American Physical Society New England Section Newsletter

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Co-editors

- Edward Deveney
- Peter K. LeMaire

Inside this issue:

Theme: Energy Matters

The meeting will address energy-matter interactions, energy production and efficiency, and unique materials that address future energy needs.

The meeting will begin on Friday, April 4, 2014 with a 12:00 pm Registration and Meet & Greet. A 2:00 pm welcome address will be followed by plenary invited talks, a poster session, and a conference banquet at 6:45 pm, featuring Professor Daniel Nocera of Harvard University. Saturday, April 5th will include light refreshments beginning at 8:00 am leading into presentations until 11:30 am. The conference will conclude with a lunch at 12:00pm.

Meeting Chair: Professor Cyril Opeil, S.J.

For registration, travel and lodging information, and an up-to-date conference schedule, and workshop information, please visit the meeting website at http://www.bc.edu/content/bc/schools/cas/physics/nes-aps.html

Contact: Programs Administrator, Stephanie Zuehlke zuehlkes@bc.edu

Department of Physics, Boston College

Spring 2014 Meeting of the New England Section of the American Physical Society

April 4-5, 2014

www.bc.edu/schools/cas/physics/nes-aps.html

Energy Matters

Energy in myriad form allows us to live in a technologically sophisticated world. Studying the interaction between matter and energy is the focus of much of modern physics. Population and economic growth lead to increased demands on natural resources, greater individual energy consumption and a tension between energy supply and demand. The challenge of creating a more secure, sustainable and affordable global energy system is one of the most important issues facing policy makers, scientists, technologists, researchers and energy industry figures today. This APS Sectional conference will address energy-matter interactions, energy production and efficiency, and unique materials that address future energy needs.

The Spring 2014 Meeting of the New England Section of the American Physical Society will be held at Boston College, Friday and Saturday, April 4th and 5th.

Featured Speakers:

Prof. Christian Wetzel, Rensselaer Polytechnic Institute
Photons in Energy Efficiency -- Solid State Lighting and Beyond

Prof. Evelyn Wang, MIT
Nanoengineered Surfaces for Thermal Energy Applications

Christopher Harrison, Ph.D., Schlumberger-Doll Research Center
Microfluidics and the Oilpatch

Banquet Talk: **Prof. Daniel Nocera**, Harvard University
The Artificial Leaf

Special Exhibit!

Attendees will have a very special opportunity to view the following rare books on exhibit in the Boston College Burns Library:

Christoph Clavius, *In Sphaeram Joannis de Sacro Bosco Commentarius* (1570)
Sir Isaac Newton, *Philosophiae Naturalis Principia Mathematica* (1687)
Nicolaus Copernicus, *De Revolutionibus Orbium Caelestium* (1617)

Online registration has closed but you may register for the conference on site. Standard registration is $85, Student registration is $30 and Emeritus or Retired is $45.

Meeting Chair, Professor Cyril Opeil, S.J., Boston College, Department of Physics
Contact: Programs Administrator, Stephanie Zuehlke, zuehlkes@bc.edu, 617-552-2195

News from Boston College

The Department of Physics at Boston College department remains in the forefront of research in basic and applied condensed matter, materials and nanoscale physics, with over $10 million in active grants, 60 papers published in 2013, and a growing number of issued and pending technology patents.

Research News

One of the most exciting developments for a department is the addition of a new faculty member, bringing fresh approaches to teaching and introducing new areas of research. In December 2013, Assistant Professor Kenneth Burch joined the faculty. Dr. Burch received his PhD from the University of California, San Diego. His research focuses on spectroscopic studies of novel solids, interfaces, and nanoscale materials. Materials of interest include topological insulators, unconventional superconductors, spin/valleytronics, thermoelectrics, and 2D atomics crystals. His group is capable of studying these materials with a wide-range of spectroscopic tools (infrared spectroscopy, Raman microscopy, tip-enhanced Raman spectroscopy, and differential conductance) as well as producing novel interfaces and nanostructure using mechanical exfoliation and bonding, using techniques he has developed.

Distinguished Research Professor Gabor Kalman, has recently been inducted as an external member into the Hungarian Academy of Sciences. His citation reads, in part: "He has developed a unique approach for the analysis of charged particle systems in the liquid state, which was applied to demonstrate that an optic mode develops in charged bilayer liquids."

Professor Vidya Madhavan was the recipient of a conference grant from the National Science Foundation to organize and co-chair the first NSF CAREER workshop designed to assist Faculty Early Career Development awardees in continuing their path to research leadership in their fields.

A new, interdisciplinary undergraduate course, Nanoscale Integrated Science, was introduced in the spring of 2013 by department chairman Professor Naughton. This course exposes students (physics majors for now; eventually the course will be open to all science majors) to materials, phenomena, and devices built at the nanoscale, with particular emphasis on the role that fundamental discoveries in physics are being used to advance not only micro- and nanoelectronics, but also biotechnology, medicine, and neuroscience. The development of this course is the result of investments in micro/nano facilities at BC, such as the Integrated Sciences Nanofabrication and Clean Room Facility on the Newton Campus, which is likely to be the busiest lab on campus.

Professor David Broido and collaborators published a paper in *Physical Review Letters* predicting that an unlikely material, cubic boron arsenide, should have an extraordinarily high thermal conductivity, on par with that of diamond, long considered to be the best conductor of heat. The finding gives new insight into the nature of thermal transport and may open new opportunities for passive cooling of microelectronics. Broido's paper was also featured in *Viewpoint* by the American Physical Society.

A collaboration led by Professor Madhavan and including Assistant Professor Stephen Wilson and graduate students Daniel Walkup, Wenwen Zhou, Chetan Dhital, and Madhab Neupane reported the discovery of coexisting massless and massive Dirac fermions in a new class of materials called topological crystalline insulators. This work was published in *Science* and was highlighted online in *Science Express*. Former Madhavan lab postdoc Yoshinori Okada was the lead author on the paper, with contributions from physics graduate students Daniel Walkup, Wenwen Zhou, and Chetan Dhital.

Professor Willie J. Padilla and researchers in his lab reported an advance in efforts to create accessible and effective THz (terahertz) imaging. Using both optical and electronic controls, the team developed a single-pixel imaging technique that uses a coded aperture to quickly and efficiently manipulate THz waves, according to their report in the journal *Optics Express*.

