WOOSTER PHYSICS

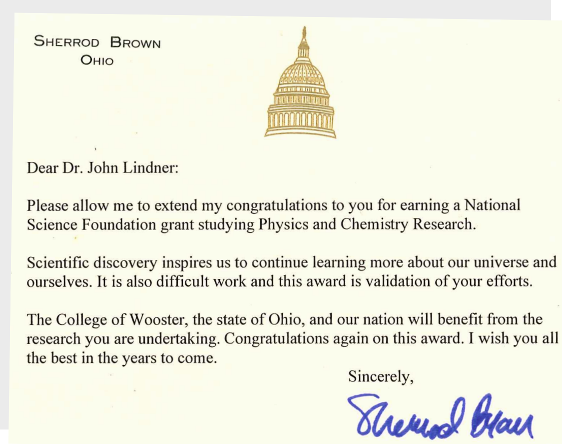
Greetings!

This past year has been a busy one as usual! We were delighted to have a record number of physics majors graduating in the class of 2016! Our previous record of 15 graduates was set with the Class of 2013, but we shattered that record this year with 18 majors! One graduating senior participated in the 3-2 engineering program, so we had 17 majors on campus for Senior IS. Fortunately, we also had a record number of full-time faculty in the department. We were happy to welcome John Lindner and Cody Leary back to campus from their research leaves last year. We also welcomed a new tenure-track faculty member, Niklas Manz, originally from Germany but coming to us most recently from Brooklyn. His research in pattern formation and excitation waves is a nice complement to what we are already doing in the department. We were also pleased to have Val Rousseau with us as a visitor for the year to help us with that record number of seniors. After these busy few years, I am happy to be handing the chair baton off to John Lindner as I look forward to my own upcoming research leave.

—Susan Lehman, Chairperson

NSF-Research Experience for Undergraduates

Robust research ramped up again in summer 2016 at The College of Wooster Department of Physics thanks to a $300,000 grant from the National Science Foundation, which will fund a Research Experience for Undergraduates (REU) Site for physics and chemistry for the next three years. The grant enables faculty to specifically target beginning students, many of which have completed just one year of college, and often from institutions where research opportunities are scarce. (See page 24.)



SHERROD BROWN
OHIO

Dear Dr. John Lindner:

Please allow me to extend my congratulations to you for earning a National Science Foundation grant studying Physics and Chemistry Research.

Scientific discovery inspires us to continue learning more about our universe and ourselves. It is also difficult work and this award is validation of your efforts.

The College of Wooster, the state of Ohio, and our nation will benefit from the research you are undertaking. Congratulations again on this award. I wish you all the best in the years to come.

Sincerely,

CLASS OF 2016

Michael Bush *Physics /Math*
Glen Burnie MD

Mitch Gavin *Physics (education minor)*
Eden Prairie MN

Carlos Gonzalez Mendoza *Physics (3/2 engineering at Washington University St. Louis)* Monterrey MEXICO

Laura Grace *Physics*
Eagan MN

Colm Hall *Physics*
Ridgefield CT

Nathan Johnson *Physics*
Danville KY

Spencer Kirn *Physics*
Lexington KY

Andrew King-Smith *Physics*
West Salem OH

Matthew King-Smith *Physics*
West Salem OH

Maggie Lankford *Physics*
Lebanon OH

Yashasvi Lohia *Physics*
New Delhi INDIA

Noah Megregian *Physics*
Highland Park IL

Calvin Milligan *Physics*
Sidney OH

Diego Miramontes-Delgado *Physics*
Chihuahua MEXICO

Paroma Palchoudhuri *Physics/ Math*
Kolkata INDIA

Graham Schattgen *Physics*
Fredericksburg VA

Nathan Stone *Physics*
Columbia NJ

Catherine Tieman *Physics*
Lee's Summit MO

HONORS & AWARDS

Maggie Lankford '16 and Paroma Palchoudhuri '16
Arthur H. Compton Prize in Physics
(awarded to the senior physics major attaining the highest standing in that subject)

Michael Bush '16 and Maggie Lankford '16
Mahesh K. Garg Prize in Physics
(awarded to upper-class physics major who has displayed interest in and potential for applying physics beyond the classroom)

Avi Vajpeyi '18 and Justine Walker '18
Joseph Albertus Culler Prize in Physics
(awarded to first- or second-year student who has attained the highest rank in general physics)

Michael Bush '16
William H. Wilson Prize in Mathematics
(awarded to member of the senior class who has shown the greatest proficiency in mathematics)

Latin Honors
Summa cum laude
Maggie Lankford '16

Magna cum laude
Michael Bush '16
Matthew King-Smith '16
Paroma Palchoudhuri '16

Cum laude
Andrew King-Smith '16
Carlos Gonzalez Mendoza '16

Phi Beta Kappa
Maggie Lankford '16 and Paroma Palchoudhuri '16

Michael Bush '16
J. Howard Morris and Josephine Morris Volunteer Service Award
(awarded to student who is judged to have excelled in volunteer service through the Wooster Volunteer Network)

Avi Vajpeyi '18
Elias Compton First Year Prize

American Physical Society Apker Finalist
Maggie Lankford '16

Andrew King-Smith '16
American Physical Society March Meeting Undergraduate Presentation Award
(for presentation of his Senior I.S. research at the National APS meeting)

2015 University Physics Competition "Accomplished Competitor"
- **Nate Moore '18, Emma Brinton '17, Michelle Bae '18**
- **Robin Morillo '17, Alishan Premani '18, Jacob Denbeaux '19**

The University Physics Competition is an international contest for undergraduate students, who work in teams of three at their home colleges and universities all over the world, and spend a weekend in November, 48 hours, analyzing a real-world scenario using the principles of physics, and writing a formal paper describing their work.

Departmental Honors in Physics
Michael Bush '16
Matthew King-Smith '16
Maggie Lankford '16
Paroma Palchoudhuri '16

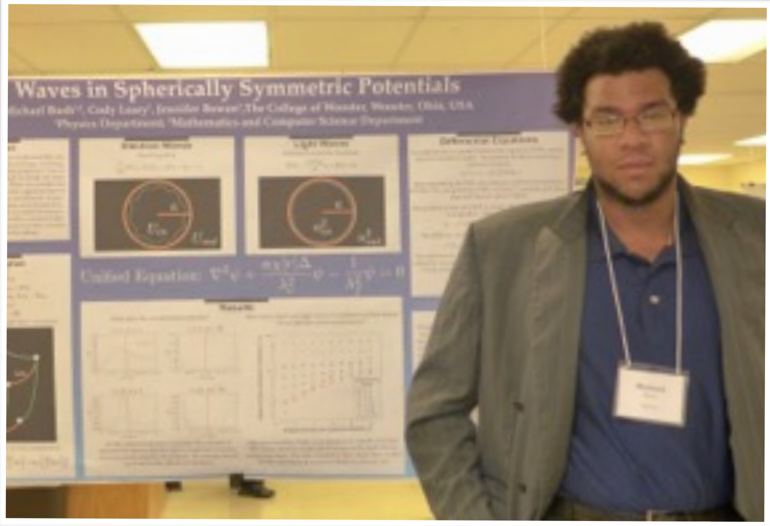
Campus Grounds crew was kept very busy replacing the Wooster bricks that were "removed" from Taylor Hall sidewalk this past spring.

SENIOR INDEPENDENT STUDY

MICHAEL BUSH

A COMPARATIVE ANALYSIS OF PHOTON AND ELECTRON WAVE FUNCTIONS IN SPHERICALLY SYMMETRIC POTENTIALS

Advised by Cody Leary, Physics, and Jennifer Bowen, Mathematics



We derived the wave function for light in a finite spherical well potential by drawing an analogy to an electron in an analogous potential energy well. The theory behind vector calculus on a spherical basis was examined. The wave equation for light, derived from Maxwell's equations, and the Pauli equation for electrons were combined into a unified form that was solved separation of variables, infinite series solutions, and numerical methods. The potential well for light was established by considering an environment with a constant index of refraction inside a spherical boundary and a different, but still constant, index of refraction outside the boundary. It was determined that the radial part of the wave function oscillated more inside the boundary as radial quantum number increased. The distance between the origin and the first peak amplitude inside the boundary increased as the angular momentum quantum number increased. For light, the wave number was found to be complex, therefore the temporal part of the wave function was a dampened oscillator. The time constant of the temporal part of the wave function increased as angular momentum quantum increased and decreased when the radial quantum number increased. *(Michael will attend the University of Delaware for graduate study in mathematics.)*

