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Welcome to the Charge and Energy Transport in Nanocrystal Assemblies workshop

We are proud to host the workshop, “Charge and Energy Transport in Nanocrystal Assemblies” (CETNA-2017) organized by the William I. Fine Theoretical Physics Institute, and cosponsored by the Material Research Science and Engineering Center at the University of Minnesota. The conference will start on the morning of Thursday, May 4th, 2017 and end at 1:00 PM on Saturday, May 6th, 2017.

Scientific Organizing Committee:

Alexander Efros (Navy Research Laboratory)
Uwe Kortshagen (University of Minnesota)
Boris Shklovskii (FTPI, University of Minnesota)
THURSDAY, MAY 4TH
Keller Hall 3-180
200 Union Street SE, Minneapolis, MN

8:45 am  REGISTRATION
Keller Hall
200 Union Street SE
Room 3-180

8:55 am  Welcome and opening comments
Boris Shklovskii
FTPI, University of Minnesota

9:00 am  Role of Surface Chemistry on Charge Carrier Transport in Quantum Dot Solids
Cherie Kagan
University of Pennsylvania

9:45 am  Charge Transport in Nanocrystal Arrays: A Chemist’s Perspective
Dmitri Talapin
University of Chicago

10:30 am  COFFEE BREAK

11:00 am  Physics of Mid-Infrared Detection with Colloidal Quantum Dots
Philippe Guyot-Sionnest
University of Chicago

11:45 am  Quantum Dot Spasers and Plasmonic Amplifiers
David Norris
ETH Zurich

12:30 pm  LUNCH BREAK
Lunch is on your own. Please refer to the dining guide in the back of this booklet.
2:00 pm  Early Time Photoconductance Dynamics in Quantum Dot Solids Probed by Ultrafast Photocurrent Spectroscopy
Victor Klimov
Los Alamos National Laboratory

2:45 pm  Field-Induced Doping of Colloidal Nanocrystal Assemblies: Traps, Transport & Utilizations
Satria Zulkarnaen Bisri
RIKEN Center for Emergent Matter Science

3:30 pm  COFFEE BREAK & POSTER SESSION

5:30 pm  Workshop ends for the day
9:00 am  Charge and Energy Transport in Films of Touching Nanocrystals  
Konstantin Reich  
FTPI, University of Minnesota

9:45 am  COFFEE BREAK

10:30 am  Electron and Exciton Transport in Plasma-Produced, Disordered Nanocrystal Films  
Uwe Kortshagen  
University of Minnesota

11:15 am  Matrix Engineering for Efficient Charge Transport in PbX Quantum Dot Solids  
Matt Law  
University of California, Irvine

12:00 pm  LUNCH BREAK  
Lunch is on your own. Please refer to the dining guide in the back of this booklet.
FRIDAY, MAY 5TH
Keller Hall 3-180
200 Union Street SE, Minneapolis, MN

2:00 pm  Bright and Dark Exciton Transfer in Quantum Dot Arrays
Anna Rodina
Ioffe Institute, St. Petersburg, Russia

2:45 pm  Visualizing Current Flow at the Mesoscale in Assemblies of Touching Semiconducting Nanocrystals
Elijah Thimsen
Washington University in St. Louis

3:30 pm  COFFEE BREAK

4:15 pm  Photogeneration, Diffusion and Decay of Charge Carriers in Quantum Dot Solids
Arjan Houtepen
Delft University of Technology, The Netherlands

5:00 pm  Workshop ends for the day

6:00 pm  WORKSHOP BANQUET
Kafe 421
421 14th Ave SE
Minneapolis, 55414
(see page 23 for map)
## Program

