IPS Meeting 2013
4 - 6 March

Institute of Physics Singapore

Conference Program

The IPS Meeting 2013 thanks its sponsors for their generous support

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1 Foreword

Dear fellow Physicists,

Just nicely at the start of the year of the snake, the IPS Meeting 2013 continues to provide a marketplace for research in physical sciences here in Singapore. This year, we meet at the School of Mathematical and Physical Sciences at Nanyang Technological University, where lot of exciting things are happening: With the recent opening of the Centre for Disruptive Photonic Technologies, a new focus are of competitive research started, which we believe will have a significant impact on tomorrow's technology. To highlight this event, we have a special symposium this year, with four sessions dedicated to research in that area. We warmly welcome visitors from a photonics cluster in Southampton, UK, to this symposium – and the IPS meeting in general. We also arranged for a special panel session with important representatives form the science and technology sector, where the impact of photonic technologies on Singapore is highlighted.

This year, we also have a strong delegation from the Institute of Physics, our big sister organization in the UK, with a topical focus on Nanoscience and technology. We hope this strengthens the ties with physicists all over the world - after all, science is a very international business. Please join us to hear the exciting news on nanoscience in the UK in a number of invited talks form this delegation.

Let us also not forget that there is a whole lot of excellent research in physical sciences going on in Singapore: this year's meeting features over 80 technical talks, and over 60 posters. With this huge number of contributions, we had to extend the IPS meeting to a full three days of program. There is lots of exciting physics in the program for everyone – have a look at the programme, and see what is going on in quarters outside your own research group.

Posters are always a very relaxing and scientifically stimulating way of communication. To make it even more attractive, we try something new this year: a poster pitch competition, where poster presenters can give you a 3-minute advertiser for their work. You get an easy overview about research you may have missed otherwise, and meet up directly with the researchers of your interest later on. We also take this short presentation as an opportunity for the Best-Poster-Award jury to get a picture of the best posters a this year's meeting. Posters will be up basically all the conference, but the central time to visit them (and be there as a presenter) would be in the Tuesday evening session. And since discussing exciting science drains a lot of energy, and also because it is a lot more fun, we add food to this session. So don't miss the opportunity to see the posters!

Again, the organization of this meeting had strong support from NTU, NUS, and IHPC. Big thanks to our logistics support team with Rebecca Won, Andreas Dewanto and many physics students both from NTU and NUS. In addition, we'd like to thank the Institute of Advanced Studies for their support in hosting the IoP delegation. We acknowledge our institutional supporters, the Department of Physics at NUS and the School of Physics and Applied Physics at NTU, as well as the Centre for Quantum Technologies. Last but not least, let's thank our exhibitors, who again help with their

sponsorship to make this conference possible - we are sure that you find a lot of new toys and services at their booths that fit very well with this year's focus topics on photonics and nanotechnology..

With this, we wish you a stimulating conference, with a lot of new ideas, contacts and collaborations for a successful year of research in physical sciences ahead!

Your organizing team of the IPS meeting 2013

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2 Schedule

Monday, 4 March

8.00 AM	Registration		
9.00 AM	Opening Address (LT1)		
9.15 AM	Plenary talk 1: David J. Richardson (LT1)		
10:00 AM	Plenary talk 2: Nikolay I. Zheludev (LT1)		
10.45 AM	Coffee/Tea Break + Exhibition + Poster mounting		
11.15 AM	Panel Discussion on Photonics and its significance to Singapore (LT1)		
12.15 PM	Lunch + Posters + Exhibition		
1.15 PM	PO1: Poster Pitch student competition (LT1)		
3.00 PM	Coffee/Tea Break + Exhibition		
3.30 PM	Technical Sessions		
	T1 (MAS-EX2) Graphene Characterization	T2 (MAS-SEM) Water, bubbles, and proton beams	T3 (MAS-EX1) Photonics I
5.00 PM	End of Monday sessions		

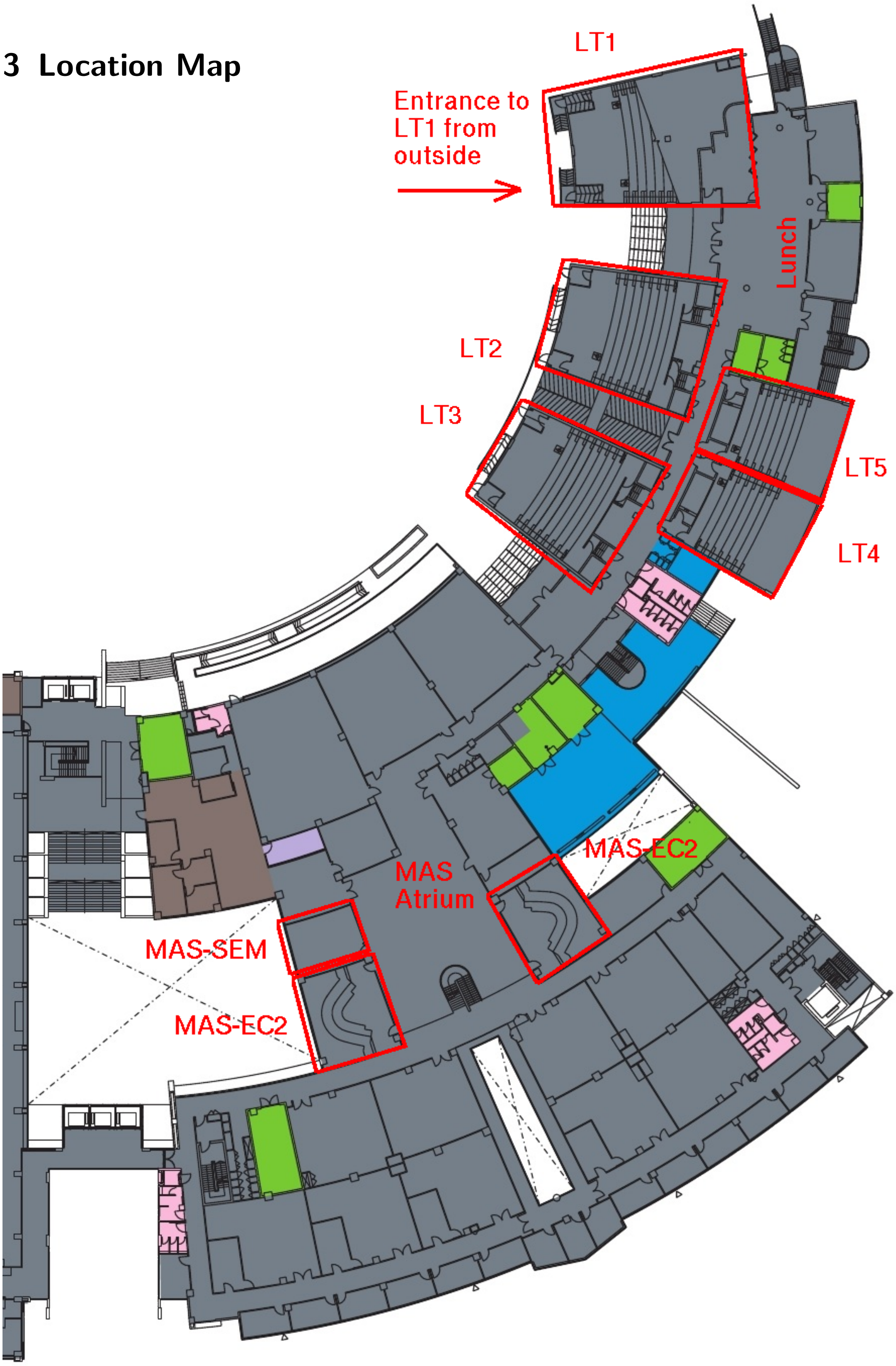
Tuesday, 5 March

9.00 AM	Plenary talk 3: Philip Moriarty (LT2)		
9:45 AM	Plenary talk 4: Barbaros Özylmaz (LT2)		
10.30 AM	Coffee/Tea Break + Exhibition + Poster mounting		
11:00 AM	Technical Sessions		
	T4 (MAS-EX2) Advanced characterization of Nanomaterials	T5 (MAS-SEM) Quantum Systems	T6 (MAS-EX1) Graphene Photonics
12.30 PM	Lunch + Posters + Exhibition		
1:30 PM	Technical Sessions		
	T7 (MAS-EX2) Nanotechnology for Energy Applications	T8 (MAS-SEM) Quantum Information	T9 (MAS-EX1) Photonics II
3.00 PM	Coffee/Tea Break + Exhibition		
3.30 PM	Technical Sessions		
	T10 (MAS-EX2) Graphene and Carbon Nanotubes	T11 (MAS-SEM) Atomic Physics	T12 (MAS-EX1) Plasmonics
5.15 PM	PO2: Posters + Poster Award + Pizza party, (MAS Atrium)		
7.00 PM	End of Tuesday sessions		

Wednesday, 6 March

09:00 AM		Technical Sessions		Symposium
	T13 (LT4) Organic and thin film Photovoltaics	T14 (MAS-EX2) Magnetism	T15 (MAS-SEM) Thin Films	SY1 (MAS-EX1) Structural nano-control for enhanced photonic functionalities
10.30 AM	Coffee/Tea Break + Posters + Exhibition			
11:00 AM		Technical Sessions		Symposium
	T16 (LT4) Nanophotonics	T17 (MAS-EX2) Plasma Science and Applications	T18 (MAS-SEM) Bio/Nanoscience	SY2 (MAS-EX1) A fresh look at photonic surface
12.30 PM	Lunch + Posters + Exhibition			
1:30 PM		Technical Sessions		Symposium
	T19 (LT4) Nanofabrication I	T20 (MAS-EX2) Solid State Physics	T21 (MAS-SEM) Novel Nanomaterials	SY3 (MAS-EX1) Nanofabrication-enhabled novel phenomena and applications
3.00 PM	Coffee/Tea Break + Posters + Exhibition			
3:30 PM		Technical Sessions		Symposium
	T22 (LT4) Nanofabrication II			SY4 (MAS-EX1) THz and lasers
5.00 PM	End of IPS 2013 meeting			

3 Location Map



4 Plenary sessions

We will have four distinguished plenary speakers this year.

4.1 David J. Richardson: The power of Light - the fiber laser revolution

Monday, 4 March, 9:00am

Abstract

Over recent years the powers that can be achieved from fiber lasers have grown rapidly due to parallel advances in the high-power semiconductor laser diodes used to energize fiber lasers, diode-to-fiber coupling schemes and doped fiber design and fabrication. Whilst the headline results have generally related to the possibilities of scaling continuous-wave fiber lasers, with 10kW now possible from an effectively single-mode core, advances in many aspects of pulsed laser performance have been just as spectacular. For example, using the fiber Master Oscillator Power Amplifier (MOPA) approach it is now possible to realise fs and ps pulsed fiber systems operating at the multi-100W level with pulse energies in excess of the 1 mJ level. In the nanosecond regime multi-100W systems have also been achieved with single mode pulse energies of several mJ, and by relaxing the mode-quality higher pulse energies are now possible.

Within this talk I shall review the state-of-the-art in high power fiber laser systems. I shall describe the key benefits of fiber lasers relative to the more established competitor technologies, describe some of the issues limiting further power and energy scaling and review the use of both temporal pulse and spatial mode shaping technology to achieve improved performance. I shall also review the wavelength coverage and frequency conversion options for fiber lasers and describe specific applications of the technology in both science and engineering - these include amongst others use in directed-energy applications, counter-measure systems for military platforms, medicine and, of course, industrial materials processing which represents the primary driver for the technology.

I shall conclude by speculating as to likely future developments and the ultimate levels of performance achievable.

About the Speaker

David J. Richardson holds a personal Chair in Photonics at the University of Southampton and is Deputy Director of the Optoelectronics Research Centre (ORC) where he is responsible for Optical Fibre Device and Systems research. His current interests include amongst others: optical fibre communications, high power fibre lasers and nonlinear fibre optics. He has published more than 900 conference and journal papers in his time at the ORC, and produced over 20 patents. He is a frequent invited speaker at the leading international photonics conferences and is an active member of both the national and international photonics communities. Prof. Richardson, a founder of SPI Lasers Ltd., was made a Fellow of the Optical Society of America in 2005, a Fellow of the IET in 2008 and most recently a Fellow of the Royal Academy of Engineering in 2009.

4.2 Nikolay I. Zheludev: What's the matter with nano-meta-matter?

Monday, 4 March, 9:45am

Abstract

We present an overview of our recent work in the field of nanostructured photonic metamaterials and metadevices.

About the Speaker

Nikolay Zheludev, directs the Centre for Disruptive Photonic Technologies at Nanyang Technological University, Singapore and is deputy director of the Optoelectronics Research Centre at Southampton University, UK. His research interests are in nanophotonics and metamaterials. His personal awards include Senior Professorships of the Engineering and Physical Sciences Research Council (UK) and the Leverhulme Trust and the Royal Society Wolfson Research Fellowship. He was awarded MSc, PhD and DSc from Moscow State University. Professor Zheludev is the Editor-in-Chief of the IOP "Journal of Optics".

4.3 Philip Moriarty: Mechanical Atom Manipulation (...and The Trouble with Tips)

Tuesday, 5 March, 9:00am

Abstract

Can we design and construct a matter compiler? That is, is it possible to conceive of a scheme whereby the fundamental atomic/molecular building blocks of matter can be autonomously and intelligently manipulated via software to form a nanoscopic, microscopic, or even macroscopic product? This is the essence of the highly controversial "molecular manufacturing" concept put forward by K. Eric Drexler in the eighties [1] (and which was originally inspired by Feynman's musings [2] on the ultimate limits of miniaturisation in 1959). In this talk I shall first reappraise Drexler's matter compilation scheme in the context of the latest developments in (sub)atomic resolution scanning probe microscopy (SPM) before describing some of our recent work in Nottingham in three areas of key relevance to the matter compilation concept:

Atom switching and manipulation driven by the making and breaking of a single chemical bond [3]; Orbital engineering - tuning the atomic and electronic structure of a scanning probe microscope tip [4]; Automated probe microscopy via evolutionary optimization at the atomic scale [5].

[1] Nanosystems, K Eric Drexler, Wiley-Interscience (New York), 1992

[2] There's Plenty of Room at the Bottom RP Feynman, 1959; see e.g. http://www.zyvex.com/nanotech/feynman.html

[3] A. Sweetman et al., Phys. Rev. Lett. **106** 136101 (2011); See also "An Atomic Switch" - see Sixty Symbols(/http://www.sixtysymbols.com), and a video at http://www.youtube.com/watch?v=KHLyrc-uoIk

[4] C. Chiutu et al., Phys. Rev. Lett. **108** 268302 (2012)

[5] RAJ Woolley et al., Appl. Phys. Lett. **98** 253104 (2011)

About the Speaker

Philip Moriarty is a Professor of Physics and an Engineering & Physical Sciences Research Council (EPSRC) Fellow in the School of Physics and Astronomy, University of Nottingham. His research interests span a number of topical themes in nanometre scale science with a particular current focus on single atom/molecule manipulation. He has coordinated a number of multi-partner European networks (including, most recently, ACRITAS), and is currently Chair of the Institute of Physics Nanoscale Physics and Technology Group committee, a member of the Science Board of the Institute of Physics, and was a member of the EPSRC Strategic Advisory Team for Physics from 2005 - 2006.

Moriarty has a keen interest in outreach activities and both science and higher education funding policy. In addition to participating in a number of research council-funded public engagement projects (including Giants of the Infinitesimal), and his membership of the Steering Committee of the Council for the Defence of British Universities, he has interacted with national and international media (including The Independent, The Guardian, Times Higher Education, BBC Radio 4, Die Zeit, and The Economist) on these issues. He is also a regular contributor to Nottingham's Sixty Symbols YouTube project which has, as of December 2012, attracted a little over 15 million views (across 200 videos).

Although he does not share his infamous namesake's fascination with the binomial theorem, in his spare time Moriarty enjoys exploring the relationships between mathematics/physics and music.

4.4 Barbaros Özyilmaz: Charge, Spin and Phonon Transport in CVD graphene

Tuesday, 5 March, 9:45am

Abstract

Here we show quasi-periodic nanoripple arrays introduce anisotropic charge transport and sets limits. I will also show our recent efforts in using a ferroelectric polymer coating to reduce the sheet resistance below values of ITO.

The technical breakthrough in synthesizing graphene by chemical vapor deposition methods (CVD) has opened up enormous opportunities for large-scale device applications. In order to improve the electrical properties of CVD graphene grown on copper (Cu-CVD graphene), recent efforts have focussed on increasing the grain size of such polycrystalline graphene films to 100 micrometers and larger. Here we show that the charge mobility and sheet resistance of Cu-CVD graphene is already limited within a single grain. We find that the current high-temperature growth and wet transfer methods of CVD graphene result in quasi-periodic nanoripple arrays (NRAs). Electron-flexural phonon scattering in such partially suspended graphene devices introduces anisotropic charge transport and sets limits to both the highest possible charge mobility and lowest possible sheet resistance values. I will also show our recent efforts in using a ferroelectric polymer coating to reduce the sheet resistance below values of ITO. I will conclude my talk with recent results on spin and phonon transport in such CVD samples.

About the Speaker

Barbaros Özyilmaz is NRF Fellow and Assistant Professor at the Department of Physics and the Graphene Research Center at NUS Singapore.

His research area is experimental condensed matter physics, and the two major thrusts of his research are charge and spin transport in lithographically patterned graphene nanostructures and the manipulation of the magnetization of nanoscale ferromagnets by means of spin currents. Prof. Özyilmaz is interested in both the fundamental properties of such systems and their potential applications in the fields of nano-electronics and nano-spintronics. While both systems are intriguing in their own right, merging them into a hybrid device allows one to take advantage of their mutually exclusive but complementary properties. Graphene is particularly attractive for nano-electronics and spintronics because it has the potential for wafer size, simple, planar fabrication of complex nanoscale high mobility devices. Equally important graphene offers thermal and chemical stability on the nanometer size range.

5 Posters

5.1 Poster pitch student competition - Session PO1 (Monday)

This year, we tried to come up with something to make poster sessions even more attractive: We will have a full session (PO1, Monday 1:30pm-3pm) with no parallel technical sessions where all IPS participants get your audience for a supershort (3 minutes) presentation on a poster if the authors want to participate. In order to encourage authors to participate, we will choose the Best Poster Award this year form those submissions where there was short presentation in this session PO1.

For this, we just project your poster on the screen in the lecture hall (please provide us with a PDF file for that purpose). You can email this to us via postersipsmeeting.org, or leave it with the reception desk.

IPS Best Poster Award

During the conference the program committee will select the three best poster presentations for the IPS Best Poster Award. The award will be handed over to the winners at the Poster & Pizza session PO2 on Tuesday evening, probably around 6pm-7pm at (Location TBA).

Logistics

Timing

Posters are presented during the whole conference; perhaps you can make sure that the posters are up as soon as you can. We encourage everyone to browse around during coffe breaks and lunchtime (where there will be catered lunch). We would recommend that the best time for the poster presenters to be around at the poster is the Tuesday evening session that comes together with some Pizza as well. Please take down the posters by latest at the end of the conference, i.e., on Wednesday evening.

Location

The main poster area will be in the MAS-Atrium. Each poster is assigned a panel which corresponds to the number listed below, e.g., the panel no. 23 is reserved for P23 and so on. We will provide Velcro strips to mount the posters on the wall, please see the reception desk for this.

Format

We have been told that the poster walls are just a little too small for A0 posters. To play safe, we recommend to use a A1 portrait poster format.

5.2 Poster Session Session PO2 (Tuesday)

Below, we show a list of abstracts submitted by the authors. We provide a panel number so you can locate the poster of your interest better, and also the easychair number from the poster submission.

P1 Ultrafast Insulator-Metal Phase Transition in Vanadium Dioxide via Optical Pump-Terahertz Probe

Hongwei Liu, Sing Hai Tang, Xinhai Zhang

Tuesday 05.15 PM, Foyer/Hallway, Panel 1 (EC number: 2)

We studied the ultrafast dynamic behavior of the photoinduced insulator–metal phase transition in VO2 thin film using optical pump–terahertz probe spectroscopy with different excitation fluences and at different temperatures. We observed two processes in the insulator–metal phase transition in VO2: a fast process and a slow process. The fast process is a nonthermal process, which is ascribed to the nucleation of the metal phase, while the slow process is strongly affected by temperature and is ascribed to the thermally driven growth and coalescence of metal domains in VO2. The transient complex conductivity spectra at different delay times are also investigated. In order to separate the ultrafast nonthermal process from the slow thermal process, we conducted an OPTP study of the photoinduced phase transition of VO2 thin film at various temperatures from 160 to 300 K. Furthermore, OPTP spectroscopy can directly measure the time-dependent change of conductivity during the phase transition. Investigation of the transient THz complex conductivity at different delays supplies further information on the dynamics of the insulator–metal phase transition in VO2. Our results help improve the understanding of the mechanism of the photoinduced phase transition in VO2 and are useful for device applications for VO2.

P2 Unique Process Directing Role of Graphene Oxide in the Formation of Metal Oxide

Suzi Deng, Chorng Haur Sow, Verawati Tjoa, Haiming Fan

Tuesday 05.15 PM, Foyer/Hallway, Panel 2 (EC number: 3)

We illustrate the interactions of graphene oxide (GO) in the morphogenesis of Cu2O mesocrystals and Co(OH)2 mesocrystals and mesocrystals. The formation of the Cu2O mesocrystals arises from the initial GO-promoted agglomeration of amorphous spherical Cu2O nanoparticles, leading to the transition of growth mechanism from ion-by-ion to particle-mediated growth. Mesoscale transformation and 3D oriented attachment of the mesocrystals are identified from the amorphous microspheres, spherical hierarchical structures and Sierpinski polyhedrons, respectively. Owing to high specific surface area and improved conductivity, the rGO-Cu2O mesocrystals achieved a higher sensitivity towards NO2 than standalone systems of Cu2O nanowires networks and rGO sheets. The mesoscale diassembly process of the Co(OH)2 flowers are as follows: the amphiphilic

GO intercalates into the tightly packed gallery of Co(OH)2 nanosheets and swells up the gallery for delamination; second, interaction between the functional groups of GO and Co(OH)2 overcomes the electrostatic forces to exfoliate the microflower into hexagonal nanosheets. The synergistic assembly of the Co(OH)2-rGO maximizes the contact area between graphene and Co(OH)2 nanosheets, thereby optimizes the utilization rate of the composite for lithium ion batteries. Our results indicate that GO can act as an unconventional surfactant for tailoring interactions between organic and inorganic molecules to realize functional mesocrystals composites.

P3 Shot Noise Signatures of Charge Fractionalization in the $\nu = 2$ Quantum Hall edge

Mirco Milletari, Bernd Rosenow

Tuesday 05.15 PM, Foyer/Hallway, Panel 3 (EC number: 10)

We investigate the effect of non-equilibrium and interactions on shot noise in $\nu = 2$ quantum Hall edges, where interactions between the two co-propagating edge modes are expected to give rise to charge fractionalization. We consider a setup consisting of a Hall bar pinched by two Quantum point contacts (QPCs). The first QPC selectively drives out of equilibrium the outer edge mode only, which then interacts with the unbiased inner one over the distance between the two QPCs. We describe the edge modes by two coupled chiral Luttinger liquids, and employ the method of non-equilibrium bosonization to study the relaxation dynamics of the inner one. We find that even asymptotically the edge distribution function does not thermalize, but instead depends in a sensitive way on the interaction strength between the two edge modes. We compute shot noise and Fano factor from the asymptotic distribution function of the inner edge mode at the second QPC, and from comparison with a reference model of fractionalized excitations we find that the Fano factor can be close to the value of the fractionalized charge.

P4 Micro/Nano fluidic device fabrication for DNA analysis using PBW

Fan Liu

Tuesday 05.15 PM, Foyer/Hallway, Panel 4 (EC number: 11)

The fabrication of micro/nano fluidic devices is an emerging field of research due to its useful application in the areas of nano and biological sciences. At CIBA, we fabricate resist and metallic mold with micro/nano features that can be used as masters for PDMS casting. Proton beam writing (PBW) is used to generate fine nano features with smooth sidewalls. UV lithography is used to fabricate supporting micro structures, resulting in a 3D mold for nano/micro fluidic chip fabrication. For DNA studies, the nanochannels are fabricated in HSQ resist via PBW and then combined to the SU8 micro channels by aligned UV process. The nano channels are either regular straight channels or complicated cross channels. To fabricate nanofluidic LOC devices featuring even smaller dimension. We need to deal with polymer with a higher Young's Modules through nanoimpringting(PMMA, PC for example). This requires stronger Ni mold.

Nickel plating and re-electroplating have been carried out to replicate the original resist master mold in to Ni.

P5 Alignment of Poly(3-hexylthiophene) (P3HT) nanofibres for Solar Cell application

Ankur Solanki, Sum Tze Chein, Lam Yeng Ming

Tuesday 05.15 PM, Foyer/Hallway, Panel 5 (EC number: 12)

Organic nanostructures based on π-conjugated semiconductors (small molecules, oligomers and polymers) form another division of molecular building blocks for micro- and nanoelectronic and optoelectronic applications. Charge transport properties are also expected to improve in the 1-D organic nanostructures compared to the amorphous bulk organic films. Better control of morphology for blends, enhanced exciton diffusivity and excellent pathways for hole transport with high carrier mobilities, are the potential merit of the 1-D nanostructure. Self-assembled nanofibres always align parallel or horizontally to the ITO surface. This nano structure demonstrates the higher mobility as compared to nonfibre organic solar cell device. It is assumed that the presence of fibres enhance the charge carrier mobility in the horizontal direction while this increment in the vertical direction is marginal. This marginal increment in the mobility results in higher power conversion efficiency. In our work, a key idea of the charge carrier mobility enhancement in fibrillar nanostructure is proposed. P3HT molecule is polar in nature with a dipole moment of ≈ 1.0–$1.6\,\mathrm{D}$. In this molecule polarity comes mainly because of the presence of an electronegative sulfur atom in the heterocycle ring. Annealing at a temperature higher than the glass transition temperature makes the polymer more mobile. Simultaneous application of an external electric field will bring about the alignment of the polar dipoles in the direction of the electric field, which is known as "dipole polarization", leading to a more oriented polymer chain along with fibre.

P6 Plasmon-Modulated Photoluminescence of Individual plasmonic Nanostructures

Hailong Hu, Huigao Duan, Joel Kwang Wei Yang, Ze Xiang Shen

Tuesday 05.15 PM, Foyer/Hallway, Panel 6 (EC number: 13)

Energy conversion between photons and electrons through plasmonic nanostructuce is one of central research topics. Photoluminescence of metal nanostructures is now gaining more interest [1-4], providing the useful information about the energy transfer from non-equilibrium electrons into photons. Plasmon resonances of metal nanostructures have been observed to play an important role in this generation of luminescence. However, the underlying mechanism of the PL process and the exact role of plasmons are still not fully understood. In this work, we performed a systematic study on the photoluminescence and scattering spectra of individual gold nanostructures that were lithographically defined. We identify the role of plasmons in photoluminescence as modulating the energy transfer between excited electrons and emitted photons. By comparing photoluminescence spectra with scattering spectra, we observed that the photoluminescence of individual gold nanostructures showed the same dependencies on shape, size and plasmon-coupling as the particle plasmon resonances, as shown in Fig.1 a. Our results provide conclusive evidence that the photoluminescence in gold nanostructures indeed occurs via radiative damping of plasmon resonances driven by excited electrons in the metal itself. Moreover, we provide new insight on the underlying mechanism based on our analysis of a reproducible blue shift of the photoluminescence peak (with respect to the scattering peak), and observation of an incomplete depolarization of the photoluminescence. In addition, a four-step process was used to describe the PL mechanism including two important aspects, the modulation of particle plasmon resonance and thermalization of non-equilibrium electrons. And a simple prediction of PL was proposed as follows. PL population profile of thermalized electrons $\times$ DOS

References: [1]. E. Dulkeith, et al. Physical Review B, 2004, 70, 205424-4. [2]. A. Tcherniak et al. J. Phys. Chem. C, 2011, 115, 15938-15949. [3]. Yorulmaz et al. Nano Lett 2012, ASAP, DOI:10.102/nl302196a. [4]. Fang et al. Acs Nano 2012, ASAP, DOI: 10.1021/nn3022469.