MITCH GAVIN

AN INJECTOR TO INVESTIGATE REACTION-DIFFUSION-ADVECTION SYSTEMS

Advised by Niklas Manz, Physics

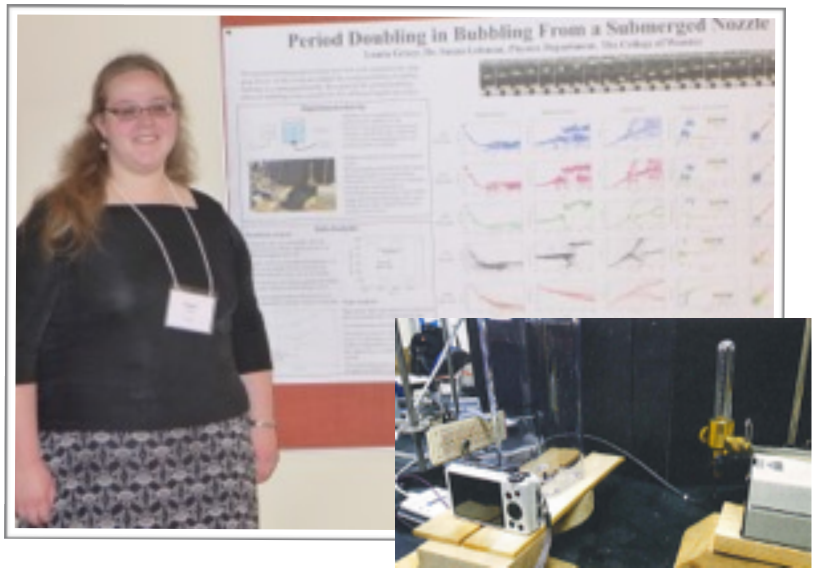
A mechanism was built to investigate the properties of chemical Reaction-Diffusion-Advection (RDA) systems. This mechanism is computer controlled and uses syringes to push, or advect, liquid at different rates. Five syringes of varying volumes, along with four different needle gauge sizes, were used to find flow rates of varying speeds. These flow rates were recorded in milliliters per second and micrometers per second with respect to where the flow was coming from or going to. The flow rates created by the mechanism were matched to theoretical flow rates and it was found that smaller syringes with smaller gauge sized needles more closely matched theoretical flow rates than larger needles and larger gauge sized needles. This mechanism has numerous experimental applications and can be used in conjunction with many ongoing RDA and hydrodynamic experiments.

SENIOR INDEPENDENT STUDY

LAURA GRACE

PERIOD DOUBLING IN BUBBLING FROM A SUBMERGED NOZZLE

Advised by Susan Lehman, Physics

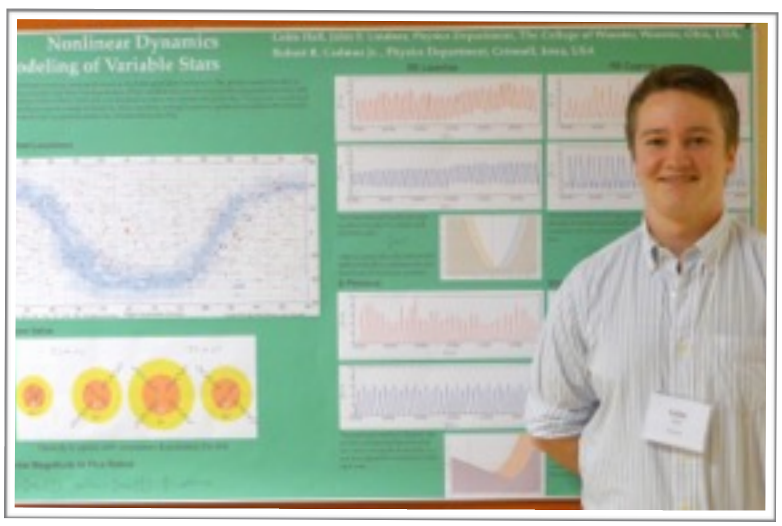


A study was conducted of the period doubling route to chaos in rising bubbles. The impact of viscosity on the period doubling route was examined. To investigate this, a laser-photodiode system was used to detect nitrogen bubbles rising from a nozzle in the base of a jar. The liquid in the jar was a solution of water and glycerin. Concentrations of 0, 25, 50, 75, and 100% glycerin were used. The rising bubbles were detected by a photodiode as the laser beam was scattered by the bubble. From the start and end times where the bubble blocked and unblocked the laser, the period between successive bubbles and duration of each bubble was calculated in *Igor Pro*. The bubbling period was found to bifurcate for all solutions tested by increasing gas flow rates. The period bifurcated again in the range of flow rates tested for all solutions but pure glycerin due to the very high viscosity of pure glycerin compared to the other concentrations tested. This period doubling behavior indicates that the system may tend toward chaos for much higher flow rates. This supports the findings of previous experiments on transitions between bubbling stages in that the bubbling period doubles to chaotic jetting for high gas flow rates. First return maps show a trend toward a set of behaviors at high gas flow rates that may be worthy of future investigation.

COLM HALL

NONLINEAR DYNAMICS ANALYSIS OF STELLAR DATA SETS

Advised by John Lindner, Physics



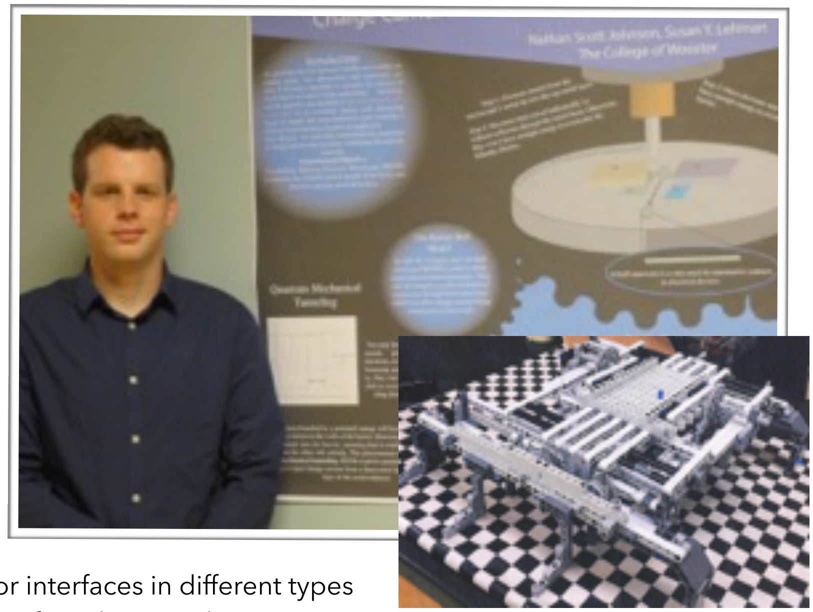
This goal of this project was the analysis of four stellar data sets provided by Dr. Robert Cadmus Jr. of Grinnell College. The apparent magnitude of the four variable starts *RS Cygnus, RS Lacertae, U Perseus*, and *SW Virginis* were the center of our analysis. We chose to first take the Fourier transform of the data and compare its result to the Lomb-Scargle periodogram. The next set of analysis was the construction of a nonlinear model to mimic the flux ratio of its corresponding star. If a continuous function can be constructed that is a match to the stellar data, any future analysis performed on that function will also be viable for the star to which it is matched. A stochastic asymmetric forced damped oscillator for each of the four stars was constructed in *Mathematica* with the adjustment of several parameters. The functions created were linearly related to the corresponding stellar fluxes.

SENIOR INDEPENDENT STUDY

NATHAN JOHNSON

CHARGE CARRIER CHARACTERISTICS IN DOPED SEMICONDUCTOR HETEROSTRUCTURES

Advised by Susan Lehman, Physics



A Dimension 3100 scanning probe microscope was modified for use in ballistic electron emission microscopy (BEEM). BEEM is a type of scanning tunneling microscopy that adds a third electrical contact in order to study electrical conduction in buried interfaces of multi-layered systems. BEEM was used in order to study the properties of majority carriers traveling across meta-semiconductor interfaces in different types of semiconductor heterostructures. Samples of Au deposited on *n*-GaAs and Ni deposited on *n*-GaN nanowire were examined. BEEM was used to measure the Schottky barrier height of AU-GaAs samples by collecting data on the current flowing from the buried GaAs layer as forward bias is applied to the sample. The Schottky barrier height for Au-GaAs was successfully measured for some samples at V_{bc} = 0.95±0.007 V, which matches well with previous experimental results. The second conductions band minimum was also detected at V_L = 1.26±0.11 V, also in agreement with other studies. Preliminary data on Ni-GaN nanowire systems were collected. The close agreement between results obtained for Au-GaAs samples and other studies means that the experimental apparatus can reasonably detect current in buried interfaces accurately.