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<th>Presenter</th>
<th>Institution</th>
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<tbody>
<tr>
<td>9:00 am</td>
<td><strong>Symmetry Breaking Induced Activation of the Nanocrystal Photoluminescence</strong></td>
<td>Alexander Efros</td>
<td>Navy Research Laboratory</td>
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<tr>
<td>9:45 am</td>
<td><strong>Disorder, Nonequilibrium Transport, and the Origin of Deep Traps in Quantum Dot Solids</strong></td>
<td>William Tisdale</td>
<td>Massachusetts Institute of Technology</td>
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<tr>
<td>10:30 am</td>
<td><strong>COFFEE BREAK</strong></td>
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<tr>
<td>11:00 am</td>
<td><strong>Tracking the Energy Flow on Nanoscale via Sample-Transmitted Excitation Photoluminescence (STEP) Spectroscopy</strong></td>
<td>Mikhail Zamkov</td>
<td>Bowling Green State University</td>
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<tr>
<td>11:45 am</td>
<td><strong>Electronic Transport Phenomena in Composite Nanocrystalline/ Amorphous and Free-Standing Nanocrystalline Thin Films</strong></td>
<td>James Kakalios</td>
<td>University of Minnesota</td>
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<tr>
<td>12:30 pm</td>
<td>Workshop ends.</td>
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THANK YOU FOR YOUR PARTICIPATION!!!
Satria Zulkarnaen Bisri  
RIKEN Center for Emergent Matter Science  

**Field-Induced Doping of Colloidal Nanocrystal Assemblies: Traps, Transport & Utilizations**  
Investigation of charge carrier transport properties in colloidal nanocrystal assemblies is recently becoming vital for the utilization of these class of materials in diverse emerging practical applications. So far, their tunability of energy bandgap and the discrete energy levels formation have attracted great interest in their applications in many devices where optical properties are primarily important. On the other hands, there are many challenging factors that hamper the colloidal nanocrystal use of where charge carrier transport is the main feature. Among the challenges are the numbers of mobile carrier density and the carrier traps in these materials, due to large surface area. Therefore, thorough investigation and control of charge carrier density are vital, especially to overcome the huge numbers of carrier traps in this kind of material system. In this talk, charge carrier density control in thin film assemblies of colloidal nanocrystals using field-effect doping will be discussed. A field-effect transistor that is a good technique to investigate charge carrier transport properties of a material is an interface device. In one viewpoint, it would have its own carrier trap site problem; yet, from another perspective, it also provide us to utilize the benefit of various gating technique to control the properties of the nanocrystal assemblies. Some hints on how to significantly reduce the trap density in field-effect transistors of colloidal nanocrystal assemblies will be discussed. Furthermore, the high carrier density accumulation using electric-double-layer EDL gating, which enables us to attain sheet carrier density in the order of 1014 cm-2, will be explained. It is virtually sufficient to fill almost all of the remaining charge carrier traps and to greatly shift the Fermi level. The use of various ionic liquids “molten salt” with wide electrochemical window and multivalency is capable of controlling the Fermi level beyond nanocrystals’ HOMO-LUMO, thus accessing the discrete energy levels to fill them. This capability also demonstrates the preservation of the nanocrystals’ quantum confinement properties although they are assembled and strongly crosslinked. The implications of these capabilities to perform such carrier control on the future utilizations of colloidal nanocrystals will be also discussed, including applications for energy harvesting devices (solar cells, thermoelectrics, etc.).

Alexander Efros  
Navy Research Laboratory  

**Symmetry Breaking Induced Activation of the Nanocrystal Photoluminescence**  
We have shown that the descent of the nanocrystal symmetry from spherical to point group Cs, which is characterized by just one mirror plane symmetry element, leads step by step to activation
of all five \( F = 2, F_z = \pm 2, \pm 1, 0 \) excitons. Even the ground exciton becomes optically active, which should be observable in low-temperature photoluminescence measurements. For several intermediate symmetries the band edge exciton fine structure consists of sets of three linearly polarized mutually orthogonal dipoles plus a dark exciton, one of which is always the ground state. We quantify the effect of symmetry descent on the exciton fine structure by introducing a charged Coulomb impurity in the nanocrystals. The calculations show that the nanocrystal symmetry breaking by a Coulomb impurity, particularly a positively charged center, shortens the radiative decay of nanocrystals even at room temperatures in qualitative agreement with the increase in PL efficiency observed in nanocrystals doped with positive Ag charge centers.

