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OSU Oregon State UNIVERSITY

Physics

Letter from the Chair

Dear Friends of the Department:

This has been another busy year, but that is certainly not a complaint! Our undergraduate population remains large, and this year most of our upper division classes had an enrollment over thirty. Even though we lost our computational and engineering physics programs, we still gained students in our major. Of course, it helps that the university enrollment increased. This latter enrollment does create a lot of stress in our lower division service courses, though, which are filled to the brim. In order to accommodate more students we need more instructional laboratory space. We have our plans ready, but are waiting for other folks to move out of Weniger Hall.

We have hired a new assistant professor, Dr. Bo Sun, who will start working at OSU this February. His field of expertise is collective cell biophysics, where he is working on questions related to how is information processed by a multi-cellular network, how cells self-organize through mechanochemical interactions, and why cancer cells employ different migratory/cell cycle/metabolism programs. Weniger 110 is currently under remodel as new research laboratory space for him. We also welcome several new postdoctoral fellows and visiting faculty members. Dr. Keshab Paudel is working with Prof. Oksana Ostroverkhova, Dr. Xiaxuan Huang is working with Prof. Michael Zwolak, and Dr. Kerstin Blank is working with Prof. Ethan Minot.

Many congratulations are in order. Profs. Ken Krane, David McIntyre, Allen Wasserman, and Rubin Landau all had new books or new editions of books published. Prof. Ethan Minot was awarded a prestigious NSF CAREER award. Profs. Oksana Ostroverkhova and David Roundy received NSF support for their work. Prof. Dedra Demaree and David Bannon received L.L Stewart Faculty Development Awards. Prof YunShik Lee received the Milton Harris Award in Basic research from the College of Science. Prof. Ethan Minot was promoted to Associate Professor with tenure and Prof. YunShik Lee was promoted to Full Professor. Prof. Oksana Ostroverkhova was selected as a College of Science Scholar for 2013 and Prof. Dedra Demaree was selected as a University Honors College HerStory Professor. Prof. Janet Tate received an OSU-RERF award. The following students received awards: Daniel Gruss, Jenna Wardini, Sam Settelmeyer, Mark Kendrick, Nick Kuhta, Lee Aspitarte, and Maxwell Atkins.

Our students are able to find jobs, which is not a minor accomplishment in the current economic climate. Several of our former PhD students are now working for Intel. We received some information from former students, and we certainly would love to hear from all of you how you are doing! An important aspect of our work is to prepare students for a productive role in society. We have started a new orientation course for lower division physics students, designed by some of our undergraduate students, which is one venue for former students to tell their stories about careers after obtaining a degree. Therefore, any information you can provide us about how a physics degree has helped your career is truly appreciated!

I hope everybody will have a wonderful 2013!

Henri Jansen, Chair

INSIDE:

Physics

Degrees Awarded

Zlatko Dimcovic, Ph. D. to Northwest Alliance for Computational Science & Engineering
Ali Almaqwashi, M.S. to King Abdulaziz University, Saudi Arabia
George S. DeBeck, M.S.
Jessica R. Hughes, M.S.
Louis Maizy, M.S.
Matthew M. Oostman, M.S.
Grant Saltzgaber, M.S. to Jireh Semiconductor, Hillsboro, OR
Peter M. Wojcik, M.S. to the Ph.D. program at University of Idaho.
Zhiyuan Zhang, M.S.
Brian T. Devlin, B.S.
Billy E. Geerhart III, B.S.
Allison M. Gicking, B.S.
Shawn M. Gilliam, B.S. to Applied M.S. program at University of Oregon
Jacob A. Goodwin, B.S.
Jonathan M. Greene, B.S.
Tom G. Hathaway, B.S. to Air Force
Jeffry N. Holmes, B.S.
David G. Jensen, B.S.
Christopher A. R. Jones, B.S.to graduate program at Oregon State University
Mason L. Keck, B.S. to Astronomy graduate program at Boston University
Nicholas C. Petersen, B.S. to graduate program in medical physics at Louisiana State U.
Tyler D. Turner, B.S. to Applied M.S. program at University of Oregon
Jaryd F. Ulbricht, B.S.
Murray A. Wade, B.S.

