American Physical Society New England Section Newsletter

Volume 21, No. 2 — Fall 2015

Co-editors

- **Edward Deveney**
- **Peter K. LeMaire**

Inside this issue:

Title: Inner Space Meets Outer Space

Topic: Frontiers in High Energy Physics, Cosmology and Exoplanetary Astronomy

Keynote address: Prof. Frank Wilczek, MIT, Nobel Prize 2004.

The registration will start at noon on Friday, and the Welcome Remarks at 1pm. Conference ends at 1pm on Saturday.

The conference will focus on open questions and challenges in high-energy particle physics, cosmology, and the search for exoplanets. With new data coming from the LHC and the many active searches for dark matter across the globe, particle physics is poised for an exciting few years, as the Standard Model gets tested as never before. At the same time, precision cosmology is going through a golden age, as more data about the early and current universe pours in at an accelerated pace testing current ideas and placing stringent constraints on many models of early universe physics. On a different track, exoplanetary astronomy is also going through a golden age, as more planets are found at increasing rates, some with promising Earth-like features. The 2015 New England APS meeting will gather some of the leading scientists working on these various topics, to inform and inspire current and future research.

There will also be sections for contributed papers on diverse topics on Saturday, as well as a poster session on Friday evening.

The conference web site is: http://www.dartmouth.edu/~aps-conference/

Fall 2015 Meeting at Dartmouth College

Wilder Laboratory

Physics at Dartmouth

The Department of Physics and Astronomy at Dartmouth is housed at Wilder Laboratory, an APS Designated Historical Site, where G. F. Hull and E. F. Nichols performed measurements of the pressure of light between 1901 and 1903. The building is a beautiful example of classic laboratory architecture at the turn of the 20th-century. With 18 full-time tenure-track faculty, another 10 research faculty and some 50 graduate students, the P&A department holds very active research programs in Space and Plasma physics, Condensed Matter physics, Cosmology, Gravitation, and Field Theory, and Astronomy.

About 40% of our graduating majors go on to graduate study in Physics or a related discipline, aiming at a career in academia or research. Others go to medical school or engineering school, some become high school teachers, and others start work immediately as research technicians. However, by no means do all our majors pursue technical careers. Because physics is, in the words of Nobel Laureate Richard Feynman, among "the most fundamental and all-inclusive of the sciences", a physics or modified degree is a good basis for any career in which scientific and technological considerations play an important role: In the modern world, this includes the entire spectrum of human activity. The study of physics provides training in problem solving by quantitative and logical thinking and by model building, and develops the habit of concentrating on essentials and eliminating irrelevant detail. These are valuable skills in every walk of life. Many analytical techniques used in business and economics, such as operational research and game theory, were originally developed by physicists. As a physics graduate you will be well equipped to start into a variety of careers with the tools and skills necessary for success.

Marcelo Gleiser
Institute for Cross-Disciplinary Engagement (I.C.E.), and Department of Physics and Astronomy, Dartmouth College, Hanover NH.

BOSTON UNIVERSITY

Recap of the Spring 2015 Meeting of the New England Section of the American Physical Society at Boston University

Advances in Two-Dimensional Crystal Physics and Multidimensional Teaching and Learning

Friday and Saturday, April 24th and 25th, 2015
Boston University
Physics Department
590 Commonwealth Ave.
Boston, MA 02215

A heartfelt thank you to all in the Boston University Physics Department staff for ensuring a well-planned and executed meeting was achieved in short period of time. A special thanks goes out to Despina Bokios, Winna Somers, and Solomon Posner; without their hard work this event couldn't have been possible.

Friday, April 24th, 2015
The Spring 2015 meeting at Boston University sought to tie together faces of the contemporary physics community and in particular, link advances in both research and teaching. Focusing the meeting around teaching and research together, rather than independently, was done explicitly because too often they are considered separate elements of a physicist's career, rather than intertwined. Further, we sought to infuse the discussions of teaching with modern research approaches, and the discussions on research with the art and science of communication and teaching.

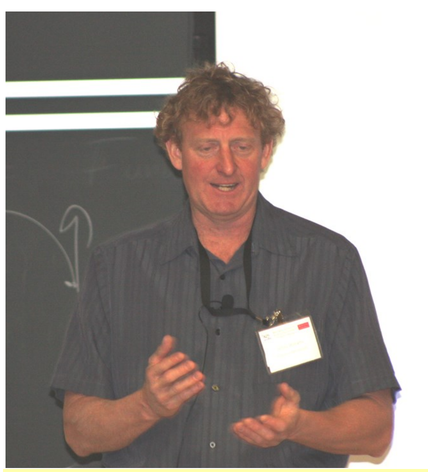
Presentation topics ranged from themes centered around materials science and biophysics to multi-dimensional teaching and learning. The breadth of topics reflected well the diversity of the discipline and the wide variety of options available to burgeoning undergraduate and graduate physicists, many of whom attended the conference.

The meeting was kick-started by a warm welcome from Boston University's physics department chair Karl Ludwig, as well as an address from Boston University's Bennett Goldberg and Charlie Holbrow of the APS. Then began a tremendous lineup of invited speakers spanning the latest advances in online physics education and 2D materials. These APS Invited Plenary talks took place in the Life Science and Engineering Building auditorium in front of a rapt audience comprised of undergraduate students, graduate students, and faculty from across the Northeast region.

Andrew Duffy of Boston University began with 'Teaching AP Physics 1 to the

Andrew Duffy, giving invited talk

World', demonstrating challenges and breakthroughs in a recent massive open online course (MOOC) designed to teach high school physics content to students from countries all over the world.
The second speaker was Jeff Williams from Bridgewater State whose talk



Jeff Williams, giving invited talk

'Evolution of teaching at an undergraduate college', showed he successfully changed a standard introductory physics course from lecture/lab to a studio style course using an NSF STEP grant.
After a short coffee break Bennett Goldberg of Boston University talked about

Bennett Goldberg, giving invited talk

'The future of STEM education: Preparing next generation of faculty'. He discussed how through the Center for the Integration of Research Teaching and Learning (CIRTL) Network he and others are working to reach over 43,000 STEM Ph.Ds that graduate annually, through a MOOC—"An Introduction to Evidence-based Undergraduate STEM Teaching".
Scott Bunch, also of Boston University, gave a talk entitled 'Atomic and Molecular Separation through Porous Graphene',

Scott Bunch, giving invited talk

where he discussed how the structure of this two dimensional atomic crystal, con-

Recap of Spring 2015 Meeting…

sisting of "carbon atoms covalently bonded in a hexagonal chicken wire lattice", results in "remarkable electrical, mechanical, and thermal properties".

Finally, Tomas Palacio of the Massachusetts Institute of Technology presented 'System-Level Applications of Two-Dimensional Materials: Challenges and Opportunities'. He discussed how two dimensional materials represents "the next frontier in advanced materials for electronic applications" due to their

Tomas Palacio, giving invited talk

unique and diverse properties, leading to usage in "a wide variety of rf and mixed applications, including frequency multipliers, mixers, oscillators, and digital modulators".

Following invited talks, conference attendees took a short jaunt down the road to the Rafik B. Hariri Institute for Computing and Computational Science and Engineering where a lively poster session ensued. Everyone gorged on an assortment of cheeses, appetizers, and a comprehensive bar selection while engaging presenters about their research. The conversations took on many forms, including both one-on-one dialogue as well as larger group discussions. In total there were 32 contributed posters with topics including biophysics, high energy physics, materials science, physics education research, and many more. In addition to local graduate students, many presenters were undergraduates as well as current and emeritus faculty.

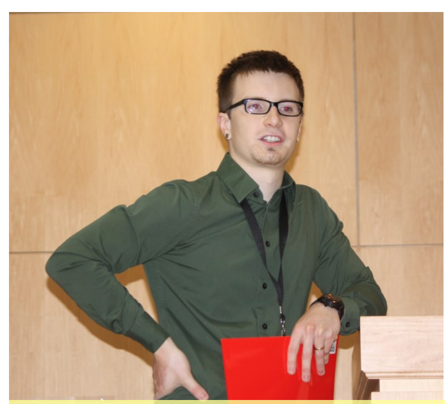
Banquet Speaker, Eric Mazur of Harvard giving talk entitled "Flat Space, Deep Learning"

The conversation and merriment continued until roughly 6:30 PM at which point a delicious banquet began. Attendees sat in groups of eight to ten and engaged in lively interactions. The food was accompanied by inquisitive debate, the exchange of calling cards, and plentiful smiles. We were able to accommodate even the 4-5 attendees who forgot to RSVP. Beginning at 7:45 PM, participants were treated to an exceptional talk entitled 'Flat Space, Deep Learning' while they digested. In this presentation, Eric Mazur of Harvard University talked about pioneering flipped classroom physics education. Mazur addressed a number of fascinating components involved in his novel approach to teaching including gender dynamics, curriculum design, and course structure. Mazur concluded with promising supporting video evidence and student testimonials regarding the efficacy of his approach. After a full day of physics content, the Friday events concluded around 9:00PM.