Philippe Guyot-Sionnest
University of Chicago

Physics of Mid-Infrared Detection with Colloidal Quantum Dots
At present, colloidal quantum dots are competing or trying to compete with cheap, large area, technologies, such as phosphors, OLED, or Si-solar. Competing with expensive technologies would be even more exciting and this could happen in infrared detection. Infrared is of great importance for military and scientific communities, but not widely used in civilian situations due to the cost of the existing technology. In the past few years since we first reported the detection of mid-infrared radiation (\( \lambda > 3 \) microns) with colloidal quantum dots, performances have steadily improved including background limited detection up to 120K at 5 microns, demonstration of imaging cameras at 5 microns and detection up to 12 microns. It is therefore interesting to evaluate the factors that presently determine performance. This talk will address some of these, including perennial issues with CQDs such as the role of disorder, 1/f noise, mobility and doping. In regards to the last topic, our most exciting result in recent years is the discovery of stably doped CQDs which allowed infrared detection based on intraband transitions. This new approach, with a-priori a much wider range of materials, will be compared to the interband approach.

Arjan Houtepen
Delft University of Technology, The Netherlands

Photogeneration, Diffusion and Decay of Charge Carriers in Quantum Dot Solids
In recent years we have studied the photoconductivity in quantum-dot solids with a combination of terahertz spectroscopy, transient absorption spectroscopy and time-resolved microwave conductivity.
Appropriate surface treatments induce controlled necking between Quantum Dots resulting in significant electronic coupling and charge carrier mobilities as high as ~10 cm²/Vs. We demonstrate that at room temperature photogenerated excitons readily dissociate into mobile charge carriers.1-3 Carrier Multiplication (CM) is observed in the photoconductivity of these films.4 The number of surviving free charges that result from CM increases with increasing charge carrier mobility as a result of the competition between Auger recombination and multi-exciton dissociation.5, 6 Finally I will discuss charge trapping at surface sites of IV-VI QD films. Using a combination of electrochemically controlling the Fermi level in QD films with ultrafast transient absorption and photoluminescence spectroscopy we demonstrate that electron trapping can be controlled and even avoided altogether.7 This also allows us to determine the density of trap states in the band gap of the quantum dots and, by comparison with density function theory calculations, to identify the chemical nature of these traps as well as the physical mechanism of charge trapping.8, 9


Cherie Kagan
University of Pennsylvania

Role of Surface Chemistry on Charge Carrier Transport in Quantum Dot Solids
Colloidal semiconductor quantum dots (QDs) are promising materials for electronic and optoelectronic devices due to their size tunable electronic and optical properties and the solution-based processes that enable the integration of these materials into devices. However, the long, insulating ligands commonly employed in the synthesis of colloidal QDs inhibit strong interparticle coupling and charge transport once QDs are assembled into the solid state as QD arrays. A general
approach to increase carrier mobility is to reduce the interparticle spacing by ligand exchange. During solution-based deposition and ligand exchange of QD thin films, the QD surfaces are often “attacked” by solvents or ligands, creating surface defect sites. These surface defects generate in-gap states that may scatter mobile carriers and reduce the lifetime of photogenerated carriers by trapping. In this talk, I will describe methods to synthetically control and spectroscopically probe the density and occupancy of defect states at the QD surface and at QD-device interfaces and their importance to creating high mobility and long lifetime QD materials for electronic and optoelectronic devices.