SPENCER KIRN

EXCITATION WAVES IN PLANAR, INHOMOGENEOUSLY ILLUMINATED SYSTEMS

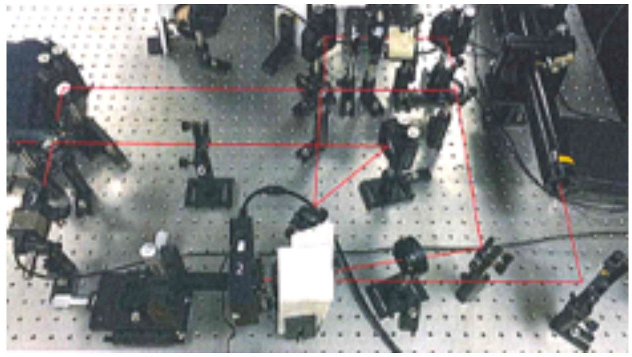
Advised by Niklas Manz, Physics

This purpose of this project was to build a system and begin to examine the propagation of excitation waves traveling through an inhomogeneous, light-sensitive Belousov-Zhabotinsky (BZ) system. Theoretical work by Schebesch and Engle produced a prediction of how the wave will be affected by a checkerboard inhomogeneity. We used a checkerboard transparency to create an inhomogeneous illumination pattern below the BZ system. The wave reacts to the light and travels at different speeds depending on the light intensity, the brighter the light the slower the wave propagates. A camera is used to track the wave as it propagates. The wave front is analyzed to create time-space plots as it travels through the BZ system. Codes were written for collecting and analyzing data, including: a program to take and save images of the wave propagating, a program to eliminate the background in every image, and a program to create time-space plots of the wave.

SENIOR INDEPENDENT STUDY

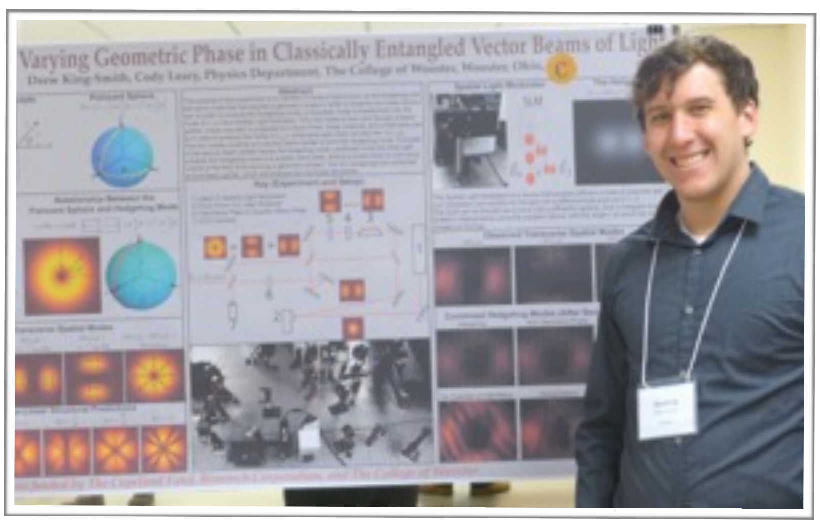
ANDREW KING-SMITH

MANIPULATION OF POLARIZED TRANSVERSE SPATIAL MODES TO INDUCE NON-LINEAR STRUCTURES USING THE GEOMETRIC PHASE



Advised by Cody Leary, Physics

The purpose of this experiment is to observe non-linear structures visible in the intensity distribution of light that are produced by the interference of a mode of light known as the "hedgehog"mode with another hedgehog mode that has acquired a geometric phase to its electromagnetic field. The hedgehog mode is the combination of two different Hermite-Gaussian modes of light: the $HG10\hat{x}$ mode and the $HG01\hat{y}$ mode. In order to produce these modes of light, a Gaussian mode is directed at a Spatial Light Modulator which converts the Gaussian mode into the $HG10\hat{x}$ mode by means of an interference pattern that acts as a diffraction grating. This $HG10\hat{x}$ mode is then directed into the first of two interferometers where the first interferometer makes the $HG01\hat{y}$ mode and the hedgehog mode. The first interferometer consists of two beam splitters, two mirrors, a Dove Prism, linear polarizer, and half-wave plate. The $HG10\hat{x}$ mode is split into two paths at the first beam splitter, where one path travels through the Dove Prism, linear polarizer and the half-wave plate in order to create the $HG01\hat{y}$ mode and the other path does not affect the original $HG10\hat{x}$ mode. These two paths combine at the second beam splitter to form the hedgehog mode and exit the first interferometer. The second interferometer consists of two beam splitters, three mirror and one quarter-wave plate. The first hedgehog mode is sent to the final beam splitter with no other optical elements acting on it, so it remains unchanged. The second hedgehog mode is directed through a quarter-wave plate in order to add phase delay to the electromagnetic field and thus acquire a geometric phase. The hedgehog mode with the acquired geometric phase is then interfered with the unchanged hedgehog mode at the last beam splitter in order to induce the non-linear structures. While no structures have been observed thus far, there are several reasons as to why the structures are not present: intensity distribution issues of the hedgehog modes and the $HG01\hat{y}$ mode and not enough control of the phase delay on the hedgehog's electromagnetic field. These issues are discussed along with possible solutions by means of a new Dove Prism and the use of a device known as the Soleil Babinet Compensator. A new Dove Prism may help for better rotating the polarization, thus keeping the full intensity distribution of the $HG01\hat{y}$ mode when passing through through the linear polarizer. An ideal replacement for the current Dove prism would be an optical rotator, which rotates modes to an arbitrary angle. The Soleil Babinet Compensator would allow greater precision for controlling the phase delay.

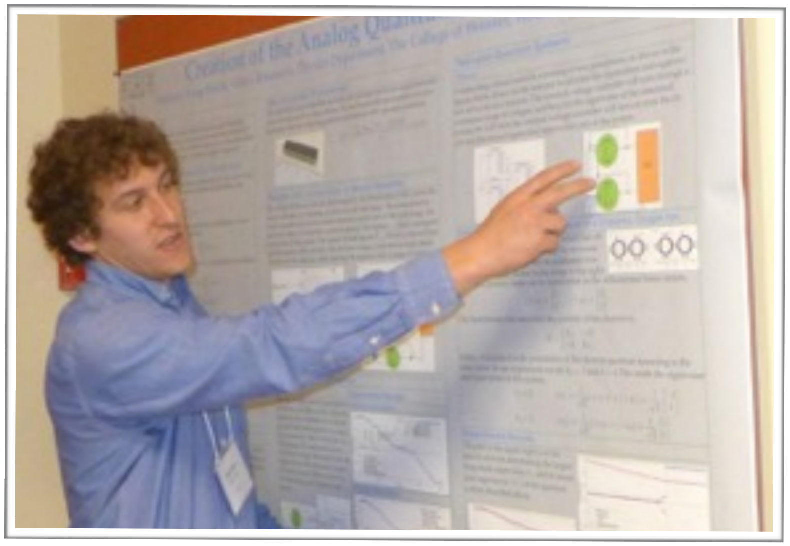


SENIOR INDEPENDENT STUDY

MATTHEW KING-SMITH

ANALOG QUANTUM SIMULATOR

Advised by Valery Rousseau, Physics

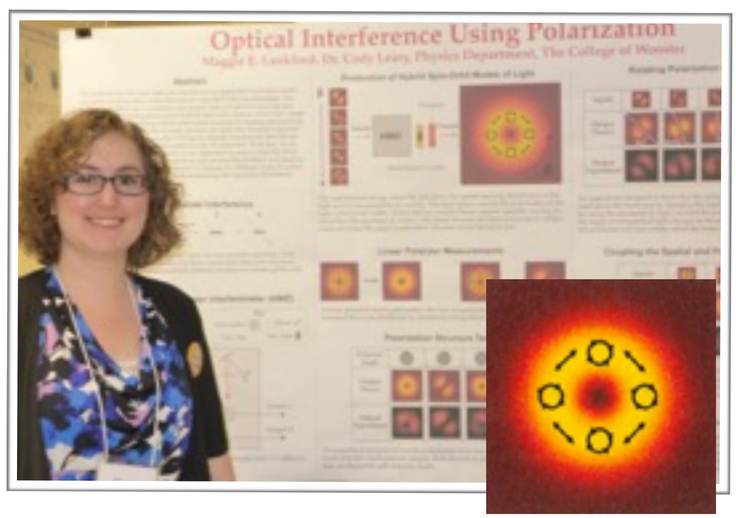


We designed an analog quantum simulator, a simple electronic device that is capable of solving quantum problems in Hilbert space of finite dimensions. In Quantum Physics, the experimental growth of the number of states with the system size is a frequent theme, which can create problems during computation. These computational problems lie in the challenge of representing the exponentially large amount of data that describes that state of the system, and the exponentially large time needed to solve the eigenvalue problem. We showed that an analog quantum simulator, through the use of neural networks, can address the computational time problem by generating quasi-instantaneous solutions to the eigenvalue problem. As an experimental realization, we designed an analog quantum simulator that solves a Hamiltonian that describes the location of an electron in the diatomic molecular ion O_2. Our experimental eigenstates and eigenvalues are in agreement with those obtained from numerical exact diagonalization. The realization of the AQS in a microchip is possible and could allow for the treatment of systems larger than those accessible by numerical exact diagonalization.

