Matthew Barlow
Advisor: Volkmar Dierolf

Modeling Laser Induced Crystal Growth

Abstract

The goal of this project is to model temperature dependent nucleation and growth rates of laser induced crystals in glasses. The laser at our disposal is a femto-second laser with a power of 800mW, moving at a speed of approximately 20um/s. Several approaches are taken to the task of modeling, primarily based off Fourier's heat equation – expanded to three dimensions. Equilibrium temperature is taken to be when heat loss to surroundings equals the heat gain from the laser, and boundary conditions are set at room temperature. Concessions are made to simplify to equation to a form which could be sufficiently approximated in Python. Variables such as specific heat capacity, thermal diffusivity, and others are taken to be constants when they are not. The derived equation is then iteratively applied across the spatial coordinates of the glass in question, with time a variable. The data obtained is then plotted as a 2D array with adjustable z-axis. The faster models are compared to a more exact solution and found to be sufficient in their capabilities to approximate temperature distribution.

I would like to thank the National Science Foundation for presenting me the opportunity to conduct this research through grant PHY-1359195.

Madison Brown, Lehigh University Summer 2017 REU Participant

Qingguo Bai, Jean-Pierre Delville, Marie-Helene Delville, H. Daniel Ou-Yang

Abstract:

Hybrid Janus Nanoparticles possess a plethora of promising scientific applications from self-assembly and active particles to Langmuir-Blodgett films. In particular, titanium dioxide is of interest because of its versatility. Select photodeposited metals on TiO_2 provide avenues for study in medicine, energy, and the environment. Using a UV Laser, gold nanoparticles were photodeposited onto nanoplatet TiO_2 particles in aqueous suspensions in pursuit of high (>80%) hybrid Janus particle yield and larger. Optimization of the experimental setup required adjustments to the intensity of the laser, the duration of UV particle exposure, and the metal ion concentration of the photodeposited solution. Promising experimental parameters, 2.5mW with surfactant at 1:4 oil to solution flow rate, resulted in <50% Janus particle yield and an average gold particle size of 12nm.

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Dr. H. Daniel Ou-Yang, Soft Matter & Biophotonics Laboratory, Lehigh University

National Science Foundation grant PHY-1359195

Comparison of Stimulated Brillouin Scattering in Different Optical Fibres

P. M. Christodoulou, J. Toulouse

Department of Physics, Lehigh University

An optical fiber set-up was assembled to measure Brillouin Scattering. Measurements of the Brillouin Scattered light as a function of frequency were obtained by mixing the optical wave backscattered from the fiber under study with reference wave coming directly from the source. Beating between these two resulted in a Brillouin signal at radio frequencies, which could be analyzed on an electrical spectrum analyzer. Using this set-up, Brillouin Scattering was measured as a function of input power in three optical fibers with different geometrical characteristics. A graph of the backscattered power as a function of input power in dBm provided a value of the SBS threshold, P_{th}, for each fiber. P_{th} is found to be directly correlated to the core area, indicating that the Brillouin gain coefficient must approximately be the same in all three fibers.

This project was supported by grant PHY-1359195 from the National Science Foundation.

A *Sine* from the Heavens: Analyzing the Light Curves of Contact Binary Systems

Brittani Costa
Joshua Pepper
Lehigh University 2017 REU

Abstract

Contact eclipsing binary stars can be used to determine the distances to stellar systems like open clusters and globular clusters. In Rucinski (2005), it was shown that contact binaries have a correlation between their orbital periods, total luminosity, and color. Therefore, if color, period, and apparent magnitude are known, distance can be calculated. In order to refine the Rucinski relation, our project aims to determine precise orbital periods of large numbers of contact binaries. We use data from the Kilodegree Extremely Little Telescope (KELT) survey, which offers over a decade worth of photometric observations of hundreds of thousands of star systems. By applying the Lomb-Scargle algorithm to the KELT data, we determine precise periods for thousands of individual star systems. By combining the more precise periods found through the L-S analysis with distances from the upcoming Gaia mission and color information from other sky surveys, we will be able to improve the calibrated parameters for the Rucinski relation to better measure the distances to contact binaries. I would like to thank the National Science Foundation (NSF), PHY-1359195 for funding the project.