James Kakalios
University of Minnesota

Electronic Transport Phenomena in Composite Nanocrystalline/Amorphous and Free-Standing Nanocrystalline Thin Films

Composite materials consisting of nanocrystalline semiconductors embedded within a bulk amorphous semiconductor or an insulator have attracted interest for applications ranging from photovoltaics, thermoelectrics, thin film transistors, particle detectors and electroluminescent devices. These materials combine the best of both worlds – the thin film large area advantages of disordered semiconductors with the superior opto-electronic properties of crystals, and often display electronic properties not observed in either material separately. Using a unique dual-chamber Plasma Enhanced Chemical Vapor Deposition system, we have synthesized nanocrystals of silicon or germanium in a surrounding hydrogenated amorphous silicon (a-Si:H) matrix (a/nc-Si:H). The dark conductivity of n-type doped a/nc-Si:H films displays three distinct conduction mechanisms: thermally activated conduction, multi-phonon hopping and Mott variable range hopping, as the crystal fraction and temperature of these films is varied. Studies of the thermopower of composite films of a-Si:H containing germanium nanocrystals find that transport changes from n-type to p-type as the nc-Ge concentration is increased, with a transition sharper than expected from a standard two-channel model for charge transport. Using the Zabrodskii analysis technique, the conductivity in the nc-Ge/a-Si:H films is described by an anomalous hopping expression, \( \sim \exp[(T_0/T)^k] \) where \( k = \frac{3}{4} \), suggesting an entirely new conduction mechanism. Similar studies of free-standing nc Si films, deposited without a surrounding matrix, find that the conduction mechanism varies with the film’s exposure to atmosphere.

This research done in collaboration with Uwe Kortshagen, C. Blackwell, Y. Adjallah, L. Wienkes, K. Bodurtha, C. Anderson and J. Trask. This work was partially supported by NSF grants NER-DMII-0403887, DMR-0705675, the NINN Characterization Facility, the Xcel Energy grant under RDF contract #RD3-25, NREL XEA-9-99012-01 and the University of Minnesota.
Victor Klimov  
Los Alamos National Laboratory

**Early Time Photoconductance Dynamics in Quantum Dot Solids Probed by Ultrafast Photocurrent Spectroscopy**

Understanding and controlling carrier transport and recombination dynamics in colloidal quantum dot (QD) films is key to their application in electronic and optoelectronic devices. Towards this end, we have conducted transient photocurrent measurements (10-50 ps time resolution) to monitor charge-transport dynamics in lead selenide QD films as a function of pump fluence, temperature, electrical bias, and surface treatment [1, 2]. Room temperature dynamics reveal two distinct timescales: one sub-nanosecond and the other, tens-to-hundreds of nanoseconds. The first of these processes is assigned to relaxation of one type of carriers (presumably, electrons) into low-mobility intra-gap states, which pins the corresponding quasi-Fermi level at below band-edge energies [3]. This effect is likely responsible for a considerable photovoltage deficit typical of QD PVs. A longer-time transient photocurrent exhibits memory-less decay due to nongeminate recombination of the remaining mobile charges with the trapped carriers of the opposite sign (pre-existing and photogenerated). In addition to potentially modifying the chemical nature and/or abundance of trapping sites, application of different QD surface treatments also alters the initial (“dark”) occupancy of intra-gap states, which has a profound effect on mobile-carrier lifetimes. The peak photoconductance observed immediately after short-pulse excitation is temperature-independent suggesting a tunnelling mechanism of early time phototransport. Further, low temperature measurements reveal an important role of the excitonic fine structure and, specifically, the electron-hole exchange interaction (exchange blockade) in early time photocurrent dynamics. This effect is likely universal as it necessarily arises following photoexcitation when an electron and a hole are generated in the same QD and hence are strongly coupled by the exchange interaction, which creates a barrier to their separation between adjacent QDs. Finally, side-by-side comparison of photocurrent transients using excitation with low- and high-photon energies (1.5 vs. 3.0 eV) reveals clear signatures of carrier multiplication (CM), that is, generation of multiple excitons by single photons [2]. Based on photocurrent measurements of QD solids and optical measurements of solution based samples, we conclude that the CM efficiency is unaffected by inter-dot coupling, and therefore, the results of previous numerous spectroscopic CM studies conducted on dilute QD suspensions should, in principle, be reproducible in electronically coupled QD films used in devices. 1. Fidler, A.F., J. Gao, and V.I. Klimov, Electron-hole exchange blockade and memory-less recombination in photoexcited films of colloidal quantum dots. Nat. Phys, 2017. advance online publication. 2. Gao, J.B., A.F. Fidler, and V.I. Klimov, Carrier multiplication detected through transient photocurrent in device-grade films of lead selenide quantum dots. Nat. Comm. 2015. 6. 3. Nagpal, P. and V.I. Klimov, Role of mid-gap states in charge transport and photoconductivity in semiconductor nanocrystal films. Nat. Comm. 2011. 2: p. 486.
Uwe Kortshagen
University of Minnesota