P7 On characterization of optical gain in CdSe/CdS dot/shell heterostructures

Jing Ngei Yip, Guichuan Xing, Yile Liao, Sabyasachi Chakrabortty, Yinthai Chan, Tze Chien Sum

Tuesday 05.15 PM, Foyer/Hallway, Panel 7 (EC number: 14)

Colloidal semiconductor nanocrystals (NCs) hold great promise as optical gain media due to their inexpensive fabrication methods, tunable emission wavelengths and high photoluminescence quantum yield. In particular, core-shell nanorods like CdSe/CdS have attracted a large research interest due to improved optical performance over traditional colloidal quantum dots. This is due to spatial separation of electron and hole wavefunctions in these kind of quasi-Type II nanocrystals. This charge separation can lead to a repulsive excition-exciton interaction and suppressed Auger recombination rates, allowing a longer optical gain lifetime.

A key experimental technique widely used in measuring the optical gain of semiconductor materials is the variable stripe length (VSL) method. The thin film sample is optically pumped with a stripe shaped beam of variable length, and the intensity of the edge emitted amplified spontaneous emission (ASE) is measured as a function of the stripe length. By fitting an appropriate equation, the optical gain can be obtained. However, there are some crucial issues in applying this method due to the assumptions in the underlying one dimensional optical amplifier model.

In our work, the new method of measuring optical gain is proposed and experimentally tested. The same sample is pumped using a focused beam and the lens is moved parallel to the beam propagation to change the spot size on the sample. By measuring the pump fluence at ASE threshold as a function of the spot size, and fitting an appropriate equation, we are able to obtain unambiguous gain values and avoid the problems associated with the traditional VSL method.

P8 Phonon Dynamics in Antimony Sulfide

Wee Kiang Chong, Guichuan Xing, Nripan Mathews, Tze Chien Sum

Tuesday 05.15 PM, Foyer/Hallway, Panel 8 (EC number: 16)

Antimony Sulfide (Sb2S3) is a promising light absorbing material due to its small bandgap and large absorption coefficient in the visible region. It has recently gained much research interest as a viable light absorbing material for semiconductor-sensitized solar cells. However, few studies have been done to investigate the carrier and quasi-particle dynamics in Sb2S3. Understanding these dynamics (preferably at the largest absorption region) would give us better insights to 1) the possible factors that could limit cell performance and 2) the possible methods to improve cell performance.

Herein, we report on the first observations of coherent phonon oscillations in the Sb2S3 system using femtosecond transient absorption spectroscopy. Based on the features of the oscillations obtained, the mechanism of phonon generation and the properties of the quasi-particle dynamics will be elucidated. Lastly, theoretical calculations of the phonon lifetime were also carried out to determine the phonon modes. Daughter phonons used for the lifetime calculations will be chosen based on the conservation of energy and momentum. These were correlated with Raman spectroscopy to gain a complete picture of the phonons in the Sb2S3 system.

P9 Ultrafast Optical Spectroscopy of Perovskite (CH3NH3)PbI3

Swee Sien Lim, Guichuan Xing, Nripan Mathews, Tze Chien Sum

Tuesday 05.15 PM, Foyer/Hallway, Panel 9 (EC number: 17)

Dye-sensitised solar cells (DSSC) are subjected to extensive research due to cost efficient solar power conversion. In a modern DSSC, a porous layer of titanium dioxide nanoparticles act as a scaffold for the light absorber. The dyes used in these cells generally have large optical cross sections, and they directly affect the thickness and composition of the cell. Recently, a mesoscopic solar cell using methyl ammonium lead iodide (CH3NH3)PbI3 nanopartiles was realised. Im et al. developed a cell that uses a redox electrolyte which had an efficiency of 6.54

Presently, reports on the photophysics of (CH3NH3)PbI3 are far and few between. Herein, we performed a systematic study involving ultrafast spectroscopic techniques such as transient absorption, temperature-dependent steady state and time-resolved photoluminescence to investigate its optical properties. Importantly, the emission peaks shift as a function of temperature, indicating the onset of crystallographic phase transitions. Previously, this material was reported to undergo one phase transition from orthorhombic to tetragonal at $\approx$162.2K, and a second transition to cubic perovskite at $\approx$327.4K. Further details on the time-resolved PL studies and the TA spectroscopy of the carrier dynamics will also be presented at the conference.

P10 Ultrafast Exciton Dynamics and Lasing in ZnSe Nanowires

Guichuan Xing, Jingshan Luo, Bo Wu, Xinfeng Liu, Cheng Hon Alfred Huan, Hongjin Fan, Tze Chien Sum

Tuesday 05.15 PM, Foyer/Hallway, Panel 10 (EC number: 18)

Zinc selenide (ZnSe) is a technologically important wide bandgap II-VI semiconductor (Eg$\approx$2.69 eV) which is commonly used in the fabrication of light emitting diodes and laser diodes operating in the blue and blue-green part of the spectrum. Despite more than a decade of research since the inception of ZnSe nanowires (NWs) in 2001, the carrier recombination dynamics in this nano materials remain poorly understood. Herein, through a comprehensive pump-fluence and temperature dependent two-photon excitation (TPE) study, we present a clear picture of the carrier relaxation pathways, intrinsic lifetimes, exciton oscillator strengths and exciton-phonon interactions in this NW system. Contrary to a common perception that the higher pump intensities needed to achieve two-photon excited photoluminescence correspond to a higher exciton density threshold (nth) for two-photon pumped lasing, it is found that a much lower nth is needed to achieve lasing with TPE compared to single photon excitation (SPE) of the same ZnSe NWs. This measurement is further supported by the greatly enhanced lasing action photo-stability characteristics of the ZnSe NWs under TPE. Our findings have significant implications on the design and the tailoring of the optoelectronic properties of nanowire lasers.

P11 Assembly of Suspended Graphene on Carbon Nanotube Scaffolds with Improved Functionalities

Sharon Xiaodai Lim, Chorng Haur Sow

Tuesday 05.15 PM, Foyer/Hallway, Panel 11 (EC number: 22)

With self-assembly being an efficient and often preferred process to build micro- and nano-materials into ordered macroscopic structures, we report a simple method to assemble monolayer graphene onto densified vertically aligned carbon nanotube (CNT) micropillars en route to unique functional three-dimensional microarchitecture. This hybrid structure provides new means of studying strain induced in suspended graphene. The strain induced could be controlled by the size and number of supporting microstructures, as well as laser-initiated localised relaxation of the graphene sheet. The assembled structure is also able to withstand high-energy electron irradiation with negligible effect on the electrical properties of the hybrid system. The hybrid system was further functionalised with quantum dots on the CNTs with the assembled top graphene layer as a transparent electrode. Significant improvements in photocurrent were achieved in this system.

P12 Micromotion in trapped atom-ion systems

Huy Nguyen Le, Amir Kalev, Murray D. Barrett, Berthold-Georg Englert

Tuesday 05.15 PM, Foyer/Hallway, Panel 12 (EC number: 23)

We examine the validity of the harmonic approximation, where the radio-frequency ion trap is treated as a harmonic trap, in the controlled collision of a trapped atom and a single trapped ion. This is equivalent to studying the effect of the micromotion since this motion must be neglected for the trapped ion to be considered as a harmonic oscillator. By applying the transformation of Cook *et al.* we find that the micromotion can be represented by two periodically oscillating operators. In order to investigate the effect of the micromotion on the dynamics of a trapped atom-ion system, we calculate (i) the coupling strengths of the micromotion operators by numerical integration and (ii) the quasienergies of the system by applying the Floquet formalism, a useful framework for studying periodic systems. It turns out that the micromotion is not negligible when the distance between the atom trap and the ion trap is shorter than a characteristic distance. Within this range the energy diagram of the system changes dramatically when the micromotion is taken into account. The system exhibits chaotic behaviour through the appearance of numerous avoided crossings in the energy diagram when the micromotion coupling is strong. Excitation due to the micromotion leads to undesirable consequences for applications that are based on an adiabatic process of the trapped atom-ion system. We suggest a simple scheme for bypassing the micromotion effect in order to successfully implement a quantum-controlled phase gate proposed previously and create an atom-ion macromolecule. The methods presented are not restricted to trapped atom-ion systems and can be readily applied to studying the micromotion effect in any system involving a single trapped ion.

P13 Direct Laser Pruning of CdSxSe1-x Nanobelts En Route to Multicolored Pattern with Controlled Functionalities

Junpeng Lu

Tuesday 05.15 PM, Foyer/Hallway, Panel 13 (EC number: 24)

CdSxSe1-x nanobelts are interesting nanostructured materials with tunable band gap from 1.7 eV to 2.4 eV depending on their stoichiometry. These nanobelts give out strong photoluminescence with unique color depending on their chemical compositions. In this work, we demonstrate that a direct focused laser beam irradiation was able to achieve localized modification of the chemical composition of the nanobelts. As a result, we could locally change the optical properties of these nanobelts. With a scanning laser beam, micro-patterns with a wide range of fluorescence color could be created on a ternary nanobelts film without a pre-patterned mask. The laser modified nanobelts showed higher resistance to corrosion by acid and exhibited more superior photoconductivity. The construction of micropatterns with functionality/color control within the sample would provide greater building blocks for photoelectronic applications.

P14 Controlled Structural Changes during Laser Pruning of GeSe2 Nanostructures with Optoelectrical Properties

Bablu Mukherjee, Govinda Murali, Xiaodai Lim, Minrui Zheng, Eng Soon Tok, Chorng Haur Sow

Tuesday 05.15 PM, Foyer/Hallway, Panel 14 (EC number: 25)

GeSe2 has interesting crystallization process which can be turned using light irradiation or temperature rises. Single-crystalline GeSe2 nanostructures are interesting nanomaterials for photoelectronic properties. As synthesized GeSe2 nanostructures exhibit beta crystalline phase with unique signature in Raman spectrum. In this report, we demonstrate that a direct focused laser beam irradiation was able to achieve localized modification on GeSe2 nanostructures film. Using scanning focus laser beam setup direct micropatters on GeSe2 nanostructures film were created with different laser power. Controlled structural changes of the nanostructures were obtained on laser modified micropatterns using Raman spectroscopy. The laser modified nanostructures film shows superior photoconductivity properties than the pristine nanostructure film. The construction of micropatterns with color control and structural changes would provide great interest for optoelectrical application.

P15 Kicked relativistic rotor: Localization and Superballistic diffusion

Qifang Zhao, Cord Mueller, Jiangbin Gong

Tuesday 05.15 PM, Foyer/Hallway, Panel 15 (EC number: 26)

We studied the kicked relativistic rotor from both quantum and classical mechanics. We found that quantum kicked relativistic rotor possess localization-delocalization transition, and superballistic diffusion. We also design the classical counterpart, and study their phase space, which gives us better understanding of the quantum model.

P16 Laser Initiated Formations of Silver Nanoparticles on Carbon Nanotbes

Xueting Liu, Bridget Ng, Yu Lian Wong

Tuesday 05.15 PM, Foyer/Hallway, Panel 16 (EC number: 30)

In this work, laser-induced reduction of silver nitrate solution was used for the localized fabrication of Ag-CNTs hybrid structures. A variation of silver nitrate concentration, laser speed and power was tested to obtain the most ideal result of highest count density and mean circularity of nanoparticles. Qualitative and quantitative analysis were conducted on the Ag-CNT hybrids. Characterizations of the samples were carried out using Field Emission Scanning Electron Microscope and Energy-Dispersive X-ray to determine the presence of silver nanoparticles in the sample. Through field emission and laser enhanced field emission, it was observed that more electrons are emitted from Ag-CNTs when photons are introduced compared to as-grown CNTs. As such, the results suggest that Ag-NPs could serve a source for additional electrons. This shows potential application of the Ag-CNTs hybrid structures as an efficient electron emitter. Its performance can be further enhanced with an external photon source.

P17 SYNTHESIS, CHARACTERISATION AND HIGH PERFORMANCE ENERGY STORAGE STUDIES ON MgCo2O4 AND MnCo2O4 AS ANODE MATERIALS FOR LITHIUM-ION BATTERIES

Valavan Rajarajan, Tianyu Ouyang, Yiming Xu, M V Venkatashamy Reddy

Tuesday 05.15 PM, Foyer/Hallway, Panel 17 (EC number: 33)

Previously, MCo2O4 (M = Mg, Mn) were prepared using urea combustion method (M = Mn) and oxalate decomposition method (M = Mg). Li-cycling studies of both compounds showed sustained reversible capacity of $200mAhg^{-1}$ at a current rate of $60mA^{-1}$. In this project, MCo_2O_4 (M = Mg, Mn) was synthesized using the molten salt method (MSM) with different M and Co salts. Powdered X-Ray Diffraction (XRD), BET method, Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) were carried out to characterize the phase, structure and morphology of the of the compound. Galvanostatic cycling of voltage 0.005 – 3.000 V were carried out on coin cells made with MCo_2O_4 as anode for up to 600 cycles with a current density of $600mAg^{-1}$ and for up to 60 cycles with a current density of $60mAg^{-1}$. At the end of the cycles using $60mAg^{-1}$, single phase $MgCo_2O_4$ showed extensive capacity fading of 37.1

P18 Design of a Low-Cost Carbon Nanotube Field Emission Electron Source

Sabrina Ho, Hao Yang Chan, Justin Yeo

Tuesday 05.15 PM, Foyer/Hallway, Panel 18 (EC number: 34)

In recent years, the unique mechanical and physical properties of Carbon Nanotubes (CNTs) have been the subject of extensive studies for use as a field emitter. Co ld cathode CNT field emitters are expected to yield better performance than traditional Si or W tip emiters and are more durable. We will discuss two methods of attaching CNT onto a common household screw substrate for use as a low-cost field emitter. They are namely, the manual attachment of a CNT sample grown on a separate substrate onto a screw using silver paste adhesive and the direct growth of CNT onto the screw. We also examine the effect of the CNT quality,density and morphometry on the performance of the proposed field emitter. CNT grown using Chemical Vapor Deposition (CVD) (C1) is found to have the largest field enhancement factor due to its high aspect ratio and consistent length. Field emitters with the low CNT density (S1, single-strand) provide the greatest field enhancement due to the enhanced field penetration provided by the pointed tip of the screw and the low screening effect. Experimental results are in good agreement with our computer simulation results using COMSOL Multiphysics Software.

P19 Optimization of Geometric Attributes on Gold Nanoparticle Nanopatterns for High Performance in Surface Enhanced Raman Spectroscopy

Sanghamitra Dinda Dalapati, F. Ling Yap, R. Kumar Gupta, Debojyoti Das, Sivashankar Krishnamoorthy

Tuesday 05.15 PM, Foyer/Hallway, Panel 19 (EC number: 39)

Surface enhanced Raman spectroscopy (SERS) serves as a highly sensitive tool for detection of trace analytes. By the virtue of delivering unique fingerprint spectra for analytes with minimal sample preparation and rapid measurement times, coupled with non-destructive testing possibility, the technique has growing impact in several application areas, e.g. Biomedicine, reaction monitoring, quality monitoring of food and environment. At the heart of the SERS technique lie the metal nanostructures, the electromagnetic field enhancement through which are responsible for the significant enhancement of Raman signals. Design and optimization of such metal nanostructure configurations capable of highly enhanced SERS detection, coupled with economy, and throughput are therefore sought, and is the focus of our current work. In this poster, we present our recent capabilities in enhancing the sensitivity of the metal nanoparticle SERS substrates with minimum error exhibiting a nanoscale pattern of gold nanoparticle aggregates by optimization of fabrication steps. The pattern of aggregates is achieved through selective attachment of gold nanoparticles from an aqueous suspension onto a surface presenting a nanopattern of polyelectrolyte features. These nanopatterns are attained through self-assembly of amphiphilic block copolymer reverse micelles on surface. We had earlier established tunability in the size and separation of the aggregates down to sub-10nm regime by manipulating the self-assembly process. Here, we present further investigations leading to unique aggregate configurations with excellent control over the aggregate shape that promise further enhancement in SERS sensitivity and its potential as SERS detection probe for chemical and biological analysis. Performance enhancement in SERS sensitivity through the controlling of shape of the aggregated AuNPs cluster arrays.

P20 Ultra Short Time Scale Growth of Multiwall Carbon Nanotubes using Dense Plasma Focus Device as Remote Plasma Source

Kin Seng Tan, Rajdeep Singh Rawat

Tuesday 05.15 PM, Foyer/Hallway, Panel 20 (EC number: 42)

Synthesis of multiwall carbon nanotubes (MWCNT) was successfully demonstrated using a short lived dense plasma generated from dense plasma focus device a remote plasma source. A mixture of methane and argon gas was used for MWCNT growth. A heating source was used to heat the stainless steel catalyst substrate. A heating source, plasma source and catalyst were the three main contributors in ensuring successful growth. MWCNT were estimated to have lengths within 3 to 4 µm and diameter of 6 to 25 nm. The as-grown MWCNT forest were densely packed and the canopy showed random sized tubes and other carbon material. Multiwall characteristics were confirmed from TEM with the measured wall spacing to be about 3.4 Å. D and G band were present as well as the overtones of G', D+G and 2G bands indicating typical MWCNT were grown. Presence of SWCNT was absent due to lack of RBM peaks. Short lived dense plasma through high speed imaging confirmed the effective plasma contact with the substrate was about 75 µs showing the growth process was indeed on an ultra-short time scale.

P21 Competition of geometric phase and dynamic phase of a Dirac fermion in a disordered potential

Kean Loon Lee, Christian Miniatura, Dominique Delande, Benoit Gremaud

Tuesday 05.15 PM, Foyer/Hallway, Panel 21 (EC number: 46)

We study the relation between disorder and topology in momentum space. We numerically observe a transient broken reflection symmetry in the momentum-space density of a spinorial wave (Dirac fermion) propagating in a disordered potential, even though the energy dispersion of the underlying clean system is symmetrical. We attribute the effect to the interference contribution of time-reversed paths, which is mainly known for coherent back-scattering effect. The two scattering paths form a closed trajectory in momentum space such that competition of the geometric phase and the dynamic phase of this closed trajectory gives rise to the observed asymmetry. It is feasible to observe this competition of phases in a cold atom experiment.

P22 Electronic Structure and Charge Carrier Dynamics of Graphene/metal Interface

Teck Wee Goh, Shi Chen, Sandy Adhitia Ekahana, Xinfeng Liu, Tze Chien Sum, Cheng Hon Alfred Huan

Tuesday 05.15 PM, Foyer/Hallway, Panel 22 (EC number: 47)

Graphene nanoribbons (GNR) are quasi-one-dimension variants of the commonly known graphene sheets. GNR, having wide bandgap tunability1 by changing its width, is an interesting material of research as it has potential applications in nanoscale devices. It also has desirable charge transport properties comparable to that of graphene. GNR of various width can now be fabricated atomically precise, hence opening up semiconductors to those made of GNR which makes them not only interesting, but also useful to be studied.

In this work, Time-Resolved Two Photon Photoemission (TR-2PPE) is used to study the electronic states present in GNR/metal and graphene/metal interface. TR-2PPE is useful as a powerful technique to probe both occupied and unoccupied states of a material. Time resolution is achieved using pump-probe technique similar to those used in transient absorption. Employing this technique a comparison study of the electronic structures and their carrier dynamics of the states in graphene/metal interface and GNR/metal interface is presented along with to compare the difference in interaction in each of the two interfaces. Effective mass calculated using angle resolved 2PPE will also enable us to understand the difference in transport properties within these interfaces.

P23 Superradiant effects in atom photon interaction

Navneeth Ramakrishnan

Tuesday 05.15 PM, Foyer/Hallway, Panel 23 (EC number: 49)

The process of spontaneous emission in a single atom is well understood. Recent papers have also shown that spontaneous emission, being unitary, is time reversible provided one chooses the appropriate photon pulse shape. We extend such results to the case of two atoms where an induced dipole-dipole interaction leads to cooperative effects known as superradiance or subradiance. Using a simple quantum optics model, we simulate atomic decay from an excited state in a vacuum where we notice superradiant effects at various interatomic separations and for varying initial conditions. The collective Lamb shift, a generalization of the single atom Lamb shift, is also seen. Finally, we observe the atomic excitation process for various photon pulse shapes and calculate the maximum excitation probability for each case.

P24 Investigating Polaron Generation in Organic Solar Cells Using Photoinduced Absorption Spectroscopy

Wei Peng Goh, Zi En Ooi, Evan Laurence Williams, Joel Kwang Wei Yang, Wee Shing Koh, Subodh Mhaisalkar

Tuesday 05.15 PM, Foyer/Hallway, Panel 24 (EC number: 54)

There are great efforts to incorporate plasmonic nanostructures in organic photovoltaic (OPV) devices as a means to increase photocurrent generation. Here, we use Photoinduced Absorption (PIA) Spectroscopy to investigate the photogeneration of charge carriers in an OPV cell. In this study, poly(3-hexylthiophene):[6,6]-phenyl-C61 butyric acid methyl ester (P3HT:PCBM) is used as the active layer. Of particular interest is the $\approx$1.25 eV signal in the PIA spectrum. This peak is a characteristic of the absorption feature arising from polarons in P3HT and is commonly observed in photoexcited P3HT:PCBM blends. The relative strength of this characteristic absorption can be interpreted as a measure of charge generation efficiency. As PIA spectroscopy does not require electrical contacts, it has the added benefit of not requiring charge carriers to be extracted from the device. Through the use of PIA spectroscopy, we aim to understand the effects on photocurrent generation when incorporating plasmonic nanostructures in a P3HT:PCBM film.

P25 Selective Silver Coating Technique for Fabrication of Metal Helices for Their Application as Chiral Metamaterial

Kwan Bum Choi, Shuvan Prashant Turaga, Yuanjun Yan, Andrew A. Bettiol

Tuesday 05.15 PM, Foyer/Hallway, Panel 25 (EC number: 55)

Metallic helices are one of the metamaterial designs that exhibit chirality, a property that can be used to circularly polarize light. Two-photon lithography has been used to fabricate a helix based chiral metamaterial using the photopolymer SU-8. One of the challenges in converting the polymer microstructure into a “true” metamaterial is the selective coating of the polymer microstructures. This requirement, to have a metallic structure on a non-conducting substrate, is necessary for the metamaterial to function. In this paper, we will present our selective silver coating technique, which uses plasma activation of SU-8. We will discuss the quality of the silver coating by looking at its morphology, surface roughness and conductivity. Furthermore, we will demonstrate how this selective silver coating procedure can be used to make a 3D helix chiral metamaterial.

P26 Vibrational ground state cooling of a neutral atom in a tightly focused optical dipole trap

Victor Leong, Gleb Maslennikov, Christian Kurtsiefer

Tuesday 05.15 PM, Foyer/Hallway, Panel 26 (EC number: 56)

Recent experiments have shown that an efficient interaction between a single trapped atom and light can be established by concentrating light field at the location of the atom by focusing [1-3]. However, to fully exploit the benefits of strong focusing one has to localize the atom at the maximum of the field strength [4]. The position uncertainty due to residual kinetic energy of the atom in the dipole trap (depth $\approx$1 mK) after molasses cooling is significant (few 100 nm). It limits the interaction between a focused light mode and an atom even for moderate focusing strength [2]. To address this problem we implement a Raman Sideband cooling technique, similar to the one commonly used in ion traps [5], to cool a single 87Rb atom to the ground state of the trap. We have cooled the atom along the transverse trap axis (trap frequency = 55kHz), to a mean vibratonal state of 0.55 and investigate the impact on atom-light interfaces.

[1] M. K. Tey, et al., Nature Physics 4 924 (2008) [2] M. K. Tey et. al., New J. Phys. 11, 043011 (2009) [3] S.A. Aljunid et al., Phys. Rev. Lett. 103, 153601 (2009) [4] C. Teo and V. Scarani Opt. Comm. 284, 4485-4490 (2011) [5] C. Monroe et al., Phys. Rev. Lett. 75, 4011 (1995)

P27 Reduction of Thermal Conductivity by Nanoscale 3D Phononic Crystal

Lina Yang, Nuo Yang, Baowen Li

Tuesday 05.15 PM, Foyer/Hallway, Panel 27 (EC number: 63)

Thermoelectric materials are important for generating electricity from waste heat and being used as solid-state Peltier coolers. One way to improve the efficiency is to reduce thermal conductivity but preserve their electronic properties of the thermoelectric material. Phononic crystal (PnC) is constructed by a periodic array of scattering inclusions distributed in a host material, which has the potential to be efficient thermoelectric material. We constructed a nanoscale 3D isotopic PnC of Si, and study how the period length and the mass ratio affect the thermal conductivity. Simulation by equilibrium molecular dynamics shows this PnC can significantly reduce the thermal conductivity of bulk Si at high temperature (1000). The thermal conductivity decreases as the period length and mass ratio increases. The phonon dispersion curves show an obvious decrease of group velocities in 3D isotopic PnCs. The phonon's localization and band gap is also clearly observed in the spectra of normalized inverse participation ratio of nanoscale 3D isotopic PnCs.

P28 Robustness of Bell inequalities against reduced "free will" attacks and its relation to Bell-based randomness expansion

Jeysthur, Phuc Thinh Le, Lana Sheridan, Valerio Scarani

Tuesday 05.15 PM, Foyer/Hallway, Panel 28 (EC number: 67)

With the advent of quantum information, the violation of a Bell inequality is used as evidence of the absence of an eavesdropper in cryptographic scenarios such as key distribution and randomness expansion. One of the key assumptions of Bell's Theorem is the existence of experimental "free will", meaning that measurement settings can be chosen at random and independently by each party. The relaxation of this assumption potentially shifts the balance of power towards an eavesdropper. We showed that the CHSH inequality is most robust against "free will" attacks.

P29 Tomography with entanglement witness

Jibo Dai, Yink Loong Len, Leonid Krivitsky, Berthold-Georg Englert

Tuesday 05.15 PM, Foyer/Hallway, Panel 29 (EC number: 68)

To determine whether a state is entangled or separable, one can achieve this with minimal tomographic effort by measuring witness operators which form an IC-POM [1]. We implement this experimentally in the case of a 2-qubit photonic system. In passing, we report a simple and controllable way to generate mixed states of a certain kind, with different degrees of entanglement.

[1] Phys. Rev. A 81, 052339 (2010)

P30 One-dimensional transport revisited: A simple and exact solution for phase disorder

Hui Khoon Ng, Berthold-Georg Englert

Tuesday 05.15 PM, Foyer/Hallway, Panel 30 (EC number: 69)

Disordered systems have grown in importance in the past decades, with similar phenomena manifesting themselves in many different physical systems. Because of the difficulty of the topic, theoretical progress has mostly emerged from numerical studies or analytical approximations. Here, we provide an exact, analytical solution to the problem of uniform phase disorder in a system of identical scatterers arranged with varying separations along a line. Relying on a relationship with Legendre functions, we demonstrate a simple approach to computing statistics of the transmission probability (or the conductance, in the language of electronic transport), and its reciprocal (or the resistance). Our formalism also gives the probability distribution of the conductance, which reveals features missing from previous approaches to the problem.