Saturday, April 25th, 2015

Saturday Morning started with a continental breakfast at 8:00 AM followed by three parallel sessions beginning at 8:30 AM. The early morning sessions fell into three broad topics categorized as General Condensed Matter Physics, 2D Structures and Upconverted White Light Emissions. The many attendees had the opportunity to learn about (this in the condensed matter session), (this in the 2D session) and the effects of nanopowder composition and pressure on broadband white light emission from IR excited composites.

In the former, attendees were treated to the physics of retinal diseases, tumor cells,



***Colin Howard**, Boston University, chairing the Saturday morning Condensed Matter Session*

Highlights of Spring 2015 Meeting at Boston University

and separation of DNA, In Vivo Tomography, photochromic protein, Higgs-like boson and the electron's angular momentum with speakers from Brandeis, Univ., of Connecticut, UMass Boston, Roger Williams Univ. UMass Lowell and a consultant. The latter break-out session included topics on teaching fluids, WikiSpapces, critical-thinking and the scientific method, photoelectric effect, white-light super-continuum generation and white-light emission from schools including Boston College, Univ. of Connecticut, UMass Boston, Univ. of Hartford, and Univ. of New England.

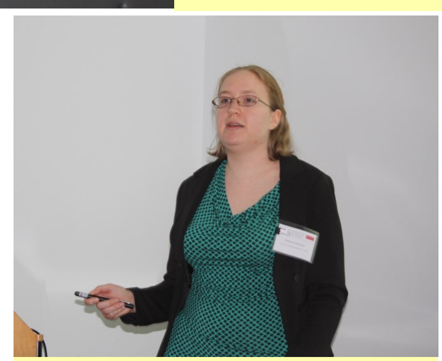
Tony Heinz ***Stanford University, giving invited talk on "Optical Properties of Two-Dimensional Materials—Graphene and Beyond***

Allan Pierce, ***Professor Emeritus, Boston University, giving talk on "Quantum mechanical aspects of the decay of mechanical vibrations by electromagnetic radiation"***

Saif Rayyan, ***MIT, giving invited talk on "Upper Level Physics MOOCs for Online and Blended Learning"***

Amadou Thiam, ***Boston University, giving talk on "The physical principles involved in the conversion of vibrational energy to electrical energy in off-shore ocean wave energy systems"***

Kun Geng, ***Boston University, giving talk on "The effect of Chain Stiffness on the Glass Transition Temperature of Polymer Thin Films"***



Melissa Spencer, ***University of Massachusetts Lowell, giving talk on "Cell Survivor: Teaching radiobiological intuition with a video game"***

(Meeting pictures courtesy of Peter K. LeMaire, Central Connecticut State University)

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CUWiP 2016 Wesleyan University

JANUARY 15^{TH} -17^{TH}

2016 APS CUWIP

Conference for Undergraduate Women in Physics

The APS CUWiP goal is to help undergraduate women continue in physics by providing them with the opportunity to experience a professional conference, information about graduate school and professions in physics, and access to other women in physics of all ages with whom they can share experiences, advice, and ideas.

Application Opens September 1, 2015

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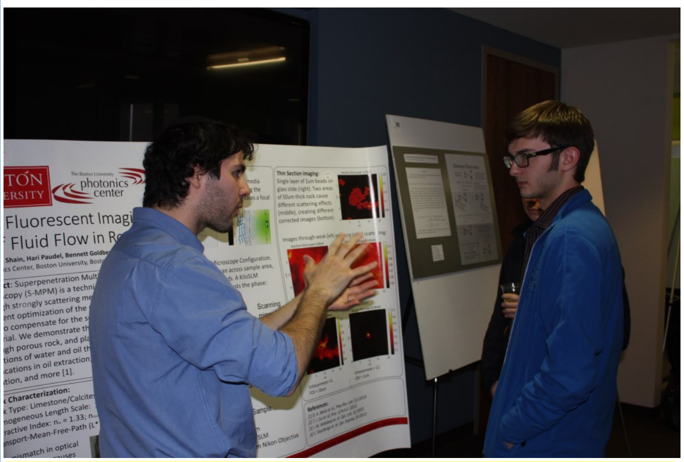
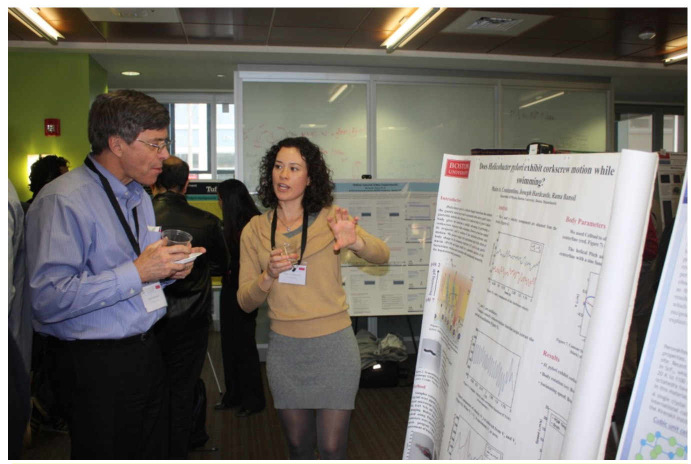
Highlights of the Spring 2015 Meeting at Boston University
Poster session and Banquet

Lasell Students at Poster session

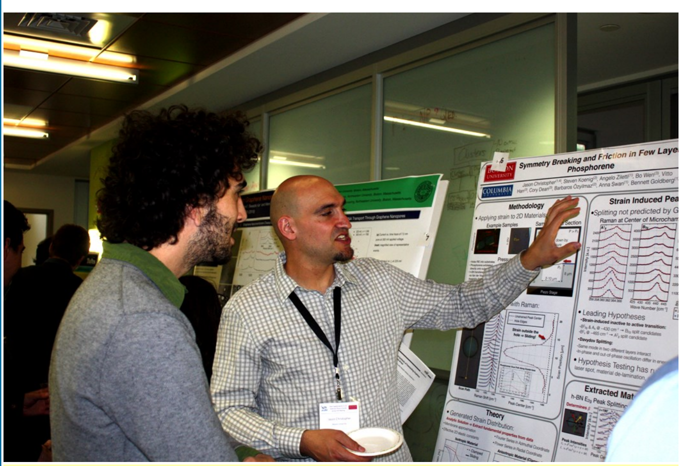
CCSU Students at Poster session



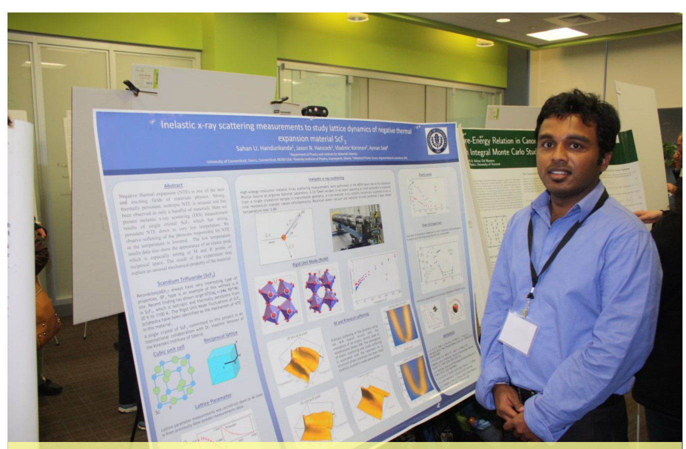
William Shain, *Boston University, presenting*
"3-D Fluorescent Imaging of Fluid Flow in Rock"



Maira Constantino, *Boston University, presenting*
"Does Helicopter pylori exhibit corkscrew motion while swimming?"