Student Awards

The annual graduate awards in the department went to **Mark Kendrick** (Physics Graduate Research Award), **Nicholas Kuhta** (Physics Graduate Research Award), and **Lee Aspitarte** (Physics Outstanding Teaching Assistant Award).

Graduate student **Jason Francis** (Tate group) received a supplement to Prof. Tate's NSF grant to work on x-ray absorption and emission spectroscopy of BiCuOSe. He traveled to Brookhaven National Lab to work with Prof. Louis Piper of the University of Binghamton, SUNY.

Graduate student **Daniel Gruss** (Zwolak group) was awarded a grant in support of his research by the Sigma Xi Committee on Grants-in-Aid of Research. The title of his proposed work is "Entanglement and correlations in transport: From nanoscale electronics to cold atoms."

Physics senior **Afina Neunzert** was awarded the Janet Richens Wiesner University Honors College (UHC) Scholarship for Undergraduate Women in Science. Physics senior **Sam Settelmeyer** has been selected as a recipient of the UHC's Honors Promise Finishing Scholarship and of the UHC's Honors Experience Scholarship.

Physics senior **Maxwell Atkins** received URISC funding for his project "Radio Telescope Development and Galactic Hydrogen Cloud Observations" under the supervision of Prof. Bill Hetherington. Physics senior **Jenna Wardini** received URISC funding for her project "Transmission Electron Microscopy as an Aid to Improve Graphene Synthesis" under the supervision of Prof. Ethan Minot.

Research Highlight: What did one nanoscale sensor say to the other?

By Michael Zwolak

Michael Zwolak joined Physics Department at OSU in 2011 as an Assistant Professor. His research interests are in computational biophysics and quantum information.

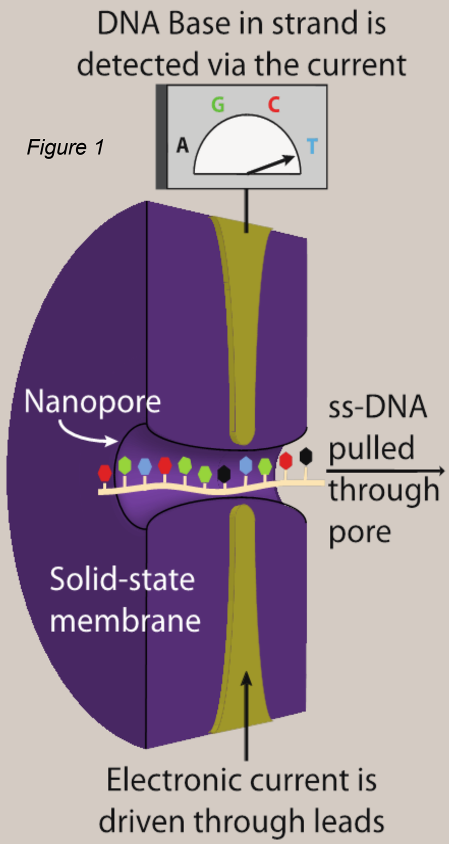
Nonequilibrium phenomena in complex, many-body systems are at the core of many projected technological developments, from electronics, to energy harvesting, to medicine. Our work is on analytical and computational approaches to investigating quantum and classical systems out of equilibrium. In the end, the main objectives are to understand how molecules and materials behave at the atomic level, determine their response to external stimuli, and develop methods to probe physical processes at the nanoscale.

For instance, we recently set the theoretical foundations for a new method for sequencing DNA based on "transverse" electronic transport, (see Figure 1). The idea is to use nanopores, i.e., holes with a nanoscale diameter, to localize single-stranded DNA molecules and, with embedded electrodes, determine the molecular contents of the electronic junction.

