-infrared region. Simulations reveal that gyroids must be composed of high refractive index materials such as a-Si in order for gyroids to possess interesting properties such as band gaps and Weyl points. We will report results of photonic crystal bandstructures probed using angle resolved mid-infrared reflectance and transmittance measurements, and give an outlook for realization of topologically-protected surface states in three-dimensional crystals in the infrared regime..

TN3.3. *Plasmonics of topological insulators*
Cesare Soci, Nanyang Technological University, Singapore

We discuss the plasmonic properties of quaternary (Bi,Sb)2(Te,Se)3 chalcogenide topological insulator compounds arising from interband transitions and Drude-like response of metallic surface states in the UV to near-IR spectral region. We combine first principles density functional theory calculations with ellipsometry to elucidate origin and composition dependence of their plasmonic behaviour, and demonstrate metamaterial structures with tunable, high quality-factor resonances at optical frequencies.

TN3.4. *Design and growth of Sb_2Te_3, Bi_2Te_3, and Bi_2Se_3 heterostructure superlattices*
Robert Simpson, Singapore University of Technology & Design

This talk will discuss how van der Waals layered chalcogenide superlattices composed of Sb2Te3, Bi2Te3, Bi2Se3, and GeTe can be designed and grown. We have developed advanced computational methods to design layered chalcogenides with specific properties, including functional properties such as optical property switching. We are also developing practical methods to grow our designs over large areas

MD1. Optical Materials and Devices

MD1.1. *Multifunctional optical surfaces for industrial applications using ultrathin materials and nano-structuring*
Valerio Pruneri, ICFO, Spain

Ultrathin materials and nano-structuring are becoming essential for the functionalization of optical surfaces, in particular glass. Examples of applications include omnidirectional antireflection screens, self-cleaning or easy-to-clean displays, efficient indium-free organic solar cells and antimicrobial surfaces.

MD1.2. *Short-Range surface plasmonics on atomically flat gold surfaces: subfemtosecond localized electron emission dynamics from a 60 nm spot and plasmons with higher orbital angular momentum*
Harald Giessen, Stuttgart University, Germany

We excite and focus short-range surface plasmon polaritons down to 60 nm using electrochemically grown, atomically flat single crystalline gold platelets on silicon substrates. Furthermore, we create plasmonic vortices using Archimedean spiral structures with different orbital angular momenta, i.e., topological charge. We observe the dynamics of the short range plasmons and investigate their subfemtosecond dynamics via two-photon photoemission electron microscopy.

MD1.3. *Nanophotonics: coherent control, strong coupling, bright photon emitters*
Niek van Hulst, ICFO, Spain

Light control with nanoantennas is presented in various applications: i) True coherent control on the nanoscale: Nanoantennas present a coherent regime in the two-photon absorption process on the sub 50 fs timescale; closed loop coherent control experiment on single coherent nanoantennas is shown. ii) Nanoantennas for cavity QED: Nanoantennas combine low Q with deeply localised mode volumes and large coupling strength g, provided exact positioning on nanoscale. We map g of dipole antenna to single emitter, obtaining max coupling rate of $2g$max = 400 GHz ~ 2meV. iii) Bright biomolecules: enhancement of emission rate, saturation level and bleach protection

QN4. Quantum @ Epsilon Near Zero

QN4.1. *Quantum optics in ENZ and absorbing metamaterials*
Daniele Faccio, Heriot-Watt University, UK

The first part of this talk will describe our recent work N00N state absorption in graphene and absorbing metamaterials where two-photon absorption, that is usually considered to be an inherently nonlinear process, is observed in a completely linear optics regime. The second part will describe recent work with extreme nonlinearities in transparent conductive oxides (TCOs) and how this can be harnessed to create a time-dependent medium. We will then look at the role of the ENZ wavelength in this time-dependent medium and explain how this can lead to strong enhancement of photon pairs excited from the vacuum state.

QN4.2. *Quantum features of near-zero photonics*
Nader Engheta, University of Pennsylvania, USA

Epsilon-near-zero (ENZ), mu-near-zero (MNZ) and zero-index (ZI) structures provide novel platforms for light-matter interaction with unprecedented quantum optical and wave features. In this talk, we discuss some of our ongoing work on quantum optics of near-zero platforms including how to manipulate decay dynamics, harness vacuum fluctuation, and engineer vacuum Rabi frequency without detuning cavities using near-zero photonics

Posters

Quantum Nanophotonics

QP1. *Optical properties of an atomic ensemble coupled to a band edge of a photonic crystal waveguide*