Jason Christopher, *Boston University, presenting*
" Symmetry Breaking and Friction in Phosphorene"



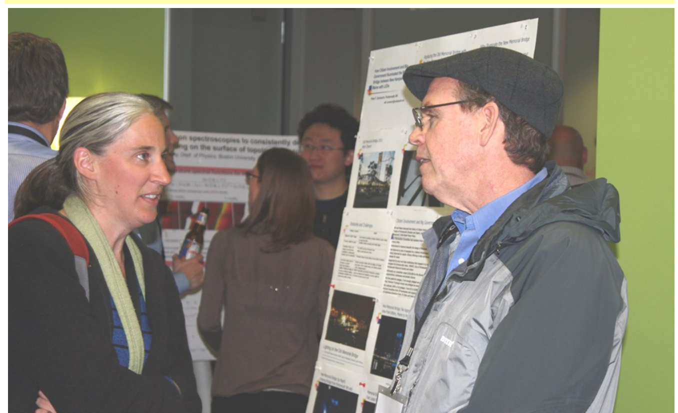
Sahan Handunkanda, *University of Connecticut, presenting*
"Inelastic x-ray scattering measurements to study lattice dynamics of negative thermal expansion material ScF_3"

Highlights of the Spring 2015 Meeting at Boston University
Poster Session and Banquet

Norma Chase, *MCPHS University, presenting "Online Tutorial Video Experiments"*

Paul Carr, *Air Force Research Lab (retired) , presenting "Oscillations from Arctic Warming: Record Cold & Hot Rising Seas"*

Meeting attendee chats with invited speakers Williams and Bunch



Naomi Ridge, *Wentworth Institute Technology, and Secretary/ Treasurer of APS-NES, chats with* **John Collins,** *Wheaton College , and Vice Chair of APS-NES*

Audience at the Banquet talk

Eric Mazur, *Harvard University, and Banquet Speaker, chats with* **David Kraft**, *Univ. of Bridgeport and APS-NES meetings coordinator*

Advanced Lab in the Spot Light: Folding Physics

Origami is generally known in popular culture as an art form where sheets of paper are folded into whimsical representations of animals, toys, and other abstract figures. What's less well-known are the deep connections to mathematics [1-4], computer science [5, 6], and physics [7-9], where the same geometric folding concepts are being systematically studied. Disk packing and skeletonization algorithms [10], advanced and reconfigurable metamaterials [11-17], as well as meso- and microscale robotics [18-21] are all benefiting from the same principles that form the basis of this art. With such progress in mind, we find origami uniting a cohort of scientists, engineers, and artists while advancing many exciting technologies and ideas.

In the physics community, much attention has focused on studying mechanical properties of folded structures where physical phenomena arise from the interaction between geometric crease patterns and their folding constraints. Some recent examples include mechanical multistability [16, 22], lattice crystallography [15], metamaterial elasticity [12, 13, 33], and even a mathematical framework inspired by the study of topological insulators [17, 24]. Much of this work is being carried out in the Miura-ori and its variants, which rapidly became the canonical folding patterns of choice for quantitative analysis. Indeed, a number of remarkable properties have already been found when this quasi-2D structure is compressed in the plane. For example, the Miura-ori's bulk elastic modulus can be varied by orders of magnitude simply by altering the crease pattern's geometry *independent of the underlying folding material*. Moreover, common experience shows most materials bulge when compressed along one axis. The Miura-ori, however, does the exact opposite. When compressed along one in-plane direction, it undergoes a proportional contraction in the orthogonal direction. Like the elastic properties, this "negative Poisson ratio" is a geometric phenomenon that can be readily attributed to the folding kinematics. Such mechanical properties as those of the Miura-ori are particularly exciting because they open the door to possibilities in mechanical metamaterials analogous to those in optical metamaterials. For example, it's now possible to imagine a pathway to design an origami folding pattern that redirects mechanical vibrations and deformations in an rationally controlled manner, e.g., a mechanical waveguide – a remarkable application indeed!

Having been an origamist for 20+ years and a physicist for far fewer, I see three especially interesting topics in the science of origami: *flat-foldability*, *rigid-foldability*, and *foldability-without-self-intersection*. The concept of flat-foldability asks whether the geometry of a given crease pattern can be completely folded, collapsing the structure flat into the plane. Though this is known to be an NP-complete problem [4, 25], whether a pattern is flat-foldable or not has dramatic implications for the mechanical properties of a structure. For example a non-flat-foldable structure resists deformation as it is compressed, resulting in an increased modulus when compared to a comparable flat-foldable crease assignment [15]. This is a useful feature for engineering applications where on-the-fly modifications to the

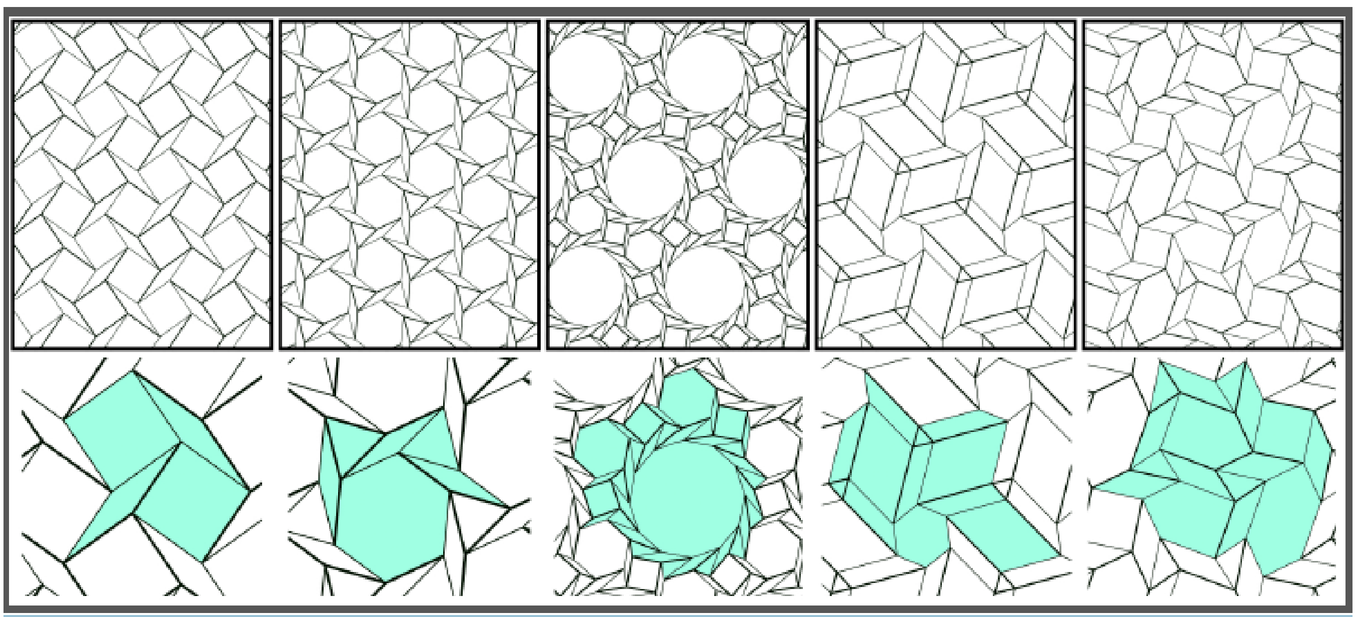


Figure 1: This collection of tessellated origami folding patterns showcases some of the possible plane-filling geometries generated in the software *Tess*. In these schematics thick and thin lines correspond to folding out-of-the-plane and in-to-the-plane, respectively. The top row shows the full tessellation, while the bottom row shows potential units of interest. The resulting bulk mechanical properties of each pattern remain to be studied and their dependence on the basic unit geometry characterized.

Advanced Lab in the Spot Light: Folding Physics

local structure can be used to alter bulk material properties. Essentially, such materials would be able to transform functionality simply by adjusting their folding configuration, similar to the robots in the science-fiction franchise *Transformers*.

Unlike flat-foldability, rigid-foldability is about the folding process itself, and asks whether the crease geometry could be folded from rigid sheets bound together by hinges. The significance of this distinction arises frequently because many crease patterns require the sheet to bend as it transitions from an unfolded to folded configuration. Thus, geometric constraints in these situations make folding from rigid materials an impossibility. An interesting case arises when non-rigidly-foldable patterns are realized in physical materials with finite bending stiffness. Here, the bending that occurs between unfolded and folded states can act as an energy barrier leading to a bistable system [16]. Ideas from stability analysis immediately come into play for these structures and an entire mathematical framework can be applied to the problem at hand.

Finally, foldability-without-self-intersection confronts global considerations about the configuration of the sheet throughout the folding process – it addresses the question of whether a sheet will self-intersect at any stage of the folding process. While physical materials are subject to such "steric interactions," the most significant progress on this front comes from full-blown numerical folding simulations that detect self-intersection events. To the best of my knowledge, no other general approach exists to analyze an arbitrary crease pattern and predict what its allowed "folding phase space" will be. Experiments with specific test patterns are useful to rapidly obtain practical results, but a more general framework would likely have major significance for this field.

Stepping back from recent advances and specific applications, there's a broader question as to where the field's frontiers will go next. One possibility is to break out from the small number of simple patterns frequently studied and move on to the vast wellspring of designs pioneered by origami artists. For example, dozens of tessellations that tile the plane have been parametrized and families of folding patterns are available, along with many others, through free software such as *Tess* (http://www.papermosaics.co.uk/software.html). A handful of the most visually striking folding patterns that call for in-depth studies are shown in Fig. 1. What new properties will these tessellated folding patterns demonstrate? At the moment, it remains entirely unknown. However, I can say with confidence that this field is in its early days and many interesting developments are waiting to be unfolded.