Professor Kris Kempa published a paper on "Plasmonic protection of hot-electron energy" that suggests a novel route to ultrahigh efficiency solar cells. The paper was selected for the Rapid Research Letters section of the journal *Physica Status Solidi*.

Professor Naughton organized an academic symposium event for the BC Sesquicentennial celebration entitled "Energy: From the Last to the Next 150 Years." It was held in October of 2013 and featured Massachusetts Senator Edward J. Markey '68, JD'72, as keynote speaker.

Student News

The Department of Physics offers a "100 percent guarantee" that a research opportunity will be made available to all physics majors who seek one. This academic year, 39 undergraduate students were awarded Undergraduate Research Fellowships funded by the College of Arts and Sciences, enabling them to participate in hands-on research alongside faculty, postdocs, and graduate students. Also, several additional undergraduates participated in academic research funded by external grants. In addition, a dozen of our graduate students were lead authors on scientific publications in 2013.

Chetan Dhital, a PhD student working with Professor Wilson, was awarded the 2013-2014 GMAG Ph.D. Dissertation Research Award from the American Physical Society (APS). This award is given annually to a maximum of two students who have conducted outstanding dissertation research in the field of magnetism.

Nathan Nesbitt, a PhD student in Professor Naughton's lab, received an NSF Graduate Research Fellowship in support of his graduate study on a project to develop highly efficient solar panels that utilize the innovative nanocoax receptor technology developed by BC Physics faculty.

Timothy Sleasman '13 received the third annual Professor George J. Goldsmith Award. Named in memory of our late, longtime faculty member, who is remembered for both his scholarship and his selfless dedication to the students of Boston College, this award is given annually to a graduating physics major in recognition of excellence in academic achievement and research. Mr. Sleasman was an exceptionally accomplished student, with a double major in physics and math, who worked throughout his tenure at Boston College in Professor Padilla's laboratory. He is now pursuing a PhD in electrical engineering at Duke University.

Recap of the Fall 2013 Meeting of the New England Section of the American Physical Society at Bridgewater State University

Heartwarming thank you from all at BSU for making this meeting a resounding success especially given the untimely forced cancelation of the planned spring meeting resulting from events related to the 2013 Boston Marathon Bombing.

Friday, Oct. 11th, 2013

Biophysics, Optics and Industry themes unified the meeting tying together the physics, interests, excitement and possibilities for the students, faculty, researchers, vendors and industry attendees throughout the New England area. Organizers had hoped to paint an expanding view of what a physics degree offers especially to young students who are excited about moving into these burgeoning directions throughout New England and beyond.

Art Goldstein, Dean of Bridgewater's School of Sciences and Mathematics, welcomed attendee's to the recently completed Bartlett College of Sciences and Mathematics Complex (2011) noting the exciting new directions and opportunities, especially for undergraduate student research, that Bridgewater State University (BSU) now offers thanks to the changes ushered in by faculty, administration, and students with the help of the Commonwealth.

Ed Deveney of the BSU Physics Dept. extended the welcome and story of the ways that BSU maintains its excellence in teacher preparation but is focusing, expanding and gaining reputation for preparation of top students ready to make immediate impacts in graduate school research as well as for those prepared and ready to make immediate impact in the New England economic scene in research, technology and medical industries. He further thanked all the sciences in particular BSU Chemistry and Biology for shared enthusiasm and motivation for the meeting and theme but noted it was really listening to the students, understanding their interests and excitement for expanding and exploring new directions in physics that motivated the theme of this meeting the most.

APS Invited Plenary Talks took place in the Sciences and Mathematics Auditorium and were all extremely well received both in terms of exciting delivery, audience questions and an audience that grew quite large with BSU students from introductory physics courses as well as Chemistry and Biology majors and faculty attending.

Ashley R. Carter from Amherst College began with 'Optical Trapping: From Untestable Measurements to Simple Biophysical Experiments' encouraging lots of audience interactions.

Mark Williams from Northeastern University spoke on 'Force-induced DNA interactions: From polymer elasticity to protein dynamics' introducing us to preliminary results from one of the Nation's top research labs in this field.

Ed Deveney introducing Nathan Derr at the Fall

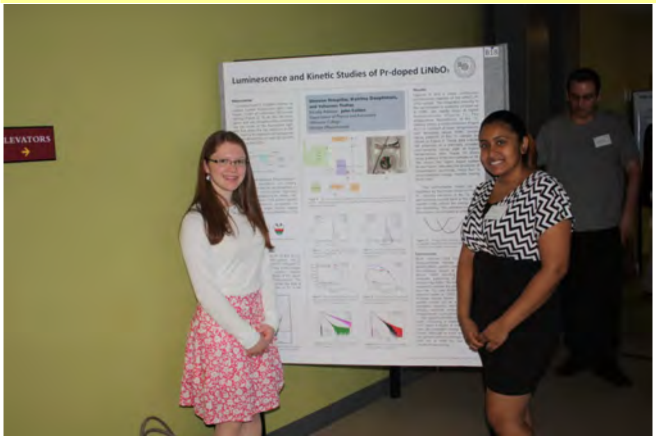
Nathan Derr from Harvard Medical School Dept. of Cell Biology and now Smith College dept. of Biology spoke on 'Coordination of individual and ensemble molecular motors studied using tools from DNA Nanotechnology' with stunning data and real and simulated videos of the workings within the cell.

