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JURP

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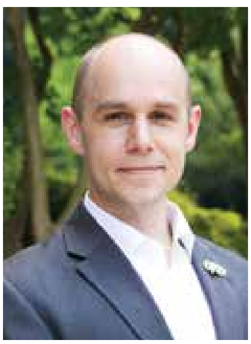
A Letter from the Director

by Brad R. Conrad, PhD

"The mere formulation of a problem is often far more essential than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old problems from a new angle requires creative imagination and marks real advances in science."

—A. Einstein



The Society of Physics Students, which is supported by the American Institute of Physics (AIP), is proud to announce the relaunch of the *Journal of Undergraduate Reports in Physics* (JURP). JURP is a familiar acronym to many SPS advisors, as it previously stood for the *Journal of Undergraduate Research in Physics.* The original incarnation of JURP was launched in 1981 out of Guilford College as a publication dedicated to the research pursuits of undergraduates. JURP's founder, Dr. Rexford Adelberger, described its origins in Volume 10:

> *The research projects that most undergraduate students can complete during their brief stay at college seldom met the rigorous requirements of [professional journals]. This does not mean that the work lacked new physics and clever insights, it was just not of the scope expected of people whose profession is to do research in physics. Yet, we were convinced that the learning and rewards that come from writing up the research in a professional manner and learning to communicate using the professional media had a definite place in the undergraduate program of study in physics.*

Undergraduate research and scholarship are the bedrock of physics and astronomy education and indispensable tools for deep learning. As Einstein alluded to in his statement above, physics is not necessarily about a solution or a final value but the process of exploring the problem itself. And, as was explained to me as a student, research that is not shared, effectively did not happen, as it is not part of the shared community's knowledge. No scientist is an island, and we must learn from each other to make progress. As such, JURP seeks to communicate the many facets of the educational experience to all undergraduates and advisors.

Moving forward, JURP will be a focal point for professional communication within the undergraduate program of study in physics and astronomy. To encompass the many facets of our community, JURP has been expanded from its original scope to more broadly include scholarly works. Scholarly works take many forms, including but not limited to research, outreach, scientific writing and reporting, and advocacy. JURP will remain a publication dedicated to research by publishing peer-reviewed research reports written by undergraduate students that aim to contribute to the field. However, JURP will now also include selected undergraduate student works that reflect the breadth and depth of the undergraduate and professional experience. We have changed the journal's name from *Journal of Undergraduate Research in Physics* to *Journal of Undergraduate Reports in Physics,* as we hope every student can find scholarly works that reflect them and further their educational experience.

It is also important to note that, moving forward, JURP will replace the summer issue of *The SPS Observer.* While *The SPS Observer* remains a focal point for our community, this change will also provide an opportunity for many more research and community-building articles and ideas to make it into the hands of all SPS members and further the mission of AIP.

Please keep JURP in mind as the school year starts, as we hope that you consider contributing a piece to next summer's issue. Learn more about the JURP submission process at http://www.spsnational.org/jurp and look for *The SPS Observer* in the fall.

JURP is no small effort and takes a team of writers, reviewers, and editors to realize. The SPS National Staff would like to extend a special word of appreciation to Dr. Will Slaton of the University of Central Arkansas for his steadfast commitment to the journal and willingness to review and provide meaningful feedback on all the research articles. SPS would also like to thank former SPS directors Gary White of George Washington University and Toni Sauncy of Texas Lutheran University for providing valuable support and feedback. While Dr. Adelberger passed away in 2018, we sincerely hope that this publication honors his vision and inspires future generations of students to pursue the areas of physics that they are passionate about.

Physics is an experimental science. Communicating that science is an integral component of scientific inquiry and a linchpin of the discipline. It is our hope you both enjoy this issue and are able to learn from your colleagues. //

Brad R. Conrad

Director, Society of Physics Students & Sigma Pi Sigma

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Research

Properties and Structure of Glassy TeO_2 and Binary Potassium and Boron Tellurites

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Abstract. Tellurite glasses show potential for use in mid-infrared optical applications[1], but their structure has not been intensively studied. While they do not conduct light better than chalcogenides, which are currently the best glasses for infrared optics, they are much easier to produce. Potassium and boron tellurite glasses, including single component, rapidly cooled TeO_2, are reported and studied here. The results include the Glass Transition Temperature (T_g) measurements and Raman spectra. Proposed structural models are also discussed.