Ewan Munro *et al*, CQT - National University of Singapore

Photonic crystal waveguides (PCWs) have attracted significant interest in recent years as a platform for realizing novel quantum light-matter interfaces. The ability to engineer their dispersive and modal properties via design and fabrication permits control of the electromagnetic environment experienced by nearby atoms, which may be leveraged to achieve strongly-enhanced atom-photon coupling efficiencies, as well as for the exploration of new regimes of quantum optics. An exciting example of the latter is the possibility of engineering long-range coherent interactions between atoms, which occurs when the atomic transition frequency is inside a band gap of the PCW. Here we investigate the fundamental optical properties of an ensemble of such atoms, finding rich features that differ markedly from standard atomic ensembles. The linear transmission spectrum exhibits a range of resonant features, whose properties we show how to characterize, and some of which may be used to obtain important information about the ensemble itself. 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.

QP2. *Towards functionality of atoms with metamaterial surfaces*

Syed A. Aljunid *et al*, CDPT - Nanyang Technological University, Singapore

Strong localization of electromagnetic field has been predicted to significantly alter the properties of quantum emitter. It has been experimentally shown that localized plasmonic properties of metamaterials strongly modify the shape of the atomic transition. In this presentation, we show that the evanescent wave of the metamaterials gives a non-trivial contribution on the atomic transition. We also demonstrate experimental results on interfacing of MM on the tip of an optical fiber with Caesium atoms, which is a stepping stone towards realization of manipulation and functionality of cold atoms with localized field on surface of optical fiber

QP3. *Geometry of system-bath coupling and gauge fields in bosonic ladders: Manipulating currents and driving phase transitions*

Dario Poletti, Singapore University of Technology & Design

Quantum systems in contact with an environment display a rich physics emerging from the interplay between dissipative and Hamiltonian terms. Here we focus on the role of the geometry of the coupling between the system and the baths. Specifically we consider a dissipative boundary driven ladder in the presence of a gauge field that can be implemented with ion microtrap arrays. We show that, depending on the geometry, the currents imposed by the baths can be strongly affected by the gauge field, resulting in nonequilibrium phase transitions. In different phases both the magnitude of the current and its spatial distribution are significantly different. These findings allow for strategies to manipulate and control transport properties in quantum systems

QP4. *Diagrammatic Approach to Scattering in Many-Body Photonic Systems*
Tian Feng See *et al*, CQT - National University of Singapore

We present a method to study the scattering properties of arbitrary many-body system amenable to a photonic quantum simulation. The system is assumed to be coupled locally to input and output waveguides and is probed via Fock states. The latter allows for the underlying many-body structure to be accurately probed and mapped out at the scattered photon spectra. Using techniques from input output theory and quantum field theory, we provide a diagrammatic approach to visualise and also calculate analytically the scattering matrix. Our method greatly reduces the effort in finding the nonlinear response of a system which is encoded in the system's Green's functions. The latter can be represented in our case by physically intuitive diagrams, where the relevant expressions can be deduced and written down directly. We also provide specific examples and applications in many-body photonics such as scattering in a Bose-Hubbard chain and lattices.

QP5. *Quantum Interference Experiments with Absorbing Plasmonic Metamaterials and Entangled Photons*
Charles M. X. Altuzarra *et al*, CDPT - Nanyang Technological University, Singapore

Plasmonic metamaterials have great potential for building devices that can control and manipulate light at the nanoscale. Here, we show two quantum coherent perfect absorption experiments. First, we show that a single path-entangled photon can be nearly perfectly absorbed by a 50nm thick freestanding gold metamaterial. Then, we demonstrate a "remote control" of coherent perfect absorption in the setting of a quantum eraser where the path-entangled photon is also polarization-entangled with nonlocal photons.

QP6. *Ultrafast time-resolved spectroscopy with quantum light*
Dmitry Kalashnikov *et al*, A*STAR Data Storage Institute, Singapore

We demonstrate the new method for measuring the coherence time of a resonance media at the femtosecond range without using of femtosecond laser. It relies upon the effect of quantum interference. Introducing the sample into interferometer results in the change of interference pattern, from which the coherence time is inferred.

Topological Nanophotonics

TP1. *Topological pumping of photons in nonlinear resonator arrays*
Jirawat Tangpanitanon *et al*, CQT - National University of Singapore

We show how to implement topological or Thouless pumping of interacting photons in one dimensional nonlinear resonator arrays, by simply modulating the frequency of the resonators periodically in space and time. The interplay between interactions and the adiabatic modulations enables robust transport of Fock states with few photons per site. We analyze the transport mechanism via an effective analytic model and study its topological properties and its protection to noise. We conclude by a detailed study of an implementation with existing circuit QED architectures.