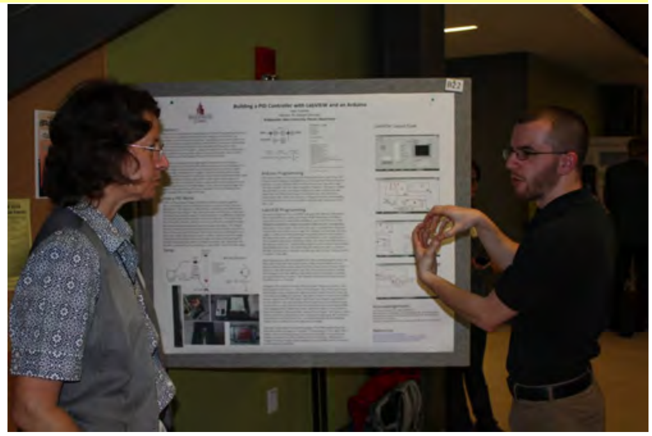
Miao Wang at the Fall 2013 meeting

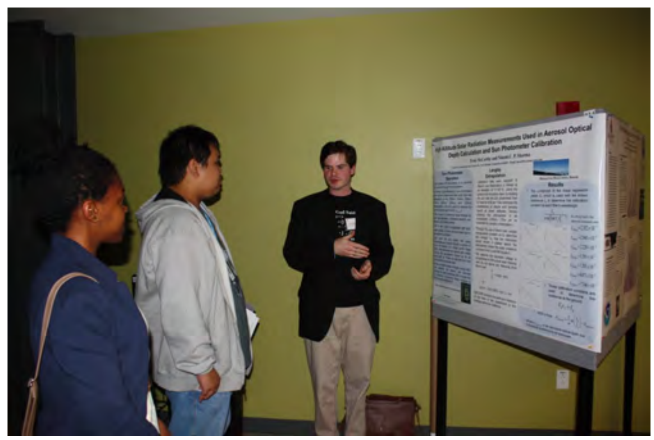
Miao (Katherine) Wang from Brown University Physics spoke on 'Electric-field driven translocation of colloidal wild and mutant fd viruses through a solid state nanopore with the physics and implications of this bio-physics technique.

Recap of Fall 2013 Meeting…

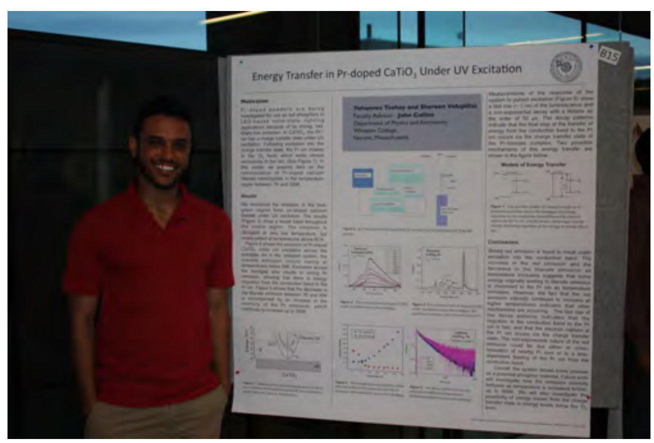
Scenes from Poster Session







A Lively Poster sessions with cheese, fruit and cash bar followed showcasing Bridgewater's new Sciences and Mathematics Complex in the sprawling atrium that included flush greenery and two display showcases; one displaying a colorful and diverse mineral collection and another a collection of intriguing Physics and mathematics memorabilia and collectables both the generous contributions of Mathematics Professor Phil Scalisi. The poster session of course was highlighted by 28 contributed posters with topics including the majority of them authored by students; biophysics, advanced laboratories, lasers and their applications, astrophysics, climate change and physics pedagogy. The Universities of Rhode Island, Connecticut, Central Connecticut State College, Bridgewater State,



MCPHS Boston, Hartford as well as Wheaton College, Yale, Boston College, CRG and AF Research Labs were all represented.

Recap of Fall 2013 Meeting…

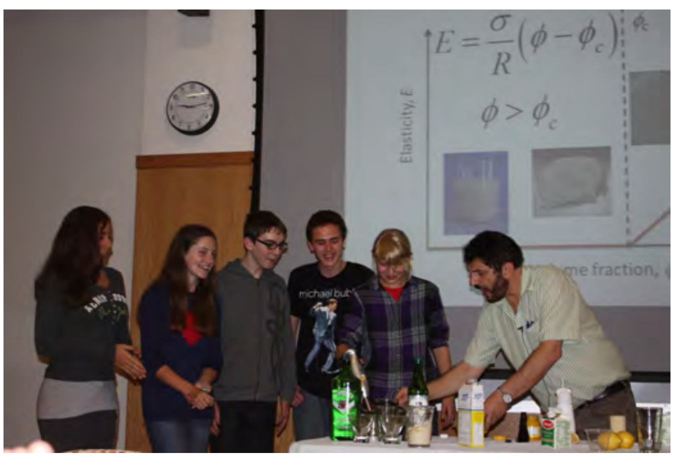
At 6.40 PM roughly 70 attendees took ¼ mile walk on a perfect fall evening from BSU's East campus to West Campus. Lively conversation and filled stomachs headed back to the BSU New Sciences and Mathematics Complex (or took shuttle provided) at about 7.45 PM for the open-to the public lecture by David Weitz of Harvard University of the 'Physics of Cooking'. We estimate roughly 120 attended including many from the general BSU community who became excited about the lecture through public announcements. The history of this talk and course at Harvard where given by one of the originators and we all clapped for physics equations as they brewed, , watched eggs cook at different temperatures, made real cream and had a martini or two along the way. A true highlight for all.

The Physics of Cooking

By
David Weitz

Right: David Weitz

(Photo courtesy of Charles Holbrow of Colgate, MIT and Harvard)



Scenes from the Physics of Cooking talk

Above: Students assisting David Weitz
Left: audience at the talk

Recap of Fall 2013 Meeting…

Saturday, Oct. 12th, 2013

Saturday Morning started with light breakfast at 7.30 AM followed by two well-attended break-out parallel Sessions each with 7 speakers at 8 AM. The sessions were roughly centered on the following themes: Biophysics and Fundamental Physics and Physics Education, Light and Devices. In the former, attendees were treated to the physics of retinal diseases, tumor cells, 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 supercontinuum generation and white-light emission from schools including Boston College, Univ. of Connecticut, UMass Boston, Univ. of Hartford, and Univ. of New England.

During break following the break-out sessions attendees snacked and were able to visit the TeachSpin vendor table and attend sessions with National Instruments equipment and software hosted by Josh Brown. Attendees were also had the chance to take Bridgewater-student guided tours of the advanced labs (Laser lab, instruments lab, advanced lab, electronic/robotics lab and machine shop) as well as the spectacular new Bridgewater Observatory facility.

Students at the National Instruments LabView Workshop

At 10 AM all attendees were invited back for an APS invited Physics Education talk by our own Tom Kling for his presentation 'STREAMS at BSU as a Catalyst for Departmental and Institutional Change' which is work he has engaged on as part of an ongoing NSF grant for course re-design and inclusion of 'structured learning assistance' programs.