As we all know, DNA is composed of four bases, or "letters", (A)denine, (G)uanine, (T)hymine, and (C)ytosine, each attached to the phosphate sugar backbone. Typically, one thinks of DNA as a "double helix", where two strands wrap around each other and "Watson-Crick" pairing holds them together (a closer inspection shows that there are two types of interactions that hold the DNA together – "stacking" and hydrogen bonding). The double-helix, though, can unravel (more on this in a moment), yielding two, complementary single strands of DNA. The human genetic code is 3 billion bases long (or 6 billion, depending on how you count): A single strand from the double helix, if stretched out, would be about 2 meters long! It should be apparent, that sequencing any given person's genome is a huge task. It doesn't make it any easier that typical methods interrogate only small bits of DNA at a time (in the 10's of bases for some modern techniques). The result is like someone handing you a billion fortune cookies and asking you to assemble your lucky numbers into a coherent message.

What if you stretched out a single strand of DNA, threaded it through a pore, and read off each base with some sensor that detects physical changes in the pore region? In this way, the sequence of bases in a DNA strand could be read off linearly as it goes through the pore. We demonstrated that embedded electrodes that drive a current across the pore ("transverse"/perpendicular to its axis) can "sense" the different bases via their modulation of the tunneling current. That is, as current-carrying electrons approach the pore, to get to the other side, they have to tunnel through the junction – a process forbidden classically – and the probability to do so depends on the base present in the junction. Thus, measuring the electronic current versus time gives you the sequence of bases. Further, we showed – using a combination of quantum mechanical current calculations and classical molecular dynamics – that this is possible even in the presence of the noisy aqueous environment (composed of fluctuating water molecules and ions), so long as the structural motion of DNA itself can be kept under control. The latter is possible via the application of external electric fields that pull on the charged DNA backbone.

Figure 1



This single-molecule approach has the potential to enormously reduce the time and cost of sequencing (i.e., towards the "$1000 genome"), and thus enhance our ability to determine genetic factors in illnesses such as heart disease and cancer. The long-term goals in this field are to develop technologies that make sequencing both rapid and inexpensive, so that a person's genetic information will allow for the prediction of their susceptibility to illnesses and for preventative action to be taken. This is known as personalized medicine. Due to its potential to revolutionize medical field, experimentalists are actively pursuing this approach, where recent experiments have confirmed our predictions (see, for instance, "Quantum steps to better sequencing," Nature Nanotechnology 5, 823 (2010)).

Despite recent progress, this field maintains an array of unanswered questions and unexplored territory. Nanopore-based sensors, in particular, open up a host of new opportunities for studying basic physics and may form the basis for a variety of technologies. These sensors have the ability to probe some small region of space where molecules/water/etc. are localized, thus, they are ideal for interrogating molecular behavior at the nanoscale. The nanopore itself can be combined with electronic (embedded electrodes for detecting electronic signals to external measurement of ionic currents), optical, and mechanical sensing. Further, they have been demonstrated to filter and sort molecules. For example, researchers have built pores that act as "molecular sieves", which could be used to purify chemi-

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cals and gases. This is not unlike Nature herself, where miniscule channels control the flow of ions and water in and out of cells. These channels can selectively filter different species (for instance, potassium channels can let potassium ions through but not the much smaller sodium ions). Faulty pores are implicated in a variety of diseases. Thus, building and understanding the behavior and "physics" of artificial pores will be an important component in determining causes and fixes to malfunctioning biological pores.

As well, we have been examining other possibilities to use nanoscale sensors/devices to understand the physics of biological systems. Recently, we proposed to use heat transport as a probe of the strong, nonlinear fluctuations that occur as DNA unravels from the double helix into two single strands, (see Figure 2). Changes in conditions, such as temperature or ionic concentration, or the application of external forces, can cause DNA to come apart. This is a complex process: The hydrogen bonds within each base pair break and stacking interactions are disrupted, all the while the surrounding water and ion environment moves in response to the structural changes in DNA. It should not be surprising that this process has been of interest since the discovery of DNA structure more than 50 years ago. It has important implications both in biology and in technology. Yet, the dynamics of this process are hard to measure and also hard to simulate. We demonstrated that if a heat current is driven through DNA, this current carries information about the nonlinear structural fluctuations. Ultimately, we hope that this type of device will help shed light, not just on DNA, but on complex, structural dynamics that are common to biological molecules and processes, from ion channels to protein folding.