Unique Divine
Susquehanna University
Dr. Slava Rotkin

Raman Imaging for Localization of Carbon Nanotubes Inside Neural Stem Cells

Abstract

The goal of this project was to localize single-walled carbon nanotubes inside of C17.2 neural stem cells. Dr. Rotkin's group already found that carbon nanotubes are not cytotoxic in ultra-low concentrations. However, the cell structure is still affected by the uptake of carbon nanotubes. In order to further understand this process, Raman spectra were collected for over 40 cells with varying concentrations of nanotubes and cell treatments. The data also included Z stacks of the cells to confirm whether or not nanotubes sat inside or on the surface. A method for acquiring large data sets of Raman spectra is now available for use in further analysis, including details on laser intensity, integration time, and how to focus the Raman microscope on transparent cells in an efficient manner.

I'd like to give special thanks to Lehigh University, the National Science Foundation for NSF REU PHY-1359195, NSF ECCS-1509786, and CREF.

Katherine Elia

Rubrene Single Crystals: Morphology and Characterization

The aim of this work was to set up and optimize an apparatus for growing high quality organic single crystals via a vapor-transport method, together with the systematic characterization of the crystals obtained in such a way. The samples grown in this study where rubrene single crystals, a material that is currently of interest for unique characteristics such as high efficiency singlet exciton fission and triplet exciton fusion, and a large triplet exciton diffusion length. Crystal growth was studied as a function of parameters such as sublimation-temperature and flow-rate — which were optimized towards obtaining different crystal geometries — and the quality of the crystals was validated by determining their photoluminescence spectrum, particularly in view of avoiding an artifact that has plagued the crystals grown by other groups. The crystals we obtained where confirmed to be of pristine quality. In addition to obtaining their photoluminescence spectra, we also conducted a study of the triplet exciton diffusion length by observing the luminescence caused by triplet-triplet annihilation in several crystals. In this way we confirmed that the triplet diffusion length in the crystals we grew reaches the same relatively long value of 4 micrometers that was previously determined in samples grown by other groups.

I would like to thank the National Science Foundation grant PHY-1359195 for financial support of this project.

Manipulation of Metal Nanoparticles in Glass: How to Make Circuits in Glass

Sarah Fordjour, Advisor: Volkmar Dierolf[1]

The goal of this project was to create metal wires in the glass. The metal wires would be used to send electrical signals to an optical integrated circuit. There were many techniques used to achieve this goal which ranged from doping $LaBGeO_5$ with gold, and doping $LiNbO_3$-SiO_2 with both gold and silver. Another technique used was ion exchanging commercial microscope slide glass with sliver nitrate. All these glasses were then irradiated with a femtosecond laser. The laser creates free electrons within the metal which helps reduce the gold or silver in the glass changing it from the ionic state to metallic state. Then both the doped glasses were annealed in a furnace which causes the single gold or silver atoms to coalesce. Annealing the glass also makes it easier for gold or silver to precipitate out of the irradiated areas. After which conductivity measurements are performed on the glass samples to see if the glass is conductive. During this project several challenges came about one being that the addition of Au or Ag into $LiNbO_3$-SiO_2 led to immediate crystallization during the glass fabrication process. Another challenge was getting gold to precipitate out of $LaBGeO_5$ after it had been irradiated. After being irradiated with the fs laser black lines formed on the ion exchanged microscope slide glass. However, after performing conductivity measurements using a probe station it was found that ion exchanged glass was not anymore conductive than piece of glass that not had been ion exchanged.