MAGGIE LANKFORD

THE PRODUCTION AND MANIPULATION OF NONSEPARABLE SPIN-ORBIT MODES OF LIGHT UNDER HONG-OU-MANDEL INTERFERENCE CONDITIONS

Advised by Cody Leary, Physics



We report the experimental production of modes of light in which the polarization (spin) and spatial (orbital) degrees of freedom are nonseparable. In addition, the spatial polarization distribution of these modes can be controllably tuned by varying the input polarization state. To achieve this, we input separable spin-orbit modes into an asymmetric Mach-Zehnder interferometer with an extra mirror in one arm. We probed the spatially varying polarization modes by combining a polarization and Stokes-based analysis with CCD imaging. In addition, we predict that two indistinguishable photons entering this device in separable spin-orbit modes can exhibit Hong-Ou-Mandel interference in conjunction with conversion to non separable modes. We further measure an additional family of tunable non separable modes with spatial polarization distributions, independent of Hong-Ou-Mandel conditions, that can be produced using this interferometer.

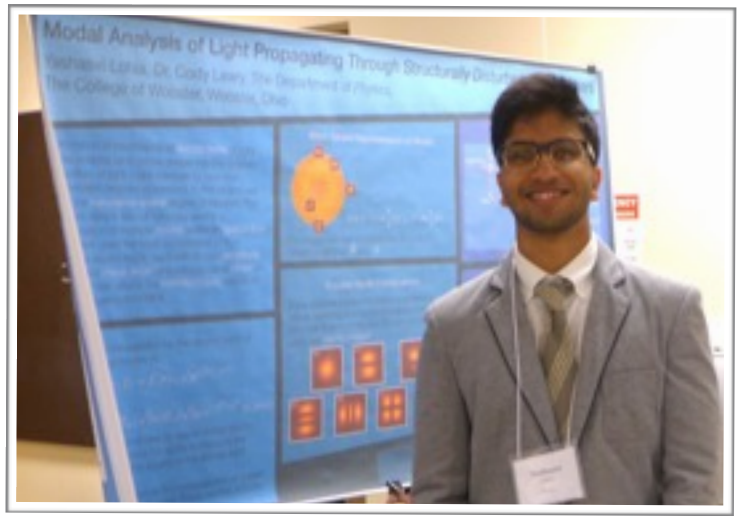
(Maggie has accepted a position as a research scientist at an optics firm that designs safety goggles.)

SENIOR INDEPENDENT STUDY

YASHASVI LOHIA

MODAL ANALYSIS OF LIGHT PROPAGATING THROUGH STRUCTURALLY DISTURBED OPTICAL FIBERS

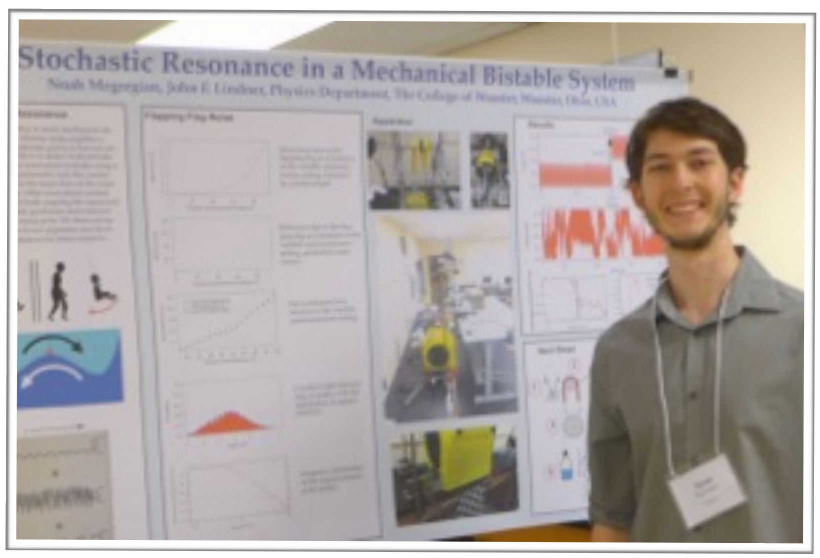
Advised by Cody Leary, Physics



A technique to control and manipulate the spatial wave function of light inside an optical fiber by structurally disturbing the fiber was devised. Two interferometers were set up to sort the Hermite-Gauss modes of light produced by the fiber. These interferometers worked on the principal of parity by separating even modes from odd modes. Theory of the operation of the interferometers was developed with linear algebra. It was demonstrated that imposing stress on the optical fiber affects the make up and the intensities of the modes propagating rather than the phase difference between the modes. Lower stress was shown to produce smaller changes in these variables. *Mathematica* programs were written to model and analyze experimental data based on input parameters.

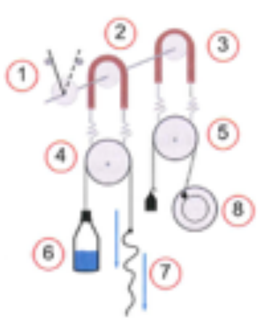
NOAH MEGREGIAN

STOCHASTIC RESONANCE IN A MECHANICAL BISTABLE SYSTEM



Advised by John Lindner, Physics

We built an apparatus to study mechanical stochastic resonance, wherein noise amplifies a weak signal. Our ultimate goal is to harvest ambient turbulent airflow to detect weak periodic signals. One of our innovations includes using a water bottle to continuously vary the counterweight that cancels the mean force of the wind on a flapping flag. Other innovations include friction pulleys for both coupling the signal and noise into a bistable pendulum and extensive use of U-shaped metal parts. We observed stochastic resonance in our apparatus and developed recommendations for future improvements.



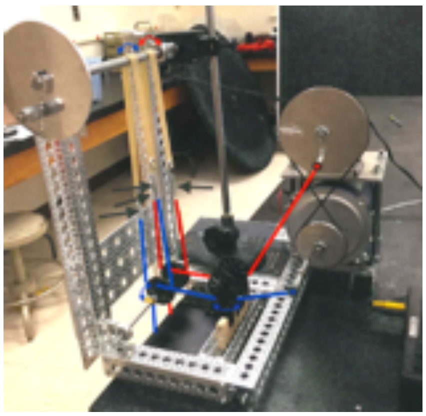
SENIOR INDEPENDENT STUDY

CALVIN MILLIGAN

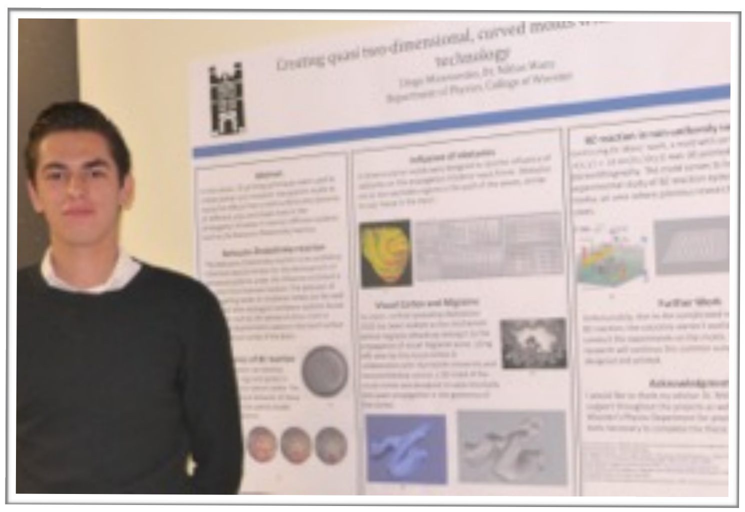
STRANGE NONCHAOTIC PENDULUM

Advised by John Lindner, Physics

Strange nonchaotic (SNC) motion is a kind of nonlinear dynamics that is fractal and nonchaotic and has only been extensively studied recently. Strange nonchaotic dynamics is characterized by a nonpositive maximum Lyapunov exponent and a fractal dimension. The goal of this project is to manifest SNC motion in a simple mechanical pendulum. The pendulum is quasi periodically driven at two frequencies near the golden ration, the most irrational number. Time series data from the physical pendulum is similar to computer simulations of an idealized model.