Electron and Exciton Transport in Plasma-Produced, Disordered Nanocrystal Films

Matt Law
University of California, Irvine

Matrix engineering for efficient charge transport in PbX quantum dot solids
Colloidal semiconductor quantum dots (QDs) are attractive building blocks for solar photovoltaics (PV). In this talk, I will highlight our recent progress in designing PbX (X = S, Se, Te) QD thin film absorbers for next-generation PV. I begin by discussing QD film fabrication, charge transport physics, insights from theory, and evidence that the carrier diffusion length is short and limited by electronic states in the QD band gap. Studies of carrier mobility as a function of basic film parameters such as inter-QD spacing, QD size, and QD size distribution have led to a better understanding of charge transport within highly-disordered QD films. Efforts to improve carrier mobility by enhancing inter-dot electronic coupling, passivating surface states, and implementing surface doping will be highlighted. Engineering the inter-QD matrix to produce QD/inorganic or QD/organic nanocomposites is presented as a powerful way to optimize coupling, remove surface states, eliminate hysteretic charge trapping and ion motion, and achieve long-term environmental stability for high-performance, robust QD films that feature good carrier multiplication efficiency. To obtain large photocurrent from QD solar cells, it is critical to increase the minority carrier diffusion length to rival the optical absorption length, possibly by harnessing band-like transport through extended electronic states. The relative roles of superlattice order, energy disorder, and surface states in this regard will be summarized. New results from in situ spectroscopic studies of QD field-effect transistors will be discussed.

David Norris
ETH Zurich

Quantum Dot Spasers and Plasmonic Amplifiers
Colloidal quantum dots are robust, efficient, and tunable emitters now used in lighting, displays, and lasers. Consequently, when the spaser, a laser-like source of surface plasmons, was first proposed, quantum dots were specified as the ideal plasmonic gain medium. Subsequent spaser designs,
however, have required a single material to simultaneously provide gain and define the plasmonic cavity, an approach ill-suited to quantum dots and other colloidal nanomaterials. Here we develop a more open architecture that decouples the gain medium from the cavity, leading to a versatile class of quantum-dot-based spasers that allow controlled generation, extraction, and manipulation of plasmons. We first create high-quality-factor, aberration-corrected, Ag plasmonic cavities. We then incorporate quantum dots via electrohydrodynamic printing or drop-casting. Photoexcitation under ambient conditions generates monochromatic plasmons above threshold. This signal is extracted, directed through an integrated amplifier, and focused at a nearby nanoscale tip, generating intense electromagnetic fields. This spaser platform, deployable at different wavelengths, size scales, and geometries, can enable more complex on-chip plasmonic devices.