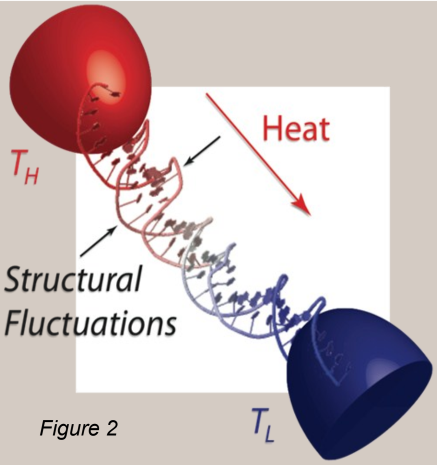


Figure 2

What lies in the future? Will nanopores and other nanoscale devices revolutionize the medical field and usher in personalized medicine? Will they set the foundation for a variety of different technologies? Will they enable the investigation of molecules, materials, and physical processes in ways not possible before? This leads us to our question, what did one nanoscale sensor say to the other? "Everyone thinks we're important, but we're really no big deal!"

Research Highlight: Looking towards new generation communication technology

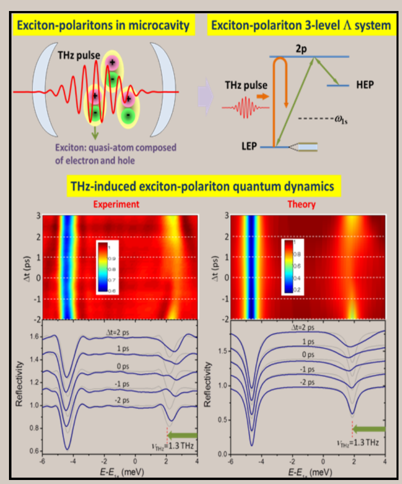
By Yun-Shik Lee

Yun-Shik Lee joined Physics Department at OSU in 2001. He was a recipient of the NSF CA-

Prof. Yun-Shik Lee and his students have demonstrated a three-level Lambda system in semiconductor nanostructures and showed that short terahertz (THz) electromagnetic pulses can control the quantum system at extremely high speed. Consisting of a single Q-bit and a control nob, a Lambda system is a basic building block for quantum information processing. The realization and control of the Lambda-system in semiconductors is an important step towards the futuristic computing and communication technology.

THz waves are electromagnetic waves whose frequencies lie between the microwave and infrared regions. Naturally occurring THz radiation fills up the space of everyday life providing warmth, yet this part of the electromagnetic spectrum remains the least explored region.

An optical microcavity enclosing semiconductor quantum wells (QWs) is an elegant material system to harness light-matter interactions. When an optical transition occurs near the energy band gap in a QW, the attractive Coulomb interaction leads to the formation of a hydrogen-like system of an electron-hole pair, called an exciton. When the exciton and cavity resonances are nearly resonant, they become strongly coupled giving rise to the so-called exciton-polaritons (an exciton polariton is a half-light/half-exciton quasiparticle). Strong and short THz pulses inducing large and fast deformation of the exciton-polariton wavefunctions, the time-resolved strong THz and weak optical probe measurements reveal that the lower and higher exciton-polariton (LEP and HEP) modes and the optically dark 2p-exciton state form a 3-level Lambda-type system. The THz-



induced low-energy transitions within the Lambda system exhibit ultrafast quantum dynamics of the unique light-matter coupled system.