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Acknowledgments: National Science Foundation Grant PHY-1359195

Cataloging Detached Eclipsing Binary Star Systems from the KELT Survey

Authors: PJ Gibson, Dr. Joshua Pepper

The aim of this project was to create catalog of detached eclipsing binary (dEB) star systems using data from the KELT survey. Due to the shape of dEB light curves, we chose to use BLS, a box-fitting algorithm, to search through 130,000 photometric light curves in search for dEBs. We eliminated certain light curves based on apparent systematic noise, only selected objects with a strong algorithmic signal, and created an outlier-elimination technique in order to reduce the number of false positives. After completing this procedure for one of roughly 40 fields in the KELT survey, we found over 500 dEBs. Moving forward, we intend on using our procedure on the remainder of the KELT fields to identify all dEBs.

This project was made possible by National Science Foundation grant PHY-1359195.

A Centrality and Event Plane Detector to Complete the Phase Diagram of Quantum Chromodynamics

George Halal

Abstract:

The properties of the nearly perfect liquid, Quark-Gluon Plasma (QGP), which filled the universe a microsecond after the Big Bang are studied by colliding heavy-ions at ultra-relativistic energies. Our project focuses on building and testing an Event Plane Detector (EPD) for the Solenoid Tracker at RHIC (STAR), where RHIC stands for the Relativistic Heavy Ion Collider and analyzing the data collected from collisions. When a charged particle hits one of the optically-isolated tiles of this detector, which are made of scintillator plastic, it lights up. The light then travels through a wavelength-shifting fiber embedded in the tile to a clear optical fiber to be detected by silicon photo-multipliers. This detector is an improved version of the Beam-Beam Counter (BBC), which is currently at STAR. It will help us measure the centrality and event plane of collisions with more precision. Data collected will aid us in mapping out the transition phase between the QGP and hadronic matter, which evolved into the chemical elements we see today. It will also help in searching for a unique critical point in the phase diagram of Quantum Chromodynamics matter. In 2017, a commissioning run has taken place at RHIC, colliding protons at $\sqrt{s_{NN}}$ = 510 GeV and gold ions at $\sqrt{s_{NN}}$ = 54.4 GeV, where data was collected from the eighth of the EPD that is installed. Finally, I would like to thank Lehigh University for making this summer research project possible for me.

Simulations of Branching Actin Filament Networks at the Leading Edge of Moving Cells

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Branched filamentous actin networks provide the driving force for lamellipodial protrusions in motile cells. Structural network changes occur due to filaments polymerizing, depolymerizing, capping, severing, and nucleating either as branches or de novo. The actin network in lamellipodia has been studied in prior mathematical and computational models; however, little is known about how network remodeling away from leading edge regulates its size and structural properties. We developed a 3D simulation of this network at the level of individual filaments, defining various processes as occurring with defined rate constants. Through changing of rates, effects on the network's structure and size due to different parameters were observed. In particular, it was seen that increased severing leads to a faster drop off in actin concentration, resulting in a shorter lamellipodium. In addition, branching not limited to occurring near the leading edge extends the depth of the lamellipodium, by allowing away from leading edge nucleation of filaments.

This project was supported by the National Science Foundation grant PHY-1359195.

Feasibility of Jet Shape Measurements at RHIC

Sean Jeffas

Abstract

One of the current main questions in nuclear physics is determining the properties of the Quark Gluon Plasma (QGP). One method of studying the properties of the QGP used at the Compact Muon Solenoid (CMS) is measuring the jet shapes, defined as the fractional transverse momentum radial distribution around the jet axis, in a heavy ion collision at $\sqrt{s_{NN}} = 2.76$ TeV. By comparing how these jets change in the presence of the QGP we can find out more about its properties. This method would be useful to measure the QGP's properties at the Relativistic Heavy Ion Collider (RHIC) at $\sqrt{s_{NN}} = 200$ GeV. Therefore simulations have been run at RHIC energies and Solenoidal Tracker at RHIC (STAR) detector specifications to see if jet shape measurements would be feasible. This work was funded through the generosity of the National Science Foundation grant PHY-1359195.