Konstantin Reich
FTPI, University of Minnesota

Charge and Energy Transport in Films of Touching Nanocrystals
This talk deals with films of nanocrystals (NC), which touch each other by small facets with radius ρ. First I calculate the matrix element for electron tunneling from one NC to another and show that it is proportional to ρ³. I use this matrix element to calculate two transport properties of NC films: conductivity and exciton diffusion length.
In the first case I focus on the critical concentration of electrons for the insulator-metal transition (IMT) in the film. The famous Mott’s criterion answers this question only in bulk materials. The same critical concentration as in a bulk material is not sufficient for the IMT in NC films because of the weak coupling between NCs. For IMT in NC films, one needs much larger concentration at which the typical electron wave packet becomes smaller than the facet radius ρ and can pass through the facet. The predicted critical concentration is proportional to 1/ρ³ and is in good agreement with experimental data obtained by Kortshagen’s group for silicon NC films.
In the second part of the talk, I consider the exciton diffusion length in NC films. In photovoltaic devices based on NC films, absorption of a light quantum creates of an exciton (electron-hole pair) in a NC. The diffusion length of an exciton is important parameter determining the volume from which photons are harvested. It is known that an exciton can hop between nearest-neighbor NC via the Forster mechanism. For touching NC, I propose another mechanism where the electron and hole tunnel through the small contact facet in tandem. The tandem tunneling occurs through the intermediate state in which the electron and hole are in different NCs. I show that for majority of materials the tandem tunneling exciton transfer rate is comparable with the Forster rate, while for silicon the tandem tunneling dominates.
Anna Rodina
Ioffe Institute, St. Petersburg, Russia

**Bright and Dark Exciton Transfer in Quantum Dot Arrays**

We theoretically study nonradiative and radiative resonance energy transfer between two localized quantum emitters, a donor (initially excited quantum dot) and an acceptor (quantum dot receiving the excitation). We find that the donor lifetime can be significantly modified only due to the nonradiative dipole-dipole Förster Resonance energy transfer process to the short living energy level in acceptor dot at donor - acceptor separations of approximately 5-15 nm (depending on the acceptor radiative lifetime) and for the energy detuning not larger than ~1-2 meV. The dark (spin forbidden) exciton states can participate in the Förster energy transfer due to the weak admixture of the bright exciton states to the dark states, which also allows the radiative recombination of the dark excitons. We demonstrate the dominant role of the dark exciton in the low temperature energy transfer in ensemble of closely packed CdTe nanocrystals by time-dependent photoluminescence spectroscopy in applied external magnetic field which considerably enhances this admixture. The Förster Resonance energy transfer in inhomogeneous dense arrays of epitaxial CdSe/ZnSe quantum dots is also demonstrated by time-and space-resolved photoluminescence spectroscopy.

The work was supported by Russian Science Foundation (Project number 14-22-00107).

Dmitri Talapin
University of Chicago

**Charge Transport in Nanocrystal Arrays: A Chemist’s Perspective**

Recent developments of nanomaterials have introduced exciting opportunities for design of electronic materials from precisely engineered nanoscale building blocks. Potentially, this approach can combine the advantages of crystalline inorganic semiconductors with size-tunable electronic structure and inexpensive solution-based device fabrication. Along these lines, colloidal semiconductor quantum dots (QDs) are widely explored as the functional elements in printable electronics (field-effect transistors, memory devices, etc), light emitting devices, photodetectors and solar cells. All the above applications rely on efficient charge transport in nanocrystal arrays, which is relatively poorly understood. In the recent years significant progress has been achieved in development of chemical approaches to improve electronic transport and control doping in nanocrystal arrays. I will review these developments and discuss recent results on inorganic surface ligands for colloidal nanomaterials. I will also discuss the charge transport in arrays of all-inorganic II-VI and III-V semiconductor quantum dots and metal/semiconductor core-shell nanostructures. Our temperature-dependent field-effect and Hall mobility measurements suggest emergence of a new regime that is
difficult to explain by hopping. By using optimized surface chemistries we prepared nanocrystal solids exhibiting band-like charge transport with high electron mobility and tunable doping level. I will discuss possible explanations for charge transport with a negative temperature coefficient of mobility, focusing on remaining issues and unsolved problems in the field.