P31 CoPt Magnetic Nanoparticles Synthesized by Atmospheric Microplasma

Ying Wang, Rohit Medwal, Kin Seng Tan, Talebitaher Alireza, Paul Lee, Tuck Lee Tan, Raju Vijayaraghavan Ramanujan, Rajdeep Singh Rawat

Tuesday 05.15 PM, Foyer/Hallway, Panel 31 (EC number: 70)

CoPt magnetic nanoparticles were synthesized using atmospheric microplasma. The anodic atmospheric microplasma was generated using a syringe needle of bore diameter less than 700 µm as the anode and the Co and Pt based chemical solution as the cathode, discharged with high voltage DC power supply. The helium, at flow rate of 50 cubic centimeters per minute at STP (SCCM), was used as the discharge medium. 2 mA discharge current was applied and the discharge duration was around 10 minutes. The molar concentration of Co in the solutions was modified from 0.4 to 0.6 M. The influence of the Co molar concentration on the magnetic properties, topographies and crystallization of the CoPt magnetic nanoparticles were studied using various characterization techniques.

P32 Interference of ultracold matter waves: Localiztion signatures in momentum space

Tomasz Karpiuk, Nicolas Cherroret, Kean Loon Lee, Cord A. Mueller, Benoit Gremaud, Christian Miniatura

Tuesday 05.15 PM, Foyer/Hallway, Panel 32 (EC number: 72)

Using analytical and numerical methods, it is shown that the momentum distribution of a matter wave packet launched in a random potential exhibits a pronounced coherent backscattering (CBS) peak. By analyzing the momentum distribution, key transport times can be directly measured. The CBS peak can be used to prove that transport occurs in the phase-coherent regime. For sufficiently strong disorder, at the onset of Anderson localization, the momentum distribution of a coherent wave packet exhibits, in the forward direction, a novel interference peak that complements the coherent backscattering peak. An explanation of this phenomenon in terms of maximally crossed diagrams predicts that the signal emerges around the localization time and grows on the scale of the Heisenberg time associated with the localization volume. Together, coherent back and forward scattering provide evidence for the occurrence of Anderson localization.

P33 Spontaneous solitons in the thermal equilibrium of a quasi-one-dimensional Bose gas

Tomasz Karpiuk, Piotr Deuar, Przemyslaw Bienias, Emilia Witkowska, Krzysztof Pawlowski, Mariusz Gajda, Kazimierz Rzazewski, Miroslaw Brewczyk

Tuesday 05.15 PM, Foyer/Hallway, Panel 33 (EC number: 73)

Solitons, or non-destructible local disturbances, are important features of many one-dimensional (1D) nonlinear wave phenomena, from water waves in narrow canals to light pulses in optical fibers. In ultra-cold gases, they have long been sought, and were first observed to be generated by phase-imprinting. More recently, their spontaneous formation in 1D gases was predicted as a result of the Kibble-Zurek mechanism, rapid evaporative cooling, and dynamical processes after a quantum quench. Here we show that they actually occur generically in the thermal equilibrium state of a weakly-interacting elongated Bose gas, without the need for external forcing or perturbations. This reveals a major new quality to the experimentally widespread quasicondensate state. It can be understood via thermal occupation of the famous and somewhat elusive Type II excitations in the Lieb-Liniger model of a uniform 1D gas.

P34 Nonlinear waveguide arrays and disorder

Amit Rai, Dimitris Angelakis

Tuesday 05.15 PM, Foyer/Hallway, Panel 34 (EC number: 76)

Waveguide arrays with quadratic non-linearity has been studied recently. We investigated the waveguide arrays with quadratic non-linearity and explored the possibility of generating broadband continuous-variable entanglement in such structures. We propose an integrated approach toward continuous-variable entanglement based on integrated waveguide quantum circuits, which are compact and relatively more stable. We further continued our work on waveguide arrays by studying a hybrid system which contains a combination of linear and nonlinear waveguides. We assume that all the waveguides except the central one are assumed to be linear. The central waveguide is assumed to have quadratic non-linearity. We assume that the central waveguide is pumped through a coherent light. The coupling between the waveguide is achieved by the evanescent overlap of the guided modes. For all the other waveguides in the array the light propagates in the linear regime. We are also interested in investigating the effect of disorder and quadratic non-linearity in the waveguide array system.

P35 Electro-induced Infrared Active Vibrational Mode Mapping of Polymer FETs

Xin Yu Chin, Zilong Wang, Jun Yin, Mario Caironi, Cesare Soci

Tuesday 05.15 PM, Foyer/Hallway, Panel 35 (EC number: 77)

We studied the distribution of charge carrier density within the conducting channel of a polymer field-effect transistor (FET) in various operating regimes by implementing medium-infrared charge modulation spectroscopy (CMS) with a confocal FTIR microscope. CMS is an electro- optic probing technique where electro-induced bleaching and polaranic absorption features of nanometers thick active layer of organic field-effect transistors (OFETs) are studied. In this work, CMS is performed on regio-regular poly(3-hexylthiophene) (rr-P3HT) transistor in the medium-infrared spectral region (680-4000 cm^{-1}) where the Infra-Red Active Vibrational (IRAV) modes and the lowest polaron band are probed. Due to Their high specificity and strong oscillator strength in the spectral regime, charge carrier densities with high sensitivity have been quantitatively estimated even at low gate modulation frequencies, and allowing isolation of localized states to the conduction. We found the induced charge carrier density in the FET channel saturates at high gate voltages around a value of 10^{16} carriers/m^3. The dependence of charge carrier distribution upon increasing source-drain bias shows the depletion of carriers at the drain side due to the reduction of local potential. The potential of this technique to characterize charge carrier distribution, transport and dynamics in organic FETs by time, frequency, and temperature dependent measurements will also be discussed.

P36 First-principles studies of phonons in Bi2S3 : Effect of supercell size and 1-D behaviour in lattice dynamics

Yun Liu, Kun Ting Eddie Chua, Chee Kwan Gan

Tuesday 05.15 PM, Foyer/Hallway, Panel 36 (EC number: 78)

We present phonon dispersions of orthorhombic bismuth sulfide Bi2S3 using the supercell approach. The force constants were obtained using density functional theorem and Hellmann-Feynman theorem. Under the Pbmn space group convention, the supercell was slowly increased from 1x1x3 to 2x2x4, which was the minimum size required for accurate dispersion relations and degeneracy. We investigated the force constants of the five inequivalent atoms and determined that a large cutoff radius of at least 15 Angstrom centered on each atom is required to include the necessary interactions. The on-site force constant is small compared to other semiconductor materials such as GaN and the decay as a function of distance is slow. From the force constant analysis, we also observe 1-D behaviour in lattice dynamics with ribbons going along the z-direction. When an atom is moved in the x and y direction, the response is similar with force constants dominated by one site atoms. When moved in the z direction, there is negligible response from atoms from the other ribbons.

P37 Interface of Superconducting Quantum States and Atomic Quantum States

Christoph Hufnagel, Chin Chean Lim, Mirco Siercke, Rainer Dumke

Tuesday 05.15 PM, Foyer/Hallway, Panel 37 (EC number: 82)

Recent progress in atomic systems have given rise to various interesting directions in quantum computation and quantum simulation. Further, hybridisation of atomic systems with solid state systems could offer a viable mean to achieve better quantum state manipulation and to study interesting physical phenomena. In our new experimental direction, we work towards the coupling between ultracold atoms, and eventually between atoms and solid state systems with the help of a superconducting resonator under applied microwave field. This will be done by trapping ultracold Rb atoms in proximity of a superconducting stripline cavity cooled to <100 mK with a dilution refrigerator, and applying a microwave field to induce coupling with the atoms. We predict coherent coupling between trapped ^{87}Rb atoms and superconducting stripline cavity, and would attempt to manipulate atomic states through the superconducting resonator.

P38 Towards exciting a Rydberg gas in optical lattices

Manukumara Manjappa, Jingshan Han, Kumar M P, Ruixiang Guo, Thibault Vogt, Wenhui Li

Tuesday 05.15 PM, Foyer/Hallway, Panel 38 (EC number: 83)

Rydberg atoms are highly excited atoms with principal quantum number n ¿ 10. They have exaggerated properties such as large dipole moment and high polarizability. Large dipole-dipole interactions between Rydberg atoms, which lead to Rydberg blockade and giant non linearity, provide unique opportunities for studying quantum many-body physics [1-3]. Rydberg excitation of ground states gases in optical lattices has already shown the formation of spatially organized structures [3] and Rydberg dressed systems are promising for entering the strongly correlated regime [2]. Our current project is to study the collective excitation to Rydberg states from a quantum gas of ground state atoms in an optical lattice. In this poster we present the latest developments in building up the experimental apparatus and our plans on spectroscopic measurements and spatially imaging of Rydberg excitations.

P39 Ultrafast Exciton Dynamics in ZnxCd1-xSe nanobelt

Arief Sulistio, Guichuan Xing, Jing Shan Luo, Hongjin Fan, Tze Chien Sum

Tuesday 05.15 PM, Foyer/Hallway, Panel 39 (EC number: 85)

ZnxCd1-xSe nanobelts are interesting ternary alloy nanostructures with many unique properties suitable for lasing applications. Herein, we investigate the potential use of ZnxCd1-xSe nanobelt as a room-temperature gain media for two-photon pump lasing. Ultrafast femtosecond laser was used to probe the exciton dynamics in this material. The emission spectra from one and two photon excitation was measured, the continuous shift of band edge emission from 470 nm to 720 nm, correspond to pure ZnSe and CdSe emission, indicating a formation of ternary alloy rather than mixed of independent binary phases. We also examined the pump power dependent of emission which exhibits a super linear relationship above certain pump threshold. This threshold increases as more Cd in the composition and jump significantly when the composition of Zn is less than 20The time resolved for each emission shows two different decay time which correspond to surface and intrinsic transitions. We find that the intrinsic transition become longer as approaching CdSe side. This result is consistent with previous observation, as fast decay will lead to faster recombination while slower decay time lead to more excitons trapped in defect state. To understand more about the origin of this superlinear increment of emission, we explore the power dependent emission from single nanobelt using micro PL setup. Above the pump threshold, we observe multiple peaks emitted from a single nanobelt with constant spacing of around 4nm, indicating that the different lasing modes to correspond to a fabry perot cavity present in the nanobelt.

P40 Green photovoltaic cells by High-density plasma immersion ion implantation (HD-PIII)

Lim Jian Wei Mark, Chia Sern Chan, Luxiang Xu, Shuyan Xu

Tuesday 05.15 PM, Foyer/Hallway, Panel 40 (EC number: 92)

The aim of this project was to investigate the feasibility of using a high-density plasma immersion ion implantation method to implant an n-layer on a crystalline silicon sample with the aid of Nitrogen plasma for fabrication of a pn junction. The focus of this investigation was the optimization of the process parameters in the implantation process so as to achieve PV cells with high efficiency. At the same time, considerations were made with regards to the cost for reproduction of the cells in a mass market and the impacts of byproducts from the processes on the environment. In this investigation, 3 process parameters were taken into consideration for the purpose of optimization. With Nitrogen as the feedstock gas in the plasma reactor, the RF power supplied to the chamber was varied. The process time for implantation was varied during the investigations. Another parameter that went under scrutiny was the bias that was supplied to the substrate holders that attracted ionic species towards the crystalline silicon samples. What resulted from these set of investigations was a photovoltaic cell, which registered a Voc (open circuit voltage) of 282.323 mV and an Isc (short circuit current) of 23.773 mA. This offers real potential for industrial applications, bearing in mind that processes that produce PV cells in the industries is economically unfeasible and come with numerous toxic byproducts and waste. The photovoltaic cell obtained in the HD-PIII method that was developed is environmentally friendly, and produced no pollutants in the process. It is also economically feasible and has the potential to be a game changer in the form of a sustainable and renewable green energy source.

P41 The role of silane concentration in microcrystalline silicon thin films by remote inductively coupled plasma

Yingnan Guo, Deyuan Wei, Shaoqing Xiao, Haiping Zhou, Shuyan Xu

Tuesday 05.15 PM, Foyer/Hallway, Panel 41 (EC number: 93)

Hydrogenated microcrystalline silicon (µc-Si:H) thin films were prepared by remote low frequency inductively coupled plasma (LFICP) chemical vapor deposition system, and the role of silane concentration in the microstructure and electrical properties of µc-Si:H films was investigated. The crystalline volume fraction Fc decreases as silane concentration increases, and the ratio of the intensity of (220) peak to that of (111) peak drops while silane concentration rises. The µc-Si:H films prepared by remote ICP have a low hydrogen content, which is in favor of reducing light-induced degradation effect. Furthermore, the processing window of the phase transition region for remote ICP is much wider than that for typical ICP. The photosensitivity of µc-Si:H films can exceed 100 at the transition region by remote ICP and this ensures the possibility of the fabrication of single junction microcrystalline silicon thin film solar cells with a open-circuit voltage of about 700 mV.

P42 Semi Intercalated Graphene Ribbon Array on SiC By Fluorine Intercalation

Swee Liang Wong, Han Huang, Wei Chen, Andrew Thye Shen Wee

Tuesday 05.15 PM, Foyer/Hallway, Panel 42 (EC number: 95)

Epitaxial graphene on SiC(0001) is a promising route towards large scale fabrication of graphene devices but is limited by the presence of an interacting substrate which is mediated through the interfacial SiC(0001) $6\sqrt{3}\times6\sqrt{3}$ R 30° layer (buffer layer). Intercalation of the buffer layer to form quasi-freestanding epitaxial graphene has been performed to minimize this interaction. However, the intermediate stages of intercalation have not been reported in detail before. In this report, fluorine intercalation of the buffer layer was carried out using fluorinated fullerenes, C60F48, as a source of fluorine at moderate temperatures of 150°C. An intermediate stage was discovered and their properties were investigated using Low Temperature Scanning Tunnelling Microscopy (LT-STM) and Spectroscopy (STS). Motifs of nanostructures with quasi-periodicity (≈2nm) similar to that of the buffer layer were observed and the scattering patterns at their edges also coincide with those associated with graphene. STS measurements reveal that these nanostructures could possibly be a network of highly p-doped graphene ribbons with a band gap of about 300 meV.

P43 Research on strong nonlinear interaction using Rydberg state atoms

Ruixiang Guo, Johannes Gambari, Kumar Molahalli Panidhara, Manukumara Manjappa, Jinshan Han, Thibault Vogt, Wnhui Li

Tuesday 05.15 PM, Foyer/Hallway, Panel 43 (EC number: 96)

Experimental demonstration of the dipole blockade of the excitation to Rydberg states due to strong dipole-dipole interactions has made Rydberg atoms very attractive candidates for studies of quantum many-body physics and applications in quantum information. Several recent theoretical proposals suggest realizing quantum gates and quantum simulators using Rydberg dipole blockade. Quantum nonlinearity at single photon level has already been observed by coherently coupling photons to atomic Rydberg states in a configuration of EIT. These results hold promise for ultimate quantum control of light quanta [1-3]. In our group, the research towards strong nonlinear interaction using Rydberg states has just started and currently the systems for laser cooling and for coherent excitation to Rydberg states are being built. The wavelengths required for two-photon coherent excitation of the Rydberg states are 780 nm and 480 nm, which are roughly 300 nm apart. Thanks to the shared facility of optical comb in CQT, an ultra-stable tool for frequency measurement, we can coherently stabilize those two lasers to the optical comb facility. A stability of 1.5×10^{-11} (<6 kHz) for a 1 s averaging time, improving toward the 3×10^{-13} (<400 Hz) level after 1000 s was realized with the 780 nm laser. Using the shared facility of optical comb, we can check, furthermore, improve the frequency stability of the existed frequency-stabilized lasers in our lab. In this poster we present the latest developments in building up the experimental apparatus for obtaining a cold Rydberg gas and the experimental results on developing and stabilizing the different lasers. References: [1] M.Saffman, T.G. Walker, K. Molmer, Rev. Mod. Phys. 82, 2313 (2010). [2] S.Sevincli, N. Henkel, C.Ates, and T.Pohl, Phys. Rev. Lett. 107, 153001 (2001). [3] Thibault Peyronel, Ofer Firstenberg, Qi-Yu Liang, Sebastian Hofferberth, Alexey V. Gorshkov3, Thomas Pohl, Mikhail D. Lukin, and Vladan Vuletic, Nature 488, 57-60 (2012).

P44 Si surface passivation by nonstoichiometric silicon oxide films deposited by low-frequency ICP for solar cell applications

Haiping Zhou, Deyuan Wei, Luxiang Xu, Yingnan Guo, Shaoqing Xiao, Shiyong Huang, Shuyan Xu

Tuesday 05.15 PM, Foyer/Hallway, Panel 44 (EC number: 99)

Hydrogenated silicon suboxide (SiOx:H) thin films are fabricated by low frequency inductively coupled plasma of hydrogen diluted $SiH_4 + CO_2$ at low temperature (100 °C). Introduction of minor oxygen into the film results in the predominantly amorphous structure, wider optical bandgap, increased H content, lower conductivity and higher activation energy. The minority carrier lifetime in the SiOx:H-passivated p-type Si substrate is up to 428 µs with a reduced incubation layer at the interface. The associated surface recombination velocity is as low as 70 cm/s. The passivation behaviour dominantly originates from the H-related chemical passivation. The passivation effect is also demonstrated by the excellent photovoltaic performance of the heterojunction solar cell with the SiOx:H-based passivation and emitter layer.

P45 Fermions in optical lattices

Jimmy Sebastian, Christian Gross, Li Ke, Wang Yibo, Thong May Han, G.H.C Jaren, Wenhui Li, Kai Dieckmann

Tuesday 05.15 PM, Foyer/Hallway, Panel 45 (EC number: 100)

Many body quantum physics describing condensed matter physics to high energy physics can be studied with much accuracy using quantum simulators such as optical lattice potentials with atoms at each lattice site. Here the potentials and interatomic interactions can be accurately tailored to create quantum matter which can be studied in a top down approach. Of particular interest for this project are Fermions in two dimensional optical lattices. Fermionic Lithium (6Li) is a perfect candidate to explore quantum many body physics in the strongly interacting regime. We desire to employ laser cooling techniques to load Lithium atoms into optical lattice. Lithium, with a Doppler temperature of 140 micro Kelvin, has so far been a notorious candidate for laser cooling due to the hyperfine level spacing of the desired transition being unresolved by the natural linewidth of the levels. Thus sub Doppler temperature needed for efficient loading into the optical lattice are far from reach. To overcome this hurdle we will employ, study and further develop a narrow line (180 kHz) cooling scheme with a wavelength in the UV [1]. In this case the narrow linewidth gives a lower Doppler temperature of 18 micro Kelvin. We have achieved the Red MOT and have identified the UV spectrum to which we have stabilized our UV laser. [1] P.M. Duarte et al, Physical Review A 84, 061406(R) (2011)

P46 Towards 6Li-40K dipolar ground state molecules

Johannes Gambari, Sambit Pal, Mark Lam, Kai Dieckmann

Tuesday 05.15 PM, Foyer/Hallway, Panel 46 (EC number: 104)

Heteronuclear molecules such as 6Li-40K, with large dipole moments, are promising tools for quantum simulation of a large class of many body effects as well as for quantum computation. Heteronuclear molecules with relatively low dipole moment have been successfully created through coherent transfer from the highly excited ro-vibrational states [1-4].

Work towards ground state transfer of the previously presented Bosonic 6Li-40K, Feshbach molecules [5], is in progress and currently a Raman laser system is being built by our group for this purpose. The wavelengths required for the Raman laser system are 767 nm and 522 nm [6,7], which are roughly 250 nm apart. Since the transition strengths are rather low, pulse sequences need to be comparatively long (100 µs or more). We expect to achieve high coherence times between the two wavelengths by locking the frequency comb to the 767 nm and the 522 nm laser to the frequency comb. To reduce short term (100 µs) linewidth down to sub-kilohertz values, the 767 nm laser is stabilised to a high finesse reference cavity using Pound-Drever-Hall lock.

We further present a calibration procedure that enhances the precision of an interferometer based frequency stabilization by several orders of magnitude. For this purpose, the frequency deviations of the stabilization are measured precisely by means of a frequency comb. This allows us to implement several calibration steps that compensate different systematic errors. The resulting frequency deviation is shown to be less than 5.7 MHz (rms 1.6 MHz) in the whole wavelength interval 750–795 nm. This wide and precise tuning range will be a very valuable tool for spectroscopy of molecular states relevant to our ground state transfer.

References: J. Ye et al., Science 322, 231 (2008) H.-C. Nägerl et al., Nature Physics 6, 265 (2010) H.-C. Nägerl et al., Appl. Phys. B 95, 219-225 (2009) H.-C. Nägerl et

al., Laser Spectroscopy 256 (2010) K. Dieckmann et al., Phys. Rev. Lett. 102, 020405 (2009). Raman-Abdoul Allouche, private communication E. Tiemann et al., PRA 79, 042716 (2009) T. Müller-Wirts, U.S. patent 6,178,002, DE 197 43 493 A 1 (3 December 1998) K. Dieckmann et al., Applied Optics, Vol 51, No. 22 (1 August 2012)

P47 Spin-Orbit Splitting in Single Layer MoS2 Revealed by Resonant Raman Spectroscopy

Linfeng Sun, Da Zhan, Jiaxu Yan, Hailong Hu, Zexiang Shen

Tuesday 05.15 PM, Foyer/Hallway, Panel 47 (EC number: 107)

The giant spin-orbit splitting of single layer MoS2 has been extensively investigated theoretically because of its potential applications in spintronics-based advanced electronic device. In this presentation, we probe the valence-band spin-orbit splitting of single layer MoS2 for the first time by studying its triply resonant Raman scattering experimentally. Second order overtone and combination Raman modes of single layer MoS2 are dramatically enhanced upon UV laser irradiation. We propose that such resonant Raman enhancement arises from the deformation potential and Fröhlich interaction involved electron-two phonon triple resonance. The direct observation of spin-orbit splitting by triply resonant Raman scattering may open a new and convenient route to study the spin physics in MoS2-like materials with strong spin orbit coupling.

P48 Recovery from Radiation Damage for Si Avalanche Photodiodes

Yue Chuan Tan, Alexander Ling

Tuesday 05.15 PM, Foyer/Hallway, Panel 48 (EC number: 109)

Single photon detection is essential in free space quantum communication and quantum key distribution, long distance entanglement measurement, satallite ranging, and etc. However, Si avalanche photodiodes (APD), which are typically used for single photon detections are susceptible to radiation damage, eg. in Low Earth Orbit (LEO) environment. Undersanding the radiation tolerance of APDs is crucial when planning to use them in LEO. However, its possible to remove radiation induced damage through annealing. I will present findings from our recent studies on APD damage and recovery in a radiation environment.

P49 Quantum plasmonics of a metal nanoparticle array for on-chip nanophotonic network

Changhyub Lee, Mark Tame, Changsuk Noh, James Lim, Jinhyoung Lee, Dimitris Angelakis

Tuesday 05.15 PM, Foyer/Hallway, Panel 49 (EC number: 112)

With the advancement of nanofabrication techniques, metallic nanoparticles have been attracting significant attention due to their novel capabilities offering the prospects of miniaturization, scalability, and strong coherent coupling to single-emitters that conventional photonics cannot achieve. In this work, we investigate an array of metal nanoparticles for on-chip quantum networking, quantum computation and communication on scales far below the diffraction limit. For this purpose, we first consider the transfer of quantum states, including single qubits as plasmonic wave packets, and explore the interference of single plasmons associated with the quantum properties of the plasmon excitation. In addition, we study dipole induced reflection effects in the plasmonic setting. The results seem promising for quantum control applications such as single-photon switching and slow light in the nanoscale. We also propose a scheme of entanglement generation between distant emitters embedded in the array of metal nanoparticles. It is shown that one can achieve high-fidelity entangled state even when the metal loss is large. The techniques introduced in this work may assist in the further theoretical and experimental studies of plasmonic nanostructures for quantum control applications and probing nanoscale optical phenomena.

P50 Nanoscale probing of electron transport on MoS2 surface at low temperature

Ramesh Thamankar, Yap Tiong Leh, Cedric Troadec, Christian Joachim

Tuesday 05.15 PM, Foyer/Hallway, Panel 50 (EC number: 113)

We have studied the electronic transport on a semiconductor (MoS2) surface at low temperature. The transport measurements are done in ultrahigh vacuum Nanoprobe and at low temperature (30 K). Nanoprobe contains four STM tips which can be controlled individually. The probe separation can be changed in a controlled way using a high resolution scanning electron microscope sitting about the nanoprobe sample stage. Two-probe current-voltage characteristics are measured at various probe separations (1micron - 50nm). The electronic transport is explained using a model which includes tunneling and the thermionic field emission. MoS2 surface maintains a surface energy gap ($\approx$1.3$\pm$0.1 eV) even at source-drain separation of 50 nm. The existence of surface energy gap at nano scale makes MoS2 a suitable candidate for future atomic scale electronic devices.

P51 Progress towards state detection of molecular ions using quantum logic techniques

Shiqian Ding, Meng Gao, Roland Hablutzel, Dzmitry Matsukevich

Tuesday 05.15 PM, Foyer/Hallway, Panel 51 (EC number: 115)

The manipulation and detection of the rovibrational states of a single molecular ion via quantum logic techniques can be utilized for precision measurements, spectroscopy and studies of quantum mechanical aspects of chemical reactions. In our proposed scheme, state transfer from the molecular ion to the atomic ion via the common mode of motion, which is realized by stimulated Raman transition using frequency comb, results in efficient state detection of the molecular ion. We report on the production of a cold silicon monoxide molecular ion achieved by laser ablation and sympathetic cooling. We also minimize bias magnetic field in order to decrease the Zeeman shifts of the molecular ion energy levels and destablize the resulting Yb171+ dark state by polarization modulation of the laser beams.

P52 Enhanced Polarization Properties of Silver Helical Metamaterials by Tailoring Their Structural Features

Shuvan Prashant Turaga, Kwan Bum Choi, Yuanjun Yan, Andrew A. Bettiol

Tuesday 05.15 PM, Foyer/Hallway, Panel 52 (EC number: 120)

Metallic helices have been extensively researched and demonstrated for their application as broadband circular polarizers in different frequency regimes. For making such 3D helices, two photon lithography(TPL) has been employed in conjunction with electroplating of metals. Recently, our group has demonstrated selective silver electroless plating of two photon fabricated polymer(SU-8) structures on silicon substrate. This procedure allows us to make metal-coated polymer helices. These helices, by virtue of their high chirality, induce circular polarization. TPL process parameters are responsible for the structural features of helices. The helices have elliptical cross-sectional profile arising due to elliptical spot size (about 3:1) in the z-direction. This elliptical profile could be used to control the chirality for these structures. Additionally, exposed SU-8 polymer shrinks after development resulting in natural tapering of these helices. In this numerical study, we will examine how these fabrication process parameters could be tailored to obtain higher extinction ratios for these polarizers in THz regime. Furthermore, we will analyse the aspect-ratio effects in these metal-coated polymer helices.

P53 Three dimensional microlasers fabricated using proton beam writing

Sudheer Kumar Vanga, Andrew A. Bettiol

Tuesday 05.15 PM, Foyer/Hallway, Panel 53 (EC number: 130)

Whispering gallery mode microresonators attains high quality factors because of its high confinements of optical fields within the microresonator resulted from the total internal reflection from its walls of the boundary. The optical resonance occurs in such resonators when the circulating optical field is in phase with the incident field that enters the resonator. As a fact these high quality factors and the sensitivity of resonance, which depends on the factors like effective refractive index of the propagating mode and physical dimension of the resonator, made these resonators applicable for variety of applications in different fields. One such application is demonstrated in this presentation is whispering gallery mode microlasers fabricated in dye doped polymer.

Circular whispering gallery mode resonator based microlasers generally yields low pump threshold. Although these microlasers showed low pump threshold but were lack in directionality, which is undesirable for practical laser devices. In this presentation semi directional microlasers based on whispering gallery modes were demonstrated. The directionality is achieved by deforming the resonator geometry, this deformation results in reduction of quality factor which reflects in increased laser pump fluence. To compensate or to reduce the input pump fluence of the planar microlaser, three dimensional microlasers were fabricated. This suspended microresonator increases the quality factors because of the increased refractive index contrast which enhances the optical mode confinement in the resonator. Three dimensional microlasers were fabricated using focused direct write ion beam technique, proton beam writing. The suspended microlasers supported from the substrate were optically characterized and the results showed improved performance of the three dimensional microlaser over the planar microlaser fabricated in Rhodamine B doped SU-8 polymer.