Neutron Study of the Boson Peak in Alkali Silicate Glasses

Viktor Krapivin and Jean Toulouse
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Atomic vibrations in solids can be studied by Raman or Neutron Scattering Spectroscopy. Unlike vibrational modes in crystals, which have ordered structures, atomic vibrations in glasses and other amorphous and therefore disordered materials are still not fully understood. One of the outstanding questions in the physics of glasses is the nature of the low energy peak referred to as the Boson peak. In an attempt to understand its origin, we have carried out neutron scattering measurements of alkali-SiO-2 glasses containing significant concentrations of a series of alkali ions (Na, K, Rb, Cs). In SiO-2, alkali ions are known to break Si–O bonds and locally modify the glass network, presumably also altering its vibrational spectrum. From our neutron scattering data we find that the Boson peak in all the glasses studied can be well described by a "Lorentzian Squared function" characterized by a single frequency parameter, ν_0, which correspondsapproximately with the maximum of the Boson peak. This parameter is found to increase monotonically as $m^{-\frac{1}{2}}$ with m the mass of the alkali (as for an effective harmonic oscillatorwith $\nu_0 = \sqrt{\kappa/m}$ with κ an effective spring constant). Surprisingly however, the slope or proportionality coefficient $\sqrt{\kappa}$obtained from the neutron results is found to be much smaller that from the Raman results suggesting a much smaller effective spring constant than that measured with neutrons. An explanation of this difference is provided in terms of the distinct characters of the two probes (photons and neutrons) and of their scattering process. Additionally, from the temperature dependence of the neutron scattering spectra, we find that the Boson peak increases in magnitude with increasing temperature and that additional modes appear at higher frequencies in the spectrum. These can be attributedto softening of the glass and the release of the structural constraints that exist in glasses at low temperatures, allowing higer frequency local modes to be activated.
We thank the National Science Foundation grant PHY-1359195 for making this work possible.

A bursting assay for Giant Unilamellar Vesicles containing gangliosides

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Cell membranes are composed of phospholipid bilayers. Phospholipids are amphiphiles, which have a hydrophilic head group and two hydrophobic fatty acid chains. When they are in water, they self-assemble so that the head groups align with each other and interact with the water, shielding the tails from the water so that they only interact with each other, forming the phospholipid bilayer. Other amphiphilic molecules can also be incorporated into the bilayer, such as cholesterol and proteins. The molecules of a membrane are held together by the hydrophobic effect, so the lipids and proteins are free to flow and diffuse along the membrane. We know that some cell types are constantly exposed to flow, that these cells sense flow and that flow is essential for normal function in these cells. We want to study the effect that flow has on membrane proteins. Our lab creates phospholipid bilayers in the form of Giant Unilamellar Vesicles (GUV), which are spheres of membrane, and grows them from lipids through electroformation, in order to investigate the effect of flow on membrane proteins. If we dilute our vesicles in a saline solution, the vesicles begin to sink to the bottom of the solution and rest on the glass, since they are more dense than the solution. The vesicles rupture on the surface and form a flat sheet (splat), which we refer to as a supported lipid bilayer (SLB). We can apply a flow to the SLB to see its effect on membrane proteins. The particular system we studied is a lipid (ganglioside) and protein, Cholera Toxin subunit B (CTB). We use ganglioside GM1 as our lipid because it has a large head group that sticks out of the membrane and acts as a receptor for the CTB protein. We can use this system to apply flow and see the effect of flow on membrane proteins, but we need to have a better understanding of how the vesicles break. This work studied how to optimize the breaking conditions of the GUV to use the SLB to study the effect of flow, since GUV breaking kinetics depend on many factors, such as lipid change and composition, surface treatment and buffer/salt concentration. In order to characterize splatting conditions, I took a movie of vesicles splatting on a glass coverslip and made a Python program to detect the vesicles in each frame of the movie to observe the properties of the splatting. The program uses the HoughCircles function in python to detect circles (vesicles) in an image. Vesicles must be diluted the appropriate amount in order to get a clear image of well-separated vesicles. The vesicles are electroformed in sucrose so you can see the phase contrast, since phase contrast shows refractive index differences. Lastly I added a high salt buffer to dilute the vesicles in order for them to splat at a reasonable rate and then took images for the movie. As time passes, there should be a decreasing vesicle count, since they are splatting and when they splat, the sucrose disperses and you can't see the vesicle in focus, and the vesicle that was there will no longer be detected. I ran each frame through the program and put it together to get an output movie of detected vesicles and plot of the vesicle count through time. I found that as expected, there was a decrease in vesicle count through time, and unexpectedly, cleaning the slides with plasma did not make the vesicles splat faster. Thank you to the National Science Foundation grant PHY-1359195 for making this work possible.