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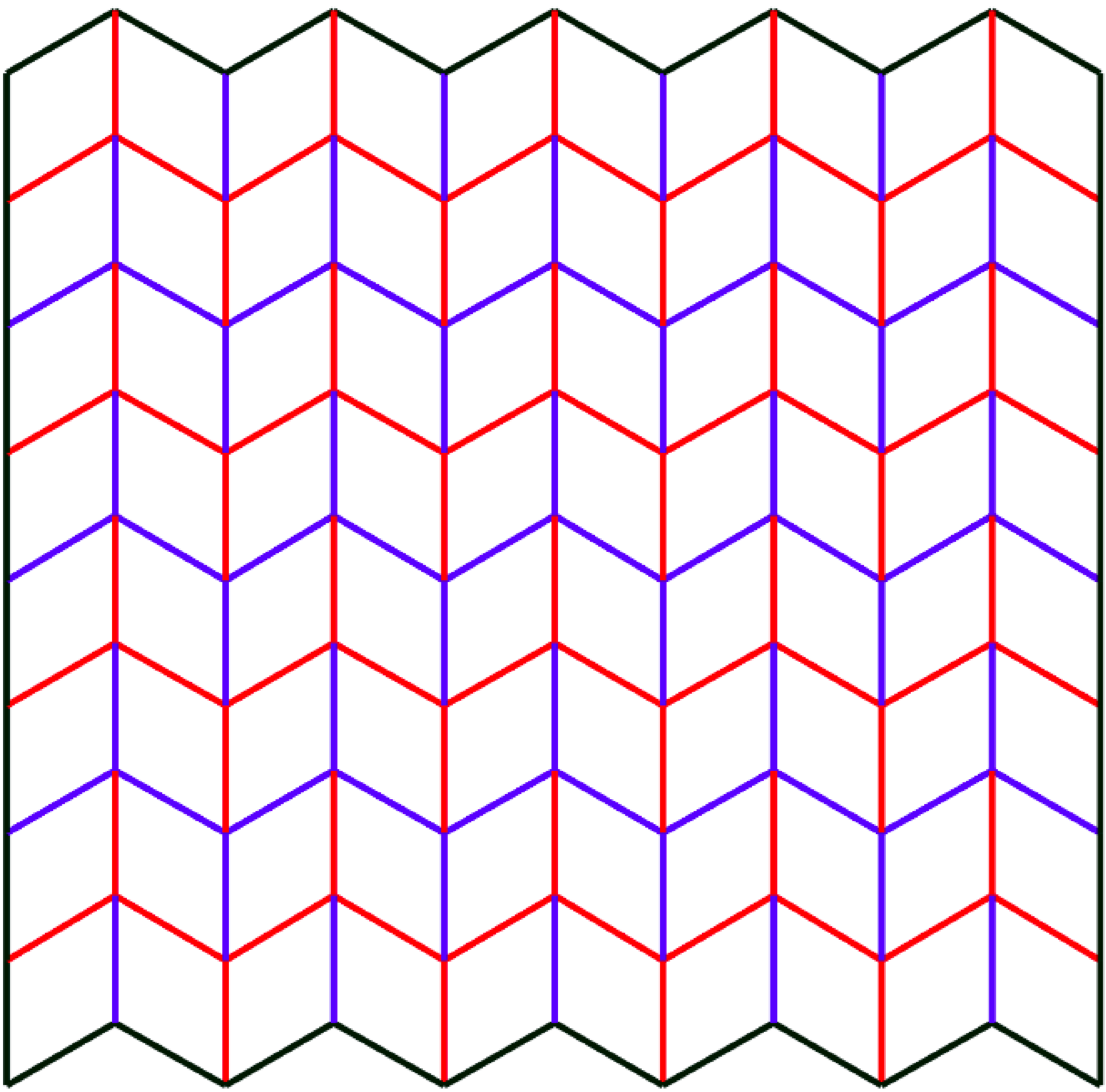
See page 11 for a "do it yourself" 4X5 Miura-ori Fold Pattern

Advanced Lab in the Spot Light: : Folding Physics

4x5 Miura-ori Fold Pattern

Jesse L. Silverberg, Arthur A. Evans, Lauren McLeod,
Ryan C. Hayward, Thomas Hull, Chris D. Santangelo, and Itai Cohen

Step 1: Cut out along black line
Step 2: Crease all red lines so they form “mountains” that point up off the page
Step 3: Crease all blue lines so they form “valleys” that point down into the page
Step 4: Collapse all creases simultaneously so the Miura-ori folds flat
Step 5: Make lattice defects by pushing vertices through themselves, “popping” them into a new position (see online video tutorial at http://cohengroup.lassp.cornell.edu)



Business and Physics

Rick Trilling, *presenting " Business and Physics" at the Fall 2014 APS-NES meeting.*

The confluence of physics and business, in the context of those within the business disciplines regularly commercializing breakthroughs achieved by those within the physics disciplines, is clearly familiar to the general populace. However a far less well-known counterpart of that confluence over the past two centuries has involved fundamental physics concepts having been adapted and applied by business researchers to become fundamental managerial practices.

Insights beneficial to the world of business have been, and continue to be, gleaned from this interdisciplinary research; from which applications senior business managers derive competitive advantages. Much more appears to be potentially available from further such interdisciplinary efforts, which should thus be encouraged.

Amongst the many examples encountered in my research, the dozen main examples analyzed in the paper that I am presently completing include, in summary form:
a) econophysics: economists applying statistical mechanics from physics to financial management; analysis of the distributions of returns in financial markets; income and wealth; economic shocks and growth rate variations; firm sizes and growth rates; city sizes; and even distribution of scientific discoveries. The conceptual sources for these have come from models of statistical mechanics, geophysical models of earthquakes and "sandpile" models of avalanches involving self-organized criticality
b) Brownian motion: application of stochastic models to stock markets and national economies
c) "unknown unknowns" in business planning and risk management
d) complexity: collective behaviors within a system, and interactions with environments
e) chaos theory studies the behavior of systems that are highly sensitive to initial conditions; applied to Modern organizations are increasingly seen as open complex adaptive systems, with fundamental natural nonlinear structures, subject to internal and external forces which may be sources of chaos
f) Newton's Laws of Motion are three laws in the physical sciences that illustrate the relationship between a body and the forces acting upon it, as well as its motion resulting from those forces; applied to The business world readily uses terms such as business acceleration and the velocity of money, albeit sometimes cavalierly. It substitutes such elements as the number of employees for the mass of the enterprise; and vendors, customers and competitors for the forces acting upon that enterprise (SWOT and 5 Forces analyses in strategic planning).
g)The Law of Conservation of Momentum states that, in a closed system – one that does not exchange any matter with its surroundings and is not acted on by external forces – total momentum is constant; managers deal with the functional equivalents of business momentum every day, trying to increase theirs while dealing with that of competitors.
h) Quantum mechanics ("QM") involves the behavior of physical phenomena (matter interacting with energy) at the atomic scale. Consider that QM not only "peels away the onion layers" to find the smallest elements, but also takes into account the relation of those elements to each other. This is why all multivariable forecasting is so difficult, despite the availability of near-continuously increasing computing power: relying upon any subset of variable elements, rather than the whole, makes forecasting less difficult but ignores the relationship between the parts. In the planning aspect of their functional role, managers commonly organize the use of their resources (financial capital, human resources, physical resources and technology) not only in terms of the quantity and qualities of each, but the interaction and integration of these as well.
i) Vilfredo Pareto devoted his life to the goal of bringing the business world closer to the conversion of economics into a science equally as exact as physics, and gave both disciplines his 80/20 "Rule" along the way. A corollary, Zipf's Law, applies mathematical formulae to statistics in order to identify power law probability distributions in both physical and social sciences.
j) A Markov chain is a mathematical model for random processes, and is commonly applied to statistics-related business areas such as networks and marketing. Truly random processes are considered to be "memory-less", meaning that a third event does not depend upon the first or second events. Therefore random walks and Monte Carlo sampling algorithms, examples of Markov chains, are beneficial whenever businesses seek to predict statistical properties rather than exact results.
k) Hypotheses, Models, Laws and the Scientific Method: where would Taylor and Gilbreth have been without them?
l) The "observer effect": in both disciplines the term refers to the impact that merely observing an action has upon that action.