Elijah Thimsen
Washington University in St. Louis

**Visualizing Current Flow at the Mesoscale in Assemblies of Touching Semiconducting Nanocrystals**

The transport of electrons through assemblies of nanocrystals is important for the performance of these materials in optoelectronic applications. The transport of electrons has primarily been studied by focusing on single nanocrystals or transitions between pairs of nanocrystals. There is a gap in knowledge of how large numbers of nanocrystals in an assembly behave collectively, and how this collective behavior manifests at the mesoscale. In this work, the transport of electrons in assemblies of touching, heavily doped ZnO nanocrystals was visualized as a function of temperature at the mesoscale theoretically using the model of Skinner, Chen and Shklovskii (SCS); and experimentally by conductive atomic force microscopy on ultrathin films only a few particle layers thick. Agreement was obtained between the model and experiments, with a few notable exceptions. The SCS model predicts that a single network within the nanocrystal assembly, comprised of sites connected by small resistances, dominates conduction - namely the well-known optimum band from variable range hopping theory. However, our experiments revealed that in addition to the optimum band, there are subnetworks that appear as additional peaks in the resistance histogram; which were not observed in the model calculations. Furthermore, the connections of these subnetworks to the optimum band changes in time. As time proceeds, some isolated subnetworks become connected to the optimum band; while some of the connected subnetworks become disconnected and then isolated from the optimum band. The subset of nanocrystals comprising the optimum band is dynamic.

William Tisdale
Massachusetts Institute of Technology

**Disorder, Nonequilibrium Transport, and the Origin of Deep Traps in Quantum Dot Solids**
Using a combination of ultrafast spectroscopy, time-resolved optical microscopy, and kinetic Monte Carlo simulation, I will illustrate the effects of structural and energetic disorder on charge and exciton transport in colloidal quantum dot solids. In particular, I will show how analysis of early-time nonequilibrium transport phenomena can yield especially useful insight into fundamental charge and exciton transport processes. Additionally, I will present experimental evidence pointing to an unexpected origin of deep electronic traps in PbS nanocrystal solids.

Mikhail Zamkov
Bowling Green State University

**Tracking the Energy Flow on Nanoscale via Sample-Transmitted Excitation Photoluminescence (STEP) Spectroscopy**

Monitoring the energy flow in nanoscale materials is an important yet challenging goal. Experimental methods for probing the intermolecular energy transfer (ET) are often burdened by the spectral crosstalk between donor and acceptor species, which complicates unraveling their individual contributions. This issue is particularly prominent in inorganic nanoparticles and biological macromolecules featuring broad absorbing profiles. Here, we demonstrate a general spectroscopic strategy for measuring the energy transfer efficiency between nanostructured or molecular dyes exhibiting a significant donor-acceptor spectral overlap. The reported approach is enabled through spectral shaping of the broadband excitation light using solutions of donor molecules, which helps suppressing the excitation of respective donor species in the sample. The resulting changes in the acceptor emission induced by the spectral modulation of the excitation beam allow determining the quantum efficiency and the rate of ET processes between arbitrary fluorophores (molecules, nanoparticles, polymers) with high accuracy. The feasibility of the reported method is demonstrated using two control donor-acceptor systems: a low-overlap protein-bridged Cy3-Cy5 dye pair, and high-overlap CdSe560-CdSe600 nanocrystal film.
WIRELESS ACCESS

Please see workshop staff for a secure Wi-Fi connection username and password in Keller Hall
INSTRUCTIONS FOR UPLOADING TALKS TO THE WORKSHOP WEBSITE

Please submit a PDF (preferred format) of your talk slides by Friday, May 12, 2017 to be included in the conference web archive. Please include your name in the file name.

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Please note that there will be a delay between your upload and final posting on the workshop website. Once all talks have been submitted, participants will be notified by email. As always, any questions may be addressed to CETNA2017@physics.umn.edu.