DIEGO MIRAMONTES



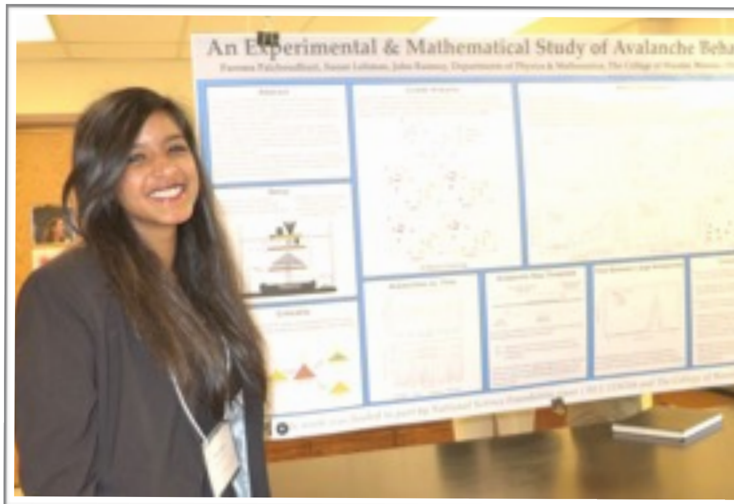
CREATING QUASI TWO-DIMENSIONAL, CURVED MOLDS WITH 3-D PRINTING TECHNOLOGY

Advised by Niklas Manz, Physics

The modeling software Rhinoceros was used to create planar and non-planar media in which to study reaction-diffusion systems, especially the Belousov-Zhabotinsky reaction. Geometrical conditions such as surface curvature and topology determine the stability or dynamical conditions that are not possible in planar systems. The first mold created contains a hollow region of depth 0.4 mm with two complementary curved surfaces described by the equation $z(x, y) = |A \sin(bx) \sin(by)|$ surrounded by a planar region which allows wave fronts to propagate. Another important aspect in the study of nonlinear waves is the study of how obstacles affect the propagation of waves. In cardiac tissue, nonexcitable tissue acts as an obstacle to electrical waves in the heart, which can cause vortex shedding and result in abnormal heart activity and in many cases death. Planar molds were created to test the influence in the propagation of planar wave fronts of four different obstacle shapes (square, rhombuses, circular and elliptical), orientations and sizes. The previously theoretically studied influence of square obstacles is complemented by the creation of analogue curved obstacles of the same dimensions as their square pairs. Cortical spreading depression has been shown to trigger migraine auras. A fMRI of the visual cortex provided by Dr. Hadjikhani from Harvard Medical School was exported into Rhinoceros and converted into a mesh. This mesh was subsequently converted into a mold with a hollow region of depth 0.4 mm that traces the surface of the visual cortex. This mold will allow for the first time to study spreading depression on a geometry that is extremely similar to that of the visual cortex.

SENIOR INDEPENDENT STUDY

PAROMA PALCHOUDHURI



AN EXPERIMENTAL AND MATHEMATICAL STUDY OF AVALANCHE BEHAVIOR

Advised by Susan Lehman, Physics and John Ramsay, Math

The avalanche distribution for a combined effect of tuning parameters was studied in a slowly-driven critical conical pile of steel beads. The tuning parameters were specifically drop height and cohesive forces between the beads. The cohesion was generated by placing the pile in between a pair of Helmholtz coils that created a uniform magnetic field in which the pile rested. The avalanche distribution was studied for a drop height of 2 cm at six different cohesion levels created by coil currents of 0, 300, 500, 630, 750 and 900 mA. Fractional occurrences of avalanches were calculated based on their size; the probability of large avalanches increased and that of mid-sized avalanches decreased with increasing cohesion resulting in humps in the probability distributions. Excessive number of double bead drops significantly effect the probability distribution of avalanches increasing the probability of mid-sized avalanches and decreasing that of smaller avalanches. New analysis techniques were developed and explored in order to study the inter-event time distributions and avalanche behavior. The waiting time after an avalanche in conjunction with k-means clustering was used to find the avalanche size threshold separating local from non-local avalanches, which was found to be at approximately 70 beads. For the inter-event time probability densities, it was found that the system spanning avalanche regime was well fit to a Brownian passage-time distribution for very large avalanches only, while the smaller and mid-sized avalanche regime was better fit by the Weibull distribution. (Popi has accepted a position as data scientist/software developer at Embarq Corp., New York City.)

GRAHAM SCHATTGEN

AIR POWERED ONE-WAY ARRAYS

Advised by John Lindner, Physics

One-way coupling is a relatively new area of study. By powering the coupling externally, an array of one-way coupled elements of an odd number will produce a single soliton that will propagate forever, while an array with an even number of elements will come to quiescence. This behavior has previously been observed extensively in hydromechanical and electrical models, and has been proven to work in short aeromechanical designs. This thesis describes the process of increasing the length of previous aeromechanical arrays by refining and miniaturizing the elements as well as reducing the number of moving parts to simplify the array. The array was inspired by Katsuo Maxted's element design in *Mathematica* and printed in smooth ABS plastics by Shapeways. I observed annihilation of soliton anti-soliton pairs and studied time to quiescence as a function of initial separation of the solitons. Further improvements of this design may allow for the development of the first mechanical two-dimensional array.

SENIOR INDEPENDENT STUDY

NATHAN STONE

CRITICAL SYSTEMS: AN EXPLORATION OF COHESION AND THE MOMENTS OF DISTRIBUTION

Advised by Susan Lehman, Physics

In this thesis, cohesion and its ability to affect the probability that an avalanche will occur on a conical bead pile were investigated. Cohesion was found to be related to the probability that an avalanche will occur through two universal variables, τ and σ, which were experimentally found and compared to past predictions. In order to find τ and σ, the moments of distribution were used. The moments for both small and large avalanches were calculated over a number of different cohesions. When using data for the moment calculations, it was important that there were no double drops when two beads fall at the same time. Double drops have higher impacts and a higher probability of causing an avalanche. In order to minimize the effects of double drops, only data runs with less than 2% double drops were used. As the cohesion was increased, the small avalanche moments decreased by a power law function dependent on both τ and σ. The values of τ and σ were found to be 1.34 and 4.43. The predicted values of τ and σ were 1.5 and 0.5. The large moments increased as the cohesion increased. Each of the data sets were then collapsed. The collapsed data provided a method, different from moment analysis, to determine τ. The collapsed data showed τ = 1.5.

The velocities of a falling bead were also calculated in order to determine if the beads were falling straight towards the pile and whether they were starting at the correct position. We found that the beads did have horizontal velocity and they were not falling directly onto the apex of the pile. The beads would fall within a 2cm radius of the apex of the pile. It was also found that the beads, more often than not, were starting at positions much different from the intended start. The beads were typically falling from heights that were within 1cm of the drop point.

CATHERINE TIEMAN

QUANTUM RING EXCHANGE INTERACTION ON A PYROCHLORE LATTICE

Advised by Valery Rousseau, Physics

We present a study of states of matter of low temperature hard-core bosons on a pyrochlore lattice with ring-exchange interactions. Simulations such as this one have recently been used to research exotic phases in various materials, with a special interest in finding phases possibly related to high temperature superconductivity, such as quantum spin liquids for fermion models or perhaps those liquids for bosons. We show the application of the Stochastic Green Function algorithm, a Quantum Monte Carlo simulation, on a highly frustrated lattice with hard-core bosons allowed to move both between nearest neighboring sites and in correlated moves around a ring of lattice sites.

PHYSICS FACULTY

NIKLAS MANZ

PH.D. 2002 UNIVERSITY OF MAGDEBURG, GERMANY

At Wooster since 2015

Teaching 2015-2016: Algebra Physics I + Laboratory, Mechanics, Physics Revolutions

Dr. Manz completed his first year on the faculty at Wooster. His research interests are in the interdisciplinary field of spatio-temporal pattern formation with a focus on reaction-diffusion systems. After joining the College last fall, Dr. Manz advised three Senior I.S. projects and one student in his Junior I.S. One senior student (Spencer Kirn) presented his results at the Spring 2016 Meeting of the APS Ohio Section in Dayton OH and at the Central Regional Meeting of the ACS in Covington KY. Dr. Manz also gave invited talks at Denison University and Embry-Riddle Aeronautical University in Prescott AZ. Dr. Manz is the faculty advisor for the CoW Student Ballroom Club and teaches their weekly dance lessons. He also organized a trip for students to attend a lecture by physics Nobel Laureate William Phillips at Otterbein University. On campus, Dr. Manz presented:

- Science Round Table "Turkey tail fungus and patterns on your skin"
- Physics Colloquium Series "The Wave Lab at The College of Wooster"
- APEX Mini Lectures for New International Students "Pattern formation in nature"

In summer 2016, Dr. Manz attended an American Association of Physics Teachers New Faculty Workshop in College Park, Maryland and a Gordon Research Conference in Stowe, Vermont on Oscillations and Dynamic Instabilities in Chemical Systems.