Analysing Brightness Limitations in Simulated LSST Images

Elle Ojala

The Large Synoptic Survey Telescope (LSST) will begin operations in 2022, conducting a wide-field, synoptic multiband survey of the southern sky. Some fraction of the objects at the bright end of the data collected by the LSST will overlap with other wide-sky surveys, allowing for calibration and cross-checking. Much of this data overlap will comprise saturated images, in which an overflow of detected photons causes bright streaks in images, making photometry difficult. This project provides the first in-depth analysis of saturation in LSST images. Using a photon simulator called PhoSim to create simulated LSST images, we evaluated saturation properties of several types of stars to determine the brightness limitations of LSST. We also collected metadata from many wide-sky surveys to provide cross-survey accounting and comparison. Additionally, we evaluated the accuracy of the PhoSim modeling parameters to determine its reliability. Our next steps will involve characterizing the limitations of PhoSim and developing methods of photometry extraction from saturated images.

Thanks to NSF grant PHY-135195 and the LSST Corporation for making this project possible.

Investigation of Charge Carrier Mobility in $Sn_2P_2S_6$

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The $Sn_2P_2S_6$ (SPS) electro-optic crystal has the potential to be optimized for dynamic holography applications based on light induced charge transport. We investigated the lifetime and mobility of photoexcited charge carriers in the SPS crystal, which is essentially a wide band gap semiconductor. The charge carrier mobility was studied by exploiting a method called "Holographic Time of Flight" which is an all-optical way to measure electric currents at nanosecond time scales and micrometer space scales. This is done by creating a transient refractive index grating in the bulk of the SPS sample via pulsed laser illumination at 532nm, then Bragg-diffracting a probe beam to investigate the buildup dynamics of the grating.
This research is funded by the National Science Foundation grant PHY-1359195.

Synthesis and *In-Situ* Testing of Metal Oxide Catalysts

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With the possibility of producing valuable C4 chemicals like butadiene from C2 feedstock, such as ethylene and ethanol, much interest is placed on finding ways to carry out these conversions. Various metal oxide catalysts have been found to accomplish this. In studying and characterizing these catalysts, the determination of acidic sites is very important, and from using *in-situ* ammonia adsorption and desorption analysis using Diffuse Reflectance Infrared Fourier Transform (DRIFT) spectroscopy, these various Lewis acid and Brønsted acid sites can be found and identified, showing what properties the catalyst may possess. In this study, catalysts containing oxides of Ni, Zr, and W are the focus.

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Raman characterization of microcrystals grown on graphene

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Abstract

Strain can be calculated from graphene's Raman signatures, and can be used to measure the force exerted by crystals grown on graphene. To do so, monolayer graphene was transferred to a glass substrate, onto which titania microcrystals were deposited via micro-pipette or grown via chemical reaction under autoclave conditions. The resultant samples were Raman-characterized before and after crystal growth. Graphene initially delaminated from the glass substrate over the course of three days during the autoclave procedure, although the grown titania produced clearly defined spectroscopic signatures. Micro-pipette deposition also yielded similar quality spectra containing both graphene and titania, even though the microcrystals were too amorphous to be ideal.

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