This work was published in J. L. Tomaino A. D. Jameson, Yun-Shik Lee*, G. Khitrova, H. M. Gibbs, A. C. Klettke, M. Kira, and S.W. Koch, "Terahertz Excitation of a Coherent Lambda-Type Three-Level System of Exciton-Polariton Modes in a Quantum-Well Microcavity," Phys. Rev. Lett. 108, 267402 (2012).

Physics

Outreach activities by students, faculty, and staff members

By James Ketter

James Ketter is an instructor at Physics Department who has been involved in the departmental outreach activities since 2005.

Some of the fun of doing physics is sharing the fun of physics with others. Students, instructors and professors share that fun of physics not only in our courses throughout the year but also through a variety of community outreach opportunities. The department hosts various groups coming to campus on field trips, for Saturday academies, and for science camps during the summer and on weekends in the winter.

For two days each autumn and spring our undergrad physics students provide hands-on activities at **Discovery Days**, visited by over a thousand students coming from middle schools throughout the region.

Other times, we take the toys to the students' schools, loading up a car trunk with the rotating chair, the Van de Graaff generator, a Dewar flask of liquid nitrogen, a vacuum pump, and other miscellaneous equipment and activities to spend an afternoon engaging young students in the fun and wonder of physics.

Summers allow for two-week long sessions. Graduate students and instructors offer classes through the **Adventures in Learning** and **Outside the Box** programs on campus. **"Phun With Physics"**, **"Roller Coaster Physics"**, **"Exploring Astronomy"**,and **"The Physics of Energy"** are examples of courses that have been offered to middle-school and junior-high students. The physics classes are usually in high demand and garner praise from the participants, often identified by the students as the best courses in the program.

One Saturday every winter term, a hundred middle-school girls and their parents visit campus for the **"Discovering the Scientist Within"** program and the physics department always hosts a large and enthusiastic group of these aspiring woman scientists.

Winter Wonderings is another pre-college program offered on weekends in the winter and another time that physics sessions are available for interested future physicists.

Teaching and Outreach: an undergraduate experience

Sam Settelmeyer came to OSU in 2009 to pursue a Physics Degree with the Education Option and a Math Minor already knowing he wanted to be a high school physics and math teacher. He is a member of the Honors College, and the recipient of two prestigious honors college scholarships. Sam is taking a unique approach to his fourth and final undergraduate year at OSU before attending the intensive 5-term Science and Mathematics Teacher Masters program, where he will obtain physics, math, and English for Speakers of Other Languages endorsement certifications (starting summer of 2013).

Sam started the summer before his fourth year teaching through the Johns Hopkins' Center for Talented Youth Program at Moravian College in Pennsylvania. During this experience he was a teaching assistant for 6th and 7th grade students focusing on Physics and Engineering. He enjoyed working with very motivated students, as well as working with peers and experienced teachers from around the United States.

He spent fall term of 2012, in Cape Town, South Africa where he has been helping to conduct research at the University of Cape Town (with collaborators of Prof. Demaree), working at Wynberg Boys' high school, and working with math students in a local township. He found the wide disparity between educations offered within the same city to be astounding. Furthermore, his experiences there have convinced him that he may have a future in working with disadvantaged student populations. Sam's adventures will continue into winter and spring term, as he will be doing an internship at a bilingual high school in the Dominican Republic. While there, Sam hopes to greatly develop his Spanish fluency while collaborating in a unique cultural context. He also hopes to establish inter-cultural connections between classrooms in Oregon and his host institution.