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)

Separation of DNA by Length using Counter-Rotating Vortices

This presentation is part of my ongoing work simulating the dynamics of polymers in microfluidic flows. Microfluidic devices may be the future platform for medical diagnostics since they have the potential to be faster and less expensive than current techniques. We aim to understand how to manipulate polymers of biological interest such as proteins, DNA, and RNA in the micrometer scale channels of these devices. We use fluid flow patterns as well as gradients in parameters such as the temperature, electric field, and salt concentration across these channels.

Most of my research uses a lattice-Boltmann based simulation to model fluid flow. In the LB method, the fluid is broken into a grid, or "lattice", and for each square of the grid the velocity distribution and its time evolution is calculated using the Boltzmann equation. The fluid will flow, interact with other fluid, then relax back to its equilibrium state, a Maxwell-Boltzmann distribution. The technique has been shown to be equivalent to the Navier-Stokes equations for fluid flow in systems such as the ones we are studying with low Mach and Knudsen numbers. For polymers, we use a bead spring model which has been parameterized to mimic lambda-phage DNA. The DNA is composed of beads connected by nonlinear springs. The beads can interact with the fluid via the viscous force and a Brownian force that produces diffusion. This interaction can also perturb the fluid leading to hydrodynamic interactions between the beads.

Specifically for the Fall 2013 APS-NES meeting, I presented our work using counter-rotating vortices to separate polymers of different lengths. Counter-rotating vortices have been used to concentrate DNA as well as separate colloidal particles of different sizes in experiments. We want to explore combining the two experiments in simulation to determine if the vortices can be used to separate DNA of different lengths. We have found good separation when the lengths of two DNA molecules are differ by 50%, we can get reasonable separation for smaller differences, and are currently exploring the sensitivity of the technique.

Jennifer Pearce at the Fall 2013 meeting

The mechanism of the separation is based on escape from a trap on one side of the channel. The fluid flow compresses the polymers, pushing them into a trapping region. In experiments, the force that traps the polymer was the result of a sharp temperature gradient. We do not incorporate a specific trapping mechanism to make the results more general to any system. Once the polymers are trapped, they escape due to the Brownian motion of the beads that make up a polymer in the simulation. The longer polymers have a higher chance of escape, since they are composed of more beads. They therefore can find stable trajectories in the fluid flow, while the shorter chains remain trapped.

All of this work is done with undergraduates, none of whom are physics majors. At RWU, we do not have a physics major currently, although we would like to build a program. This work then serves to expose mostly biology majors interested in cutting edge molecular biology techniques to computational methods and the physics of these systems. Many of them fully understand why physics is a required course for biology majors once they start on the projects. This has caused some of my students to continue on with computational studies at the graduate level. For me, at an undergraduate institution without a physics degree, research has become a good way to show students who would normally never consider physics important for their field of study just how many advances in biology have been driven by physics research. This then inspires them to learn more physics and consider interacting more with our community. It will hopefully help promote more interdisciplinary science in the future as these students become mature researchers in the future.

Author:
Jennifer Kreft Pearce
Assistant Professor of Physics
Roger Williams University

High Altitude Solar Radiation Measurements Used in Aerosol Optical Depth Calculation and Sun Photometer Calibration

Evan McCarthy at the Fall 2013 meeting

Aerosols are small particles suspended in the atmosphere that may be either naturally occurring or manmade. Their characteristics and distribution with altitude impact air quality, human health, pollution studies, rainfall patterns and climate. They also serve as tracers for atmospheric dynamics studies. AOD is an important parameter for these studies. CCSU instruments for measuring AOD include a Micro-Pulse Lidar (Light Detection and Ranging, or laser Radar) system (MPL), a CCD Camera Lidar system (CLidar), and two hand-held Solar Light sunphotometers. While the Lidar systems map AOD as a function of altitude, the sunphotometers provide the total AOD integrated through the entire vertical column of the atmosphere. Sunphotometer measurements are used in conjunction with the lidar measurements. CCSU Physics major Evan McCarthy participated in the optics research, focusing on converting sunphotometer detector voltages into calibrated AOD measurements, and presented his results at the NES-APS meeting.

Sun photometers use light that has traveled through that atmosphere and has been scattered by aerosols to determine the aerosol optical depth. At CCSU two sun photometers are used to determine how much light is attenuated during the trip from the top of the atmosphere to the ground at the 380 nm, 440 nm, 500nm, 675 nm, 870 nm, 936 nm, and 1020 nm wavelengths. Irradiance values determined from these data are used to measure the AOD for use alone or in conjunction with the Micro Pulse LIDAR and CLIDAR systems for studies on concentration of aerosols in the atmosphere.

Light from the sun enters the upper atmosphere at a solar zenith angle (SZA) and traverses an optical path length through the atmosphere known as the air mass (AM) as it travels through a column of air to the sensor. These are derived from time and location coordinate data. As the sun light passes through varying AMs and reaches the sensor, the recorded voltages for each bandpass filter change due to scattering (and absorption). Converting these voltages to AOD requires calibration.

Calibration constants were determined after taking calibration data with the sun photometers at the Mauna Loa Observatory in Hawaii, at an elevation of 11,141ft. It was crucial to take calibration data at this altitude above the aerosol rich boundary layer so to minimize the interference from clouds and aerosols found at lower elevations. Data were measured over a long time span from near dawn to near noon local time so that the air masses varied widely. Plots at each wavelength of natural log of the signal versus air mass yield a linear slope.

Using Beer's law, Langley extrapolation allows us to determine the voltage the sun photometer would record if it were placed above the atmosphere, where solar irradiance is known and air mass is zero. Assuming the recorded voltage on the ground is proportional to the true solar intensity, it is possible to extrapolate a linear expression that - in conjunction with the known solar irradiance at the top of the atmosphere - may be used to determine a calibration constant for each wavelength filter to convert the measured voltage at each filter wavelength to AOD. The successful calibration of these instruments now allows the sunphotometers to be used for AOD determination for further atmospheric studies.