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## WORKSHOP PARTICIPANT LIST

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<thead>
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Towards High Carrier Mobility in Quantum Dot Superlattices Linked with Conjugated Molecular Wire Ligands
Alex Abelson
University of California, Irvine

Mid-Infrared Detection with HgTe Quantum Dots
Matthew Ackerman
University of Chicago

Exploring Transport and Superradiance in Pathologically Coherent Molecular Aggregates
Justin Caram
Massachusetts Institute of Technology

Mobility in the Films of HgX(X=S,Se,Te) Quantum Dots
Menglu Chen
University of Chicago

Hopping Conductivity and Insulator-Metal Transition in Lms of Touching Semiconductor Nanocrystals
Han Fu
FTPI, University of Minnesota

Origin of Trap States in PbS Quantum Dot Solids
Rachel Gilmore
Massachusetts Institute of Technology

Photoconductivity and Insulator-Metal Transition in ZnO Nanocrystal Networks
Benjamin Greenberg
University of Minnesota
Triplet Exciton Transfer in Solid-State PbS Nanocrystal-Sensitized Photon Upconversion
Lea Nienhaus
Massachusetts Institute of Technology

Exciton Diffusion Through Functionalized Silicon Nanocrystalline Films
Zachary Robinson
University of Minnesota

How to Achieve Large Thermopower at Very Low Temperature Using a Magnetic Field
Brian Skinner
Massachusetts Institute of Technology

Silicon Nanoparticles with PL Lifetimes of a Few Hundred Microseconds
Wenbi Wu
Massachusetts Institute of Technology
WORKSHOP DINNER

Kafe 421
421 14th Avenue Southeast
Minneapolis, MN 55414

WALKING DIRECTIONS FROM THE COMMONS HOTEL (1 mil, 16 min):

From the front of the hotel head southwest (105 ft)
Turn Right toward SE Harvard St (62 ft)
Turn Right toward SE Harvard St (190 ft)
Turn Right onto SE Harvard St (558 ft)
Turn Right toward SE 4th Street (535 ft)
Slight Left onto SE 4th St (.393 mi)
Turn Right onto 14th Ave SE (256 ft)
ADDITIONAL LOCATIONS

1) **CETNA Workshop Location:** Keller Hall 3-180, 200 Union Street SE

2) **East Bank Station & Platform:** Light Rail Station

3) **CETNA Workshop Lodging:** The Commons Hotel, 615 Washington Ave SE
STADIUM VILLAGE DINING GUIDE

1. Starbucks
2. The Beacon Public House
3. Applebee's
4. Haiku Japanese Bistro
5. Caribou Coffee
6. Afro Deli
7. Little Szechuan
8. Kimchi Tofu House
9. Chipotle Mexican Grill
10. SotaRol
11. Stub and Herb's
12. Bona Vietnamese Restaurant
13. Bar Luchador
14. Raising Cane's Chicken Fingers
15. Hong Kong Noodle
16. Jimmy John's
17. Korea Restaurant
18. My Burger
19. Domino's Pizza
20. Caribou Coffee
21. Mesa Pizza Stadium Village
22. Kowloon Restaurant
23. Burger King
24. Blaze Pizza
25. Sprout Salad Company
26. Buffalo Wild Wings
27. Naf Naf Grill
28. Noodles and Company
29. Punch Pizza Stadium Village
Thank you for your participation!
The William I. Fine Theoretical Physics Institute (FTPI) was established in 1987 as part of the School of Physics and Astronomy at the University of Minnesota, with the goal of conducting research in theoretical physics at a worldclass level.

The most important function of FTPI is to produce exciting and sound theoretical physics that will have an impact on physics as a whole. To this end the Institute provides a meeting place for theorists from around the globe to exchange and develop ideas.

FTPI sponsors short-term workshops and longer-term programs, as well as hosting visiting scholars for long-term stays. Through these and other outreach programs, the Institute serves to advance theoretical physics and to further develop its links to other science and engineering research disciplines, industrial research initiatives, and other academic sectors.

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