CODY LEARY

PH.D. 2010 UNIVERSITY OF OREGON

At Wooster since 2011

Teaching 2015-2016: Calculus Physics I and II + Laboratory, Modern Physics Laboratory, Electricity and Magnetism, Thermal Physics

Fresh from a productive research leave, Cody Leary continued his research with Wooster students in quantum optics. Dr. Leary advised four Senior I.S. projects. Maggie Lankford's I.S. thesis research contributed directly to two journal articles which have been published*. Maggie presented her work at two international quantum optics conferences, in Prague, Czech Republic, and San Jose, CA; Another of Dr. Leary's advisees, Andrew King-Smith, won an American Physical Society (APS) Undergraduate Presentation Award for his IS work after presenting it at the National Meeting of the American Physical Society March meeting. Dr. Leary gave an invited talk at Kenyon College, and a series of invited lectures at the Okinawa Institute of Science and Technology (OIST) in Japan, where he began a research collaboration with OIST's light-matter interactions unit during a weeklong trip there.

* C.C. Leary, Maggie Lankford and Deepika Sundarraman, "Polarization-based control of spin-orbit vector modes of light in biphoton interference", Optics Express vol. 24, 3, pp. 14227-14241, 2016.

* Leary, Cody C., Maggie Lankford, and Deepika Sundarraman, "Polarization-Based Control of Spin-Orbit Hybrid Modes of Light in Biphoton Interference," in Conference on Laser and Electro Optics 2016 and 2016 Quantum Electronics and Laser Science Conference (CLEO/QELS), San Jose, CA, 2016.

PHYSICS FACULTY

JOHN LINDNER

PH.D. 1988 CALIFORNIA INSTITUTE OF TECHNOLOGY

At Wooster since 1988

Teaching 2015-2016: First Year Seminar "Belief in God in an Age of Science", Algebra Physics Laboratory, Nonlinear Dynamics, Astronomy of Stars and Galaxies, Computational Physics, 4 Senior Independent Study advisees

In addition to being the advisor to the Physics Club, Astronomy Club, and Robotics Club, Dr. Lindner found time to give several talks on campus and locally: Theology & Science (Medina Presbyterian Church), Quantum Reality (Wooster Rotary Club), Strange Nonchaotic Stars (Faculty at Large), Strange Nonchaotic Stars (Science Round Table), Unveiling Pluto: New Horizons Flyby of the Pluto-Charon Double Planet (Wooster Science Café). He also co-authored several publications that appeared in 2016:

• A Simple Nonlinear Circuit Contains an Infinite Number of Functions, B. Kia, J. F. Lindner, W. L. Ditto, *IEEE Transactions on Circuits and Systems II* volume TBA, pages TBA (2016)
• Superlinearly scalable noise robustness of redundant coupled dynamical systems, V. Kohar, B. Kia, J. F. Lindner, W. L. Ditto, *Physical Review E* volume 93, pages 032213(1-9) (2016)
• Role of network topology in noise reduction using coupled dynamics, V. Kohar, S. Kia, B. Kia, J. F. Lindner, W. L. Ditto, *Nonlinear Dynamics*, volume 84, pages 1805–1812 (2016)
• Reduction of additive colored noise using coupled dynamics, V. Kohar, B. Kia, J. F. Lindner, W. L. Ditto, International *Journal of Bifurcation and Chaos*, volume 26, pages 1650005(1-9) (2016)
• Simple nonlinear models suggest variable star universality, J. F. Lindner, V. Kohar, B. Kia, M. Hippke, J. G. Learned, W. L. Ditto, *Physica D*, volume 316, pages 16-22 (2016)

Dr. Lindner is Co-PI of a three-year $300,00 NSF-REU grant which began in the Department during summer of 2016.

VALÉRY ROUSSEAU

PH.D. 2004 UNIVERSITY OF NICE (FRANCE)

At Wooster since 2015

Teaching 2015-2016: Calculus Physics I and Laboratory, Electronics, Calculus Physics II Laboratory, Modern Optics, Math Methods for Scientists

Dr. Rousseau, a one-year visiting assistant professor, was the I.S. advisor for two students. Senior physics major Catherine Tieman presented her senior I.S. research in an oral presentation (co-authored by Dr. Rousseau) at the National Meeting of the American Physical Society in Baltimore last March. A few of Dr. Roussea's recent publications:

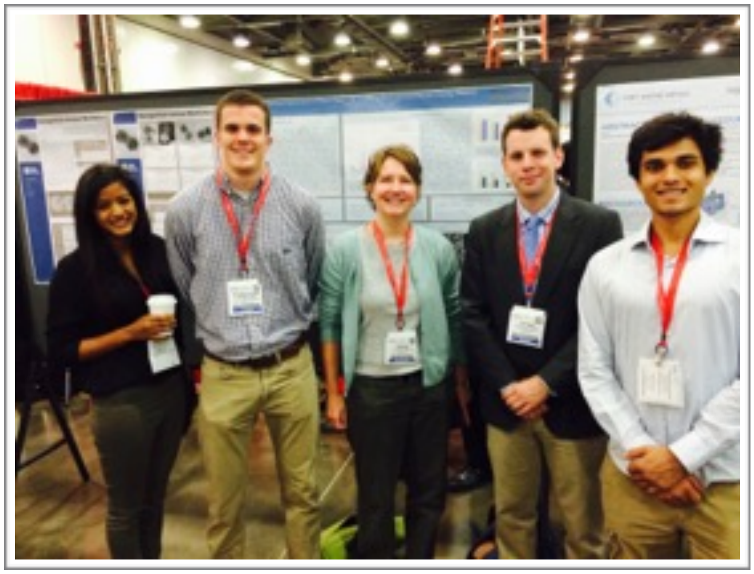
• Cooling Atomic Gases With Disorder
Thereza Paiva, Ehsan Khatami, Shuxiang Yang, Valery Rousseau, Mark Jarrell, Juana Moreno, Randall G. Hulet, Richard T. Scalettar, Phys. Rev. Lett. 115, 240402 (2015)
• Competing exotic quantum phases of spin-1/2 ultra-cold lattice bosons with extended spin interactions
Chia-Chen Chang, Valéry G. Rousseau, Richard T. Scalettar, and George G. Batrouni, Phys. Rev. B 92, 054506 (2015)

PHYSICS FACULTY
SUSAN LEHMAN, CHAIR

PH.D. 1999 NORTH CAROLINA CHAPEL HILL

At Wooster since 2003

Teaching 2015-2016: Modern Physics and Laboratory, Quantum Mechanics, Junior Independent Study, 4 Senior Independent advisees



Dr. Lehman and four of her research students attended the 2015 Materials Science and Technology conference in Columbus, Ohio. *From left: Popi Palchoudhuri '16, Nate Stone '16, Dr. Lehman, Nate Johnson '16, and Avi Vajpeyi '18.*

In March, Dr. Lehman attended the national Meeting of the American Physical Society in Baltimore with four Wooster students. She gave a talk at the conference entitled "Tuning Parameters and Scaling for Avalanches on a Slowly-driven Conical Bead Pile with Cohesion".

Woo Women in Physics!

JUNIOR INDEPENDENT STUDY

A SAMPLING OF PROJECTS

Herokazu Endo

Proving the Coulomb's Law and Finding the Coulomb's Constant from Two Charged Spheres

Alex Gould

Acoustic Trapping: A Theoretical Analysis and Computational Implementation

Dylan Hamilton

Singing in the Wind: Numerically Solving the Navier-Stokes Equations with Movable Boundary Conditions

Roy Hadfield

Rotational Analogies for Viscous Drag

Marc Manheim

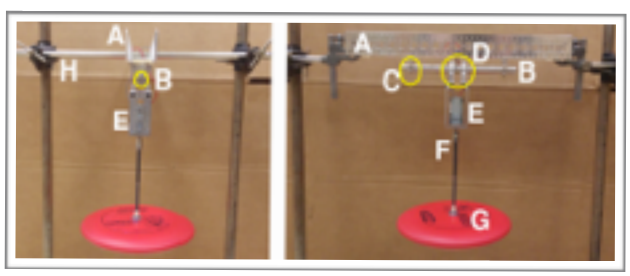
Lead Zeppelin: An Investigation into the Feasibility of a Modern Vacuum Balloon

Robin Morillo

The Effect of Slope Upon Forest Fire Propagation

Preston Pozderac

Gone with the Wind: An Investigation into the Flight Dynamics of Discs



Ziyi Sang

Quantum Decoherence - The Emergence of the Classical World from the Quantum World

Michael Wolff

Measuring Thermal Conductivity by Ångstrom's Method

PHYSICS COLLOQUIUM SERIES

SPRING SEMESTER COLLOQUIA

Junior I.S. self-designed presentations, 3 May 2016

Audrey Mithani, Tufts University, Did the Universe Have a Beginning?, 1 April 2016

Tess Oliver, West Virginia University, Inverting the Rate Equation to Understand Charge Dynamics in Light Based Technologies, 30 March 2016