Author:
Evan McCarthy
Central Connecticut State University

A Protein-Based, Ion-Mediated Retinal Implant for the Treatment of Retinal Degenerative Diseases

Jordan Greco at the Fall 2013 meeting

The global incidence of blindness due to retinal degenerative diseases, including retinitis pigmentosa (RP) and age-related macular degeneration (AMD), is increasing at a significant rate due to a rise in average lifespan and an expansion of the global geriatric population. Retinitis pigmentosa is the most common inherited retinal degenerative disorder and affects roughly 1.5 million people worldwide. Age-related diseases, like AMD, have a larger prevalence in the aging community and affect over 30 million people worldwide. In fact, AMD is the leading cause of irreversible vision loss and legal blindness in individuals over the age of 55 years old and continues to lead to a significant decline in the quality of life of individuals and families affected by the disease. Both RP and AMD are characterized by the loss of the photoreceptor cells, which are specialized neurons found in the retina that absorb light and convert the signal into an electrochemical impulse. Through synaptic preprocessing mechanisms in the bipolar and ganglion cells, our brains interpret this impulse as a visual percept. It is important to note that throughout the degradation of photoreceptor cells, the bipolar and ganglion cells of the retina do remain largely intact, and it is this characteristic that is exploited by scientists developing retinal prosthetics.

There is currently no cure for these retinal degenerative diseases, although there are treatments that slow the progression, including intraocular injections and nutritional drug supplements. The fact remains that these treatments only slow the inevitable reality of permanent blindness. Thus, there is a significant need for the development of novel treatments and retinal prostheses in order to restore meaningful vision to those affected by RP and AMD.[1] These implants must replace the function of the damaged photoreceptor cells, and do so in such a way as to take advantage of the presence of the remaining neural circuitry of the retina. Recent efforts have focused on the development of electrode-based implants, which consist of electrode arrays that generate an electrical impulse to stimulate the damaged retina. Electrode-based implants have achieved some success, however, the designs lead to low resolution and require external hardware, goggles, or glasses to magnify or manipulate the incoming signal. Furthermore, the implants have a rigidness and structural complexity that has often elicited surgical and immunological complications. More recently, advances in nanobiotechnology have lead to the use of retinylidene proteins, particularly microbial rhodopsins, as the photoactive elements to restore vision through gene therapy, optogenetics, and visual prosthetics.[2] Here, the focus will be on the design and indications of a flexible, high-resolution retinal implant that is comprised of the light-activated protein, bacteriorhodopsin (BR).

Bacteriorhodopsin is a light-activated, trans-membrane proton pump that converts light energy into chemical energy within the *archaeon*, *Halobacterium salinarum.*[3] The retinal implant makes use of the proton pumping capability of the protein in order to create a directional ion gradient, which stimulates the retina and leads to the electrochemical impulses necessary for vision. In addition to this function, the protein is a favorable candidate as the photoactive medium in an implant due to a high thermal and photochemical stability, a high quantum efficiency that is equivalent to the native visual pigment, rhodopsin, and a tolerance to genetic engineering for optimizing performance.[4]

The retinal implant is generated using layer-by-layer electrostatic adsorption, in which the negatively charged protein layers alternate with a polycation. An ion-

A Protein-Based, Ion-Mediated Retinal Implant …

permeable, biocompatible substrate is used as a scaffolding to facilitate the adsorption of these alternating protein-polymer layers. The protein can be layered with a homogenous orientation throughout the manufacturing of the implant by exploiting an inherent dipole moment. The result is a multilayer thin film that generates a unidirectional ion gradient. Multiple layers of BR within the implant are necessary to absorb enough incident light and to ensure that there is a sufficient number of protein molecules to generate an appreciable ion gradient. The implant is placed in a subretinal orientation and converts incident light energy into a proton gradient used to generate an electrochemical impulse that activates the remaining bipolar and ganglion cell network.

In order to test the efficacy of the design, a series of *ex vivo* extracellular recording experiments were undertaken with the degenerated retinas of P23H-1 homozygous rats, which serve as a model of the human form of autosomal dominant RP. Throughout these experiments, the retinal implant was placed in a subretinal orientation relative to the excised retina, and the ion gradient was directed towards the bipolar and ganglion cell milieu (see Figure 1), thereby making the local environment more acidic. While pulses of light are directed at the retina and implant assembly, a recording electrode was then used to selectively monitor individual ganglion cells in order to measure the action potentials that are generated by the implant. Figure 1 also illustrates a set of control experiments, in which the ion gradient was directed in the reverse orientation. The extracellular recording experiments have demonstrated that the ion-mediated retinal implant is capable of reproducibly stimulating the degenerated retinas when the proton gradient is pumped towards the bipolar and ganglion cells. Furthermore, the relative activation efficiency of the ganglion cells directly correlates with incident light intensity, and, more importantly, the results indicate that light intensities comparable to average indoor ambient light are sufficient to induce a retinal response. These results provide strong support for our concept as we move forward towards preclinical and clinical evaluations of the retinal implant. In addition to parallel biocompatibility and safety studies, surgical development is currently underway and preliminary *in vivo* experiments will be ongoing throughout the year.