TP2. *Gate-Tunable Mid-IR Optical Response in Bismuth Antimony Telluride Topological Insulators*
William Whitney *et al*, CALTECH, USA

We discuss FTIR transmittance experiments in which we demonstrate gate-tunable mid-infrared optical and plasmonic properties of bismuth antimony telluride electronic topological insulators. We model this modulation as a combination of Pauli blocking of bulk interband transitions and shifting of the plasma edge with both topological surface and bulk carrier densities

TP3. *Mapping plasmonic response of topological insulator nanostructures in the visible range*
Alexander M. Dubrovkin *et al*, CDPT - Nanyang Technological University, Singapore

Chalcogenide topological insulators were recently identified as plasmonic materials with highly conductive surface states, providing a novel platform for metamaterials and plasmonic applications. We analyze the optical properties of a family of chalcogenide topological insulator compounds by ab-initio band structure calculations taking in account spin-orbit interaction in the medium. Knowledge of surface charge distribution in thin TI slabs allows isolating plasmonic contribution coming from surface electrons, which indicates that a conventional three dimensional Drude model for few-nm metallic layer appropriately describes the optical response of the topologically protected surface states in the visible range. Calculated permittivity shows that plasmonic behavior of these compounds in UV-NIR spectral region arises from the interplay between a bulk negative permittivity and a contribution from metal-like surface states, where the bulk part contribution may be switched off by tuning the excitation wavelength above interband transitions in the medium. We report phase-resolved real-space observation of the localized plasmons in Bi1.5Sb0.5Te1.8Se1.2 (BSTS) topological insulator in the visible range. Scattering-type scanning near-field microscopy is applied for resolving plasmon amplitude and phase distributions. Various shape and size BSTS nanostructures were fabricated on top of 285-nm SiO2 on Si wafer. Direct near-field imaging of the plasmons in nano and micro structures shows a clear evidence of dipolar and higher order surface plasmon modes with well-defined field amplitude and phase profiles. Experimental data are supported by full wave numerical simulations. We also experimentally map propagating plasmons in both ultrathin and optically thick films of the material and extract the plasmon wavelength

TP4. *Wideband visible absorbers by $Ge_2Sb_2Te_5$ and Al nanogratings*
Weiling Dong *et al*, Singapore University of Technology & Design

In this research, we experimentally compare two different candidates for broadband absorbers in the visible. One based on a planar Al/Ge 2 Sb 2 Te 5 stacked structure, the other is based on a Ge 2 Sb 2 Te 5 /Al nanograting structure. The planar structure is a good absorber in the near infrared but its absorptance is relatively low in the visible. In contrast, the Ge 2 Sb 2 Te 5 /Al nanograting structure can shift the absorptance peak to 400 nm with an absorptance bandwidth of 120 nm. This structure has potential applications in light harvesting, sensing and tunable filters.

TP5. *Photocurrent in biased bilayer graphene by elliptically polarized light*
Mustafa Eginligil *et al*, Nanjing Tech University, China & Nanyang Technological University, Singapore

Helicity dependent photocurrent in monolayer graphene has been the subject of intense debate, and was recently ascribed to the photon drag and the circular photogalvanic effects. Here we report the experimental determination of the photocurrent response of bilayer graphene as a function of light intensity and state of polarization, as well as carrier density and polarity. The data show qualitative features in common with the photocurrent that is expected to arise from the photon drag and the circular photogalvanic effects, as seen in monolayer graphene. In addition, we identify a non-negligible contribution to the photocurrent of different nature, with anomalous dependence on light polarization. These results highlight the richness of bilayer graphene photoresponse, providing an opportunity to establish light helicity as a means to manipulate the photoconductive behaviour of future optoelectronic graphene devices.

TP6. *Optical range plasmonics of niobium around the superconducting transition temperature*

Harish N. S. Krishnamoorthy *et al*, CDPT - Nanyang Technological University, Singapore

We present the first experimental evidence of a direct link between the optical properties of a material and onset of the superconducting state. By measuring the dielectric constants of an unpatterned niobium film as well as the reflectivity of a nanostructured niobium metamaterial, we demonstrate a critical dependence of niobium optical response on temperature near its superconducting transition at 9K. This suggest a hitherto unknown connection between superconductivity and optical range plasmonics.