Rob Owen, Oberlin College, An Entirely New Kind of Astronomy, 11 February 2016

FALL SEMESTER COLLOQUIA

Senior Independent Study Fall Semester Oral Reports Round 2,10 December 2015

Senior Independent Study Fall Semester Oral Reports Round 1 December 2015

Erzsebet Regan, Assistant Professor of Biology, The College of Wooster "Principles of dynamical modularity in biological regulatory networks, 20 October 2015

Niklas Manz, Assistant Professor of Physics, The College of Wooster "The Wave Lab at The College of Wooster, 22 September 2015

"Tell me what you did last summer" - Physics student summer research experiences", 1 September 2015

ELECTRONICS CLASS ROBOTS

Come check out

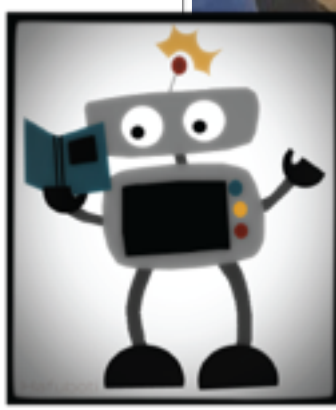
ROBOT MANIA

presented by students

in Professor Rousseau's

Physics 220

Electronics



Friday, 12/11

4:00 pm

Taylor 205

Sheila the Dancing Robot

Maggie Lankford and Popi Palchoudhuri

1D Bot

Gabe Dale-Gau, Arpan Roy, and Yashavi Lohia

Pathfinder Bot

Michael Bush and Hero Endo

Waiter Bot

Nate Johnson and Kyle McNickle

PHYSICS CLUB & ASTRONOMY CLUB

Physics Club Officers

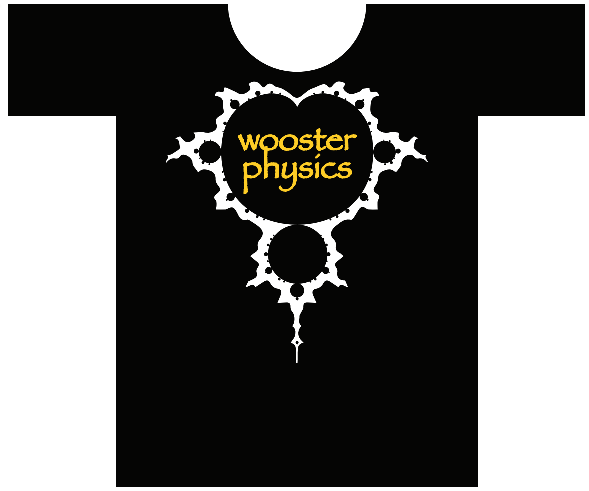
President Michael Bush

Vice-President Maggie Lankford

Treasurer Robin Morillo

Secretary Colm Hall

Faculty Advisor John Lindner



Fall Semester Events

2015 September 4: Scot Spirit Day

2015 September 9: Luce Dinner

2015 September 16: Viewing stars at the observatory

2015 September 24: General Meeting

2015 September 27: Viewing supermoon eclipse at the observatory

2015 October 29: Air Pressure demo & video recording

2015 November 12: Forces & Motion demo & video recording

2015 November 19: E & M demo & video recording

2015 November 21: Great Lakes Science Center trip & dinner in Cleveland

2015 December 3: Summer research & internships meeting

2015 December 6: Physics at STEM bash in Kittredge

2015 December 10: Waves & Sound demo & video recording

Astronomy Club Officers

President Colm Hall

Treasurer Zane Thornburg

Faculty Advisor John Lindner

PHYSICS CLUB

Spring Semester Events

2016 January 28: General Meeting + REU Workshop

2016 February 4 (Thursday) 7-8 PM: States of Matter demo and video recording

2016 February 11: LaTeX Tutorial

2016 February 18: Trip to Otterbein for talk by Nobel Laureate William Phillips

2016 February 25: Mathematica Tutorial

2016 March 3: Igor Pro Tutorial

2016 March 10: Adobe Illustrator Tutorial

2016 March 31: Science Day info and assignments

2016 April 7: Taylor Bowl Challenge general meeting

2016 April 14: Science Day practice in Taylor 101

2016 April 16: Science Day 8

2016 April 24: Taylor Bowl 27

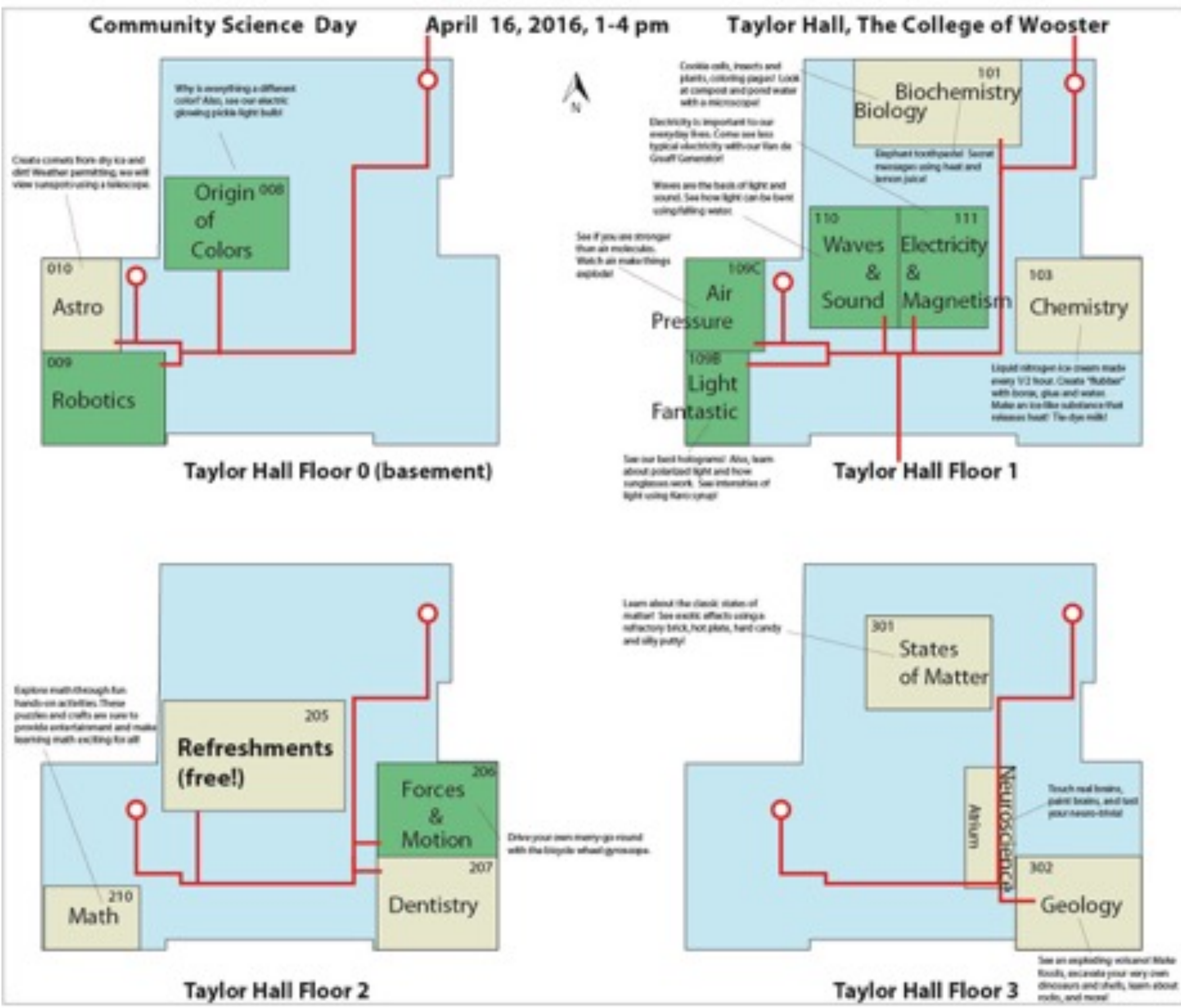
The Dude and Walter Sobchak from The Big Lebowski (Zane Thornburg and Nate Moore)

Taylor Bowl 27 Physics 96.3 Math/CS 103.8

PHYSICS OUTREACH

The Physics Club made 13 visits to local elementary schools this past year and held Community Science Day in Taylor Hall in April. A new demo was added to their outreach repertoire: States of Matter. It was very well received by students and teachers alike and employed the use of refractory bricks, silly putty, a hot plate and hard candy to show some exotic effects of the classic states of matter.