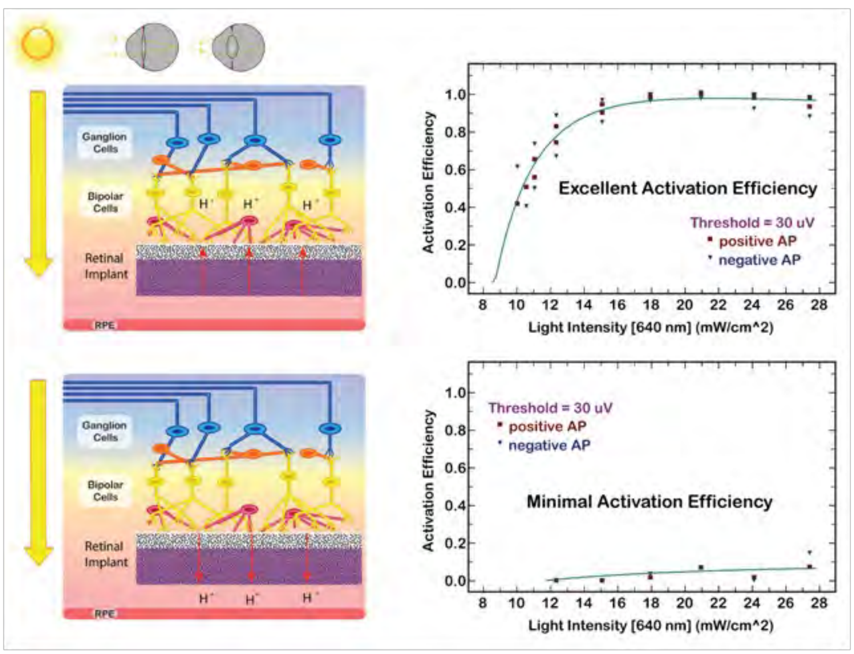


Figure 1. *Activation efficiency of an excised P23H-1 rat retina in response to the ion-mediated retinal implant as a function of implant orientation. Action potentials (AP) are monitored (at a 30 µV threshold) with correction for random background events, which are common in the P23H-1 rats. Note that when the implant is oriented so as to make the bipolar and ganglion cell milieu more acidic, activation efficiency is excellent (upper right). In contrast, the reverse orientation leads to little, if any, activation (lower right).*

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2. Wagner, N. L., Greco, J. A., and Birge R. R. Visual Restoration using Microbial Rhodopsins. In *Bionanotechnology: Biological self-assembly and its applications*, B. H. A. Rehm, ed. Caister Academic Press, Norfolk, United Kingdom (2013), pp 205-240.

3. Oesterhelt, D. and Stoeckenius, W. (1971), *Nature,* **233**, 149-152.

4. Wagner, N. L., Greco, J. A., Ranaghan, M. J., and Birge, R. R. (2013) Directed Evolution of Bacteriorhodopsin for Applications in Bioelectronics. *J. R. Soc. Interface,* **10**, 20130197.

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University of Connecticut

White-light supercontinuum generation in SF_6

Hui Chen at the Fall 2013 meeting

When I was asked to write an article about the research in our group, High-Intensity Laser Physics Group at the University of Connecticut, I appreciated and welcomed the opportunity. We have been studying the behavior of molecules in strong femtosecond laser fields for many years, using a variety of techniques. We are interested in the fact that intense laser fields can produce rotational, vibrational and electronic excitation of a molecule. We have focused on diatomic molecules [1-5], due to their simplicity.

Our two femtosecond laser systems produce 35 fs and 50 fs pulses at 800 nm, which can resolve the vibrational motion of heavy molecules, like I_2 [1-5]. However, to resolve the motion of light molecules, like H_2, sub-10 fs pulses are needed. To shorten the transform-limited pulse duration, one has to broaden the spectrum first. There are two ways to broaden the spectrum: nonlinear self-phase modulation (SPM) [6] and filamentation [7]. Spectral broadening via SPM can be achieved when a pulse is propagating through a gas-filled hollow-core optical waveguide [8]. However, fiber only supports low energy. It is lossy, and sensitive to alignment and damage at the input. Unlike SPM, spectral broadening through filamentation requires a relatively simple setup since no fiber is needed and the energy loss is lower. The formation of filaments is believed to be from the dynamic balance between self-focusing, diffraction and ionization defocusing. The main disadvantages to filamentation are a high energy threshold [7, 9] and relatively low pointing stability [10].

In our group, we produce white-light supercontinuum with a simple experimental setup through filamentation in SF_6, with an input laser energy as low as 0.35 mJ and a transform-limited pulse duration (TLPD) of 50 fs. The experimental setup is shown in Fig. 1. The experiments are performed with our Ti:sapphire laser system (Spectra-Physics). The laser produces linearly polarized pulses with a central wavelength of 800 nm, a pulse duration of 50 fs, and an output energy of up to 0.75 mJ at 1 kHz. A transparent plastic tube is filled with SF_6 with a pressure up to 1 atm. The beam is focused by a f=1.5 m focal length lens located on the input end of the tube. There is a 1-mm-thick fused silica window on the output end. The beam is collimated by another f=1.5 m lens and then sent into a pair of chirped mirrors (Venteon DCM7 mirrors, -120 fs^2/ pair at 800 nm) to compensate the positive dispersion. The dispersion is finely adjusted by several small pieces of fused silica glass with known dispersion. The recompressed pulse duration is measured by a home-built third-order autocorrelator. A small aperture on a translational stage selects certain parts of the beam to investigate the spatial chirp of the output beam with or without a filament. The spectra are measured with one of two spectrometers (Ocean Optics). Finally, there is a card sitting at 1.7 m after the focus of the beam and a camera (PixeLINK PL-B953U) to measure the intensity centroid of the beam in order to investigate the pointing stability. The experimental setup is simple and easy to build, as seen in Fig. 1.

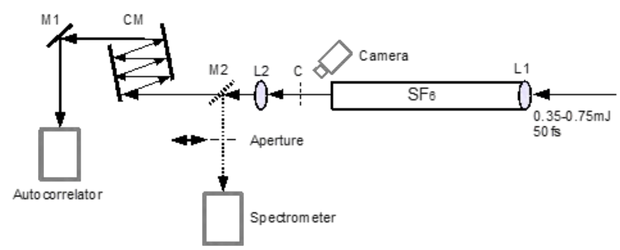

Fig. 1. *The experimental layout. L1: focusing lens with f=1.5 m and antireflection coating for 800 nm; L2: collimating lens with f=1.5 m; M1 and M2: silver mirrors with reflectivity ≥ 95% for 450 nm - 12 μm; M2: flip mirror; CM: chirped mirror; C: card.*

First, we fill the tube with SF_6 to a pressure of 735 torr, and increase the input laser energy to see whether we can produce a filament. When the energy reaches 0.35 mJ, we do see a filament in the tube. With 0.35 mJ input, the laser energy at the output of the tube is ~ 0.3 mJ which gives an efficiency of ~ 86%.