Incorporating Computational Scientific Thinking into Teacher-Education Classes

By Prof. Emeritus Rubin Landau

Rubin Landau's latest project includes a biology educator at the University of Connecticut, a physics educator at Linn-Benton Community College, a computational science educator at the Shodor Educational Foundation in Durham, and a science and math educator in the OSU

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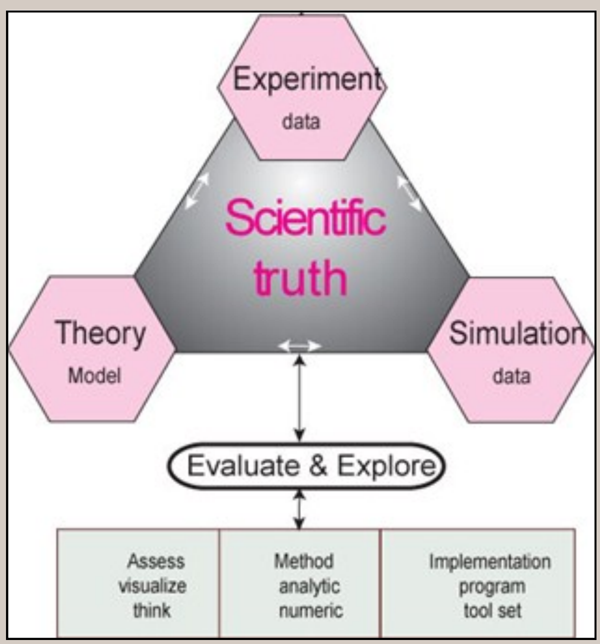
College of Education. The project is called **INSTANCES**, an almost-acronym for Incorporating Computational Scientific Thinking Advances into Education & Science Courses, and is funded by the National Science Foundation as part of their Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics program.

The project aims to extend some of the materials and philosophies of the Physics Department's previous Computational Physics program (which unfortunately was eliminated in 2010 due to university's major financial cutbacks) into the classes taken by pre- and in-service education majors. INSTANCES wishes to pave the way for future science and math education that recognizes the fact that computation has become an essential element in all sciences, with Simulation being added to Experiment and Theory as part of the scientific paradigm. Although present-day science and engineering research and development deal with realistic problems of practical importance that typically do not have analytic or simple solutions, classes in traditional disciplines like physics still seem to find it difficult to adapt to the changes. Consequently, and unfortunately, science and math teachers are often not prepared well for their work with computers in K-12 classrooms. Even after taking CS classes in college, they may not be prepared to explain what is occurring within a computer application run by students (a "black box").
The INSTANCE's viewpoint, which is now being integrated into plans for the future of OSU's College of Education, is encapsulated in the phrase Computational Scientific Thinking (CST). The concept, originating in an OSU Honor's class proposed by Landau, now signifies, among other things:

- Using simulation and data processing to augment the scientific method's search for scientific truth, and in the process, for the realities hidden within data and revealed by abstractions.
- How simulation, visualization, data analysis and abstraction serve the scientific method's search for mechanisms and relationships within data.
- Understanding why multiple disciplines may be needed to solve a problem, and how these disciplines become more understandable when placed in context.
- Being able and confident enough to look inside a computer application's black box.
- Understanding why a mathematically "exact" solution may not be as "correct" as an approximate solution.

Understanding how simplicity may be present in complexity, once we expand the way we look at objects.



The project's Web page http://science.oregonstate.edu/~rubin/INSTANCES/ contains a number of modules already developed, some of which have already been tested in OSU and LBCC classes. These include Random Numbers, Random Walks, Exponential & Spontaneous Decay, Bug Population Dynamics, and Machine Precision. The modules can be used to supplement existing classes, or combined into a full course.

Alumni update:

Undergraduates:

Bruce Scott (B.S. 1979) is doing research in plasma physics at Max-Planck-Institute fur Plasmaphysik, Euratom Association. Bruce enjoys working in the center of Europe on a variety of international projects and is also a soccer fan.

Steve Berukoff (B.S. 1999) is Assistant Director for Data Products at the National Ecological Observatory Network (NEON), an NSF-funded large facilities project aimed at improving understanding of ecosystem driver/response feedbacks.

Levi Kilcher (B.S. 2003) received a Ph.D. from the College of Oceanic and Atmospheric Sciences at OSU and now is working at the National Wind Technology Center which is a part of the National Renewable Energy Lab.