Maggie Lankford demonstrates total internal reflection to children at Science Day



WOOSTER STUDENTS @ CONFERENCES

Materials Science & Technology Conference, Columbus OH, October 2015

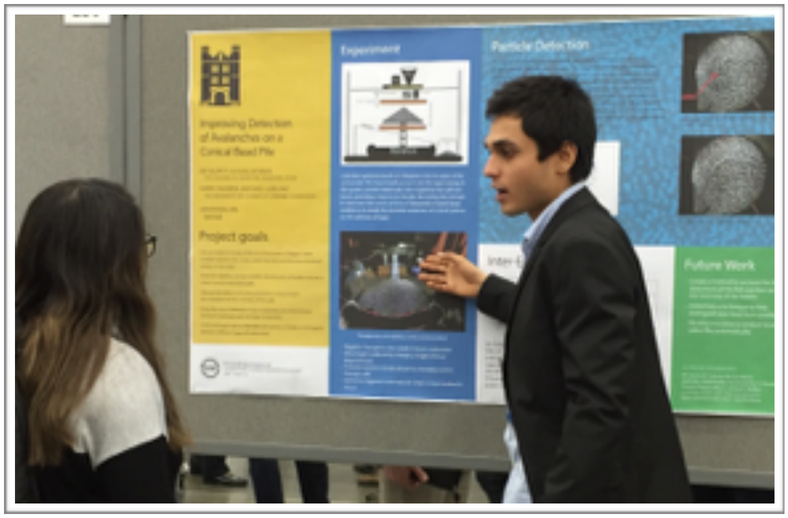
Dr. Susan Lehman and four of her research students, Popi Palchoudhuri, Nate Stone, Nate Johnson, and Avi Vajpeyi, attended the 2015 Materials Science and Technology conference in Columbus, Ohio. MS&T brings together scientists, engineers, students, suppliers and more to discuss current research and technical applications, and to shape the future of materials science and technology.

National Meeting of the American Physical Society, Baltimore MD, March 2016

"Improving detection of avalanches on a conical bead pile", Avi Vajpeyi*, Susan Lehman, K. Dahmen, M. LeBlanc, J. Uhl. (poster presentation)

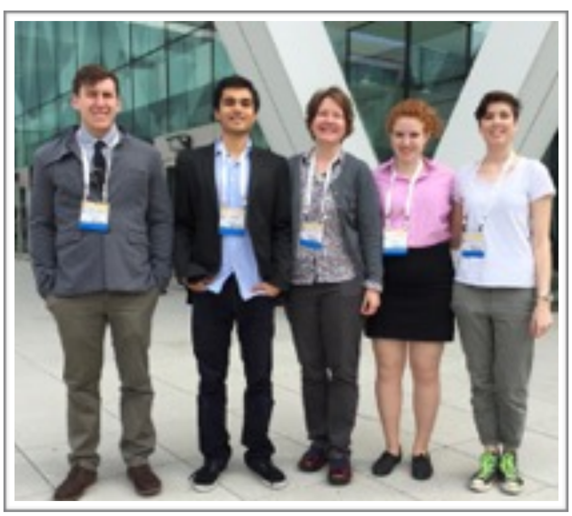
"Quantum Monte Carlo study of hard-core bosons in a pyrochlore lattice with six-site ring-exchange interactions", Catherine Tieman*, Valery Rousseau. (oral presentation)

"Changes in the Distribution of Avalanches on a Conical Bead Pile with Cohesion," Justine Walker*, Susan Lehman, K. Dahmen, M. LeBlanc, J. Uhl (poster presentation)



"Tuning Parameters and Scaling For Avalanches On A Slowly-Driven Conical Bead Pile with Cohesion," Susan Lehman, D.T. Jacobs, Paroma Palchoudhuri*, Avi Vajpeyi*, Justine Walker*, K. Dahmen, M. LeBlanc, J. Uhl (oral presentation by Dr. Lehman)

*student presenter/co-author



Wooster Physics at Nat'l Meeting of the APS

"Spatially varying geometric phase in classically entangled vector beams of light", **Andrew King-Smith***, Cody Leary. (poster presentation)

2016 APS Undergraduate Presentation Award

WOOSTER STUDENTS @ CONFERENCES

Ohio Section of the American Physical Society, Dayton OH, April 2016

"Light-sensitive reaction-diffusion waves in a checkerboard-like illumination system", Spencer Kirn* and Niklas Manz (poster presentation)

Central Regional Meeting of the American Chemical Society, Covington KY, May 2016

"Light-sensitive reaction-diffusion waves in a checkerboard-like illumination system", Spencer Kirn* and Niklas Manz (poster presentation)

George and Mildred White Science Lecture: Nobel Laureate William Phillips, February 2016

Dr. Manz organized a trip to Otterbein University for The George W. and Mildred K. White Science Lecture Series for a talk by by Nobel Prize winner Dr. William D. Phillips. Dr. Phillips discussed "Time, Einstein and the coolest stuff in the universe." It was a lively, multimedia presentation, including experimental demonstrations and down-to-earth explanations about some of today's most exciting science. The students were privileged to meet and chat with Dr. Phillips too!

ON-CAMPUS SUMMER RESEARCH

NSF/REU Research Experience for Undergraduates

Advisors: S. Lehman, J. Lindner, C. Leary, N. Manz and P. Bonvallet (Chemistry)

The department provided research opportunities to 15 students this past summer, including 5 students from other colleges : University of Dallas, Ursinus College, Wittenberg, Arizona State and Lorain Community College. The summer was filled with picnics, tutorials and workshops, star parties at the observatory, ice cream, and even a pie fest! And yes, there was plenty of research going on too!

Geometric Phases and Anholonomy:
Things That Don't Return after 360° Rotations
by Michelle Bae (CoW '19)

Creating Strange, Non-chaotic Behavior
by Angelica Berner (Arizona State '19)

Synthesis and Analysis of High-Swell, Silica-based Gels
by Tyler Branscum (Lorain Community College, Ohio University '18)

Blowing Bubbles: The Route to Chaos
by Jordan Dennis (CoW '19)

Bead Pile Video Analysis: Tracking a Needle in a Needle Stack
by Haidar Esseili (CoW '19)

Simulating Reaction-Diffusion Waves around Obstacles
by Alex Gould (CoW '17)

Sliding on a Tumbling Asteroid: Geodesics on a Rotating Ellipsoid
by Nate Moore (CoW '18)

Waiting for the Big One: Inter-event Time
by Sam Nash (CoW '19)

Reaction-Diffusion-Advection Systems
by Jersson Pachar (Wittenberg '18)

Alignment of a Down Conversion System for Coupled Photon Experiments
by Jacob Paul (Ursinus College '17)

Radial Solutions of the Finite Spherical Well for Electrons and Photons
by Preston Pozderac (CoW '17)

The Expressions of Light: Simulating Modes in a Circular Dielectric Wave Guide
by Alishan Premani (CoW '18)

Aeromechanical One-Way Array
by Tessa Rosenberger (University of Dallas '19)

Bond, Si-O-Si Bond:
Characterizing the Swelling of Osorb Using Computational Chemistry and Spectroscopy
by Zane Thornburg (CoW '18)

STRICTLY BALLROOM

When Wooster Physics professor Niklas Manz and his wife Yvonne twirl in time across the floor in a dance studio at the Wayne Center for the Arts, they make ballroom dancing look deceptively simple.

What now is second nature for the pair is the sum total of hours and hours of practice, much of it in Germany, where they both started dancing as teenagers. And now the couple shares their love of everything ballroom with locals who can enroll in two classes they teach at the center.

The couple came to the area last year, when Niklas Manz took a job as a physics professor at The College of Wooster. And while they started a ballroom dancing club at the school, neither had given much consideration to an affiliation with the arts center.

Turns out, they've done a bit more than wow the crowd at a wedding reception or two. They are former members of the German national team and represented their home country in seven European and six world championships. They placed 12 times, won two European championships and were World Champions in 2000.

The couple participated in formation dancing, which involves eight couples on the floor for a six-minute routine. Think, Niklas Manz said, of synchronized swimming, but on land and in tuxedos and ballgowns. "No one has to stand out," he said, "because it is as synchronized as possible." In fact, his wife said, the best dancers often moved through the formation ranks, because in addition to being able to dance well "in a team, you need to be more mature, responsible."

They got a late start, by German standards. In a country where children often take to the dance floor to learn basic movement at 3 or 4 years old and often compete by age 5 or 6, the Manzes began as teenagers.

Niklas Manz said, "I just loved dancing. I'm not the most talented person, but you can compensate with more work and more practice." In fact, he was already on the team when Yvonne Manz came to it. They were not paired off at first. But when they were, she said, "we took two steps together and it worked."

The teams are separated into three levels and dancers ideally move up with time and practice. The Manzes had the opportunity to dance as substitutes on the top team, while still rehearsing with a lower-level group. Learning the dances on two different teams required 10- to 12-hour long practices on the weekends, as well as a few hours each weekday. It took four years to get to the top, where they stayed. *(excerpts from The Daily Record article, June 5, 2016)*.

Niklas and Yvonne Manz once danced as part of the Braunschweiger DanceSport Club, which won the German national championship four times in nine appearances.