White-light supercontinuum generation …

By inserting M2, we align the output beam into a spectrometer to measure the spectra. The spectra as a function

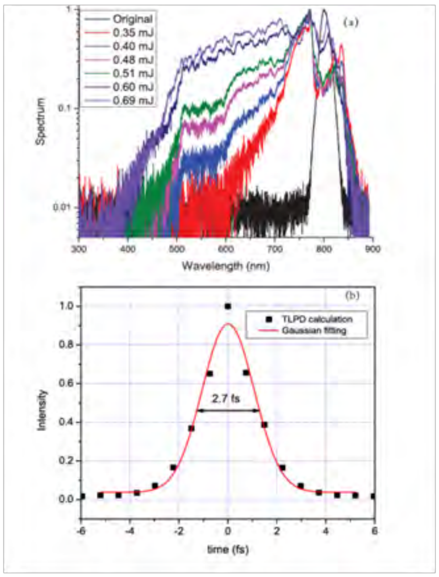

Fig. 2. *(a) The spectra as a function of laser input energy when the pressure of the SF_6 is 735 torr. (b) The TLPD calculated with 0.69 mJ input energy.*

of the input laser energy are shown in Fig. 2 (a). As seen in the figure, higher input energy extends the spectrum to shorter wavelengths, with 0.35 mJ input having a cutoff at ~ 550 nm and 0.69 mJ at ~ 350 nm. We calculate the TLPD based on the spectra with 0.69 mJ input pulse energy, as seen in Fig.2 (b), and obtain a TLPD of 2.7 fs. This demonstrates that we can produce a spectrum wide enough to produce few-cycle laser pulses.

Next, we fix the input laser energy at 0.75 mJ, and increase the pressure of SF_6 in the tube to investigate the change in the spectra with the pressure and the pressure threshold at which the filament starts to appear. When the pressure is lower than 370 torr, there is some spectral broadening but no filament generated. When the pressure reaches 370 torr, a filament is seen in the tube. The pulse

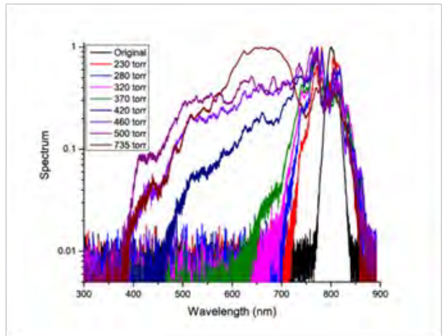

Fig. 3. *The spectra as a function of the SF_6 pressure when the input energy is 0.75 mJ.*

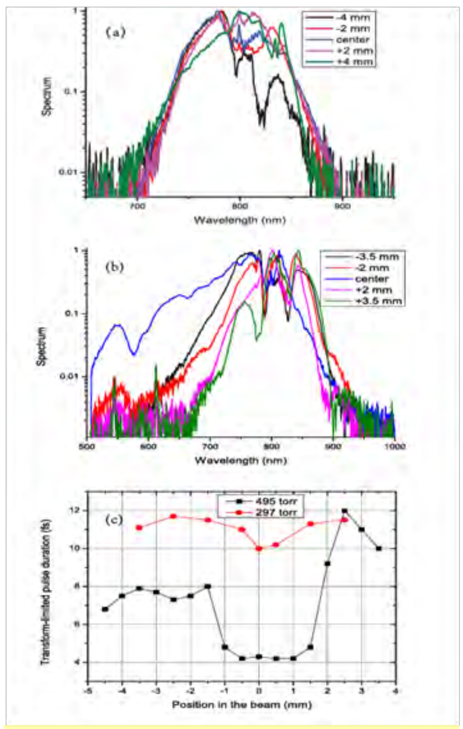

Fig. 4. *The spectra as a function of the position in the horizontal direction in the beam when the SF_6 pressure is (a) 300 torr (below filamentation threshold) and (b) 495 torr (above filamentation threshold). The input energy is 0.75 mJ and the pulse duration is 50 fs. (c) The TLPD calculated as a function of the positions in the beam.*

spectrum as a function of the pressure is shown in Fig.3.
An important question is whether the spatial chirp [5] of the output beam changes below or above the filamentation threshold. At 300 torr, below the filamentation threshold, the spectra look uniform, as seen in Fig.4 (a), and the TLPD calculated at different parts of the beam is close to that of the center of the beam, as seen in Fig.4 (c). However, at 495 torr, above the filamentation threshold, the spectra at the center are much broader than at the edge, as seen in Fig.4 (b). It is easy to see from Fig.4 (c) that the TLPD is roughly 4.2 fs only within a radius of 1.5 mm. Therefore, the broadening below the filamentation threshold does not have a spatial chirp, however, the one above threshold does.

The pointing stability is a main concern for filamentation as it can be worse than broadening methods using a fiber [10]. In this experiment, we perform a pointing stability measurement for the following three cases: original laser beam, spectral broadening below and above the filamentation threshold. The tube is filled with 1 atm SF_6. We place a card at ~ 1.7 m after the focus of the beam and record the beam's intensity profile on the card and then determine the (x,y) coordinates of the intensity centroid for every 50 consecutive laser shots. By increasing the input laser energy, we go through the three cases: 0.06 mJ input giving the original beam, 0.26 mJ giving spectral broadening below the filamentation threshold and 0.35 mJ giving broadening above the filamentation threshold. As seen in Fig.5, the three cases give similar pointing stability. The results indicate that the spectral broadening process

White-light supercontinuum generation…

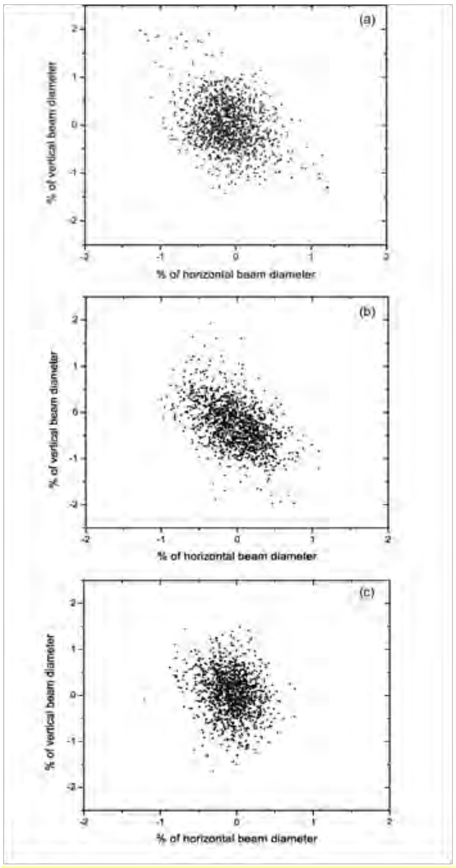

Fig. 5. *The intensity centroid movement of the laser beam for (a) original beam; (b) spectral broadening below filamentation threshold; (c) above filamentation threshold.*

with or without filamentation does not introduce significant pointing fluctuation.