P54 Spin-exchange relaxation-free (SERF) atomic magnetometers

Ley Li Yuan, Herbert Crepaz, Rainer Dumke

Tuesday 05.15 PM, Foyer/Hallway, Panel 54 (EC number: 131)

At sufficiently high atomic density and low magnetic field, spin exchange collision can be suppressed. This lead to high sensitivity magnetometer($1\,\mathrm{fT\,Hz^{-1/2}}$) since spin exchange collision is one of the main contribution for spin relaxation. With a coated cell, spin relaxation due to wall collision can also be suppressed. In our experiment, we will use potassium for constructing the atomic magnetometer.

P55 SOG Signatures of Financial Market Crashes

Siew Ann Cheong, Boon Kin Teh

Tuesday 05.15 PM, Foyer/Hallway, Panel 55 (EC number: 133)

Market crashes are just like earthquakes. Both are sudden, catastrophic, and seemingly unpredictable. Recently, we have explored the soup-of-group (SOG) model, originally developed for understanding global terrorism, as the unifying framework for understanding earthquakes. Preliminary results obtained thus far have been very encouraging. We would therefore like to use the SOG model as a point of departure to understand market crashes.

In this project, we aim to understand large market crashes in terms of the equilibrium and out-of-equilibrium dynamics of the SOG model. In particular, we would like to test the reliability of precursor signatures that has been developed for the SOG model of earthquakes. Ultimately, we would like to develop an early warning system based on the most reliable precursors that can monitor the stock market in real time, giving the instantaneous likelihoods of crashes of various sizes and the minimum time to a complete collapse as outputs.

We will start by estimating the equilibrium SOG parameters using high-frequency data across the entire SGX, in periods where there are no large market crashes. This includes checking the SOG power-law exponent of the distribution of event sizes. We will then consider out-of-equilibrium dynamics in the SOG model, and use signatures derived from this analysis to look at the period leading up to a large market crash, and the relaxation that follows.

P56 Ionization Potential Dependent Air Exposure Effect on the MoO3/Organic Interface Energy Level Alignment

Jian-Qiang Zhong, Hong Ying Mao, Rui Wang, Jia Dan Lin, Yong Biao Zhao, Jia Lin Zhang, Dong Ge Ma, Wei Chen

Tuesday 05.15 PM, Foyer/Hallway, Panel 56 (EC number: 136)

We reported an ionization potential (IP) dependent air exposure effect on the MoO3/organic interface energy level alignment by carrying out in-situ ultraviolet photoelectron spectroscopy and synchrotron light based x-ray photoelectron spectroscopy investigations. The electronic structures at MoO3/organic interfaces comprising various π-conjugated small organic molecules with different IP on MoO3 substrate have been systematically investigated. For the molecules with low IP, MoO3/organic interface electronic structures remained almost unc hanged after air exposure. In contrast, for the molecules with high IP, the highest occupied molecular orbital (HOMO) leading edge (or hole injection barrier) increases gradually with the increasing molecule IP after air exposure. For the MoO3/copper-hexadecafluorophthalocyanine (F16CuPc, IP: $\approx$6.58 eV) interface, air exposure can induce a significant downward shift of the HOMO level as large as $\approx$0.80 eV. Our findings could have great implications when using MoO3 as an effective hole injection layer via low-cost device manufacturing under low vacuum or non-vacuum conditions.

P57 Two-photon-induced Singlet Fission in Rubrene Crystal

Lin Ma, Gegham Galstyan, Keke Zhang, Christian Kloc, Handong Sun, Cesare Soci, Maria-Elisabeth Michel-Beyerle, Gagik G. Gurzadyan

Tuesday 05.15 PM, Foyer/Hallway, Panel 57 (EC number: 138)

The two-photon-induced singlet fission was observed in rubrene single crystal and studied by use of femtosecond pump-probe spectroscopy. Dynamics of the two-photon excited state and non-degenerate two-photon absorption (TPA) spectrum were monitored by two-photon induced transient absorption, which reveal the higher location and direct singlet fission from the two-photon excited states. The TPA absorption coefficient of rubrene single crystal was measured by use of Z-scan method. Quantum chemical calculations based on time-dependent density functional theory (TDDFT) support our experimental data.

P58 Materials Characterization by Ion Beam Analysis at CIBA

Taw Kuei Chan, Minqin Ren, Thomas Osipowicz

Tuesday 05.15 PM, Foyer/Hallway, Panel 58 (EC number: 155)

Ion Beam Analysis (IBA) methods allow for non destructive depth profiling, which is the measurement of the variation in quantities, e.g. material composition or defect distributions with depth. In specific cases, properties that cannot be measured by other techniques can be determined, eg, crystal lattice strain as a function of depth below amorphous thin films. This is important in research fields such as nanoelectronics and solar energy, where device properties depend significantly on the quality of interfaces between active layers beneath the surface. At CIBA, novel materials research is carried out with local and international collaborations by applying various IBA techniques for depth profiling. Being uniquely quantitative and non-destructive, IBA methods are highly versatile, being applicable to almost all aspects in next generation device research. In keeping with the fast pace of evolution of the requirement in modern research due to the continuing reduction of device dimensions, the high-resolution IBA endstation at CIBA employs an advanced detection system with sub-nanometer depth resolution, capable of measuring depth profiles of ultra-thin films with thicknesses of only a few nanometers. Here, we present examples of the materials science work done at CIBA, using conventional as well as high-resolution IBA techniques.

P59 Spectroscopic Properties of Lead Borax Glasses doped with Ytterbium

Sujeet Jain

Tuesday 05.15 PM, Foyer/Hallway, Panel 59 (EC number: 157)

A new lead borax glasses (PbO-Na2B4O7.10H2O) doped with Yb(III) is presented for the study of emission, absorption and other optical properties of borax glasses. Samples with different concentrations of Yb(III) were produced had their emission cross-sections, fluorescence lifetimes and minimum pump intensities determined. Changes in the position and the intensity parameters of the transitions are closely related to structural changes in the glass network. Specimen have high refractive index of 2.1 and a density of 4.2 g/cm^3 for a doping level of 0.5

P60 Extracting entropy from quantum random walks

James Grieve, Alexander Ling

Tuesday 05.15 PM, Foyer/Hallway, Panel 60 (EC number: 159)

The random choice of output channel of a single photon incident upon a 50:50 beamsplitter can be exploited for the generation of random numbers, yielding one bit of entropy per photon. This system may be thought of as the simplest case of the quantum random walk: a process in which a quantum particle explores an arbitrarily large mode space before detection at some output distance. More complex random walks can be realised by adding several generations of beamsplitters, forming a beamsplitter tree with each output monitored by a suitable detector. While such a system does not scale well in bulk optics, the use of an embedded, waveguide-based platform could allow much larger trees to be demonstrated, and even built into a practical device. In this way, it should be possible to increase the number of random bits available per photon, with a corresponding increase to the maximum theoretical random bit rate.

P61 SU(3) Quantum Interferometry with Single-Photon Input Pulses

Si-Hui Tan, Yvonne Y. Gao, Hubert de Guise, Barry C. Sanders

Tuesday 05.15 PM, Foyer/Hallway, Panel 61 (EC number: 162)

We develop a framework for solving the action of a three-channel passive optical interferometer on single-photon pulse inputs to each channel using SU(3) group-theoretic methods, which can be readily generalized to higher-order photon-coincidence experiments. We show that features of the coincidence plots vs relative time delays of photons yield information about permanents, immanants,and determinants of the interferometer SU(3) matrix.

6 Technical Sessions

6.1 T1 Graphene Characterization

This session on "Graphene Characterization" will be held on Monday, March 04, from 03.30 PM to 05.00 PM. The venue for this session is MAS-EX2. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T1.1 Graphene Nanoribbon Fabrication and Characterization (INVITED)

Andrew T.S. Wee, Han Huang, Dacheng Wei, Wei Chen

Monday, March 04, 03.30 PM, MAS-EX2

For future electronics applications of graphene, a key challenge is to make it semiconducting. One approach to opening a band gap in graphene is to reduce the dimensionality of graphene from 2D to 1D graphene nanoribbons. We present bottom up and top down methods of fabricating graphene nanoribbons and investigate their electronic properties. First, we present the surface-assisted bottom-up fabrication of atomically precise armchair graphene nanoribbons (AGNRs) with predefined widths, namely 7-, 14- and 21-AGNRs, on Ag(111) as well as their spatially resolved width-dependent electronic structures [Huang et al, Sci. Rep. 2 (2012) 983]. The local density of states (LDOS) observed by scanning tunneling spectroscopy (STS) reveal the atomic scale electronic structure and the influence of the substrate. Second, we demonstrate an intramolecular junction produced by the controllable unzipping of single-walled carbon nanotubes, which combines a graphene nanoribbon and single-walled carbon nanotube in a 1D nanostructure [Wei et al., Nat. Comm. 4 (2013) 1374]. This junction shows a strong gate-dependent rectifying behaviour. We demonstrate the use of the junction in prototype directionally dependent field-effect transistors, logic gates and high performance photodetectors, indicating its potential in future graphene-based electronics and optoelectronics.

T1.2 Local electron field emission study of two-dimensional carbon (INVITED)

Ying Wang, Yihong Wu

Monday, March 04, 04.00 PM, MAS-EX2

Two-dimensional (2D) nano-carbon has been expected to have an electron field emission (EFE) characteristic distinctive from other materials, which generally show a linear Fowler-Nordheim (F-N) relationship between emission-current and applied filed. Nevertheless, despite intensive efforts in the recent years, a commonly accepted EFE behavior of 2D carbon has yet to be established. More specifically, the reported shape of the F-N curve scatters from linear to sub-linear region with either downward or upward bending at high bias. This inconsistency may result from the fluctuation of quality of the 2D carbon used or uncertainty in experimental conditions such as cathode-anode distances and displacements of nano-carbon during the measurement. In order to establish the true EFE characteristic of 2D carbon, we performed systematic studies of localized field emission from three types of single flake of 2D carbon, namely, carbon nano-wall on Cu, CVD graphene on Cu and carbon nano-wall on SiO2, using a tungsten tip in an UHV environment. The turn-on field for all three types of samples decreases from >11 kV/µm to <1 kV/µm with increasing sample-tip distance in the range of 1.38 nm - 60.72 nm. This is attributed to the increase of geometric enhancement factor with increasing the distance. The F-N curve for the first two types of samples was linear with a slight upward bending feature at small sample-tip distances and became linear at higher distances. However, the same trend is not obvious in carbon nano-walls on SiO2. The reason for causing the different F-N curves will be discussed.

T1.3 Terahertz conductivity of twisted bilayer graphene (INVITED)

Elbert Chia, Xing Quan Zhou, Jingzhi Shang, Jianing Leaw, Zhiqiang Luo, Liyan Luo, Chan La-O-Vorakiat, Liang Cheng, Siew Ann Cheong, Haibin Su, Jian-Xin Zhu, Yanpeng Liu, Kian Ping Loh, Antonio Helio Castro Neto, Ting Yu

Monday, March 04, 04.30 PM, MAS-EX2

Using terahertz time-domain spectroscopy, the real part of optical conductivity $[\sigma_1(\omega)]$ of twisted bilayer graphene was obtained at different temperatures (10 – 300 K) in the frequency range 0.3–3 THz. On top of a Drude-like response, we see a strong peak in $\sigma_1(\omega)$ at 2.7 THz. We analyze the overall Drude-like response using a disorder-dependent (unitary scattering) model, then attribute the peak at 2.7 THz to an enhanced density of states at that energy, that is caused by the presence of a van Hove singularity arising from a commensurate twisting of the two graphene layers. Accepted for publication by Physical Review Letters.

6.2 T2 Water, bubbles and proton beams

This session on "Water, bubbles and proton beams" will be held on Monday, March 04, from 03.30 PM to 05.00 PM. The venue for this session is MAS-SEM. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T2.1 A synchronized view of bubble impact with the glass surface (INVITED)

Rogerio Manica, Maurice Hendrix, Raghvendra Gupta, Evert Klaseboer, Derek Chan, Claus-Dieter Ohl

Monday, March 04, 03.30 PM, MAS-SEM

We observed bubble rise and bounce from a glass surface as well as thin film drainage using two synchronized high-speed cameras. This experiment allowed us to better understand the coupling between phenomena happening at the millimeter and the micrometer scales when the bubble hitting the glass. Even though the global Reynolds number of the system is large, the film Reynolds number becomes progressively small as the bubble interacts with the surface. Therefore we apply lubrication theory to model the experiments and the results agree quantitatively without any fitting parameter. The boundary condition at the air-water interface during rise agrees with the immobile surface, but during drainage it can be either mobile or immobile depending on the amount of surface-active materials presented in the water.

T2.2 Hidden force in water (INVITED)

Cq Sun, Xi Zhang

Monday, March 04, 04.00 PM, MAS-SEM

As the key to food chemistry, the H-bond and water has poorly understood. Here I show that the ultra-short-range interactions of inter-electron-pair Coulomb repulsion, intermolecular wan der Waals force, and intramolecular exchange interaction serve as the key to the unusually asymmetric relaxation in length and stiffness of the master-slave-segmented "O2-:H+/p-O2-" hydrogen (H)-bond, and hence anomalies of water ice in response to cooling [1], clustering [2], and squeezing [3]. Consistency between experimental observations and numerical calculations, verified our expectations: i) Compression shortens-and-stiffens the softer "O2-:H+/p" non-bond, and meanwhile, lengthens-and-softens the stiffer "H+/p-O2-" real-bond, through Coulomb repulsion, leading to the O2-:H+/p–O2- proton symmetrization towards ice-X phase, low compressibility, phase-transition temperature (TC) depression, band gap expansion, softer phonon ($<300\,\mathrm{cm}^{-1}$) stiffening and stiffer phonon ($>3000\,\mathrm{cm}^{-1}$) softening; ii) Molecular-undercoordination [4] of (H2O)N clusters functions oppositely to compression, resulting in molecular volume expansion, melting point (viscosity) elevation, binding energy entrapment, bonding charge densification and polarization, stiffer phonon stiffening and softer phonon softening of water surface, clusters, and ultrathin films that manifest glue- and ice-like and hydrophobic nature at the ambient; iii) Because of the segmental-thermodynamic-disparity of the H-bond, cooling contraction happens alternatively to the non- and the real-bond in the 373 – 50 K temperature range, subjecting to the relative specific heat of the segments in a given temperature range. In the liquid and the solid phase, the non-bond serves as the "master" (of lower specific heat) that contracts largely and meanwhile forces the stiffer real-bond as "slave" into Coulomb-repulsion-driven slight elongation, causing the O2-:H+/p–O2- contraction and the seemingly normal cooling densification of water and ice; at the transition phase, the master-slave swap roles, turning the O2-:H+/p–O2- into freezing elongation and volume expansion. We also clarified the following: i) The extraordinarily-high heat capacity of liquid water arises from the stronger real-bond (3.97 eV) instead of the non-bond lone pair; ii) The thermal stiffening of the stiffer phonons in liquid water indicates the persistence of the fluctuating H-bond; iii) The O—O distance is longer in ice than it is in water, and hence, ice floats; iv) Both the TC and the O 1s energy are proportional to the real-bond energy, and they change accordingly under stimulation. Understanding may extend to other areas such as cell- and protein mechanics. Further exploitation of other anomalies would be even more challenging, fascinating, promising, and rewarding.

1. Sun, C.Q., et al., Hidden force resolving water-ice densities. communicated, 2012. 2. Sun, C.Q., et al., Hidden force stiffening undercoordinated water molecules. communicated, 2012. 3. Sun, C.Q., X. Zhang, and W.T. Zheng, Hidden force opposing ice compression. Chem Sci, 2012. 3: 1455-1460. 4. Sun, C.Q., Size dependence of nanostructures: Impact of bond order deficiency. Progress in Solid State Chemistry, 2007. 35(1): 1-159.

T2.3 Next Generation Focused MeV Proton Beams in Nanotechnology (INVITED)

Jeroen A van Kan

Monday, March 04, 04.30 PM, MAS-SEM

To overcome the diffraction constraints of traditional optical lithography, the next generation lithographies (NGLs) will utilize any one or more of EUV (extreme ultraviolet), X-ray, electron or ion beam technologies for producing deep sub-100 nm features. Electron beam lithography (EBL), a candidate for direct-write technology at nanodimensions has extensively been investigated for the last four decades. However, proximity effects from high energetic secondary electrons initiating from adjacent and nearby features gives rise to structure broadening. Perhaps the most under-developed and under-rated is the utilisation of ions for lithographic purposes. Ion beam techniques like PBW, Focused Ion Beam (FIB) and Ion Projection Lithography (IPL) have the flexibility and potential to become leading contenders as next generation lithographies. Recently PBW has been incorporated in the Japanese government's road map for the nanotechnology business creation initiative which was updated in 2010. A second generation proton beam writing line has been installed at the Centre for Ion Beam Applications at the National University of Singapore. Here we introduce this new system for proton beam witting (PBW), this system is able to focus MeV proton beams down to $13 \times 29\,\mathrm{nm}^2$ [1]. PBW is a promising technique for proximity free structuring of high aspect ratio, high density 3D nano structures. The latest achievements in PBW of high aspect ratio metallic nanowires, nanofluidic lab on chip experiments for DNA dynamics studies using proton beam written templates as well as the first lithographic results with the 2nd generation proton beam writing line will be presented. PBW and Ni electroplating will be introduced as a platform technique for the fabrication of 3D Nano Imprint Lithography (NIL) molds. Finally an outlook will be given how to achieve sub 10 nm focusing for fast 3D nano lithography using MeV light ion beams.

The authors acknowledge the support from A-Star (R-144-000-261-305), MOE Singapore (R-144-000-265-112) and the US Air Force.

1 J.A. van Kan, P. Malar, and A. B. de Vera, Rev. Sci. Instrum., 83, (2012) 02B902-1 02B902-3.

6.3 T3 Photonics I

This session on "Photonics I" will be held on Monday, March 04, from 03.30 PM to 05.00 PM. The venue for this session is MAS-EX1. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T3.1 Nano-Fano resonances and topological optics (INVITED)

Boris Lukiyanchuk

Monday, March 04, 03.30 PM, MAS-EX1

Fano resonances and optical vortices are two well-known interference phenomena associated with the scattering of light. Usually, these two phenomena are considered to be completely independent, and in many cases Fano resonances are observed without vortices and the vortices with the singular phase structure are not accompanied by Fano resonances. However, this situation changes dramatically when we move to the nanoscale. In this chapter we demonstrate that Fano resonances observed for the light scattering by nanoparticles are accompanied by the singular phase effects (usually associated with the topological optics) and the generation of optical vortices with the characteristic core size well beyond the diffraction limit. Such effects are found for weakly dissipative metallic nanoparticles within the Mie theory. Important peculiarities of the far-field scattering and near-field Poynting flux are manifested in the so-called "nano-Fano resonances" introduced and discussed here. Control of the orbital momentum of photons with the help of nanostructures is a novel research direction which is very attractive for many applications in quantum optics and information technologies, and it opens an unprecedented way for manipulating optical vortices at the nanoscale.

T3.2 Coherent forward multiple scattering of waves in the Anderson localization regime. (INVITED)

Christian Miniatura

Monday, March 04, 04.00 PM, MAS-EX1

The concepts of random walks and Brownian motion were developed at the beginning of the 20th century after groundbreaking founding works on the kinetic theory of gases. They could successfully explain numerous statistical phenomena ranging from the transport of classical particles (Boltzmann's kinetic equation, Drude's electronic transport) in physics to the migration of mosquitoes in a forest in biology.

The propagation of waves in complex media did not escape this description, as exemplified by Lord Rayleigh's pioneering works in acoustics (Rayleigh's law) or those of Chandrasekhar and Milne in astrophysics (radiative transfer theory). Within this framework, a wave packet propagating in a disordered medium is multiply scattered in all directions by the heterogeneities of the medium. The scattered partial waves acquire random phases and, on average, the interference between these partial waves are smoothed out although the initial wave packet can be perfectly coherent. In turn, the memory of the initial propagation direction is rapidly lost and the wave packet spreads diffusively in space, just like the swarm of mosquitoes in a forest.

This powerful and fruitful description of propagation in a random medium was nevertheless questioned in the late 50s when Anderson showed that disorder could bring wave transport to a halt, an interference phenomenon known as strong localization. In fact, we now know that phase coherence is not completely scrambled even far from the localization regime as exemplified by weak localization corrections to the diffusion constant, universal conductance fluctuations and by the celebrated coherent backscattering (CBS) phenomenon. The latter manifests itself as an interference peak in the momentum distribution of the wave packet centered in the direction opposite to the initial propagation direction. Even if the CBS effect has been thoroughly studied, both experimentally and theoretically, its fate in the strong localization regime was largely unknown.

This is what we have studied in a recent paper [PRL 109, 190601, (2012)]. We have performed a numerical study of the time evolution of the momentum distribution of a quasi-monochromatic matter wave packet evolving in a speckle potential. Much to our surprise, we have found that a new multiple scattering interference effect is triggered by strong localization in the forward direction. It manifests itself as a coherent forward peak (CFS) which starts to grow when strong localization sets in and it raises on the time scale of the Heisenberg time of the system. In the end, both CBS and CFS appear as twin peaks. I will present and explain these results in as much simple terms as possible.

T3.3 Small Photon-Entangling Quantum System (SPEQS) for field-deployable communication platforms

Alexander Ling, Zhongkan Tang

Monday, March 04, 04.30 PM, MAS-EX1

Polarization-entangled photon pairs are widely used in Quantum Communication. We present a compact and efficient system for generating and detecting photon pairs (300 gm, approx. 1W). This package achieves high entanglement fidelity and enables a quantum light source to be deployed on mobile field communication systems where resources are scarce.

T3.4 Entangled Source Subsystems testing in near SPACE

Rakhitha Chandrasekara, Alexander Ling, Yue Chuan Tan, Cliff Cheng

Monday, March 04, 04.45 PM, MAS-EX1

Hosting quantum experiments in satellite technology will open up a new range of experiments in fundamental aspects of quantum physics and extend quantum communication applications in to a global level. The success of such quantum experiment depends on robustness of the subsystems against the outer space environment. Our work aims at demonstrating a polarization entangled photon pair source in Low Earth Orbit hosted by a small satellite called CubeSat. In this talk I will talk about how these crucial subsystems have been tested in a near space environment.

6.4 T4 Advanced characterization of Nanomaterials

This session on "Advanced characterization of Nanomaterials" will be held on Tuesday, March 05, from 11.00 AM to 12.30 PM. The venue for this session is MAS-EX2. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T4.1 Advanced Surface Analysis Protocols for Nanoscale Characterisation at ICL (INVITED)

David McPhail

Tuesday, March 05, 11.00 AM, MAS-EX2

In this talk I will describe some improvements that have been made in secondary ion mass spectrometry (SIMS) over the last twenty years and I will show how the combination of stable isotope exchange protocols and SIMS can yield the mechanisms and kinetics of a variety of processes such as diffusion, segregation and oxidation in a wide range of materials. Examples will be drawn from a variety of fields including energy (solid oxide fuel cells and solar cells), transport (aerospace materials), nanotechnology (semiconductors), and biomaterials (tissue scaffolds and soft tissue).

In our laboratory we have recently commissioned a combined Time of Flight SIMS – Low Energy Ion Scattering apparatus (TOF-SIMS LEIS) and this exciting new development involving the combination of two analytical techniques on one UHV platform. This represents another strategy that is becoming increasingly common in the analytical community. Another approach is to make full use of all the analytical signals available in the analysis chamber and so we have placed a SIMS analyser on our FEI FIB-200 focused ion beam system for 5nm resolution FIB-SIMS studies. We are also incorporating a low energy oxygen ion beam on the FIB-SIMS for secondary ion yield enhancements.

I will present results from these instruments and will try to stimulate discussion on the key challenges the materials analysis community will need to meet in the months and years to come.

T4.2 Surface and interface studies of nanostructured materials by X-ray photoemission spectroscopy (XPS) (INVITED)

Jisheng Pan

Tuesday, March 05, 11.30 AM, MAS-EX2

It is well known that XPS is a very powerful tool for understanding the nature of solid surfaces. Although advances in existing and newly developing tool with high spatial resolution receive a good deal of press if they improve the analysis quality of individual nanosized features of materials. XPS is an important, established and frequently essential tool for understanding several important aspects of nanostructured natural that cannot easily be obtained using other techniques. However, the question of how the nanosized sample features impact XPS data have been heavily debated in the scientific community, which limits its application in characterization of nanostructured materials. For example, there is consistent observation of cluster-size-dependent binding energy

(BE) shifts. But there is substantial disagreement over the assignment of these shifts to initial or final state effects. As a result, the measured PES data can't directly match to the electronic property of clusters because among the initial and final state effects, only the initial state effect involves information of changes in the electronic structure before photoemission, and hence is directly related to nanostructured material properties and is relevant for understanding other chemical process and reactions. In the first part of the presentation, I will talk to you some general information about XPS. The issues raised specifically for XPS analysis of nanostructured materials and some limitations will be discussed in second part. Finally, I will provide you some examples of application of XPS to study nanostructured materials (nanolayers and nanoparticles).

T4.3 Ultra Low Energy SIMS (uleSIMS) Depth Profiling for NanoScale Material Analysis (INVITED)

Richard J.H. Morris

Tuesday, March 05, 12.00 PM, MAS-EX2

Ultra low energy secondary ion mass spectrometry (uleSIMS) is a technique which can remove planes of atoms from a solid surface and provide a 3-dimensional chemical profile with sensitivities in the ppm-ppb range and depth resolution on the nanometre scale. To achieve nm-sub nm depth resolution, an atomically smooth starting surface is mandatory (unless the ion bombardment is planarizing) and the probesample interaction must be optimized. However, even when the material does not allow for an atomically smooth surface, uleSIMS can enable informative structural and chemical information to be obtained. In this talk a number of applications where uleSIMS has been used for the analysis of different materials will be presented. Examples include nanometre scale pure germanium quantum wells where understanding and controlling the ion beam interaction process (ionisation and erosion rate) is required if quantifiable depth profiles are to be obtained.

Possibly the ultimate challenge for uleSIMS is self assembled monolayers or other similar superficial features in the top 5 nm of samples. Depth profiles taken at the limits of low beam energy (90 eV O_2^+ or 45 eV per O) from superficial polymeric copper phthalocyanines (poly(CuPc)) ($C_{32}H_{12}N_8Cu$)n and Co_2TaPor (5,10,15,20-tetrakis-(2-aminophenyl) porphyrin-cobalt(II)) deposited on gold films have been obtained and show that these types of layers are resolvable. Nanoparticles are currently attracting significant interest and although samples of this type do not have the planar topography usually associated with nm-sub-nm depth resolution, we have recently obtained depth profiles from superficial silica-Au and silica-Ag core shell nanoparticles. Once again the findings show strong evidence to support that the nanoparticles are resolvable as well as potentially offering information about their structure.

6.5 T5 Quantum Systems

This session on "Quantum Systems" will be held on Tuesday, March 05, from 11.00 AM to 12.30 PM. The venue for this session is MAS-SEM. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T5.1 How system-environment coupling affects the equilibrium statistics and the dynamics of open quantum systems (INVITED)

Jiangbin Gong

Tuesday, March 05, 11.00 AM, MAS-SEM

Understanding fundamental aspects of open quantum systems is an important step towards quantum control and quantum information processing. This talk is concerned with how a finite coupling strength of system-environment coupling (which is often assumed to be zero) might lead to interesting physics. For equilibrium statistics, a spin-boson model is used to illustrate the emergence of analytically predictable non-Gibbs statistics of the system after tracing out the environment. We then discuss how pointer states of decoherence, namely, the representation in which decoherence quickly turns a superposition state to an incoherent mixture of basis states, may vary with system-environment coupling strength. It is emphasized that pointer states themselves can be rich superposition states for intermediate system-environment coupling strength. Finally, which is also the main part of this talk, I shall discuss how initial system-bath correlations due to a nonzero system-bath coupling may affect the dynamics in a dramatic way and advocate a new type of quantum master equation to study system-bath correlation effects.