Jonathon Gillen (B.S. 2003) completed a post-doctoral fellowship at MIT with Wolfgang Ketterle. He is now a Technology Specialist at Proskauer Rose LLP in Boston, and is attending law school.

Winston Burbank (B.S. 2004) joined BP, Alaska after obtaining his Ph.D. from U. Alaska, Fairbanks. He is involved in recruitment of college interns and full-time hires.

Jim Brookhyser (B.S. 2004) is working as a Laser and Optics Engineer for ESI in Portland.

Doug Fettig (B.S. 2006) received an M.S. in Optics from the University of Rochester and is now a Senior Optical Engineer at Aptina Imaging, San Jose CA.

Sol Torrel (B.S. 2010) has started in the Ph.D. program in Materials Science at Rutgers in Manish Chhowalla's group, working on graphene.

Graduate Students:

Fuxiang Han (Ph.D. 1993) is a professor of physics at Dalian University of Technology in China, working in the field of condensed matter physics and ultracold Fermionic gases.

Ashley Shultz (Ph.D. 1996) taught.for 8 years.at Durango's Fort Lewis College, where she received tenure. She now lives with her husband Jonathon and their 8-year-old twins in Spokane. She teaches on an ad-hoc basis in the Gonzaga physics department.

Annette Richard (Ph.D. Chem. 2010) is working for Praxair in Indianapolis.

Matt Price (M.S. 2005) is now in a tenure-track position at Ithaca College.

Andriy Zakutayev (Ph.D. 2010) has moved from postdoc to staff scientist at the National Renewable Energy Lab in Golden, CO.

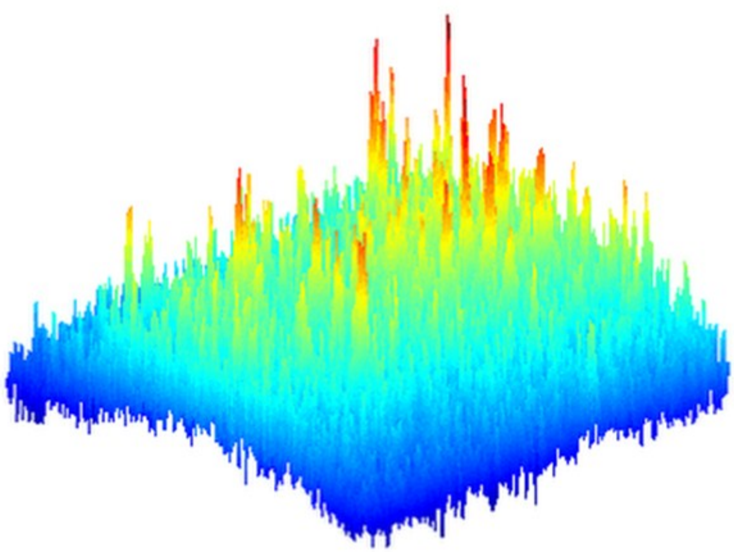
Dara Easley (M.S. 2005) moved from her position with an IP firm in Portland to Vernier in Portland where she works in the Tech Support/R&D department (physics) and with publications and editorial review.

Sissi Li (Ph. D. SMED 2011) is a postdoctoral scholar for the California State University Fullerton Catalyst Center.

Staff:

Wanda Moeller (former office manager) celebrated 50th Wedding Anniversary with her husband Willie in April 2012. Wanda and Willie have been spending their winters in Yuma, AZ since 1999.

Oregon State University
College of Science
Department of Physics
301 Weniger Hall
Corvallis, OR 97331-6507



Fluorescence of functionalized pentacene molecules embedded in a thin polymer film, imaged on a single-molecule level in Oksana Ostroverkhova's Organic Photonics and Optoelectronics lab. The imaged area is ~15 x 50 mm. The spike positions on the image correspond to locations of the single pentacene molecules.

The differences in spike heights (fluorescence signal) are due to various molecular orientations, which result in differences in coupling between the transition dipole moment of the molecule and the electric field of the polarized excitation light, affecting the strength of the fluorescence.