It has been nearly a thousand years since Bernard of Chartres reputedly said: "We [the Moderns] are like dwarves perched on the shoulders of giants [the Ancients], and thus we are able to see more and farther than the latter"; a phrase ironically later popularized by Sir Isaac Newton as "If I have seen further it is by standing on ye shoulders of giants." The interdisciplinary value for managers in building upon the ideas of physicists is to unlock further business applications; Bachelier did so in 1900, and econophysicists are doing so now. Despite almost three decades of managerial and academic experience, I was unaware of the subject matter in this area, as was nearly every manager with whom I have since discussed this. Most had the same double-pulse response: first "hmm", then "aha"; hopefully this will have the same effect upon you.

Author: Rick Trilling
is an Associate Professor of Business Management at Wentworth Institute of Technology in Boston. He speaks and writes about interdisciplinary education, spoke earlier in the year on social entrepreneurship at Oxford University, and can be reached at TrillingF@wit.edu.

Observance of Negative Photocurrent in amorphous thin films of $Se_{75}Te_{20}Ag_5$

Dipti Sharma, giving talk at the Spring 2015 meeting

Abstract:
This study explores the effect of Ag+ ions on transient photoconductivity of thin films of $Se_{75}Te_{20}Ag_5$. The thin films of $Se_{75}Te_{20}Ag_5$ chalcogenide alloys were made by evaporation method using a vacuum chamber at HBTI Kanpur, India. This amorphous system showed the presence of negative photocurrent when white light was stopped showing on the sample. The rise and decay of photoconductivity was observed. The photoconductivity increased initially, reached to a maximum value and then decreased with time. Under the same experimental conditions, the decay of photocurrent showed a negative current and indicated the presence of negative photoconductivity during the transient process that finally recovered and reached to zero in many days. The photoconductivity was studied as a function of temperature, and exposure times. The results have been explained in terms of interaction between photo-excited holes and Ag+ ions present in the system[10, 11].

Keywords: Photocurrent, Transient photoconductivity; Amorphous, Thin films, $Se_{75}Te_{20}Ag_5$, Vacuum, Evaporation method, chalcogenide glassy alloys.

Introduction:
Ag doped chalcogenide glasses are interesting materials for study because of their ionic nature. These type of materials exhibit electrical and optical properties, characteristic of ionic conductors and semiconductors. The electrical conductivity is governed by Ag+ ions. Much attention has been devoted to structures and (super) ionic conductivities of these ion conducting semiconductor glasses [1-7]. A conductivity increase in Ag doped glasses under illumination has been demonstrated in this paper.

Experimental:
Glassy alloy of $Se_{75}Te_{20}Ag_5$ was prepared by the quenching technique. High purity (99.999%) materials were weighed according to their atomic percentages, and were sealed in a quartz ampoule (length ~5 cm and internal diameter ~8 mm), with a vacuum ~10-5 Torr. The sealed ampoule was kept inside a furnace where the temperature was raised to 1000oC, at a rate of 3-4oC/min. The ampoule was frequently rocked for 10 h at the maximum temperature to make the melt homogeneous. Quenching was done in ice-cooled water. Thin films of the glassy alloy were prepared at room temperature by vacuum evaporation, at a base pressure ~10-5 Torr, on well degassed glass substrates which had pre-deposited Indium electrodes. The coplanar structures (length ~1.2 cm and electrode gap ~0.5 mm) were used for the photoconductivity measurements. For the measurement of photoconductivity, the sample was mounted inside a metallic cryostat, with a transparent window which allowed light to shine on the sample. A vacuum of ~10-2 Torr was maintained throughout the measurements. The temperature of the sample was controlled by a heater mounted inside the cryostat, and measured by a calibrated copper constantan thermocouple. The source of light was a 200 W tungsten lamp. Interference filters were used to obtain light of the desired wavelength. The intensity of light was varied by changing the voltage across the lamp. The intensity was measured by a Luxmeter. To measure the rise of photoconductivity, the light was shone on the sample, generally for 30 min, through a transparent window of a metallic cryostat. The resistance was measured as a function of time by a Keithley Electrometer (model 614). The light was then turned off, and the resistance measured with time for 9 h by the same electrometer. All measurements were carried out after annealing the sample, in a vacuum (~10-2 Torr), at 100o for 1 h inside the same cryostat. The dark conductivity (sd) is measured as a function of temperature (297 - 346 K).

Results:
(a) Rise and Decay as a function of Time:
Figs. 1 and 2 show the rise and decay of photoconductivity at different illumination times (15, 30 and 45 min) at room temperature (297 K) at the highest intensity (1450 lux) of light. It is clear from these figures that, for lower illumination times (15 min), the anomalous behavior of photo-conductivity in rise and decay are not seen, even at the highest intensity of light (l450 lux). As illumination time increases, the anomalous behavior of photoconductivity in rise and decay increases.

(b) Rise and Decay as a function of Temperature:
Figs. 3 and 4 show the rise and decay of photoconductivity with time at different temperatures (at 297, 317, 327 and 337 K) at the highest intensity of light. It is clear from these figures that, at higher temperatures, the photoconductivity also becomes negative during illumination, and that the subsequent photoconductivity decay phase of the experiment starts from a negative value and becomes more negative before reaching zero.

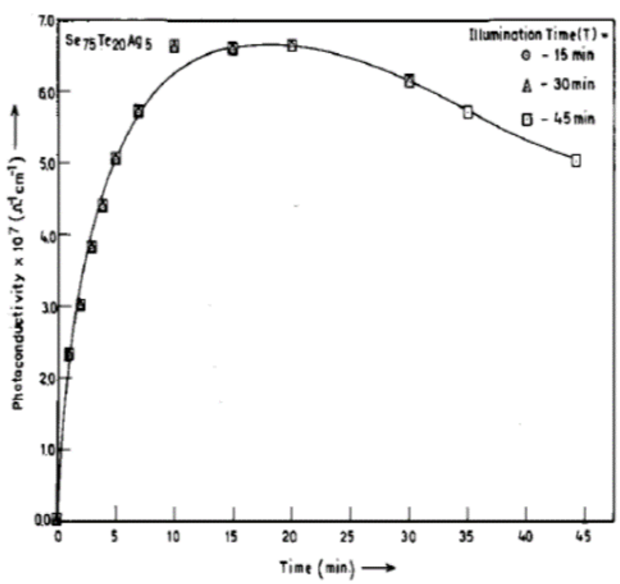


Figure 1: Shows the rise of photoconductivity at different illumination time i.e. 15, 30 and 45 min.

Observance of Negative Photocurrent in amorphous thin films of $Se_{75}Te_{20}Ag_5$

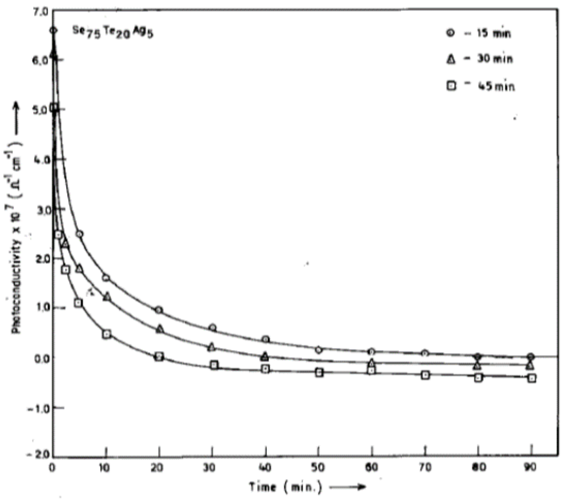


Figure 2: Shows the decay of photoconductivity at different illumination time i.e. 15, 30 and 45 min.

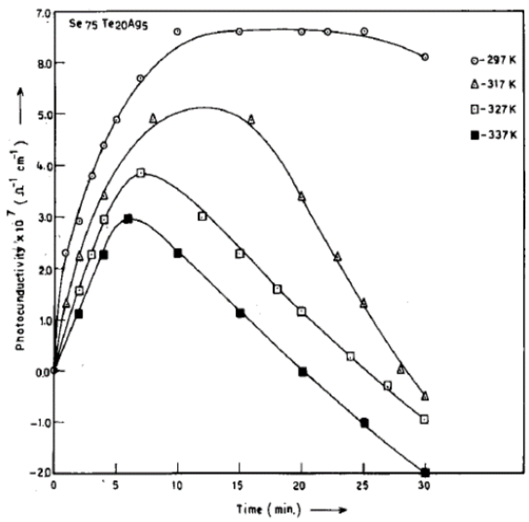


Figure 3: Shows the rise of photoconductivity with time at different temperatures i.e. 297, 317, 327 and 337 K at the highest intensity of light.