References:

C.K. Lee, J.S. Cao, and J.B. Gong, "Non-Canonical Statistics of an Open Quantum System: Theory and Exact Monte-Carlo Simulations", Phys. Rev. E. Vol. 86, 021109 (2012).

W. G. Wang, L.W. He, and J.B. Gong, "Preferred States of Decoherence under Intermediate System-Environment Coupling", Phys. Rev. Lett. 108, 070403 (2012).

A.Z. Chaudhry and J.B. Gong, Amplification and Suppression of System-Bath Correlation Effects in an Open Many-Body System, Phys. Rev. A (in press),.

T5.2 Usual suspects: classical to quantum transition (INVITED)

Dagomir Kaszlikowski

Tuesday, March 05, 11.30 AM, MAS-SEM

Quantum mechanics marks a radical departure from the classical understanding of Nature, fostering an inherent randomness which forbids a deterministic description; yet the most fundamental departure arises from something different. As shown by Bell and Kochen-Specker, quantum mechanics portrays a picture of the world in which reality loses its objectivity and is in fact created by observation. Quantum mechanics predicts phenomena which cannot be explained by any theory with objective realism, although our everyday experience supports the hypothesis that macroscopic objects, despite being made of quantum particles, exist independently of the act of observation; in this paper we identify this behavior as classical. Here we show that this seemingly obvious classical behavior of the macroscopic world cannot be experimentally tested and belongs to the realm of ontology similar to the dispute on the interpretations of quantum mechanics. For small systems such as a single photon or a pair, it has been experimentally proven that a classical description cannot be sustained. Recently, there have also been experiments that claim to have demonstrated quantum behavior of relatively large objects such as interference of fullerenes, the violation of Leggett-Garg inequality in Josephson junction, and interference between two condensed clouds of atoms, which suggest that there is no limit to the size of the system on which the quantum-versus-classical question can be tested. These behaviors, however, are not sufficient to refute classical description in the sense of objective reality. Our findings show that once we reach the regime where an Avogadro number of particles is present, the quantum-versus-classical question cannot be answered experimentally.

T5.3 Quantum Discord Bounds the Amount of Distributed Entanglement

Tan Kok Chuan, Jean Maillard, Kavan Modi, Tomasz Paterek, Mauro Paternostro, Marco Piani

Tuesday, March 05, 12.00 PM, MAS-SEM

The ability to distribute quantum entanglement is a prerequisite for many fundamental tests of quantum theory and numerous quantum information protocols. Two distant parties can increase the amount of entanglement between them by means of quantum communication encoded in a carrier that is sent from one party to the other. Intriguingly, entanglement can be increased even when the exchanged carrier is not entangled with the parties. However, in light of the defining property of entanglement stating that it cannot increase under classical communication, the carrier must be quantum. Here we show that, in general, the increase of relative entropy of entanglement between two remote parties is bounded by the amount of nonclassical correlations of the carrier with the parties as quantified by the relative entropy of discord. We study implications of this bound, provide new examples of entanglement distribution via unentangled states, and put further limits on this phenomenon.

T5.4 High fidelity gates in quantum dot spin qubits

Teck Seng Koh, John Gamble, Mark Friesen, Mark Eriksson, Susan Coppersmith

Tuesday, March 05, 12.15 PM, MAS-SEM

A variety of logical qubits and quantum gates have been proposed for quantum computer architectures using electrostatically-defined quantum dots. Despite their differences, we show that many combinations of qubits and gates can be evaluated on an equal footing by optimizing the gating protocols for maximum fidelity. Here, we evaluate single-qubit gate operations for two types of logical-qubits: singlet-triplet qubits and quantum dot hybrid [1] qubits. In both cases, transitions between the qubit states are controlled by the exchange interaction between the dots, which in turn depends on the tunnel coupling and the detuning. We compute the fidelities for three exchange gate protocols: a dc pulsed gate [2], an ac resonant gate, and an adiabatic protocol called stimulated Raman adiabatic passage (STIRAP). Remarkably, our results [3] show that the optimized fidelities for all three gates and protocols follow a simple scaling law; the maximum fidelity depends only on the range of parameters that can be achieved experimentally. We discuss the limitations of exchange gating fidelity for each type of qubit.

Ref: [1] Zhan Shi et al., Phys. Rev. Lett. 108, 140503 (2012). [2] Teck Seng Koh et al., Phys. Rev. Lett. 109, 250503 (2012). [3] Teck Seng Koh, PhD Dissertation: Theoretical issues in silicon quantum dot qubits, University of Wisconsin-Madison (2012). (Paper in preparation for peer review).

6.6 T6 Graphene Photonics

This session on "Graphene Photonics" will be held on Tuesday, March 05, from 11.00 AM to 12.30 PM. The venue for this session is MAS-EX1. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T6.1 Graphene and InSb for mid-far-IR plasmonics and photonics (INVITED)

Jing Hua Teng

Tuesday, March 05, 11.00 AM, MAS-EX1

Mid-far-infrared is the fingerprint spectral range for molecules and has far-reaching applications from molecular spectroscopy to security screening and bio-imaging. The strong field confinement offered by surface plasmons is attractive for many new device applications. In this talk, I will introduce the broadband plasmonic response from InSb touching disk structures and the direct optical tuning of the terahertz plasmonic response in InSb sub-wavelength gratings. I will also introduce the coupling of surface plasmon polaritons in graphene sheet arrays with interesting phenomena and potential applications in photonics.

T6.2 One-Photon Absorption Saturation vs Two-Photon Absorption in Graphene (INVITED)

Wei Ji

Tuesday, March 05, 11.30 AM, MAS-EX1

We report our investigation into both one-photon absorption saturation and two-photon absorption in epitaxial graphene and CVD-grown graphene with femtosecond laser pulses. Femtosecond time-resolved transient absorption measurements demonstrate that the two processes in bilayer epitaxial graphene are in competition with each other and two-photon absorption overplays its one-photon counterpart at the excitation intensities exceeding $10\,\mathrm{GW/cm^2}$. But two-photon absorption is negligible in single-layer epitaxial graphene. The experimental measurements are in agreement with a theory that we develop for the first time. Our theory reveals that the hopping energy between the two graphene layers of AB-stacking plays an essential role in the increase in two-photon absorption, as it alters graphene's electronic band structure from the two bands to four bands, thereby increasing the density of states. Furthermore, we also present our latest experimental findings on multi-layer CVD-grown graphene.

T6.3 Complete light absorption in graphene-metamaterial corrugated structures

Aires Ferreira, N. M. R. Peres

Tuesday, March 05, 12.00 PM, MAS-EX1

The scope of surface plasmon-related phenomena has been increasing swiftly in the past decade, spanning metallic nano-wires, band-gap nano-structures, metallic nanoparticles, and other nano-engineered materials. With the recent advent of graphene and related two-dimensional crystals, a new playground for plasmonics has emerged. The characteristic electronic properties of graphene originate the most distinct electromagnetic confinement behaviour, such as plasmonic propagation lengths exceeding those of conventional metal-dielectric interfaces, and guided transverse-electric modes with tunable frequency.

The observation of prominent plasmonic absorption peaks in graphene micro-arrays has triggered a new research line, in which plasmonic excitations are explored to overcome the major obstacle in graphene-based opto-electronics: the small light absorption in one-atom thick graphene systems.

In this work, we propose a hybrid graphene-metamaterial system, where a single and continuous graphene sheet is seen to absorb all the light impinging on it. The frequency range for enhanced absorption is determined by the properties of the metamaterial alone, allowing subsequent control over the absorbed plasmonic waves to be performed in the graphene sheet (e.g., via chemical doping).

T6.4 Optical study of 2D nano materials

Zexiang Shen, Da Zhan, Jiaxu Yan, Linfeng Sun

Tuesday, March 05, 12.15 PM, MAS-EX1

2D nanomaterials such as graphene and MoS2 have been the subject of intense study due to its many unique properties. Monolayer graphene exhibits many exciting properties, such as anomalously quantized Hall effects, massless Dirac-Fermions like charge carrier, existence of a minimum conductivity, while monolayer MoS2 has a direct band gap and is an important material for spintronics. Stacking of the monolayer 2D materials in different fashion provides a very useful way of further tailoring the optical and electronic properties. In this presentation, we show that optical characterization is an extrememly useful and fast method for the study of such 2D materials. Fundamental properties such as oping, stacking order and thickness, optical properties, electronic energy band gap and spin-orbital coupling can be inferred from such study.

6.7 T7 Nanotechnology for Energy Applications

This session on "Nanotechnology for Energy Applications" will be held on Tuesday, March 05, from 01.30 PM to 03.00 PM. The venue for this session is MAS-EX2. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T7.1 From Polymer Nanocomposites to Organic Electronics (INVITED)

Nigel Clarke

Tuesday, March 05, 01.30 PM, MAS-EX2

Since nanoparticles are increasingly being added to polymers to impart mechanical and functional properties, we are exploring how nanoparticles impact polymer dynamics and ultimately how these dynamics impact the processing of polymer nanocomposites. Well-dispersed nanoparticles may aggregate if the diffusion rate is too rapid, whereas interfaces between different layers in multi-layer coatings, may not develop sufficiently to prevent delamination if the diffusion rate is too low. Motivated by experiments that show anomalous behaviour of polymer dynamics with carbon nanotube concentration, we have simulated how structure and dynamics of chains are affected by the nanotubes. We are are now turning our attention to the effect of spherical nanoparticles that are comparable in size to the polymer chains and have been observed to have a greater than anticipated impact on dynamics.

Organic electronics, in particular polymer based photovoltaics, are effectively self-assembled polymer nanocomposites with structures that evolve at the scale of tens of nanometres. We are developing models of both the structure formation during processing and how the structure impacts upon device performance. By coupling the two processes we aim to develop guidelines for optimum process conditions.

T7.2 Structural and Energy storage performance of Novel Metal Nitrides and Oxides (INVITED)

M V Reddy

Tuesday, March 05, 02.00 PM, MAS-EX2

Commercial lithium ion batteries (LIBs) use layer-type compounds, lithium cobalt oxide (LiCoO2) as the cathode (positive electrode) and graphite (C) as the anode (negative electrode) material, and a non-aqueous Li- ion conducting electrolyte. The liquid electrolyte in the form of a solution or immobilized in a gel-polymer. LIBs with an operating voltage of 3.6 V are extensively used in the present-day portable electronic devices like, cell phones and other low power operated devices. For high-power applications like, electric/hybrid electric vehicles and back-up power supplies and, the LIBs need to satisfy several criteria, namely, cost-reduction, improvement in the energy density, safety-in-operation at high current charge/discharge rates and improvement in the low-temperature-operation. To satisfy the above criteria, researches are being carried out worldwide to find alternative novel nanostructured electrode materials. In my my talk, I will discuss our group studies on novel cathode and novel materials for Li-ion batteries. Specifically, I will focus novel metal nitrides, CoO (thin film and bulk), CrN, VN and Ni-doped CoN and other oxides like CoO, SnO, MCo2O4 (M= Co, Zn, Mn, Mg) and (M1/2Sb1/2Sn)O4 M= V,Fe,In and Li(MMn11/6)O4 (M=Mn1/6, Co1/6, (Co1/12Cr1/12)). It includes preparation of simple and complex oxides by molten salt method, carbothermal reduction method, polymer precursor method and ammonolysis methods. Materials were well characterized by Rietveld refinement X-ray diffraction, Neutron diffraction, X-ray absorption spectroscopy, XPS, SEM, TEM, density and BET surface area methods. Electro analytical studies like cyclic voltammetry, galvanostatic cycling and electrochemical impedance spectroscopy techniques.

References: 1. M.V. Reddy*, G.V. Subba Rao, B.V. R. Chowdari* "Metal oxides and oxysalts as anode materials for lithium ion batteries" Chemical Reviews (2013) (Critical review article, In press, cr-2012-001884, pages 1-98, 1250 refs are covered) (I.F.: 40.197, ACS). 2. B. Das, M. V. Reddy, B. V. R. Chowdari "X-ray absorption spectroscopy and energy storage studies on Ni- doped Cobalt Nitride, (Ni0.33Co0.67)N prepared by a simple synthesis route NanoScale (2013) (DOI:10.1039/C2NR33675H). 3. T.C. Christie, M.V. Reddy, C.H. Sow, Chowdari, B. V. R., "Facile synthesis and Li-storage performance of SnO nanoparticles and microcrystals". RSC Advances 3 (9) (2013) 3118- 3123. 4. M. V. Reddy*, A. Sakunthala, S. Selvasekarapandian, B.V.R. Chowdari, Preparation, comparative energy storage and impedance studies of low cost, environmental friendly cathode material, Li(MMn11/6)O4 (M=Mn1/6, Co1/6, (Co1/12Cr1/12)) Journal of Physical Chemistry C (2013) (revisions submitted). 5. M.V. Reddy*, Zhang Beichen, K.P. Loh, B.V.R. Chowdari, "Facile synthesis of Co3O4 by molten salt method and its storage performances" CrystalEngComm (2013) (accepted).

T7.3 Nanostructures for Energy Storage and Carbon Capture (INVITED)

Zheng-Xiao Guo

Tuesday, March 05, 02.30 PM, MAS-EX2

Energy Storage and Carbon Capture are two key measures to reduce CO_2 emissions and enable energy security. Storing and delivering energy carriers pose great scientific and practical challenges. New emphases on power smoothing in electricity grid and on energy supply from off-shore wind open up new opportunities for energy storage systems. Clear understanding of carrier interactions with host structures is essential to design efficient energy storage systems, particularly for H2 and Li+ ion for clean transport applications. CO_2 activation has been a challenging issue in carbon capture. Fundamental simulations were employed to study the specific mechanisms of binding, activation and sorption of gaseous molecules in representative host structures for the design of efficient hydrogen/Li+ storage systems, as well as sorbents for CO_2. Both experimental and theoretical approaches were applied to selected materials of high promise, including doped/defective carbon, doped hydrides, metal/amine complexes and stable electrode materials. Simulations have shown an exceptional capability of CO_2 activation by metal doped carbon structures. Important avenues for further study are discussed to speed up the development of clean energy technologies.

Sample References:

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6.8 T8 Quantum Information

This session on "Quantum Information" will be held on Tuesday, March 05, from 01.30 PM to 03.00 PM. The venue for this session is MAS-SEM. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T8.1 Maximum-likelihood regions and smallest credible regions (INVITED)

Berthold-Georg Englert, Hui Khoon Ng, Arun, Jiangwei Shang, Xikun Li

Tuesday, March 05, 01.30 PM, MAS-SEM

Rather than point estimators, states of a quantum system that represent one's best guess for the given data, we consider optimal regions of estimators. As the natural counterpart of the popular maximum-likelihood point estimator, we introduce the maximum-likelihood region—the region of largest likelihood among all regions of the same size. Here, the size of a region is its prior probability. Another concept is the smallest credible region—the smallest region with pre-chosen posterior probability. For both optimization problems, the optimal region has constant likelihood on its boundary. We discuss criteria for assigning prior probabilities to regions, and illustrate the concepts and methods with several examples.

T8.2 Device-Independent Bounds for Hardy's Experiment

Rafael Rabelo, Yun Zhi Law, Valerio Scarani

Tuesday, March 05, 02.00 PM, MAS-SEM

In this Letter, we compute an analogue of Tsirelson's bound for Hardy's test of nonlocality, that is, the maximum violation of locality constraints allowed by the quantum formalism, irrespective of the dimension of the system. The value is found to be the same as the one achievable already with two-qubit systems, and we show that only a very specific class of states can lead to such maximal value, thus highlighting Hardy's test as a device-independent self-test protocol for such states. By considering realistic constraints in Hardy's test, we also compute device-independent upper bounds on this violation and show that these bounds are saturated by two-qubit systems, thus showing that there is no advantage in using higher-dimensional systems in experimental implementations of such a test.

T8.3 Self Testing of Quantum Systems

Tzyh Haur Yang, Miguel Navascues, Tamas Vertesi, Valerio Scarani

Tuesday, March 05, 02.15 PM, MAS-SEM

Self testing is a device independent method to deduce the nature of the states and measurement devices within a quantum system. Unlike tomography, self testing do not require the need to know the dimension of the quantum system, which in principle can be arbitrarily large if it was interfered by an adversary. This is important in the scenario of quantum cryptography for instance. Here, we show that indeed one can self test quantum systems by utilizing the concept of nonlocality. More specifically, we can self test any bipartite pure qubit states. In addition, the method is robust to small but unavoidable experimental errors.

T8.4 Towards a loophole free Bell test

Siddarth Koduru Joshi, Chen Ming Chia, Qixiang Leong, Antia Lamas-Linares, Sae Woo Nam, Christian Kurtsiefer, Adriana Lita

Tuesday, March 05, 02.30 PM, MAS-SEM

We present our efforts towards performing a loophole free Bell test. Using Transition Edge Sensors (TES) with near unit detection efficiency (>95%) [1] we observe a 74% pairs to singles ratio of polarization entangled photon pairs obtained from downconversion in a PPKTP crystal. This efficiency is above the threshold (66.7%) for a loophole-free Bell test using a particular non-maximally entangled state [2]. In addition to a loophole free Bell test, our high efficiencies allow us to implement other protocols including device independent fast random number generation. Our experimental setup consists of 3 parts: the source of entangled photon pairs, fast polarization modulators and TES detectors.
2.1. Source of polarization entangled photon pairs. A pump laser (λ=405 nm) is focused into a type-II PPKTP crystal, where it causes spontaneous parametric downconversion into signal and idler modes collinear with the pump mode, maximizing the mode overlap between the target modes. To obtain polarization entangled photons, we pump the crystal from both directions and interferometrically combine the two downconverted paths in a Sagnac-like interferometer. We experimentally optimized the focusing parameters for a maximal efficiency, and observe uncorrected efficiencies >35%. This efficiency is the value obtained from uncorrected count rates from Silicon Avalanche Photo Diodes (Si APDs) of 49(2)% and 48(2)% connected directly to the single mode fibers supporting the downconverted photons with non-maximally entangled states. Our source efficiency (74%) thus starts to reach the threshold for a loophole free Bell test. Further, to obtain the required non maximally entangled state we adjust the ratio between the two decay components (HV and VH in the target modes) by controlling the pump power in each arm. We can also control the phase difference between the pump and target modes.
2.2. Fast polarization modulators. A test of Bell's inequality requires switching between two measurement bases (e.g. horizontal/vertical (HV) and a ±45°linear polarizations). We use a transverse electro-optical MgO:LiNbO3 modulator for this purpose. We see a transmission of 97.8% and a switching time of 11 ns in the optical signal. Eventually these modulators would be connected to random number generators. This will allow us to implement a random choice of measurement basis.
2.3. TES detectors. Transition-edge superconducting bolometers have been demonstrated to show very high quantum efficiencies for single photon detection [1]. In a collaboration with NIST Boulder we connect such detectors to our photon pair source. We place the detectors in an Adiabatic Demagnetization Refrigerator (ADR), at a stabilized 70(2) mK base temperature. We observe 74.1(2)% pairs to singles ratio (with no corrections applied) using 2 TES detectors connected to our PPKTP source. Our current time resolution of these detectors is limited by our SQUID amplifiers. The FWHM of the measured temporal correlation function peak is 200 ns which is sufficient to ensure

a low rate of accidental coincidences.

References:[1] A.E. Lita, A.J. Miller,S.W. Nam, Counting near-infrared single-photons with 95% efficiency Opt. Express 16, 3032 (2008); [2] P.H. Eberhard, Background level and counter efficiencies required for a loophole-free Einstein-Podolsky-Rosen experiment Phys Rev. A 47, R747 (1993)

T8.5 Structure of minimum-error state discrimination in quantum theory
Joonwoo Bae

Tuesday, March 05, 02.45 PM, MAS-SEM

We consider minimum-error quantum state discrimination, and show its general properties useful to derive solutions in the minimum-error discrimination. We show that, for a set of quantum states to discriminate among, there exists a single positive operator, which we call a symmetry operator, that completely characterizes optimal parameters in minimum-error state discrimination, such as optimal measurement and minimal errors. Using symmetry operators, we introduce equivalent classes among sets of quantum states: those sets in the same class are defined as they share an identical symmetry operator, meaning that their optimal discrimination is already characterized. In the other way around, from a given symmetry operator, we provide a systematic way of constructing a set of quantum states for which optimal discrimination can be found by the operator. We then provide a geometric formulation for solving minimum-error state discrimination, exploiting the underlying geometry of given quantum states. All these obtained general properties are then illustrated with qubit states and solutions to various cases of multiple qubit states are obtained. We explicitly show how to find optimal measurement and a symmetry operator for a given set of qubit states. On the fundamental aspects, we first show that, when ensemble steering is applied with shared entanglement, steerability of quantum states in the ensemble is proportional to the success probability in state discrimination under the no-signaling condition. We also show equivalent expressions of the success probability, according to different approaches of solving state discrimination. Finally, we observe a distinguished feature of an asymptotic quantum cloning as state discrimination: relations of given quantum states conditionally play a role in quantum cloning, depending on whether quantum cloning is non-asymptotic or asymptotic.

6.9 T9 Photonics II

This session on "Photonics II" will be held on Tuesday, March 05, from 01.30 PM to 03.00 PM. The venue for this session is MAS-EX1. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T9.1 Laser Cooling of Semiconductors (INVITED)

Qihua Xiong

Tuesday, March 05, 01.30 PM, MAS-EX1

Optical irradiation accompanied by spontaneous anti-Stokes emission can lead to cooling of matter, a phenomenon known as laser cooling or optical refrigeration proposed in 1929 by Peter Pringsheim. In solid state materials, the cooling is achieved by annihilation of lattice vibrations (i.e., phonons). Since the first experimental demonstration in rare-earth doped glasses, considerable progress has been made particularly in ytterbium-doped glasses or crystals with a recent record of $\approx$110 K cooling from ambient, surpassing the thermoelectric Peltier cooler. On the other hand, it would be more tantalizing to realize laser cooling in direct band-gap semiconductors. Semiconductors exhibit more efficient pump light absorption, much lower achievable cooling temperature and direct integrability into electronic and photonic devices. However, so far no net-cooling in semiconductors has been achieved despite of many experimental and theoretical efforts in the past few decades, mainly on III-V group gallium arsenide quantum wells. Here we demonstrate the first net laser cooling in semiconductors using cadmium sulfide (CdS) nanobelt facilitated by multiple longitudinal optical phonon assisted upconversion due to strong and enhanced Fröhlich interactions. Under a low power excitation, we have achieved a $\approx$40 K and $\approx$20 K net cooling in CdS nanobelts starting from 290 K pumped by 514 nm and 532 nm lasers, respectively. The cooling effect is critically dependent on the pumping wavelength, the blue shifting parameters and the absorption, the latter of which can be evaluated from photoconductivity measurement on individual nanowire level. Detailed spectroscopy analysis suggests that cooling to even lower temperature is possible in CdS nanobelt if thermal management is optimized. Our findings suggest alternative II-VI semiconductors for laser cooling compared to III-V GaAs-based heterostructures and may find promising applications in the field of cryogenics with the advantage of compactness, vibration- and cryogen-free, high reliability and direct integrability into nanoscale electronic and photonic devices.

T9.2 Spin and collective phenomena in the intersubband polaritonics (INVITED)

Oleksandr Kyriienko, Ivan Shelykh

Tuesday, March 05, 02.00 PM, MAS-EX1

Intersubbband transition in semiconductor quantum well (QW) plays significant role in the modern optoelectronics due to numerous possible applications in optical devices operating in the infra-red and terahertz frequency domains. The dependence of energy distance between subbands on QW width allows to adjust the frequency of photon emitter or detector in relatively easy way comparing to the usual interband transition. The implementation of multiple QW samples gives the possibility to create devices with high efficiency, in particular quantum cascade lasers. Furthermore, it is possible to improve the efficiency of light interaction with absorbing media by placing it into the semiconductor microcavity. This allows to achieve the strong coupling regime when in case of intersubband transition cavity photons are constantly absorbed and emitted and mixed light-matter modes are formed.

Previously it was believed that intersubband polariton represents cavity photon strongly coupled to intersubband single particle excitation. We revisited the field of intersubband polaritonics and found that, contrary to the general opinion, the Coulomb interactions play a crucial role in the processes of light-matter coupling in the considered system. They radically change the nature of the elementary excitations, which represent the result of the coupling of a photonic mode with collective excitations. Two particular cases of intersubband pasmon polariton and intersubband exciton polariton are studied.

Additionally we investigate intersubband polaritons formed in the asymmetric quantum well (AQW) embedded into the semiconductor microcavity and study the effects of spin-orbit interaction (SOI) acting on intersubband excitations. The spin-orbit interactions of Rashba and Dresselhaus type remove the spin degeneracy of electrons with finite value of in-plane momentum and allow four types of intersubband excitations. While optical spin-flip transitions are suppressed, the spectrum of elementary excitations shows the appearance of upper, lower and middle polariton branches based on spin-conserving transitions. The accounting of finite photon momentum leads to non-zero average spin projection of electronic ensemble in the first excited subband under cw excitation for both isotropic (Rashba) and anisotropic (Rashba and Dresselhaus) SOI. We predict the possibility of spin current generation in the considered systems with long coherence length.

T9.3 Enhanced performance in plasmonics light emitting diode (INVITED)

Ee Jin Teo

Tuesday, March 05, 02.30 PM, MAS-EX1

There have been huge initiatives in developing light emitting diodes for the next generation of visible light communication for RF-restricted areas, such as airplanes, military installations and hospitals. One of the main challenges facing this technology is the slow spontaneous emission of LEDs that limits the rate at which the LED can switch on/off resulting in a low data transfer rate. In this talk, I will describe how a new plasmonics based design can be incorporated into a conventional GaN blue LED device for enhanced modulation speed with high efficiency. Significant improvement in the modulation speed to hundreds of Mbps is also shown. I will also demonstrate how polarized light with high transmission can be obtained from LED using sub-wavelength metallic grating. This can result in a much thinner and compact LED backlit LCD display. Plasmonics can potentially lead to a new class of LED that has immediate impact and importance to the solid state lighting and display industry.

6.10 T10 Graphene and Carbon Nanotubes

This session on "Graphene and Carbon Nanotubes" will be held on Tuesday, March 05, from 03.30 PM to 04.30 PM. The venue for this session is MAS-EX2. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T10.1 Atomic Scale Investigation of CDV Graphene Growth Mechanism on Cu(111) (INVITED)

Wei Chen

Tuesday, March 05, 03.30 PM, MAS-EX2

We report an atomic scale investigation of growth mechanism and direct observation of growth intermediates for CVD graphene on Cu(111) under ultrahigh vacuum condition using methane as precursor, by in-situ low-temperature scanning tunneling microscopy (LT-STM), and corroborated by density-functional theory (DFT) calculations. It is found that methane molecules first decompose on Cu(111) surface and form carbon dimers (C2Hx), and various larger carbon clusters comprising carbon chains and square. Upon the saturation of these carbon species on Cu(111), they can evolve into defective graphene with pseudo-ordered vacancies and dislocations. These defects can only be healed through annealing in the presence of methane, leading to the formation of single layer graphene on Cu(111). Such atomic insights of the structural evolution at different stages of graphene grown on Cu(111) can help to better understand the growth mechanism of CVD graphene on Cu, and hence provide design rules for the large scale growth of single crystalline and monolayer graphene.