Finally, we need to investigate whether the pulse is recompressable. To compensate the positive dispersion introduced by the SF_6 gas cell, the collimating lens, the glass at the output end of the tube, and the glass and lens in the autocorrelator, 9 pairs of bounces on the chirped mirrors are applied. With 0.35 mJ, 50 fs input pulses, the spectrum in the autocorrelator is seen in Fig.6 (a). The TLPD of 12 fs is calculated , as seen in the in-

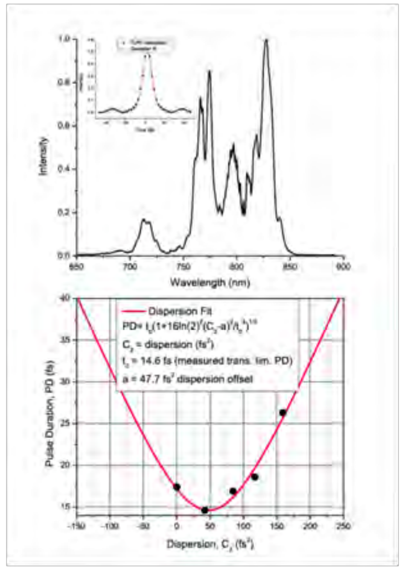

Fig. 6. *(a) The spectrum measured in the autocorrelator with 0.35 mJ, 50 fs input pulses and 1 atm of SF_6 pressure. Inset: the TLPD calculated which is 12 fs based on the spectra; (b) The pulse duration measured as a function of the dispersion introduced by several small pieces of glass with 9 pairs of bounces on the chirped mirrors.*

set of Fig.6 (a). The pulse duration measurements are shown in Fig.6 (b). With 9 pairs of bounces on the chirped mirrors, the net dispersion is slightly negative, ~ -48 fs^2. The negative dispersion is then compensated by a small piece of glass and a shortest pulse duration of 14.6 fs (1.2 × TLPD) is obtained. Furthermore, the pulse duration as a function of positive dispersion added by different pieces of glass is obtained (see the data points in Fig.6 (b)). The data points are fit well by theoretical calculations.

In conclusion, we discuss filament formation in SF_6 with an input laser energy as low as 0.35 mJ with 50 fs pulse duration. The spectral broadening increases with pressure or input laser energy. At 736 torr, the spectrum obtained with a 0.69 mJ input pulse is capable of producing sub-3 fs pulses. In addition, the spatial chirp in the presence of filament is discussed and the spectra are uniform only within a radius of 1.5 mm. Further, the below or above filamentation threshold is found to be similar to that of the original beam. Finally, with 0.35 mJ input, the pulse is recompressed by a pair of chirped mirrors and a pulse duration of 14.6 fs is obtained.

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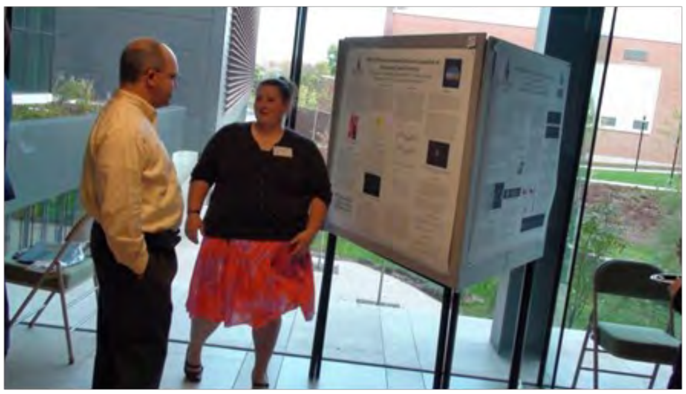

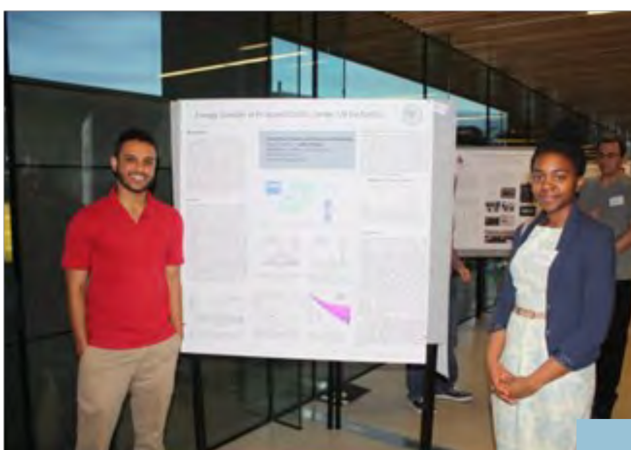

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Biophysics and Optics - By The Numbers

Fall 2013 Meeting of the New England Section of the American Physical Society

When possible, we have decided to publish the rough past-meeting statistics for general information. We hope you find it interesting.

Total registered attendees: 91
- Full registration: 31
- Emeritus registration: 8
- Student registration: 42
- Other: 10

Of these:
- Citing association with APS: 38
- Citing associations AAPT & SPS : 2
- Citing associations APS & AAPT: 11
- Invited plenary speakers: 9

When did you register?
- Two weeks prior (or earlier) to meeting date: 44
- Within two of meeting date: 37
- 'Day of' registrations: 10

Vendors:
- Josh Brown of National Instruments (classroom & demo).
- TeachSpin (table).

Donations:
- TeachSpin: $100.

Finances (approximate):
- Total registration: $3,485
- Banquet registration: $2,060
- Total Registration: $5,545
- Donations: TeachSpin: $100
- Vendor Fees: National Instruments: $100

Total received: $5,745

Organizations Contributing to Programs

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Boston College
Brandeis University
Bridgewater State University
Brown University
Central Connecticut State University
CRG and AF Research Labs
Harvard Medical School Dept. of Cellular Biology/Smith College
Harvard University
MCPHS Boston
Northeastern University
Roger Williams University
The Universities of Rhode Island
University of Connecticut
University of Hartford
University of Massachusetts Boston
University of Massachusetts Lowell
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