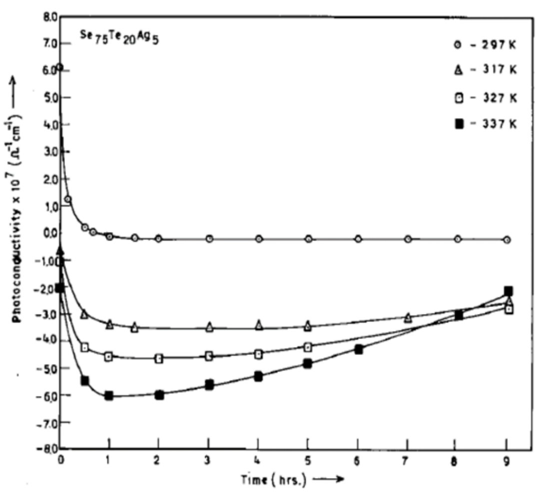


Figure 4: Shows the decay of photoconductivity with time at different temperatures i.e. 297, 317, 327 and 337 K at the highest intensity of light.

Discussion and Conclusion:

When Ag is added into the Se-based glasses, Ag-Se ionic bonds are formed. In Ag-rich chalcogenide glasses, the mobility of Ag+ ions is highest whereas holes has moderate type and the electrons has least mobility [5,8-9]. When a film is connected to an external source and light is shone on it, photoexcited holes flow from the positive electrode to the negative electrode. And the photocurrent can be considered due to only holes. The photoconductivity rises with time, reaches its maximum value within a few minutes from the start of illumination and then decreases under illumination. In Ag-rich chalcogenide glasses, upon illumination, a negative Dember photovoltage is reported [9-11], with a time constant of 10^3 s and then it decays slowly. The response after terminating illumination is also slow, continuing for hours and days. The reason for such a Dember voltage, is given in terms of the diffusion of holes towards the back electrode, as holes are more mobile than electrons in silver rich glasses [9]. Hence, the front electrode will provide negative photovoltage. In conclusion, ®rst, the bulk of photoconduction may occur where photocurrent rises to the maximum value; and then due to the appearance of Dember Voltage, photocurrent starts decreasing, and may also be negative at very high temperatures where Ag+ becomes more mobile. When the 1ight is switched off, the photocurrent reaches zero slowly, and takes 4-5 days as the Dember voltage approaches zero. It is interesting to note that the fall-off of photoconductivity from its maximum is faster as the temperature is increased, due to more rapid movement of silver ions at high temperatures. The decay curves at different temperatures, indicate that the photocurrent approaches zero at a faster rate at higher temperatures. This is also expected to be due to rapid movement of Ag+ ions at higher temperatures.

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Mode-Locking Behavior of Izhikevich Neuron under Periodic External Forcing

AmirAli Farokhniaee, *giving talk at the Spring 2015 meeting*

Abstract
Many neurons in the auditory system of the brain must encode amplitude variations of a periodic signal. These neurons under periodic stimulation display rich dynamical states including mode- locking and chaotic responses[1]. Periodic stimuli such as sinusoidal waves and amplitude modulated (AM) sounds can lead to various forms of n:m mode-locked states, similar to the mode-locking phenomenon in a LASER resonance cavity. Obtaining Arnold tongues provides useful insight into the organization of mode-locking behavior of neurons under periodic forcing. In this study we obtained the regions of existence of various mode-locked states on the frequency-amplitude plane, which are called Arnold tongues, for Izhikevich neurons. This study is based on the model for neurons by Izhikevich (2003), which is a reduced model of a Hodgkin-Huxley neuron[2]. This model is much simpler in terms of the dimension of the coupled non-linear differential equations compared to other existing models, but excellent for generating the complex spiking patterns observed in real neurons[3]. Hence we can describe the construction of harmonic and sub-harmonic responses in the early processing stages of the auditory system, such as the auditory nerve and cochlear nucleus.

I. INTRODUCTION

Phase-locking and mode-locking phenomena have a long history in Physics. For instance in producing high intensity LASER beams. These phenomena lead us to synchronization of input and output signals under study, either in the laser cavity system or the auditory system. Investigating how neurons synchronize their firing patterns to an external stimulus and generalizing it to a population of neurons we can describe the behavior of the whole network such as auditory system.

II. MODEL AND METHODOLOGY

Izhikevich model
There are more than 11 main mathematical models of neuron firing patterns. They can be used in different kinds of neurons and each of them has a good description of some particular neurons. One of the most important models in computational neuroscience is the Hodgkin-Huxley model of the squid giant axon[2] (section 2.3.1). Using pioneering experimental techniques of that time (1952), Hodgkin and Huxley shared the Nobel prize in Physiology or Medicine in 1963 with Sir John Eccles in 1963.

This model is very complete but not computationally economic at all. It has Four differential nonlinear coupled equations with lots of parameters that should be obtained by experiment. We are interested in simulating the models computationally. For this purpose, we apply Izhikevich model (2003) because of its simplicity and broad application to almost all kinds of neurons with high precision. The spiking model of Izhikevich (2003) is a canonical model based on the Hodgkin-Huxley model. This simple model consists of two coupled nonlinear differential equations that give the time evolution of the components of the system in phase space[4]:

$$\dot{v} = 0.04v2 + 5v + 140 - u + I$$

$$\dot{u} = a(bv - u)$$

$$\text{if } v \geq 30\text{mv then } v \leftarrow c \text{ and } u \leftarrow u + d$$

where v is the membrane potential and u is the membrane recovery variable which accounts for the activation of K+ ionic currents and inactivation of Na+. u provides negative feedback to v. The coefficients are chosen such that the model provides the units of mv and ms for potential and time, respectively.

This model exhibits firing patterns of all known types. It is efficient in large-scale simulation of cortical networks[4].

Different values of the parameters a, b, c, d in the model correspond to known types of neurons. Regular spiking, intrinsically bursting, chattering and fast spiking are subtypes of Class 1 and Class 2 neurons, studied here. Each inset shows a voltage response of a model neuron to a DC step current I = 10 A/cm^2 (bottom). Time resolution is 0.1 ms. To obtain Arnold tongues, we consider I as a direct current plus a sinusoidal current

Different classes of neuron
In Class 1 neurons (Fig. 1), the frequency of response increases smoothly as we increase the direct current. The resting state disappears via a saddle-node on an invariant circle (SNIC) bifurcation. In Class 2 neurons (Fig. 2), the frequency of response suddenly changes from zero to a positive value and the resting state disappears via an Andronov-Hopf bifurcation.

III. RESULTS

Arnold Tongues Diagram for Class-1 Neuron

Fig. 3 shows the regions of amplitude-frequency plane where different ratios of mode- locking happen. This plot represents the mode- locked regions as

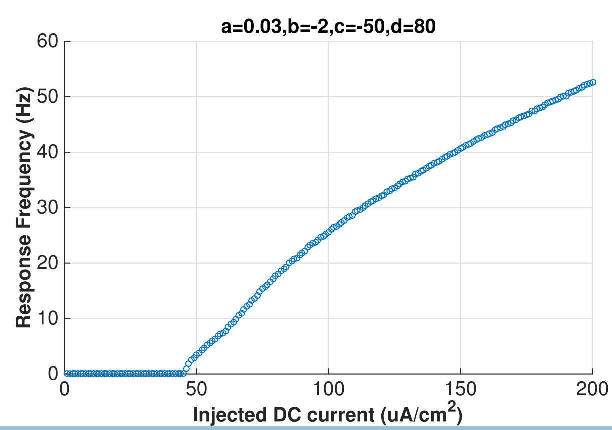

Figure 1: Class I neuron frequency-current diagram (F-I curve)

Mode-Locking Behavior of Izhikevich Neuron under Periodic External Forcing

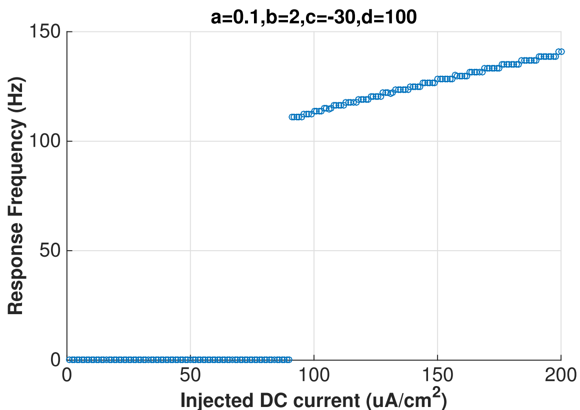

Figure.2 Class II neuron frequency-current diagram (F-I curve)

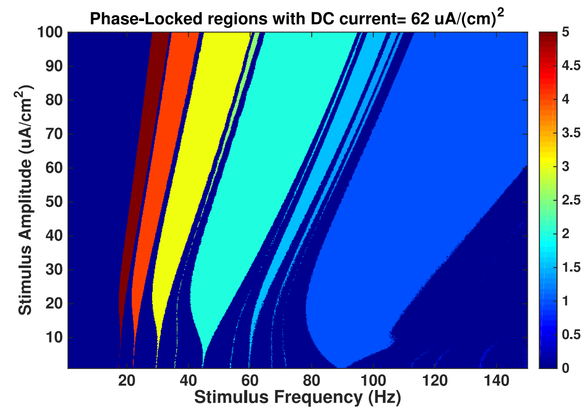

Figure 3. Arnold tongues diagram for a class-1 Izhikevich neuron with the parameters a = 0.03, b = −2, c = −50, d = 80 driven by an external sinusoidal forcing. The DC current is 62 (μA/cm^2). This diagram corresponds to the neuron that has the F-I curve shown in Fig. 1.

a function of the amplitude and frequency of this sinusoidal forcing. Each colored region represents a different phase- locked regime in terms of an integer ratio. Here, an n:m ratio means the neuron produces n action potentials in response to every m cycles of the stimulus. For example, for stimulus amplitudes and frequencies corresponding to the yellow region, the neuron exhibits 3:1 mode- locking.