T10.2 Carbon Nanotubes Functionalized by Dichlorocarbene (INVITED)

Qing Zhang, Kang Zhang, Chao Liu

Tuesday, March 05, 04.00 PM, MAS-EX2

In this talk, we shall present our recent progress in carbene-based covalent functionalization of single welled carbon nanotubes [1,2]. Dichlorocarbene functionalization process essentially involves refluxing SWCNTs with chloroform and a phase transfer catalyst in a highly basic solution of sodium hydroxide. The prepared SWCNT transistors were immersed in 150 mL of 10-4 M NaOH solution in the presence of 10 mg of catalyst (Aldrich: Triethyl Benzyle Ammonium Chloride). 1 mL of chloroform (99.9 percent) was then added into the mixture dropwisely. Then, the devices were thoroughly rinsed with acetone, IPA and de-ionized water in sequence. We find that dichlorocarbene has high selectivity in modulating the electrical conductance of metallic(m)- and semiconducting(s)-SWCNTs, in agreement with relevant theoretical predictions [1]. Very recently, the functionalization has been conducted on SWNTs with diameters ranging from 1.2 to 2.2 nm. Small diameter SWNTs are found to react much more easily than large diameter SWNTs. Upon functionalization, the conductance could be largely preserved for almost all SWNTs, while an effective bandgap increase for functionalized metallic SWNTs (m-SWNTs) and a bandgap reduction for functionalized semiconducting SWNTs (s-SWNTs) are generally observed. The results suggest that [2+1] cycloaddition is an excellent choice of processing, resulting in SWNTs over a large diameter range with electronic properties that are almost unaffected [2].

[1] Chao Liu et al, SMALL 7(2011)1257; [2] Kang Zhang et al, A.F.M. 22(2012)5216

6.11 T11 Atomic Physics

This session on "Atomic Physics" will be held on Tuesday, March 05, from 03.30 PM to 05.00 PM. The venue for this session is MAS-SEM. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T11.1 Atomic systems as quantum probes of nanosurfaces and nanobodies (INVITED)

Martial Ducloy

Tuesday, March 05, 03.30 PM, MAS-SEM

The interaction between microscopic quantum systems (like atomic systems) and material (dielectric or metallic) nanobodies is a case study in quantum physics, with many applications in cavity QED, engineering of atom-surface forces, matter-wave interferometry, nanotechnology, surface metrology etc. It allows one to apply atomic physics, with its ultra-high resolution processes, to condensed matter physics. Interacting atomic systems provide original probes of nanosurfaces, nanostructures and nanofields. Recent advances about resonant coupling between atomic systems and surface polariton modes, effect of thermal surface excitations, fundamental symmetry breaking, influence of nanobody form and structure, surface allowing of forbidden transitions, will be reviewed. Current prospects concern atomic/molecular interactions with novel materials like metamaterials, chiral nanoparticles or graphene. Work partly supported by CNRS international programme (PICS #5813) with Russia.

References: D. Bloch, M. Ducloy, Adv. At. Mol. Opt. Phys. 50, 91 (2005); M. Boustimi et al, Phys. Rev. Lett. 86, 2766 (2001); V. Klimov, M. Ducloy, Phys. Rev. A 62, 043818 (2000); 72, 043809 (2005); J. Baudon et al, J. Phys. Chem. A 113, 15188 (2009); V. Klimov et al, EPL 97, 47004 (2012); M. Hamamda et al, EPL 98, 23001 (2012)

T11.2 Self-Organization Threshold Scaling for Thermal Atoms Coupled to a Cavity

Markus P. Baden, Kyle J. Arnold, Murray D. Barrett

Tuesday, March 05, 04.00 PM, MAS-SEM

Ultra-cold atoms coupled to a high-finesse optical cavity exhibit the phenomenon of self-organization. When probed from the side, atoms initially in a thermal cloud will not scatter into the cavity until the probe power reaches a critical value. Above critical probe power a runaway process leads to scattering into the cavity while the atoms localize on a lattice formed by interference between the probe and the scattered light. We give a detailed experimental study of the onset of self-organization and discuss it's application as a possible cooling mechanism, as well as give an outlook on related collective scattering phenomena.

T11.3 Electric Fields in Proximity to Cryogenic Surfaces

Chan Kin Sung, Siercke Mirco, Hufnagel Christoph

Tuesday, March 05, 04.15 PM, MAS-SEM

Atom adsorbed on a dielectric/metallic surface will form a metastable adsorbate with an induced dipole moment. In a typical atom chip experiment, due to experimental cycle, an electric dipole layer is formed and gives rise to a spatial dependence electric field emitted away from the surface. Rydberg atom has large polarizability and dipole moment which results in large level shift with small electric field. We demonstrate the use of Rydberg atom as an electrometer to measure the electric field emitted by the adsorbates at room temperature and cryogenic temperature.

T11.4 Characterization of the ionization avalanche in an ultra-cold Rydberg gas

Fong En Oon, Mirco Siercke, Rainer Dumke

Tuesday, March 05, 04.30 PM, MAS-SEM

Over the past few years ultra-cold Rydberg gases have come into the spotlight as a possible implementation of quantum computation as well as strongly-interacting many body systems. The wide variety of interesting physics to be explored in this system stems from the strong van der Waals interactions between the atoms, as well as their strong coupling to weak light fields under the conditions of Electromagnetically Induced Transparency (EIT). Exciting such loosely bound atomic states however can lead to ionization of the Rydberg atoms and the eventual formation of an ultracold plasma. We report on the ionization dynamics of such a Rydberg gas of Rubidium created by doubly-resonant excitation from the ground state. We observe an initial slow ionization rate followed (at large enough densities) by an avalanche process which rapidly converts the remaining atoms into ions. Interestingly, at the highest densities achievable in our experiment the avalanche is suppressed, a process that is not yet fully understood.

T11.5 Narrowband source of correlated photon pairs via four-wave mixing in a cold atomic ensemble

Bharath Srivathsan, Gurpreet Kaur Gulati, Mei Yuen Brenda Chng, Gleb Maslennikov, Dzmitry Matsukevich, Alessandro Cerè, Christian Kurtsiefer

Tuesday, March 05, 04.45 PM, MAS-SEM

We observe narrowband pairs of time-correlated photons at 776nm and 795nm from non-degenerate four-wave mixing in a laser-cooled atomic ensemble of ^{87}Rb using a cascade decay level scheme. Coupling the photon pairs into single mode fibres, we see an instantaneous rate of 7700 pairs per second with silicon avalanche photodetectors, and an optical bandwidth below 30 MHz. Detection events exhibit a strong correlation in time and a high coupling efficiency, indicated by a pair-to-single ratio of 23%. The violation of the Cauchy-Schwarz inequality by a factor of 8.4 x $10\hat{6}$ indicates a strong non-classical correlation between the generated fields, while a Hanbury–Brown–Twiss experiment in the individual photons reveals their thermal nature. The narrow linewidth and brightness of our source makes it ideal for interacting with atomic ensembles in quantum communication protocols.

6.12 T12 Plasmonics

This session on "Plasmonics" will be held on Tuesday, March 05, from 03.30 PM to 05.00 PM. The venue for this session is MAS-EX1. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T12.1 A plasmonic sensor design with near field coupling (INVITED)

Zhengtong Liu, Erping Li

Tuesday, March 05, 03.30 PM, MAS-EX1

A plasmonic sensor design, which makes use of superlens and nanoantenna, is proposed. Plasmonic nanostructures have gained much popularity due to their unique light-matter interaction behaviors. Many of them, such as superlens and nanoantenna, are of particular interest due to near field applications such as super-resolution imaging and subwavelength light focusing. Our design combines these two concepts to form a sensor that can be used for fluorescence and surface enhanced Raman scattering (SERS). It has the potential to make use of the hotspot generated by a nanoantenna while avoid the unwanted quenching effect. However our design based on the superlens concept suffers from serious limitations due to the permittivity matching condition required for superlens operation. This condition makes the device work only at a narrow wavelength range due to the availability of materials and requires metal-dielectric materials, which are difficult to control. To overcome this limitation we developed a semi-analytical method to study the near-field coupling effect in plasmonic structures. The analysis shows that when dealing with near fields of plasmonic nanostructures, the near field coupling effect plays an important role and has to be taken into account, and a plasmonic system that consists of several components has to be studied as a whole. In light of this finding, we have redesigned the sensor using only pure metal and re-optimized the parameters. The redesigned sensor can work at a broad range of wavelengths.

T12.2 Tuning plasmonic properties of a single metallic nanostructure by electrochemical methods (INVITED)

Shuzhou Li

Tuesday, March 05, 04.00 PM, MAS-EX1

Metallic nanoparticles are of particular interest for biosensing and photovoltaic cells because of their unique optical properties. Their localized surface plasmon resonances (LSPR) strongly depend on their electron densities. We have demonstrated that the LSPR of a single gold nanostructure can be tuned by electrochemical methods. The LSPR is blue-shifted when the electron density of the gold nanostructure increases and it is red-shifted when the electron density decreases. These observations are in an excellent agreement with the results of numerical simulations. The intensities of surface-enhanced Raman scattering can vary several orders of magnitude under different bias. That's mainly due to the shift of LSPR positions. Our results pushed one step forward for application of active plasmonic devices that are controlled by electrochemical methods.

T12.3 Plasmonic Applications in Data Transmission and Sensing (INVITED)

Ping Bai

Tuesday, March 05, 04.30 PM, MAS-EX1

Plasmonics has shown a wide range of applications, such as in sensing, imaging, communication, energy harvest, and bioscience. It has caught a great attention in the research community. The Electronics and Photonics Department at A*STAR Institute of High Performance Computing (IHPC) has started research on plasmonics since 2006. The research activities include plasmonic applications in photovoltaic, imaging, communication and sensing. Recently the research is also extended to quantum plasmonics and graphene plasmonics. In this talk, I will present the latest progress in IHPC on the plasmonic applications in the on-chip optical interconnects and sensing. For interconnect application, a novel CMOS-compatible plasmonic hybrid plasmonic waveguide platform has been developed. This waveguide platform shows excellent performance and has been used as a building block to build various high-performance plasmonic devices, such as filters, splitters, multiplexes and modulators. Since the waveguide platform can be easily coupled with Si photonic waveguides, this research enables an unprecedented synergy by integrating photonic, plasmonic and electronic devices into the same platform with fully exploiting the advantages of photonics, plasmonics and nanoelectronics technologies. As for plasmonic sensing, I'll show a sensing method based on localized surface plasmon resonance (LSPR). Various sensing structures are proposed to enhance the LSPR to directly detect large molecules or detect small molecules with a signal enhancement element. The fabrication and characterization of the proposed sensing structures will also be briefed. The measured preliminary results show that the LSPR based sensor can provide high sensitivity and has potential to be developed into portable sensing systems for a wide range of applications such as diagnostics, food testing and environment monitoring.

6.13 T13 Organic and thin film Photovoltaics

This session on "Organic and thin film Photovoltaics" will be held on Wednesday, March 06, from 09.00 AM to 10.30 AM. The venue for this session is LT4. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T13.1 Transparent Conducting Oxide Top Contacts for Organic Photovoltaics; Structural and Electronic Properties and Devices (INVITED)

Joseph Franklin

Wednesday, March 06, 09.00 AM, LT4

Deposition of transparent conducting oxides generally requires temperatures greater than 350 °C which make them unsuitable for use as top contacts in organic optoelectronic devices. Here, we demonstrate the use of pulsed laser deposition (PLD) as a method for depositing highly crystalline, highly conducting ($<50\,\Omega$/sq) and transparent ($> 90\%$) aluminium-doped ZnO and indium tin oxide (ITO) at low temperatures (<200 °C) directly on to a functional organic layer, under conditions that do not degrade the optical or electronic properties of the organic materials. The technique allows precise control of the oxide film thickness, orientation and stoichiometry. Microstructural and morphological data of the oxide and organic layers are presented alongside photovoltaic device data with transparent metal oxide top contacts. This deposition technique and flexibility of the materials available opens possibilities into unexplored photovoltaic architectures specifically the incorporation of transparent interlayers and the ability to fabricate devices from metal electrode up.

T13.2 Variation of intrinsic defects on surface and bulk of Cu2ZnSn(S,Se)4 monograin for photovoltaic application

Kong Fai Tai, Chin Fan Ng, Xinfeng Liu, Kaia Ernits, Mai Nguyen, Subodh Mhaisalkar, Tze Chien Sum, Cheng Hon Alfred Huan

Wednesday, March 06, 09.30 AM, LT4

Cu2ZnSn(S,Se)4 (CZTSSe) solar cell has currently reached an efficiency of 11.1%. It is a significant progress in photovoltaics as it represents an earth-abundant, environmental friendly thin film solar cell. Although a high efficiency solar cell was fabricated, little scientific effort has been done to probe the fundamental limitation, especially the defect physics which are of utmost importance that affect the solar cell performance. In single-crystalline CZTSSe, variation of defects across the monograins' depth affects the transport of photo-generated carriers across the p-CZTSSe/n-buffer interface. We investigated the nature of defect on the surface (unpolished) and in the bulk (polished) of monograin by micro-photoluminescence (PL). Our findings revealed that PL at the surface of the monograin originates from the radiative recombination between free electron and hole bound to Cu-vacancy acceptors (V-Cu). In contrast, no PL was detected from the bulk of the monograin, thereby suggesting the presence of deep carrier traps that provide non-radiative relaxation channels for the excited carriers. Depth profile X-ray photoelectron spectroscopy validates that the Cu content on the surface was indeed poor relative to the monograin's bulk. Importantly, these surface V-Cu defects are beneficial for electron transport across the p-n heterojunction as they lower the valence band maximum due to the reduced Cu d-S p hybridization. However, elemental engineering of the monograins need to be optimized to eliminate deep traps in the bulk.

T13.3 Fluence dependence studies on the Differential Reflection Spectra of P3HT in femtosecond transient absorption

Ho Fai Leung, Michael Kurniawan, Tze Chien Sum

Wednesday, March 06, 09.45 AM, LT4

Femtosecond transient absorption (TA) is a widely-used technique for analysing the non-equilibrium dynamics of a material following excitation by a laser pulse. Information that can be derived from this technique includes lifetime of excited species, energy transitions involved, and degree of order in the material, among others. Typical TA set-ups include 2 pulsed beams, a 'pump' beam to excite the sample and a 'probe' beam which passes through the sample at a specified delay time after the excitation. The difference between transmitted wavelengths contained in the 'probe' beam before and after excitation then serves as the basis for analysis of the dynamics. If the sample includes an opaque layer, such as the metal electrode of an organic electronic device, it becomes necessary to perform the study in reflection geometry. Spectra observed in this configuration are termed as Differential Reflection Spectra (DRS), and are expected to resemble Differential Transmission Spectra (DTS). In this study, we present femtosecond transient absorption pump fluence dependence studies on a poly-3-hexathiophene (P3Ht) thin film coated with a thin opaque Al layer on a glass substrate. For samples exceeding 60nm in thickness, our data shows negative DRS at wavelengths less than 600nm at low fluences, which contradicts reports found in literature. A sufficient increase in pump fluence subsequently reproduces the reported spectra. We believe the anomalous spectra seen at low fluences arise from strong photoinduced absorption (PIA) signal and thus seek to understand the origination of this phenomenon. Key focuses of study include the effects of annealing, high fluence saturation, angle of incidence studies, as well as the reproducibility when applied to other materials.

T13.4 P3HT/GaAs Heterointerfaces: a First-Principle Study of Polar GaAs(111)B and Nonpolar GaAs(110) Surfaces

Jun Yin, Dmitri B. Migas, Majid Panahandeh-Fard, Zilong Wang, Shi Chen, Cesare Soci

Wednesday, March 06, 10.00 AM, LT4

In this work we compare structural and electronic properties of polar GaAs(111)B and nonpolar GaAs(110) surfaces when interacting with P3HT molecules by means of density functional theory (DFT) calculations. After determining the stable interfacial configurations of GaAs(111)B and GaAs(110)/P3HT interfaces, we find that the polarity of the GaAs surface strongly affects the overall charge redistribution because the GaAs(111)B surface tends to facilitate hole transfer from the valence band state of

GaAs(111)B to the HOMO states of P3HT, whereas the overlap between the conduction band states of GaAs(110) with the LUMO states of P3HT induces electron transfer across the GaAs(110)/P3HT interface. These predictions correlate well with experimental observations made by ultrafast spectroscopy and XPS measurements and suggest possible ways to optimize photovoltaic performance in polymer/III-V heterointerfaces.

T13.5 Ultrafast Charge Transfer Dynamics in P3HT-GaAs Heterointerfaces

Majid Panahandeh-Fard, Jun Yin, Michael Kurniawan, Zilong Wang, Manoj Kumar, Tze Chien Sum, Cesare Soci

Wednesday, March 06, 10.15 AM, LT4

Fairly efficient hybrid photovoltaic cells based on group III-V (GaAs and InP) nanowires and conjugated polymers have been recenty reported in the literature. Motivated by this, we studied the photoinduced interfacial charge transfer dynamics of P3HT-GaAs thin film heterojunctions using a combination of steady-state and ultrafast spectroscopy, as well as Density Functional Theory (DFT) simulations. Transient absorption and photoluminescence probed with excitation below or above the conjugated polymer HOMO-LUMO gap revealed the co-existence of electron and hole transfer at the hybrid heterointerface. The signatures of interfacial charge transfer are manifested in transient absorption measurements by the appearance of a new photoinduced band attributed to P3HT positive polarons generated upon exciton dissociation at the organic/inorganic interface. These observations, validated by DFT calculations, highlight the potential of organic/III-V heterostructures for engineering the photovoltaic performance of hybrid solar cells with enhanced light absorption, charge separation, and charge transport.

6.14 T14 Magnetism

This session on "Magnetism" will be held on Wednesday, March 06, from 09.00 AM to 10.30 AM. The venue for this session is MAS-EX2. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T14.1 Advanced Nanostructured Materials: Rational Synthesis and Potential Applications for Magneto-Optoelectronic Devices (INVITED)

Guozhong Xing

Wednesday, March 06, 09.00 AM, MAS-EX2

The prospect of incorporating magnetic properties into semiconductor devices has provoked intensive research in developing diluted magnetic semiconductors, in particular, for transition-metal-doped ZnO. Cu as the dopant can eliminate the possibility of ferromagnetic clusters in the host. I report a comparative study of room temperature ferromagnetism (RTFM) in Cu-doped ZnO nanowires (NWs) and our experiments demonstrate that the structure inhomogeneity can enhance the RTFM. Moreover, our transient optical orientation experiments reveal the occurrence of long-lived, highly spin-polarized exciton emissions from Cu-doped ZnO NWs. It generates our great interest to further exploit its physical performance for the applications of magneto-optoelectronic devices. Furthermore, envisioned as the emerging building blocks, a synergistic combination of CdSe and CdTe nanocrystals (NCs) offers favorable conditions for the charge separation of photoexcited carriers at the interfaces. Most recently our experiments reveal the energy transfer dynamics between the neighboring NCs in CdSe/CdTe system. This work demonstrates that efficient energy transfer can be achieved through engineering binary NCs with tunable particle size and band structure modulation, which may find potential applications as solar energy conversion devices.

T14.2 Origin of ferromagnetism in ZnO:Mn nano-structured thin films by altering material composition and deep level photoemissions

Usman Ilyas, Tuck Lee Tan, Paul Lee, R.V. Ramanujan, Sam Zhang, Chen Rui, H.D Sun, Rajdeep Rawat

Wednesday, March 06, 09.30 AM, MAS-EX2

Dilute magnetic semiconductors continue to be at the forefront of spintronics research due to the demonstration of room-temperature ferromagnetism (RTFM) in these materials. The narrow-size-distributed ZnO:Mn based powders were synthesized by using wet chemical method rather than commonly used solid-state reaction method. ZnO:Mn thin films with wurtzite structure were grown under different Ar:O2 partial pressures along with in-situ annealing using pulsed laser deposition (PLD) technique. This study investigates the effect of substrate temperature and ambient gas pressure on the concentration of oxygen in enhancing material composition and its correlation with the optical quality and magnetic response in ZnO:Mn thin films. The optimum growth conditions were deduced from structural measurements, photoemission from native defects, micro-structures and magnetic ordering. X-ray measurements reveal that there was an optimum substrate temperature where the thin films showed relatively stronger texture, better crystallinity and improved ferromagnetic response. Annealing temperature tuned the deep level recombination centers in ZnO:Mn which changed the optical quality by altering their electronic structure. The detailed analysis of Zn 2p3/2 and O 1s core level XPS spectra revealed that the structural disorder was considerably reduced by oxygen diffusion in the thin film samples thereby enhancing the Zn-O bonding for better optical quality and stronger exchange interaction. The ferromagnetic origin in narrow-size-distributed nanoparticles was attributed to the strong p-d hybridization between oxygen 2p and Mn 3d orbitals in ZnO:Mn thin film with improved material composition annealed at a substrate temperature of 450 °C under Ar:O_2 pressure of 2.5 mbar.

T14.3 Phase Diagram and Magnetic Excitations of Anisotropic Spin-One Magnets
Zhifeng Zhang, Pinaki Sengupta

Wednesday, March 06, 09.45 AM, MAS-EX2

Spin wave theory is an efficient tool to study the ground state and the excitation spectrum of a spin system. We have used both standard and generalized spin wave theory to study the quantum phase diagram and quasiparticle excitations of the S=1 Heisenberg model with an easy-plane single-ion anisotropy in dimensions d = 2 and 3. The result is in a good agreement with our large scale Quantum Monte Carlo simulation.

T14.4 Experimental determination of nuclear magnetic octupole moment of $^{137}Ba^+$ ion
Nick Lewty, Boon Leng Chuah, Murray D. Barrett

Wednesday, March 06, 10.00 AM, MAS-EX2

We have performed precision measurements of the $5D_{3/2}$ and $5D_{5/2}$ manifolds hyperfine intervals of a single trapped ion, $^{137}Ba^+$. We have used rf spectroscopy to measure the hyperfine intervals to an accuracy of a few Hz. Our results provide a three orders of magnitude increase in accuracy over previous work. These results allow the calculation of the nuclear octupole without using any theoretical correction factor caused by the mixing between $5D_{5/2}$ and $5D_{3/2}$ states

T14.5 Supersolid phases in a generalised Shastry-Sutherland model
Keola Wierschem, Pinaki Sengupta

Wednesday, March 06, 10.15 AM, MAS-EX2

Supersolids are unique states of matter that combine diagonal and off-diagonal long-range ordering into a single phase. We demonstrate the existence of several spin supersolid phases in a generalised Shastry-Sutherland model. This model adds exchange anisotropy and extended interactions to the canonical Shastry-Sutherland model. The transverse components of the exchange coupling are taken to be ferromagnetic, which not only allows for accurate numeric investigation using quantum Monte Carlo methods, but also captures the low-energy magnetic properties of certain rare-earth tetraborides. We study the emergence of spin supersolid phases in this model for different parameter regimes. Further, we demonstrate the existence of a spin supersolid phase in the experimentally relevant parameter range of ErB4: strong Ising-like anisotropy and zero-field columnar antiferromagnetic ground state magnetic ordering.

6.15 T15 Thin Films

This session on "Thin Films" will be held on Wednesday, March 06, from 09.00 AM to 10.30 AM. The venue for this session is MAS-SEM. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T15.1 Charge Distribution in Epitaxial Ti2AlN Thin Films (INVITED)

Shijie Wang

Wednesday, March 06, 09.00 AM, MAS-SEM

Ti2AlN is a member of the MAX phases, which is a family of nanolaminate ternary compounds. This group of materials has regained significant attentions recently owing to their unique combination of ceramic properties (high melting point and high temperature oxidation resistance) and metallic properties (good electrical and thermal conductivity, high ductility, easy machinability, superior thermal shock resistance and damage tolerance). These properties lead to a variety of applications including high temperature protective coatings on turbine blades, structural components and fuel pellet coatings for next generation nuclear power plant. The distinctive combination of these properties is attributed to the layered hexagonal structures. The strong covalent-ionic nature of the M-X bonds accounts for the ceramic properties while the weak metallic M-A bonds are the basis for the metallic properties. In this talk, I will present the study of micostructure, mechanical properties, chemical states of epitaxial Ti2AlN thin film probed in-situ by X-ray photoelectron spectroscopy (XPS) and its electronic structures calculation by density function theory (DFT).

T15.2 Challenges of Thin Film Processing in the Deep Nanoscale (INVITED)

Mike Cooke

Wednesday, March 06, 09.30 AM, MAS-SEM

Layer thicknesses and feature sizes below 100 nm present certain challenges to the etching and deposition process engineers. In some cases, existing techniques are already robust. Most techniques can still be used, but require enhancements for processing in the nanoscale. Some techniques such as atomic layer deposition have become the preferred method in the deep nanoscale. We will consider the physical challenges of etching and deposition in scale lengths down to 1nm in thickness and lateral dimension, and suggest possible solution routes.

The FP7 European project (2013-17) on 'Single nanometre manufacturing' will be presented, particularly from the perspective of a process equipment partner.

T15.3 Gasless sputtering and large metal ion currents for thin film deposition

Joakim Andersson

Wednesday, March 06, 10.00 AM, MAS-SEM

Sputtering is a well known method for deposition of thin film materials, usually implemented by a direct current discharge in low pressure argon. This leads to a small ion current (typically ≈1% of the discharge current) to the substrates and limited usefulness of sample biasing. By instead letting the plasma from a short arc discharge flood a sputter target, a very high current, pure self-sputtering discharge can be initiated - even at the base pressure of the chamber. The result is a very large current of useful ions to the substrates (≈250% of the discharge current has been recorded). This surprising and counter intuitive result will be explained. Such a discharge is limited by the power supply and the tremendous need for target cooling. Hence this process is only carried out in pulsed mode, usually called High Power Impulse Magnetron Sputtering (HiPIMS). The combination of high metal ion current and gas-free operation makes the process useful for coating complex surfaces, surface transformation and deposition of pure metal films. It also implies magnetrons can be used for metalization in space and even the use of metal ions for propulsion of satellites.

T15.4 Low-energy effective model for Bi(1-x)Sb(x) alloys

Ziyu Luo, Guanggeng Yao, Wentao Xu, Yuan Ping Feng, Xue-Sen Wang

Wednesday, March 06, 10.15 AM, MAS-SEM

Bi(1-x)Sb(x) is a 3D topological insulator for $0.07 < x < 0.22$. Moreover, Bi(1-x)Sb(x) alloys for $x > 0.04$ have a topologically non-trivial band order, so there are topological surface states on their surfaces. Therefore, thin films and nanostructures of Bi(1-x)Sb(x) alloys in a broad composition range may be topological insulators due to quantum confinement effect on the bulk states and topological protection to the surface states. We calculated the electronic structures of Sb, Bi and their alloys using first principle DFT method. Based on the parameters acquired from the result of DFT calculations, we constructed a low energy effective model near the Fermi energy, and determined the topological property of these materials, the spin characteristic and penetration depth of the surface states, which will be important for the application of the topological surface states in the ultra-thin films and nanostructures of these materials.

6.16 T16 Nanophotonics

This session on ”Nanophotonics” will be held on Wednesday, March 06, from 11.00 AM to 12.30 PM. The venue for this session is LT4. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T16.1 Nanoelectronic and Nanophotonic Materials and Devices at UCL (INVITED)

Tony Kenyon

Wednesday, March 06, 11.00 AM, LT4

In this talk I will give an overview of work in the Photonic Materials lab at UCL on nanostructured materials for photonic, plasmonic and electronic applications. Our particular areas of interest cover light emission from silicon, rare-earth doped photonic materials, silicon-based resistive switching and memristance, and self-assembly of nanostructures from metallic nanoparticles. We have worked on the optical and electronic properties of silicon nanoclusters and nanocrystals for many years. Such materials offer the possibility to tailor the band structure and band gap energy of silicon to permit optical emission across much of the visible and near-ir part of the optical spectrum.