TP7. *Non-interferometry Measurement of Gigantic Wavevector and Energy Backflow in a Super-oscillatory Field*

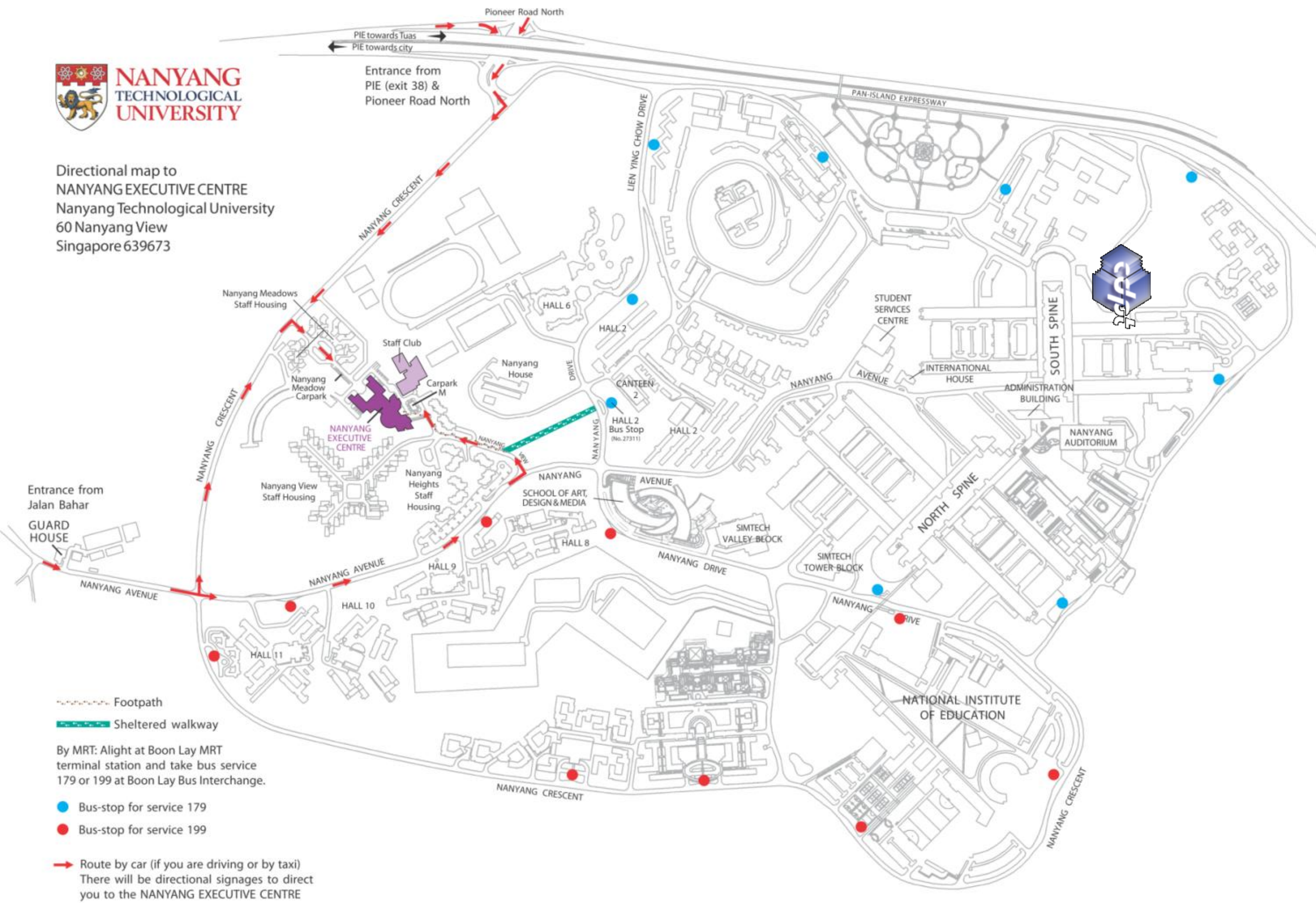
Guanghui Yuan *et al*, CDPT - Nanyang Technological University, Singapore

It is commonly believed that only the non-propagating electromagnetic field in the vicinity of nanostructures can be structured on sub-wavelength level and thus could be decomposed into plane waves with wave-vectors exceeding that of incident light creating the high spatial frequency near-field. Here we show that super-oscillatory fields in free space could feature energy backflow and gigantic local wavevectors that are several times higher than that of incident light.

With the aid of an appropriately designed plasmonic metasurface, we experimentally measured the phase of the super-oscillatory field and visualized fast-variation phase singular points. Unlike conventional phase measurement techniques where an interferometry setup is usually required, our metasurface serves as a built-in interferometer which is capable of retrieving the phase by simply adjusting the incident polarizations and recording the corresponding intensity components. Then the local wavevectors are calculated from the phase gradient, and the transverse local wavevector exceeding the highest allowable one ($kx>2\pi/\lambda$) and negative longitudinal wavevector ($kz<0$) are demonstrated. Two cases in terms of different degree of super-oscillation will be discuss

NANYANG TECHNOLOGICAL UNIVERSITY

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