For one point of this diagram that corresponds to one particular amplitude and frequency amplitudes of the stimulus, we demonstrate the time series of the spiking pattern plus the frequency spectrum of the response.

For A = 50 (μA/cm^2) and f = 8.3 (Hz), we have 4 : 3 mode-locking that is presented in Fig. (4).

For the corresponding values of A and f, frequency spectrum of the output has been computed by a Fourier transform and presented in Fig. (5):

There is a sharp peak observable in Fig. (5) that corresponds to the driving frequncy of the neuron, i.e. the frequency of the sinusoidal input. There are peaks that are multiples of this driving frequency which are presenting the harmonics of the input. Also, there are smaller ratios of the driving frequency that correspond to sub-harmonics of the input, i.e. smaller ratios of the input.

<u>Arnold Tongues Diagram for Class-2 Neuron</u>

Computing Arnold tongues for a class-2 neuron that behave as in Fig. (2) leads to the illustration in Fig. (6).

Note the difference between class-1 and class-2 Arnold tongues diagrams. One of the differences is that in class-1 neurons the tongues do not interfere with each other hence there is no chaotic behavior observable. But in class-2 neurons the tongues interfere with each other at higher amplitudes of the stimulus, leading to chaos (refer to upper left corner of Fig. (8). Second there is no divergence of the tongues as we increase the amplitude of the stimulus in class-1 neurons, but class-2 neurons diverge to two or higher number of different branches.

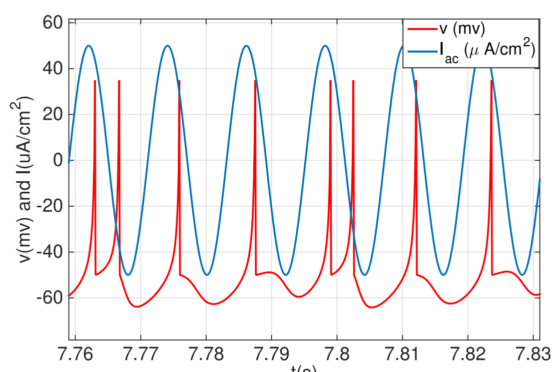

Figure 4. Time series diagram of a sinusoidal stimulus with amplitude of A = 50 (μA/cm^2) and frequency of f = 8.3 (Hz) (blue) and the corresponding spike pattern (red).

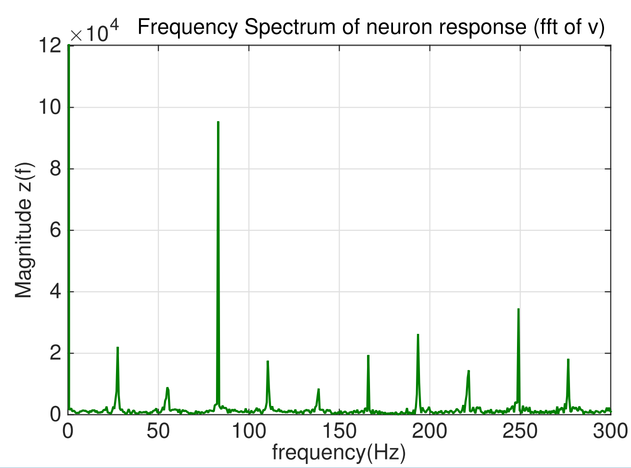

FIG. 5. Frequency spectrum of the spike pattern corresponding to a sinusoidal stimulus with amplitude of A= 50 (μA/cm^2) and frequency of f= 83 (Hz).

Mode-Locking Behavior of Izhikevich Neuron under Periodic External Forcing

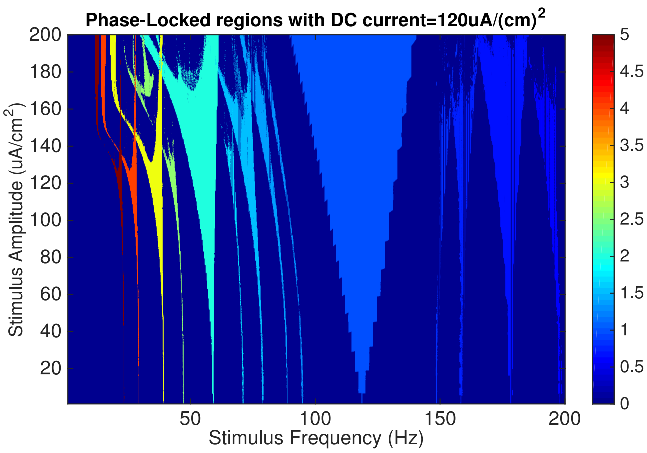

Figure 6. Arnold tongues diagram for a class-2 neuron with a = 0.1, b = 2, c = −30, d = 100. The DC current is 120 (μA/cm^2). This diagram corresponds to the neuron that has the F-I curve shown in Fig. 2.

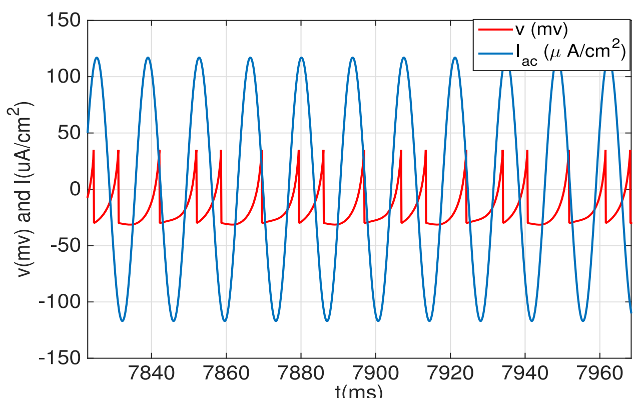

Figure 7. Time series diagram of a sinusoidal stimulus with amplitude of A= 117 (μA/cm^2) and frequency of f= 73 (Hz)(blue) and the corresponding spike pattern (red).

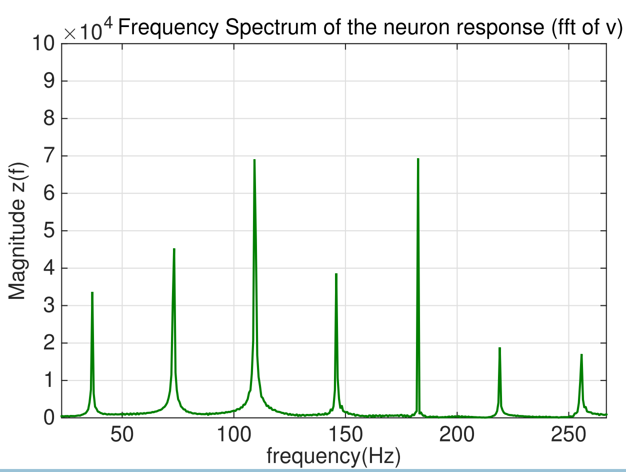

Figure 8. Frequency spectrum of the spike pattern corresponding to a sinusoidal stimulus with amplitude of A= 117 (μA/cm^2) and frequency of f= 73 (Hz).

Again we consider a point of the diagram to observe if it really gives us the phaselocked behavior.

Note the formation of harmonics and subharmonics again. But this time the interesting part is that the amplitude of subharmonics are much greater than class-1 neurons and they are more dominant. Subharmonics amplitudes are still smaller than the amplitude of the first constructed harmonics.

IV. CONCLUSION

By obtaining Arnold tongues diagrams, we can predict the ratio of mode-locking that happens in the layer of the auditory system under study, given the amplitude and frequency of the perceived sound.

Knowing the type of mode-locking, we can predict and justify the formation of harmonics and sub harmonics of the perceived sound.