By confining carriers within nanocrystals in real space, their wavefunctions spread in momentum space, offering the possibility of pseudo-direct band gap transitions. Moreover, by co-doping silicon dioxide with both silicon nanoclusters and erbium it is possible to exploit excitation exchange between the nanoclusters and erbium ions to increase the Er excitation cross-section and open up the possibility of broadband-pumped optical sources. Recent work has concentrated on resistive switching in silicon oxides, a phenomenon that promises extremely high density semiconductor memories that use a fraction of the power of Flash memory, and can be scaled to the 10nm node and beyond. Our self-assembly work looks at ways to generate highly linear 1D and 2D arrays of metallic nanoparticles using simple chemistry-driven assembly methods. We have been able to achieve linear arrays of 4nm diameter silver nanoparticles that extend for several micrometres. The arrays promise interesting optical, electronic and plasmonic properties.

T16.2 Ultrafast Carrier and Quasi-particle Dynamics in Semiconductor Nanostructures (INVITED)

Tze Chien Sum

Wednesday, March 06, 11.30 AM, LT4

Ultrafast optical spectroscopy (UOS) techniques such as time-resolved photoluminescence and transient absorption are very powerful probes of carrier and quasi-particle dynamics in semiconductor nanostructures. These techniques involve the interaction of femtosecond laser pulses with matter. The short pulse duration allows us to study energy and charge transfer phenomena in semiconductors that are highly inaccessible by many other techniques. New insights into the mechanisms of charge generation, transfer, trapping, recombination and interactions with the lattice can be gained through these studies. Detailed knowledge of such ultrafast dynamics is essential for the development of novel materials for nanophotonics, optoelectronics, photovoltaics and photocatalysis. In this talk, I will showcase some of our group's efforts in the study of carrier and quasi-particle dynamics in semiconductor nanoparticles and nanowires. Our work is of both fundamental interest and technological relevance – crossing multi-disciplinary boundaries of physics, chemistry, materials science and photonics.

T16.3 Origin of the Green Emission and the Charge Trapping Dynamics in ZnO Nanowires

Mingjie Li, Guichuan Xing, Tze Chien Sum

Wednesday, March 06, 12.00 PM, LT4

The origins of the commonly observed green emission (GE) from ZnO nanostructures remain highly controversial despite extensive studies over the past few decades. Herein, through a comprehensive ultrafast optical spectroscopy study, new insights into its origin and the charge trapping dynamics at the GE-centers in ZnO nanowires prepared by vapor transport method are gained. It is found that the GE involves the transition of the electrons in the conduction band and/or shallow donor levels with holes trapped at the deep levels. A sub-bandgap absorption bleaching band was observed in Transient absorption spectroscopy (TAS) due to the state-filling of the electrons in the conduction band and holes trapped in the GE-centers. TAS revealed that the GE-centers mainly located at $\approx 0.7\,\mathrm{eV}$ above the valence band. Importantly, an ultrafast Auger-type hole-trapping process to GE-centers that occurs in a sub-ps timescale was uncovered by TAS — shedding new light on the mechanism behind the fast and efficient charge trapping of photoexcited carriers. The knowledge gained is crucial for the development of ZnO-based optoelectronic devices.

T16.4 Near resonant and nonresonant third-order optical nonlinearities of colloidal InP/ZnS quantum dots

Wang Yue, Sun Handong

Wednesday, March 06, 12.15 PM, LT4

We investigate the third-order optical nonlinearities of high quality colloidal core/shell InP/ZnS QDs using Z-scan technique in both near resonant and off resonant regimes for the first time. A femtosecond amplified-pulsed laser system with wavelength tunable was utilized as the light source. The pulse width and repetition rate of the pulse laser are 100 fs and 1 KHz, respectively. The colloidal InP/ZnS QDs exhibit strong saturable absorption within the absorption band. The saturation intensity is as low as those of the best saturable absorbers. Such excellent saturable absorbing properties in the colloidal InP/ZnS QDs are in agreement well with the theoretical predictions. Furthermore, the two-photon absorption cross-sections as high as 6.2×103 GM at 800 nm is observed in InP/ZnS QDs with diameter of 2.8 nm, indicating that the colloidal InP/ZnS QDs can be exploited as an excellent bio-imaging probse. The increased two-photon absorption cross-sections of InP/ZnS QDs with size rising is attributed to the increased density of state.

6.17 T17 Plasma Science and Applications

This session on "Plasma Science and Applications" will be held on Wednesday, March 06, from 11.00 AM to 12.30 PM. The venue for this session is MAS-EX2. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T17.1 Plasma Focus as a Multiple Radiation Source (INVITED)

Paul Lee, Rajdeep Singh Rawat, Springham Stuart, Darren Wong, Augustine Tan, Roshan Deen

Wednesday, March 06, 11.00 AM, MAS-EX2

Much effort has been put into plasma physics and fusion research with "big science" projects like ITER and NIF. It is expected that the issues to be resolved before controlled nuclear fusion becomes a practical power source will not be resolved in the near future implying a global need for plasma physic researchers for at least the next 100 years. The plasma focus has been used in training manpower for the plasma research community for many decades but still represents a significant scientific challenge in understanding the plasma physics leading to the production of plasma parameters suitable for producing fusion neutrons and various other radiations. In addition to the wealth of physical phenomena that can be investigated, the use of the plasma as a radiation source still has potential to be exploited. This paper presents the investigations done on the plasma focus and future directions of plasma focus research in NIE.

T17.2 Particle-in-Cell simulation and its application in plasma study (INVITED)

Wen Jun Ding, Wee Shing Koh

Wednesday, March 06, 11.30 AM, MAS-EX2

Particle-in-Cell simulation is a powerful tool for kinetic plasma studies. PIC code solves Maxwell equations and Newton-Lorentz equation. By FDTD (finite difference time domain) method, the space is divided in cells, where fields and other macro quantities are defined. And plasma particles: electrons and ions continuously move in space. It calculates motion of every particle, obtaining all macro quantities (density, current . . .) from the position and momentum of these particles. Then the Maxwell equations are solved with these quantities for electric and magnetic fields. The trajectory of particles is updated using these EM fields. And both the fields and plasma are modeled spatially and temporally with the loop goes on. Because of using fundamental equations and minimum assumptions, PIC simulation is extensively used in studies of laser- plasma, plasma-plasma interactions, plasmonics, astrophysics and so on.

T17.3 Role of Krypton Seeding in DD Fusion Reaction in Plasma Focus Device

Alireza Talebitaher, S. M. P. Kalaiselvi, Lee Paul, Stuart Springham, Tuck Lee Tan, Rajdeep Singh Rawat

Wednesday, March 06, 12.00 PM, MAS-EX2

A comparative study of DD fusion in a moderate (NX2 / 2 kJ) and miniature (FMPF

/ 0.2 kJ) plasma focus devices operated with pure deuterium and a deuterium-krypton (D2-Kr) admixture has been performed. Typical neutron yields were in the range of 108 n/shot and 106 n/shot for NX2 and FMPF respectively. Fast-neutron beryllium activation detector and He-3 thermal-neutron detector measured the time-integrated neutron yield. A Coded Aperture Imaging (CAI) technique has been employed to image the fusion source using the $\approx$3 MeV protons emitted from D(d,p)T reactions. An x-ray pinhole system was employed simultaneously to image the hot dense plasma column. The results show the different shape, size and density of the final pinch plasma column and fusion source for pure deuterium and admixture gas operation. Fusion images for the D-Kr case show a significantly smaller fusion emission region indicating a tighter confinement of the hot plasma interacting with the energetic deuteron beam. Moreover, they show the geometry of the electrode assembly and the electrical coupling play a critical role in determining the influence of the admixture gas; for the well-optimized plasma focus device, the admixture gas even may not enhance the neutron yield.

T17.4 From plasma control to properties tuning of thin films

Chia Sern Chan

Wednesday, March 06, 12.15 PM, MAS-EX2

Nowadays, plasmas driven by DC, RF, microwave and pulsed power sources are used widely in both research and industrial applications since they can provide high radical production rate even at room temperature. Direct tuning properties of films through plasma control is quite attractive but challenging and unsolved until now since each simulation involves complex mathematics and the outcome may not be accurate or useful. Under such a circumstance, we proposed and developed an engineering approach to link up all macro properties of a film from its internal microstructure based on size-dependence theory. The internal microstructure of the thin film can be further correlated to plasma parameters (such as electron density) as well. Hence, by controlling plasma parameters through power, gas ratio, external bias setup, and so on, we are able to tune the properties of our synthesized films with ease.

6.18 T18 Bio/Nanoscience

This session on "Bio/Nanoscience" will be held on Wednesday, March 06, from 11.00 AM to 12.45 PM. The venue for this session is MAS-SEM. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T18.1 Are Nanoparticles Environmentally Safe? (INVITED)

Alison Crossley

Wednesday, March 06, 11.00 AM, MAS-SEM

Nanotechnology will enable the production of new materials, structures and devices with social, economic and environmental benefits. However careful risk and safety assessment is needed to ensure these products are safe – not only in their intended product usage but also in the ensuing journey of the product as waste.

This talk will describe a multi partner European Union project, NanoFATE, Nanoparticle Fate, Assessment and Toxicity, which aims to fill gaps in our scientific knowledge and methological arsenal improving our ability to conduct sound safety assessment. We will assess environmental ENP fate and risk in selected high-volume products for which recycling is not an option, namely: fuel additive, personal care and antibacterial products. Market ENPs from each product (CeO_2, ZnO, Ag of varying size, surface and core chemistries) will be followed through their post-production life cycles - from environmental entry as "spent product", through waste treatment to their final fates and potential toxic effects.

While characterisation of nanoparticles in their pure 'as manufactured' form is important for controlled experiments, when added to to any environment – whether simple fresh water or complex media such as soils – they react and modify. So we must not only locate ENPs in different media and also assess their rate of change. NanoFATE partners are applying many different characterisation techniques to analyzing and tracking nanoparticles in different media such as electron microscopy, neutron scattering, coherent anti-stokes Raman scattering (CARS) and X-ray absorption spectroscopy at the Diamond Light Source (UK). The talk will present some of the results to date

The three metal-based ENPs behave differently to the non-nano forms in certain cases, but we are starting to gather evidence that there is little reason to suspect that the use of ENPs will have any widespread deleterious effect in the environment.

T18.2 Clean bipedal nanomotor that mimics biological counterparts in design but draws energy from light (INVITED)

Zhisong Wang

Wednesday, March 06, 11.30 AM, MAS-SEM

Artificial track-walking nanomotors are inspired by biomolecular counterparts from living cells, but remain far from comparable to the latter in design principles. The walkers reported to date mostly rely on chemical mechanisms to gain a direction; they all produce chemical wastes. This paper reports a light-powered DNA bipedal walker based on a design principle derived from cellular walkers. The walker has two identical feet and the track has equal binding sites; yet the walker gains a direction by pure physical mechanisms that autonomously amplify an intra-site asymmetry into a ratchet effect without producing any chemical waste. It has a distinct thermodynamic feature that it possesses the same equilibrium before and after operation, but generates a truly non-equilibrium distribution during operation. The demonstrated design principle exploits mechanical effects for symmetry breaking and direction rectification, hence is adaptable for use in other nanomachines. The walker is advantageous for certain applications, especially biomedical ones, as it is free of chemical wastes, remotely controlled by light, and requires a low-level irradiation within the safety limit of biological tissues.

T18.3 Rapid, High-throughput 3D Tracking of Bacterial Motility using Video Holography (INVITED)

Fook Chiong Cheong

Wednesday, March 06, 12.00 PM, MAS-SEM

Tracking fast swimming bacteria in three-dimensions (3D) can be extremely challenging with current optical techniques. For studying 3D dynamics of fast moving microorganisms, a microscopy technique that can rapidly acquire volumetric information is required. Here, we introduce phase contrast holographic video microscopy as a solution for the high-throughput simultaneous tracking of multiple fast moving cells in 3D. Phase contrast holographic video microscopy makes use of interference patterns formed between the scattered field and the incident field to infer the 3D position and size of individual bacterium. We demonstrated the ability of this method to track motile Escherichia coli and Rhizobium radiobacter bacteria.

T18.4 Conformational Changes of Single DNA Molecule in Nano-channel by Nucleoid Associated Proteins

Durgarao Guttula, Dr Ce Zhang, Dr Johan R C Van Der Maarel, Dr Piravi P Malar, Jeroen A van Kan

Wednesday, March 06, 12.30 PM, MAS-SEM

The typical dimensions of DNA and Cells are in mm's and um, however the macro object is compacted inside of a cell, and performing enormous unique biological activities, nevertheless the origin of this compactness is not completely known. And, it is an urge to discover its origin in both biology as well as physics point of views. In order to hunt for this problem we confined the DNA molecules in nano channels artificially, and thereafter physical properties of DNAs are measured in such confinements.

The nanochannels were first fabricated using proton beam writing in silicon and replicated on PDMS, with the typical dimensions of the channels are in the range of 140–300 nm. We used nucleoid-associated proteins like H-NS, HU, and Hfq, and then measured the extensions of single DNA molecule in various environmental conditions using fluorescence microscopy. Here, we report firmly, that the effects of salt in conjunction with Nano confinement on the conformation of DNA-Protein complex.

Nucleoid-associated proteins (NAPs) are DNA binding proteins, those change the conformation of DNA. Here we used 200nm X 300nm and 250nm X 140nm nano channels, and observed the conformation of DNA-NAP complex. Our observations confirmed the changes are different from the bulk phase experiments. DNA-HNS and DNA-HU show condensation in Nano channels, which is not observed in bulk phase experiments. We also did experiments DNA-Hfq; it shows condensation more easily in Nano channels. In all these experiments we observe strong effect of confinement on these DNA-Protein complexes.

6.19 T19 Nanofabrication I

This session on "Nanofabrication I" will be held on Wednesday, March 06, from 01.30 PM to 03.00 PM. The venue for this session is LT4. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T19.1 Self-Assembly of 2D Colloidal Alloys (INVITED)

Martin Buzza

Wednesday, March 06, 01.30 PM, LT4

We study both experimentally and theoretically the self-assembly of mixed monolayers of hydrophobic and hydrophilic colloidal particles at oil/water interfaces. Experimentally, we find that by tuning the interactions, composition and packing geometry of the mixed monolayer, a rich variety of two-dimensional super-lattice and cluster structures are formed which are stabilised by strong electrostatic interactions mediated through the oil phase. The 2D structures obtained are in excellent agreement with zero temperature calculations and finite temperature simulations, indicating that the self-assembly process can be effectively controlled for the creation of novel 2D structures.

T19.2 "Plasma Nanotechnology" using Non-conventional Plasma Sources (INVITED)

Rajdeep Singh Rawat

Wednesday, March 06, 02.00 PM, LT4

The plasmas based and plasma assisted processes, popularly referred as "Plasma Nanotechnology", have become one of the most versatile tools of nanoscale fabrication as plasmas provide a complex, reactive and far from equilibrium chemical factory. The plasmas used in plasma nanotechnology are essentially the low temperature plasmas with densities varying over a very wide range from 10^{13} to $10^{23}\,\mathrm{m}^{-3}$ and conventionally most commonly used plasmas are created using continuous ac or dc electric gas discharge or by continuous gas discharges initiated by RF or microwave electromagnetic fields. This paper will present a review of two non-conventional plasma sources for plasma nanotechnology. The first part will concentrate on high energy density dense plasma focus (DPF) device which offers a complex mix of high energy ions of the filling gas species, immensely hot and dense decaying plasma, fast moving ionization wave-front and a strong shockwave that provides a unique plasma and physical/chemical environment that is completely unheard of in any other conventional plasma based deposition or processing facility. The nanoscale fabrication using DPF device will be elaborated and discussed in two broad categories: (i) top-down nanoscale fabrication by processing of bulk or thin film target materials that is placed downstream the anode axis, and (ii) bottom-up nanoscale fabrication by deposition of nanostructured thin films of metals and/or their nitrides, carbides and oxides by ablating the metal fitted on to the anode top under suitable reactive or inert background plasma. The second part will focus on nanoscale fabrication using atmospheric microplasmas. The atmospheric microplasmas represent a special class of electrical discharges formed in geometries where at least one dimension is reduced to sub-millimetre length scales. The processing of thin films or discharges on liquid surfaces of electrolyte, using atmospheric microplasmas, for inducing nano-structures on thin films and synthesizing nanoparticles in electrolytic solutions or on substrate will be discussed.

T19.3 Direct Fabrication of Ordered Hybrid Nanostructure Arrays Using Ion-Sputtering (INVITED)

Yizhong Huang

Wednesday, March 06, 02.30 PM, LT4

Hybrid nanostructure is a material system consisting of two or more nanostructures that allows the significant property enhancement for individual nano-components. More recently, the ability to produce hybrid nanostructures has been of growing interest worldwide. Due to the difficulty of control during their fabrication, most available hybrid nanostructures, at present, are generally arranged in a random order leading to the significant degeneration of performance in comparison with the perfectly-ordered hybrid nanostructures. Thus, it is reasonable that there have been very few reports of methods on the fabrication of the ordered hybrid nanostructures. Notwithstanding, these methods require mask/template and involve a fairly complex procedure during the fabrication although the production of the ordered non-hybrid nanostructures has been well established. Recently, we have discovered a special material system that allows the self-organization of a unique hybrid nanonipple structure, consisting of a nanoneedle with a small nanodot sitting on the top. Such hybrid nanonipples provide building blocks to assemble functional devices with the significantly-improved performances.

6.20 T20 Solid State Physics

This session on "Solid State Physics" will be held on Wednesday, March 06, from 01.30 PM to 03.00 PM. The venue for this session is MAS-EX2. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T20.1 Ultrafast Photoinduced Insulator-Metal Phase Transition in VO2 Probed with Terahertz Spectroscopy (INVITED)

Xinhai Zhang

Wednesday, March 06, 01.30 PM, MAS-EX2

The insulator-metal transition in metal oxides has attracted a great deal of research. However, the physical mechanism of the phase transition is still under debate in many systems. Interestingly, the insulator-metal transition can not only be induced thermally but also optically in an ultrafast time scale. This phenomenon has been demonstrated in some material systems, such as manganite, organic conductors and spin-crossover complexes. Converting the phases of the materials by light excitation is very important and useful not only in fundamental physics but also in applications. Vanadium dioxide (VO2) is a typical example that has attracted considerable attention for fundamental reasons as well as for possible applications. VO2 exhibits a reversible, first-order insulator-metal phase transition at Tc $\approx$340 K. The transformation is associated with a structural transition, from a low-temperature monoclinic crystal structure, in which the material is insulator, to a high-temperature rutile crystal structure, in which the material is metallic. Using terahertz spectroscopy, we study the dynamic behavior of the photoinduced insulator-metal phase transition in VO2. It was found that the photoinduced phase transition in VO2 consists of a fast and a slow process. The fast process is a nonthermal driven process, corresponding to photodoping and nucleation of metal phase. The slow process is a thermally driven process, corresponding to growth and coalescence of metal domains. We also studied the effects of the oxygen stoichiometry on the insulator-metal phase transition in VO2. We found a strong correlation between photoinduced phase transition and oxygen stoichiometry. The increased oxygen content in vanadium dioxide will reduce the magnitude of phase transition. Our results help improve the understanding of the physics of the photoinduced insulator-metal phase transition, optimize the growth condition of VO2 thin films, and are useful for the design of VO2 based optical devices.

T20.2 Evolution of Topological Surface States in Antimony Ultra-Thin Films (INVITED)

Xuesen Wang, Guanggeng Yao, Ziyu Luo, Feng Pan, Wentao Xu, Jiatao Sun

Wednesday, March 06, 02.00 PM, MAS-EX2

Based on an inverted bulk band order, antimony thin films presumably could become topological insulators if quantum confinement effect opens up a gap in the bulk bands. Coupling between topological surface states (TSSs) from nearby surfaces, however, tends to degrade or even destroy their novel characters (e.g., spin polarisation). We investigate the evolution of TSS on Sb(111) thin films and their inter-surface coupling as the thickness is reduced from 30 bilayers (BL, 1 BL = 3.75 Å) to 4 BL using in-situ Fourier-transform scanning tunneling spectroscopy (FT-STS) and density functional theory computations. Due to strong distortion in TSS Dirac cone, rich quasi-particle interference (QPI) patterns have been observed in FT-STS mapping. On a 30-BL sample, these patterns are generated by the scattering of TSS from the top surface only. As the thickness decreases, inter-surface coupling degrades spin polarisation of TSS and opens up new scattering channels which show as additional features in the QPI patterns. The strength of inter-surface coupling is found varying dramatically with the wavevector, resulting in spin degenerate states in a large part of the surface Brillouin zone, whereas the TSS survive near the zone centre without opening a gap at the Dirac point for films thickness >6 BL. Our results also demonstrate quite different behaviors among SSs, surface resonances, and bulk states as the film changes from thick to ultrathin category. Based on the understanding of these behaviors, the surface energetic and transport properties of Sb films can be tailored for potential applications.

References: [1] D. Hsieh et al., "Observation of unconventional quantum spin textures in topological insulators," Science 323, 919 (2009). [2] K. K. Gomes et al., "Quantum imaging of topologically unpaired spin-polarized Dirac fermions," e-print arXiv:0909.0921 (2009). [3] Y. Zhang et al., "Crossover of the three-dimensional topological insulator Bi2Se3 to the two-dimensional limit," Nature Phys. 6, 584 (2010). [4] G. Bian, T. Miller, T.C. Chiang, Passage from Spin-Polarized Surface States to Unpolarized Quantum Well States in Topologically Nontrivial Sb Films. Phys. Rev. Lett. 107, 036802 (2011)

T20.3 Recent Advances in LaAlO3/SrTiO3 Interfaces (INVITED)

Ariando

Wednesday, March 06, 02.30 PM, MAS-EX2

In the last ten years, atomically controlled oxide interfaces and heterostructures have attracted a great deal of attention because of the large number of emerging properties that these systems can offer which cannot exist in the bulk. These properties are believed to emerge due to the strong correlation and interplay between charge, spin and orbital degree of freedom at the interface between these complex oxides. The capability to control the interfaces and heterostructures at an atomic level provide a way to disturb or modify these correlations, leading to the new emerging properties. In particular, the interface between polar and nonpolar nonmagnetic insulating oxides LaAlO3 and SrTiO3 has been shown to exhibit various electronic and magnetic phases such as two dimensional electron gas, superconductivity, magnetism and electronic phase separation. In this talk I will discuss our progress in understanding this interface system and the current status of this field.

6.21 T21 Novel Nanomaterials

This session on "Novel Nanomaterials" will be held on Wednesday, March 06, from 01.30 PM to 03.00 PM. The venue for this session is MAS-SEM. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T21.1 Novel materials for organic optoelectronics: from graphene to near-infrared polymers (INVITED)

Giulia Tregnago, Emanuele Treossi, Vincenzo Palermo, Franco Cacialli

Wednesday, March 06, 01.30 PM, MAS-SEM

Organic and polymeric light-emitting diodes (OLEDs) and polymeric solar cells (OPVs) have attracted significant interest for application in low-cost and flexible devices. However, further investigation on materials to improve performance and to extend the spectral working range beyond the visible spectrum is required. In particular, graphene oxide (GO), a graphene derivative with functional groups such as carboxylic acids, epoxides and hydroxide, has been demonstrated to be an effective hole transport layer in organic optoelectronics as an additive and/or replacement of poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate) (PEDOT-PSS)[1,2]. We report OLEDs with a blend of GO and PEDOT-PSS as hole transport layers that show a higher light output compared to OLEDs with PEDOT-PSS. Concerning OLEDs, most efforts have been directed towards emission in the visible spectral range. Nevertheless, a near-infrared (NIR) emission would be of interest for a variety of applications, e.g., optical communication, night-vision devices, medical science. Various approaches have been explored for obtaining infrared emission, in particular our group has been working on organic molecules and polymers, e.g., linear and cyclic porphyrin hexamers[3], diketopyrrolopyrrole[4], cyclopentadithiophene-based polymers[5]. Here we report some example of OLEDs incorporating NIR emitting materials.

[1] Lee, B. R., et al. "Highly Efficient Polymer Light-Emitting Diodes Using Graphene Oxide as a Hole Transport Layer." ACS nano, (2012) 6(4), 2984-2991.

[2] Li, S. S., et al. "Solution-processable graphene oxide as an efficient hole transport layer in polymer solar cells." ACS nano, (2010) 4(6), 3169-3174

[3] Fenwick, O., et al. (2011). Linear and Cyclic Porphyrin Hexamers as Near-Infrared Emitters in Organic Light-Emitting Diodes. Nano letters, 11(6), 2451-2456.

[4] Stas, S., et al. (2013). Straightforward access to diketopyrrolopyrrole (DPP) dimers. Dyes and pigments.

[5] Li, P., et al. (2011). Dual functions of a novel low-gap polymer for near infra-red photovoltaics and light-emitting diodes. Chemical Communications, 47(31), 8820-8822.

T21.2 Controlled Growth and Applications of Nanoscale Materials (INVITED)

Chorng Haur Sow

Wednesday, March 06, 02.00 PM, MAS-SEM

Nanoscale materials have attracted great interests in recent years. One-dimensional and two-dimensional nanostructures such as nanowires, nanorods, nanowalls, nanosheets, and nanojunctions or networks are an important category of nanostructured materials with great potential as important components for nanoscale devices with various interesting functions. Thus, in the past decade, many techniques have been developed for the synthesis of such nanostructured materials. Some examples of these techniques include chemical vapor deposition, vapor-liquid-solid growth, vapor-solid growth, oxide-assisted growth, carbothermal synthesis, hydrothermal growth and etc. With these methods, one can synthesize a wide variety of nanostructured materials including binary and ternary II-VI alloys, hierarchical metal oxide and etc. In addition to the above mentioned techniques, a wide variety of nanoscale metal oxide materials with fascinating morphologies can be synthesized by heating pure metallic foils or wires in appropriately controlled atmospheres. Many of these nanoscale material exhibits unique properties rendering them potentially attractive materials for possible applications. In this report, we will present our recent efforts in the growth and characterizations of these nanoscale materials with emphasis of the growth mechanism and potential applications of these nanoscale materials.

References: [1] “Reduced Graphene Oxide Conjugated Cu2O Nanowire Mesocrystals for High-Performance NO2 Gas Sensor” J. Am. Chem. Soc. 2012, 134, 4905-4917, Deng, S; Tjoa, V; Fan, HM; Tan, HR; Sayle, D. C.; Olivo, M.; M., Subodh; Wei, J.; Sow, CH [2] “K-Enriched MoO3 Nanobundles: A Layered Structure with High Electric Conductivity” J. Phys. Chem. C, 2012, 116, 3962-3967, Hu, Z.; Zhou, C.; Zheng, M.; Lu, J.; Varghese, B.; Cheng, H.; Sow, CH [3] “Optical and electrical applications of ZnSxSe1-x nanowires-network with uniform and controllable stoichiometry”, Nanoscale, 2012, 4, 976-981, Lu, J.; Liu, H.; Sun, C.; Zheng, M.; Nripan, M.; Chen, G.S.; Subodh, G. M.; Zhang, X.; Sow, CH [4] “Facile One-Step Synthesis of CdS(x)Se(1-x) Nanobelts with Uniform and Controllable Stoichiometry”, J. Phys. Chem. C, 2011, 115, 19538-19545, J., Lu; C., Sun; M., Zheng; M., Nripan; H., Liu; GS, Chen; X., Zhang; M.G., Subodh; CH Sow [5] “Photothermoelectric Effects in Localized Photocurrent of Individual VO(2) Nanowires” J. Phys. Chem. C, 2010, 114, 15149-15156, Varghese, B., Tamang, R., Tok, ES, M.G., Subodh G, Sow, CH [6] “Structure-Mechanical Property of Individual Cobalt Oxide Nanowires”, Nano Lett. 2008, 8, 3226-3232, Varghese, B., Zhang, YS, Dai, L., Tan, V. B. C. Lim, CT, Sow, CH [7] “Nb2O5 nanowires as efficient electron field emitters”, J. Phys. Chem. C 2008, 112, 10008-10012, Varghese, B., Sow CH, Lim CT [8] “WO3-x nanorods synthesized on a thermal hot plate”, J. Phys. Chem. C, 2007, 111, 17193-17199, Cheong, Fook Chiong , Varghese, B., Zhu, YW, Tan, E.P.S., Dai, L., Tan, V. B. C. , Lim, C.T., Sow, CH [9] “alpha-Fe2O3 nanoflakes as an anode material for Li-ion batteries”, Adv. Funct. Mater. 2007, 17, 2792-2799, Reddy, M. V. , Yu, T., Sow, CH, Shen, ZX, Lim, CT, Rao, G. V. S., Chowdari, B. V. R. [10] “Co3O4 nanostructures with different morphologies and their field-emission properties”, Adv. Funct. Mater. 2007, 17, 1932-1939, Varghese, B., Teo, CH, Zhu YW, Reddy, MV, Chowdari, B.V.R., Wee, ATS, V., Tan B. C. , Lim, CT, Sow, CH [11] “Co-synthesis of ZnO-CuO nanostructures by directly heating brass in air”, Adv. Funct. Mater. 2006, 16, 2415-2422, Zhu, Y, Sow, CH, Yu, T, Zhao, Q, Li, P., Shen, ZX, Yu, D., Thong, J.T.L [12] “Controlled growth and field-emission properties of cobalt oxide nanowalls” Adv.

Mater. 2005, 17, 1595, Yu T, Zhu YW, Xu XJ, Shen ZX, Chen P, Lim CT, Thong JTL, Sow CH.

T21.3 Length-Independent Transmission Peaks in Nanostructured AGNR-Junctions

Suchun Li, Chee Kwan Gan, Young-Woo Son, Yuan Ping Feng, Su Ying Quek

Wednesday, March 06, 02.30 PM, MAS-SEM

The prospect of all-carbon nanoelectronics has motivated significant interest in the transport of electrons through graphene nanoribbon (GNR) junctions. Bottom-up synthesis approaches now offer atomic control over the widths of armchair edge GNRs (AGNR) [1] while top-down lithographic methods offer possibilities of creating nanostructured GNR junctions [2]. In this work, we explore, using first principles scattering state [3] and Non-Equilibrium Green's Function [4] approaches, electron transport through nanostructured AGNR junctions, in which the central scattering region consists of an AGNR connected seamlessly to wider AGNRs (which make up the two electrodes of the junction). At the interface between the central AGNR segment and the wider AGNR electrodes, the armchair edges of the narrower and wider AGNRs are joined by either zigzag edges or armchair edges (the two most stable edge configurations). We show that when both interfaces have zigzag edges, transmission near the Fermi level is dominated by resonant transmission peaks whose energies are, contrary to expectation, independent of the length of the central AGNR region. We demonstrate that these peaks arise from interactions between a new class of "zigzag-edge + narrow-AGNR" states, and discuss why the energies of these peaks are length-independent. We also predict that these peaks are useful in producing negative difference resistance.

[1] S. Linden et al., Phys Rev Lett 108, 216801 (2012) [2] L. Tapaszto et al., Nature Nanotechnology, 3, 397 (2008); X. Wang et al., Nature Chemistry 2, 661 (2010) [3] H. J. Choi et al., Phys Rev B, 76, 155420 (2007) [4] M. Brandbyge et al., Phys. Rev. B 65,165401 (2002)

T21.4 Tailoring the Lasing Wavelength in Semiconductor Nanowires using Intrinsic Self-absorption

Xinfeng Liu, Qing Zhang, Qihua Xiong, Tze Chien Sum

Wednesday, March 06, 02.45 PM, MAS-SEM

Understanding the optical gain and mode-selection mechanisms in semiconductor microcavities is key to the development of high-performance nanoscale oscillators, amplified semiconductor/plasmon lasers and single photon emitters, etc. Modification of semiconductor band structure/bandgap through electric field modulation, elemental doping or alloying semiconductors has so far gained limited success in achieving output mode tunability of the microcavities. One stifling issue is the considerable optical losses induced in the microcavities by these extrinsic methods that limit their applicability. Herein we demonstrate a new optical self-feedback mechanism based on the intrinsic self-absorption of the gain media to achieve low-loss, room-temperature nanowire (NW) lasing with a high degree of mode selectivity (over 30 nm). The cadmium sulfide (CdS) NW lasing wavelength is continously tunable from 489 nm to 520 nm as the length of the NWs increases from 4 µm to 25 µm. Our straightforward approach is widely applicable in most semiconductor or semiconductor/plasmonic microcavities.

6.22 T22 Nanofabrication II

This session on "Nanofabrication II" will be held on Wednesday, March 06, from 03.30 PM to 04.45 PM. The venue for this session is LT4. Time allocated for invited talks is 25 min speaking time, plus 5 min questions, and time allocated for contributed talks is 12 min speaking time plus 3 minutes questions.

T22.1 Nanoscience Research and Graduate Training at the University of Bristol (INVITED)

Annela Seddon

Wednesday, March 06, 03.30 PM, LT4

In the last 5 years, the University of Bristol has seen the completion of its dedicated Centre for Nanoscience and Quantum Information Building, a dedicated facility with world class low-noise laboratory space custom designed to house cutting-edge nanoscience research. Also housed within the facility is the Bristol Centre for Functional Nanomaterials; a GBP7M centre for doctoral training whose remit is to produce the next generation of interdisciplinary graduate nanoscientists. I will introduce the facilities and opportunities currently available within Bristol in the area of nanoscience and highlight some current research areas which span chemistry, physics, engineering and the medical sciences. These will include applications in microfluidics, self-assembly and bio-inspired structures.

T22.2 A Novel Approach for High Performance InAs FinFETs on Silicon

Xing Dai, Yoontae Hwang, Binh-Minh Nguyen, Wei Tang, Cesare Soci, Shadi A. Dayeh

Wednesday, March 06, 04.00 PM, LT4

Since its invention in the late 1940s, the semiconductor transistor, the building block of all nowadays electronic devices, has reduced in size by over a million times, thereby increasing density and functionality while simultaneously reducing chip power consumption and production costs, and its speed of operation increased by over a billion times. Si CMOS performance boosters such as stressors, high-k dielectrics, metal gates, and recently FinFET architectures have allowed Si to deliver performance not inherent to its material capabilities. A viable approach for cultivating enhanced performance per unit area is the heterointegration of the higher capable III-V materials on a Si platform. Hybrid integration using wafer bonding is a potential route for such integration. However, popular wafer bonding techniques such as smart-cut, BCB, and epitaxial lift-off require high processing costs and has limited thermal budget. We have developed a fab-compatible process that allows integration of III-V materials to Si and (i) is CMOS compatible, (ii) has a wide thermal budget, (iii) can be applied to patterned substrates, and (iv) overcomes the shortcomings of eutectic bonding and the high costs and limitations of smart-cut and epitaxial lift-off. This bonding technique relies on the formation of a nickel-silicide layer at a temperature as low as 300 °C and can applied to a wide range of bonded materials with the insertion of thin dielectric layer between the Si and the bonded structure. We have utilized this integration scheme to fabricate 3D InAs FinFET transistors with deeply scaled dimensions down to 20 nm.

T22.3 DEVELOPMENT OF LOW ENERGY PLASMA FOCUS DEVICE AS A SOFT X-RAY SOURCE FOR APPLICATION IN X-RAY LITHOGRAPHY

S. M. P. Kalaiselvi, T. L. Tan, Alireza Talebitaher, Lee Paul, Rajdeep Singh Rawat

Wednesday, March 06, 04.15 PM, LT4

Physical configuration of the electrodes and filling gas pressure are the major factors determining the SXR emission from the dense plasma focus device. Furthermore, admixture of high-Z impurity ions to the plasma gas also influences the SXR emission from the device. Hence, a detailed investigation on the neon soft X-ray (SXR) emission characteristics of a Fast Miniature Plasma Focus (FMPF-3) device has been performed through optimization of geometrical configurations of anode, filling gas pressure and the proportion of admixture gas to be added to the plasma gas and there-by make it a potential source for SXR lithography. The device used for our experiment is of sub-kilojoule (100 - 240 J) energy capacity which is an order of magnitude lesser than the other well established plasma focus devices on which most of the neon x-ray emission studies have been performed. The highest SXR yield achieved so far was 1.2 J/shot, corresponding to a wall plug efficiency of 0.6%.

T22.4 Free-standing Large Area Single Crystalline Ultra Thin Silicon Membrane: Application in Ion Channeling

Mallikarjuna Rao Motapothula

Wednesday, March 06, 04.30 PM, LT4

We fabricated a $\approx 2\times2\,\mathrm{mm}^2$ large area free standing 55 nm thick [001] single crystalline Silicon membranes recently using a polymer based mask for KOH etching for the first time and achieved low roughness, defect free crystals for ion channeling applications.

However, as the membranes are ultra-thin and having very large areas, they do get bend. We quantified the bend angle, it typically varies by 0.05°for a 25 µm lateral distance nevertheless, they are sufficiently flat to perform ion channeling experiments using a focused MeV proton beam from a nuclear microprobe at the CIBA accelerator laboratory.

After fabrication and characterization of those membranes, we explored axial and planar ion channeling phenomena in the early stage of its motion. Such studies confirm many simulations previously done in the past 25 years and provide experimental evidence to the existence of the super focusing effect, which can then be used in Subatomic/nuclear Microscope.

This new fabrication process opens a route to a better understanding of ion channeling phenomena under highly non-equilibrium conditions.

We are looking for other applications (welcome for collaboration) using these ultra thin crystalline membranes.

7 Symposium on disruptive photonic technologies

In conjunction with the recent opening of the Centre for Disruptive Photonic Technologies (CDPT), a dedicated symposium together with guests from Southampton will be held together with the IPS meeting on the third day.

7.1 SY1 Structural nano-control for enhanced photonic functionalities

This session on "Structural nano-control for enhanced photonic functionalities" will be held on Wednesday, March 06, from 09.00 AM to 10.36 AM. The venue for this session is MAS-EX1. Time allocated for all talks in this Symposium is 20 minutes presentation, plus 2 minutes discussions.

SY1.1 Nanomechanical control of metamaterial optical properties (INVITED)
Eric Plum, Jun-Yu Ou, João Valente, Jianfa Zhang, Nikolay Zheludev

Wednesday, March 06, 09.00 AM, MAS-EX1

Dynamic control over metamaterial optical properties is the basis for active metamaterials devices from optical switches and modulators to tunable spectral filters and programmable transformation optics devices.

Here we demonstrate that reconfigurable photonic metamaterials provide a flexible platform for fast dynamic control of metamaterial optical properties. The properties of virtually any metamaterial structure strongly depend on the spatial arrangement of its components. By manufacturing plasmonic metamaterials on a grid of elastic dielectric strings of nanoscale thickness, we are able to dynamically rearrange plasmonic building blocks of sub-micron size across the entire metamaterial array. We demonstrate that this approach allows tuning, modulation and switching of photonic metamaterials via (i) applied electric voltages of a few volts, (ii) currents of a few milliamperes and (iii) magnetic fields of about 100 millitesla.

Electrostatic forces become large across nanoscale gaps while elastic restoring forces are small in nanoscale structures. Exploiting this, we electromechanically modulate the optical properties of reconfigurable photonic metamaterials at a rate of up to 20 megahertz at microwatts power consumption. We also achieve electro-optic switching with a contrast of up to 250% and a switching energy of only about 100 femtojoules.

Resistive heating of bimaterial structures leads to their deformation due to differential thermal expansion. Additionally, electrical currents in metamaterial structures placed in a magnetic field will be subject to the Lorentz force. Exploitation of these phenomena allows us to electromechanically modulate the optical properties of photonic metamaterials with a contrast of up to 60%.

 This work is part funded by the Ministry of Defence and is published with the permission of the Defence Science and Technology Laboratory on behalf of the Controller of HMSO.

SY1.2 Photocurrent generation based on TiO2 inverse opals (INVITED)
Hongjin Fan, Jingshan Luo, Siva Krishna Karuturi, Alfred Iing Yoong Tok

Wednesday, March 06, 09.22 AM, MAS-EX1

TiO2 nanostructures are being extensively studied for the solar energy applications, such as DSSC, QDSSC, photocatalysts and solar water splittings. When working as photoelectrodes in these energy devices, TiO2 nanomaterials with tailored structural complexity and appropriate heterojunction formation will provide new pathways to enhance the performance. My talk will start with introduction of photo-to-current conversion based on semiconductor nanostructures, namely, photoelectrochemical (PEC) electrode materials. Then I will elaborate our work on the design of 3D TiO2 inverse opals, and its smart combination with 1D nanorods. The light harvesting and photocurrent properties will be discussed. A novel method by combining atomic layer deposition and ion exchange reaction (ALDIER) towards homogeneous coating of photosensitzer on arbitrary TiO2 substrates will be introduced.

SY1.3 Super high-order plasmon modes in nanostructures and their application in plasmonic biosensors (INVITED)

Hailong Liu, Zilong Wang, Cesare Soci, Ning Xiang

Wednesday, March 06, 09.44 AM, MAS-EX1

Since the extraordinary optical transmission properties of nanoholes were demonstrated in 1998, plasmonics has become a vast discipline and found many potential applications: plasmonic biosensing is one of the most promising. How to improve the biosensitivity and resolution of plasmonic biosensors is one of the most important problems. Higher order plasmon modes of nanostructures have high quality factor, and thus they can be used to realize supersensitive biosensors. Here, we will present our new progress about the application of super high-order plasmon modes (hexadecapole and triakontadipole) of nanostructures in ultrasensitive biosensors.

SY1.4 Structural Phase Change Functionality in Photonic Metamaterials (INVITED)

Kevin F. MacDonald, Jianfa Zhang, Behrad Gholipour, Daniel W. Hewak, Nikolay I Zheludev

Wednesday, March 06, 10.06 AM, MAS-EX1

The next phase of the photonic technological revolution will be driven by the development of switchable and nonlinear metamaterials, with properties surpassing those of natural media, as functional platforms for nanoscale all-optical data processing 'meta-devices'. We report here on recent advances in the development of versatile, planar photonic metamaterial solutions to provide a new generation of nanoscale optical switching and memory devices: Optically-induced phase transitions in germanium antimony telluride (GST) – a member of the chalcogenide alloy family upon which re-writable optical disc and phase-change RAM technologies are based – provide for the engineering of non-volatile metamaterial transmission/reflection modulators for the near- to mid-infrared range with thicknesses down to 1/27 of the operating wavelength; Dielectric optomechanical metamaterials, wherein optical forces drive spatial rearrangements of the structural elements, offer a new paradigm (which is inherently free of Joule losses) for achieving strong optical nonlinearity, optical bistability and asymmetric transmission at intensity levels of only a few hundred $\mu W/\mu m^2$.

7.2 SY2 A fresh look at photonic surface

This session on "A fresh look at photonic surface" will be held on Wednesday, March 06, from 11.00 AM to 12.36 PM. The venue for this session is MAS-EX1. Time allocated for all talks in this Symposium is 20 minutes presentation, plus 2 minutes discussions.

SY2.1 Limitations and solutions in cloaking of propagating and surface electromagnetic waves (INVITED)

Baile Zhang

Wednesday, March 06, 11.00 AM, MAS-EX1

Cloaking research has trigged a lot of efforts to develop novel wave manipulation strategies whose solutions can be potentially used in various applications. In this talk, I will introduce our recent progress in this research field. Firstly, as is well-known, the superluminal propagation is the main limitation of cloaking phenomena. We will first introduce how to implement an invisibility cloak without superluminal propagation. Secondly, we will talk about how to cloak sharp corners and obstacles for surface electromagnetic waves. Both of them are of significance to solve realistic challenges in related applications.

SY2.2 Mesoscopic transport and light trapping by very strong collective scattering in nanowire nanophotonic media (INVITED)

Otto Muskens, Tom Strudley, Erik Bakkers, Duygu Akbulut, Allard Mosk

Wednesday, March 06, 11.22 AM, MAS-EX1

Semiconductor nanowire mats are important new materials for applications in light emission and solar cells. Nanowires mats are amongst the strongest scattering materials in the world, with a mean free path significantly smaller than visible wavelengths. With light being scattered multiple times within the space of one wavelength, the crossing probability of light paths within the medium is dramatically increased. This presents the exciting opportunity to demonstrate clear mesoscopic effects for light. Using methods from statistical optics, we show that transport through dense GaP nanowire mats is governed by only a small number of open transmission channels. As a consequence, the light transmitted through such mats is characterized by large intensity fluctuations and strong long-range correlations. In addition, we measured optical transmission matrices of the nanowire mats, which reveal the presence of correlations in the transmitted fields. By comparing the measured matrices with a theoretical reconstruction based on random matrix theory, we are able to retrieve the optical properties of the samples.

SY2.3 Optical Topological Insulator Realized With Ring Resonators (INVITED)

Guanquan Liang, Yidong Chong

Wednesday, March 06, 11.44 AM, MAS-EX1

A lattice of optical ring resonators can act as a photonic topological insulator, with the resonator mode's direction of rotation playing the role of spin. We describe the band structure and phase diagram, and demonstrate the existence of robust edge states using transfer matrix and FDTD simulations. When gain and loss are introduced, the system functions as an optical diode for coupled resonator modes.

SY2.4 Cooperative Responses of Metamaterial Systems: Manipulating light using interactions between electromagnetic emitters (INVITED)

Stewart Jenkins, Janne Ruostekoski

Wednesday, March 06, 12.06 PM, MAS-EX1

How electromagnetic (EM) radiation propagates through matter ultimately depends on how individual emitters interact with the EM field. In many circumstances, the EM properties of a material are well described by an effective medium theory. In finite or irregular metamaterials, or even cold atomic gases, however, the discrete nature of the emitters can become apparent. Recurrent scattering, in which the same photon repeatedly scatters from the same emitter, leads to collective interactions within the material that can be exploited to manipulate light [2-5].

In this talk, we will discuss how the EM field scattered between emitters mediates interactions between them, leading to a cooperative material response. We present a theoretical formalism developed to model collective interactions in metamaterials [1]. One can exploit this formalism to show how collective effects can lead to phenomena such as light localization in either two-dimensional optical lattices [2] or metamaterial arrays [3]. These effects arise from the formation of collective modes of excitation distributed though out the material sample, each with a particular resonance frequency and decay rate.

Here, we will show how an experimentally observed transmission resonance through a planar metamaterial emerges from interactions with a particular subradiant mode phase matched with an incident field [4]. The lifetime of this mode varies with the size of the system, in excellent agreement with previously reported experimental observations [5]. This phenomenon is reminiscent of electromagnetically induced transparency where the dark mode of single atomic emitters has been replaced by a collective dark mode whose existence depends on interactions between emitters distributed over the whole of the metamaterial.

[1] S. D. Jenkins and J. Ruostekoski, Phys. Rev. B 86, 085116 (2012). [2] S. D. Jenkins and J. Ruostekoski, Phys. Rev. A 86, 031602 (2012). [3] T. S. Kao, S. D. Jenkins, J. Ruostekoski and N. I. Zheludev, Phys. Rev. Lett. 106, 085501 (2011). [4] S. D. Jenkins and J. Ruostekoski, New Journal of Physics 14, 103003 (2012). [5] V. A. Fedotov et al, Phys. Rev. Lett. 104, 223901 (2010).

7.3 SY3 Nanofabrication-enhabled novel phenomena and applications

This session on "Nanofabrication-enhabled novel phenomena and applications" will be held on Wednesday, March 06, from 01.30 PM to 03.06 PM. The venue for this session is MAS-EX1. Time allocated for all talks in this Symposium is 20 minutes presentation, plus 2 minutes discussions.

SY3.1 Plasmonic amplification of free-electron evanescent fields (INVITED)

Jin-Kyu So, Jun-Yu Ou, Giorgio Adamo, Javier García de Abajo, Kevin F. MacDonald, Nikolay I Zheludev

Wednesday, March 06, 01.30 PM, MAS-EX1

We show experimentally for the first time that free-electron evanescent fields can be amplified by a plasmonic nanolayer in a manner analogous to the way in which optical fields are amplified in the poor-man's superlens.

The manipulation of evanescent electromagnetic fields has been a key motivation in the field of plasmonics. However, one class of evanescent field has been excluded from consideration here - the evanescent field of moving free electrons. The electromagnetic energy of free electrons exists in the form of evanescent waves and it can be out-coupled to light only when the electrons are in close proximity to a 'slow-wave medium' or optical inhomogeneity. The former causes the well-known phenomenon of Cerenkov radiation, the latter diffraction or Smith-Purcell radiation. Here, in analogy to the 'poor-man's superlens', wherein the evanescent component of light from an object is restored by a thin silver layer to beat the diffraction limit, we demonstrate the use of an intermediate silver layer to amplify the free-electron evanescent field before it is out-coupled into light by a nano-grating. The presence of a silver layer provides for the excitation of phase-velocity matched surface plasmons, and leads to the amplification of the electrons' evanescent field.

SY3.2 Super-oscillatory Optical Needle for Heat Assisted Magnetic Recording (INVITED)

Guanghui Yuan, Edward R F Rogers, Zexiang Shen, Nikolay I Zheludev

Wednesday, March 06, 01.52 PM, MAS-EX1

Hard drive technology is starting to approach the superparamagnetic limit which threatens the approximate doubling of magnetic disk data density every two year that has historically been achieved. Heat assisted magnetic recording (HAMR) is one of the leading technologies in development to beat this limit. Currently, the preferred technology for applying heat to the platter is tapered plasmonic waveguides which suffers from considerable manufacturing challenges.

The super-oscillatory lens (SOL) is a promising technology for subwavelength focusing and imaging beyond the near field and provides an alternative to plasmonic focusing. However, use of the hotspots in some applications is limited by the presence of sidebands in the region of the spot owing to the intrinsic characteristics of super-oscillation. We have recently shown that a new type of SOL, the optical needle SOL (ONSOL), can focus light into a subwavelength needle well separated from any sidebands. This separation allows easy separation of the sidebands from the spot using an aperture, provided that the magnetic disk is maintained within the near-field of the immersion medium and aperture. Previously, spots of around λ/3 were experimentally achieved, but for HAMR applications, spots of around 40 nm are needed. Using the commercially available diode laser wavelength of 473 nm, we are able to produce a focal spot of FWHM 51 nm, separated by 6μm from the nearest sidebands of significant intensity, by combining the ONSOL with a gallium phosphide solid immersion lens with a high refractive index $n = 3.72449 + 0.01002i$ at the operating wavelength. This spot can be used for heating of the magnetic disk in HAMR. The coupling of light emerging from the solid immersion medium into the magnetic disc needs to be more fully investigated, but we do not anticipate this causing a significant problem.

SY3.3 Tesla Magnetic Pulses by Optical Excitation of Plasmonic Nanostructures (INVITED)

Evangelos Atmatzakis, Anagnostis Tsiatmas, Nikitas Papasimakis, Vassili A. Fedotov, Boris Luk'Yanchuk, Javier García de Abajo, Nikolay Zheludev

Wednesday, March 06, 02.14 PM, MAS-EX1

Magnetic sources with high spatial and temporal resolution are crucial in order to study and understand ultrafast magnetic phenomena. However, there is currently no practical method that meets these criteria. Here we introduce a metamaterial source that allows for direct generation of ultrafast Tesla-scale magnetic pulses localized at the nanoscale.

SY3.4 Towards integrated optics at the nanoscale : examples of quantum nanodevices (INVITED)

Christophe Couteau

Wednesday, March 06, 02.36 PM, MAS-EX1

In the last 10 years, and especially in the last 5 years, the field of nanooptics has experienced a huge development for various applications such as sensing, telecommunication, quantum information or biophysics. This emerging field has a great potential for applied physics as well as for testing fundamental laws of physics. In this seminar I will review briefly the possibility of integrating optics for quantum devices and in particular using plasmonics which allows us to scale down to the nanometer range, usually forbidden by standard laws of optics. I will describe recent experiments showing that quantum systems can also be scale down to nanometer size. In particular, I will develop recent results towards two quantum nanodevices which are an ultimate integrated single photon source and a semiconductor nanowire-based single photon detector.

7.4 SY4 THz and lasers

This session on "THz and lasers" will be held on Wednesday, March 06, from 03.30 PM to 05.06 PM. The venue for this session is MAS-EX1. Time allocated for all talks in this Symposium is 20 minutes presentation, plus 2 minutes discussions.

SY4.1 Superconducting metamaterial bolometer for harvesting the sub-THz radiation (INVITED)

Vassili A. Savinov, Vassili A. Fedotov, Peter A. J. de Groot, Nikolay I Zheludev

Wednesday, March 06, 03.30 PM, MAS-EX1

We demonstrate a sub-THz superconducting metamaterial bolometer with selective response that exploits inter-molecular electromagnetic interactions in the electrically interconnected network of superconducting resonators, and superconducting phase-transition edge sensitivity of the electrical interconnect.

SY4.2 Single-mode surface-emitting concentric-circular-grating terahertz quantum cascade lasers (INVITED)

Guozhen Liang, Qijie Wang

Wednesday, March 06, 03.52 PM, MAS-EX1

We demonstrate single-mode surface-emitting terahertz frequency quantum cascade lasers utilising non-uniform second-order distributed feedback concentric-circular-gratings. The grating is designed for single-mode operation and surface emission for efficient and directional optical power out-coupling. The devices exhibit single-mode operation over the entire dynamic range with a side-mode-suppression-ratio of around 30 dB at 78 K, and a six-fold rotationally symmetric far-field pattern. In addition, the devices show a peak output power approximately three times higher than in ridge-waveguide lasers of similar size, whilst maintaining similar threshold current densities for the 3.8 THz emission and without remarkably sacrificing the maximum temperature operation performance. Owing to the high symmetry of the structure and the broad area light emission from surface, the devices are potentially very suitable for use as single-mode, high power emitters for integration into two-dimensional laser arrays.

SY4.3 High Quality Flexible Microlasers and Their Applications (INVITED)

Van Duong Ta, Rui Chen, Handong Sun

Wednesday, March 06, 04.14 PM, MAS-EX1

In this work, we demonstrate two different kinds of microlasers and their applications as ultra-sensitive sensors. These structures are microfibers and hemispheres with tunable diameter ranges from 5 to 100 μm, which were self-assembly by surface tension. The host material is a composition of polymethylmethacrylate and Araldite 506 (both from Sigma-Aldrich). By incorporating dye molecules into these structures, whispering gallery mode (WGM) lasing was observed under optical pulse excitation at room temperature. The line-width of lasing mode is around 0.09 nm. This narrow lasing peak verifies high quality (Q) factor of our resonators, owing to their smooth outer surface.

Due to high Q factor, microfiber and hemisphere lasers exhibit as excellent refractive index sensors. The sensing mechanism is based on interaction of evanescent wave of WGMs and detected molecules attached on the surface of the resonators, indicated by optical shift of lasing modes. Following this principle, the fiber and hemisphere were employed for refractive index sensing of Tetrahydrofuran (THF) solution and acetone vapour with sensitivity around 300 and 130 nm per refractive index unit (RIU), respectively. Our finding provides a simple but very effective method to obtain flexible high quality microlasers, which may find potential applications in optoelectronic devices, chemical and biological sensors.

SY4.4 High-repetition-rate low-noise mode-locked fiber lasers at 1.55 μm (INVITED)

Kan Wu, Cesare Soci, Nikolay Zheludev, Perry Ping Shum

Wednesday, March 06, 04.36 PM, MAS-EX1

Low-noise mode-locked lasers with high repetition rate have attracted intense interest for the applications of frequency comb, clock distribution and microwave synthesis, etc. We discuss the design of mode-locked fiber lasers at 1.55 μm with high repetition rate and low timing noise. Various noise properties of mode-locked fiber lasers are investigated. Applications based on these lasers for low-noise microwave synthesis are also demonstrated.

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special thanks to Markus BADEN, CQT/NUS for help with the programme

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