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Report from the NES-APS Chair, Charles H. Holbrow

Charles H. Holbrow (center), ***APS-NES Chair, at the Poster Session of the Spring 2015 meeting***

2015 Spring Meeting

Bennett Goldberg of Boston University put together a first-rate program for our spring meeting. Its topics were a nice mixture of front-line research in two-dimensional crystal physics and descriptions and assessments of ideas and approaches for better physics education.

The meeting was a fine occasion for students and early career physicists to meet each other and get experience presenting at a physics conference. Keep in mind how useful NES-APS meetings are for providing young physicists a chance to interact as professionals, and bring them with you. NES-APS will give first-author student presenters up to $150 for expenses of attending a regular NES-APS meeting.

Co-operation with the NES-AAPT

To re-energize the longstanding co-operation of the NES-APS with the New England Section of the American Association of Physics Teachers, the two groups are making the November 6-7 meeting at Dartmouth College a joint meeting.

In March at the NES-AAPT spring meeting at Salem State University, I arranged with their president Gary Garber (BU) to have Evan Ellerson be a liaison to Marcelo Gleiser, host and principal organizer of our meeting at Dartmouth College. Marcelo has arranged to include NES-AAPT papers as part of the meeting's program.

Deborah Mason-McCaffrey (Salem State) has succeeded Gary as NES-AAPT president and has been doing a great job publicizing the meeting to her constituency and helping me smooth the way for their participation. To encourage NES-AAPT members to attend, the NES-APS executive committee has authorized a lower registration fee for high-school teachers and NES-AAPT members who are not APS members.

Boston Local Link

To foster communications between academia and industry, APS has set up what it calls Local Links (http://www.aps.org/membership/locallinks/index.cfm). John Collins and I attended the first meeting of the Boston Local Link, and I have attended several since then. The interests of the BLL and the NES-APS are similar enough that co-operation should be useful. One of this fall's candidates for an at-large position on the NES-APS Executive Committee was proposed by the BLL Steering Committee. I hope they will suggest candidates for future elections.

Future Meetings

Courtney Lannert (Smith College) chairs the NES-APS committee that finds sites for our meetings. This is a very important committee. Don't delay. Get in touch with her (clannert@smith.edu) and offer to host an NES-APS meeting in 2017 or 2018.

The 2016 meetings will be April 1-2 at Wheaton College in Norton, MA with John Collins as host, and October 7-8 rd W.

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Report from the NES-APS Chair, Charles H. Holbrow

at MCLA (Massachusetts College of the Liberal Arts) in North Adams, MA with Adrienne Wootters as host. At a time when so much attention is placed on educating students to be a work force, it will be good to have our meetings at schools that are attentive to educating people to have full and meaningful lives.

Publicity for your institution and your programs is an important benefit of hosting an NES-APS meeting. If you are host, your school and your program is featured in two issues of our newsletter that go to the nearly 2500 members of NES-APS. Equally important, you draw to your campus a select group of physicists who can appreciate what you do, and this group will include people who are parents with children approaching college age, and it will include early-career physicists who may soon be looking for jobs at places like yours.

Newsletters
Ed Deveney (Bridgewater State) and Peter Lemaire (Central Connecticut State) do a great job editing and producing our twice-a-year newsletter. The newsletter goes by email to every member of NES-APS. If you have lost that email, you can find the newsletter online at http://www.aps.org/units/nes/newsletters/index.cfm along with all past newsletters back to 1996.

The newsletters are an important benefit of membership in the NES-APS, and we are always looking for ways to make them better. Aparna Baskaran (Brandeis) is chair of our publications committee charged with reviewing the newsletters and setting overall policy. If you have suggestions for newsletter topics, coverage, format, distribution, or other aspects of communicating with NES-APS, send them to aparna@brandeis.edu.

Membership
Ted Ducas (Wellesley College) and I are the membership committee. We want more members for two reasons.

First, we want members to make the NES-APS more diverse and useful. Right now the main efforts of NES-APS are to find sites and hosts and sites for two annual meetings and to publish two newsletters each year. These tasks take most of the discretionary time we have as volunteers.

But can you imagine other activities consistent with our mission that you or other members might organize and run? NES-APS has funds to support programs and activities consistent with our mission. Can you think of creative ways to spend them? Send your suggestions to me, cholbrow@mit.edu.

Second, more members bring us more income. APS allocates to NES-APS $4.50 for each member. Because you are already a member, you know NES-APS membership does not cost you anything; the $4.50 allocation comes out of general funds. But do your colleagues understand this? Membership in NES-APS is free.

Please, for NES-APS, ask your APS colleagues if they are members of NES-APS. If they are not, be warmly persuasive and show them how easy it is to become a member. All they need to do is email membership@aps.org and ask to become a member of the New England Section of the APS.

If you recruit five new members, let me know who they are, and I will personally issue you a glorious certificate of commendation.

Help NES-APS Spend Some Money
If you skipped all the other items in this message, go back and read the one about membership. It says that we have money to spend on activities or programs that support our mission of diffusing understanding and knowledge of physics among professional scientists and to the general public of New England. Send us your ideas for doing this (cholbrow@mit.edu).

Last Words: Nominate Some One
This is my last report as Chair of the NES-APS. On January 1, 2016, John Collins will become Chair and I will become Past Chair. It has been enjoyable to work with the members of the Executive Committee. They have varied and interesting perspectives and are an amiable group. The work of being Chair has not been onerous because Naomi Ridge is an excellent Secretary/Treasurer who knows how to elicit abundant support and service from the national office of the APS. Consider nominating yourself (or one or more esteemed friends) for NES-APS Vice-Chair; send your suggestion to me cholbrow@mit.edu. It will be good for you and good for the NES-APS.

Do you have interesting Physics related articles, new programs, research report, physics talking points etc. that you will like to share with the New England Physics Community?

Send them to the co-editors:
Ed Deveney (edeveney@bridgew.edu)
Peter LeMaire (lemaire@ccsu.edu)

A New Foundation for Enhancing Advanced Laboratory Physics Instruction

Barbara and Jonathan Reichert

Advanced labs have served as the incubation space for the development of budding experimental physicists at the undergraduate level throughout the years. The future of research and development is linked to the continued growth in this area of undergraduate physics education. To continue to grow and enhance this all important area, the Advanced Lab Physics Association (ALPhA) was formed in 2007 dedicated to advanced experimental physics instruction, and became an affiliate of AAPT in 2010. The New England Section of the American Physical Society newsletter has been working to provide information on interesting advanced physics labs through its "Advanced Lab in the Spot Light" section. There is no doubt that the future of experimental physics research is critically linked to the growth and ready availability of inexpensive and affordable lab equipment.

The continued efforts by various groups working to improve and make advanced labs affordable and accessible, took a giant step forward in 2014 when Dr. Jonathan F. Reichert, the founder and President of TeachSpin, a company well known for its dedication to "enhancing advanced laboratory instruction", and his wife Barbara, created the Jonathan Reichert Foundation and gifted TeachSpin to the new Foundation. They also provided a seed of 1.1 million dollars to the foundation, to begin "building a substantial permanent endowment for the Foundation". Dr. Reichert hopes to see this seed grow to about 10 million dollars to secure the future of the foundation "as a transforming force for the improvement of physics education in the United States". "The foundation will provide funds to colleges and universities for purchasing hands-on apparatus for their advanced laboratory programs. Funds will also support time and expenses for advanced lab practitioners to mentor other faculty, and for students to build advanced laboratory experiments as their capstone senior projects. Bringing current research results effectively into the advanced laboratory canon is another priority of the foundation. In short, the Foundation will keep the spotlight on the advanced lab." Dr. Reichert hopes that, with this emphasis on experimental physics at the undergraduate level, all experimental physicists, will end the half-joking classic distinction between the basic sciences – "if its slimy its Biology; if it smells, its Chemistry; and if it doesn't work, its Physics", with "and if it's stimulating, exciting, and fun, its Physics!"

The Jonathan F. Reichert Foundation is "a self-perpetuating private foundation run by a board dedicated to its mission", and as such is open all to contribute and support. It will be great if physicists and lovers of physics will contribute to the building of such an important resource for physics education. This piece is a call to all who care about experimental physics to consider supporting this very important foundation. You may become a "member" of the foundation, and more information is available at

www.jfreichertfoundation.org

The founding Board of Directors: Standing, left to right: Gerald D. Verdi (Verdi & Company), Peter J. Collings (Swarthmore), Richard W Peterson (Bethel), Robert A. Eisenstein (Santa Fe Alliance for Science), Gabriel C. Spalding (Illinois Wesleyan), David A. Van Baak (TeachSpin), Michael D. Salzman (Signature Place Advisors), David T. Hartney (First Hand Learning). Seated: Barbara Wolff-Reichert and Jonathan F. Reichert (TeachSpin). Not pictured: Norman Jarosik (Princeton)

Author: Peter K. LeMaire
Central Connecticut State University

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