Keywords: Glass Structure, Glass Transition Temperature, Raman Spectroscopy, Tellurites
PACS: 81.05.Kf, 81.70.Pg, 42.55.Ye

INTRODUCTION

Tellurium dioxide (TeO_2) is a conditional glass former and the application of rapid cooling through the twin roller technique has enabled glass formation to a limited extent. Modification of tellurium by boron oxide and potassium oxide results in much easier glass formation with slower cooling rates, and consequently, produces higher glass yield.

In this paper we report on physical properties and structure of these tellurite glasses, including measurements on single phase TeO_2 glass. The physical properties measured were the glass transition temperature (T_g) and the crystallization temperature (T_x). Raman spectroscopy was used to infer structural information.

Most glass forming oxides have a coordination number that is a whole number and a glassy structure that is similar to the corresponding crystalline structure. Originally, it was assumed that tellurium dioxide also followed this trend, but according to neutron scattering and Raman spectroscopy, that does not seem to be the case.[1] Instead of the pure glass consisting of only four coordinated units (where the tellurium is bonded to four oxygen atoms), it also includes three coordinated units (where the tellurium is bonded to three oxygen), as shown in Figure 1. Most likely, the pure TeO_2 glass forms in about two-thirds four coordinated units and one-third three coordinated units with a double bonded oxygen, due to a broad distribution of Te-O bond lengths and asymmetrical bonds.[1]

EXPERIMENTAL PROCEDURE

Glass Preparation

The glasses were made from reagent grade or better tellurium dioxide, boric acid, and potassium carbonate. The boron tellurites, potassium tellurites, and pure TeO_2 glasses were made in 4 to 10 gram well-mixed batches. The batches were heated at 800 ºC for 10 minutes, after which a weight loss was determined, and the glass was heated at the same temperature for another 10 minutes, at which point the samples were quenched into glasses as described below.

All samples were made and heated in platinum crucibles. Glasses were roller quenched[2], which produced clear yellow or orange tinted glasses, likely due to small amounts of platinum contamination in the ppm range.[3] The cooling rate was about 500,000 ± 100,000 ºC/s.

Thermal Measurements

Thermal measurements using differential scanning calorimetry (DSC) were performed by heating from room temperature at 40 ºC/min to 400 ºC using a TA model Q200 Differential Scanning Calorimeter. The onset method was used to determine the T_g. A baseline was run before every measurement and the instrument was calibrated frequently. The error in the reported T_g is approximately ± 3 ℃.

Raman Measurements

Raman spectroscopy was run using a JASCO NRS-3100 Laser Raman Spectrophotometer with a 785 nm laser, employing a silicon crystal reference for calibration at 520.52 cm^{-1}. The sample was focused using a 5x, 20x, and 50x lens successively and the intensity of the laser was optimized to minimize noise. Two 30 second runs were averaged to eliminate cosmic ray events.

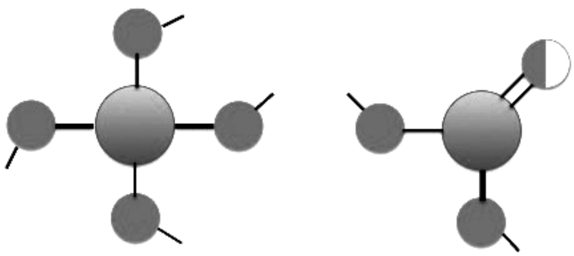

FIGURE 1. A four-coordinated unit shown on the left and a three-coordinated unit on the right. The larger circles are the tellurium atoms while the smaller circles are the oxygen.

RESULTS

Table 1 lists all T_g and T_x results obtained from DSC measurements. T_g results from pure amorphous TeO_2 were prepared using roller quenching. In Figure 2, the T_g was shown to be 305 ± 3 °C, consistent with trends/extrapolations from other families of doped tellurium glasses that have been studied and with a recent report from the Kamitsos group by Tagiara et al.[4]

Raman spectroscopic results from pure TeO_2 and boron tellurites were obtained to verify glassiness and to determine structure. This was done for 3, 2, 1, 0.5, and 0.25-mol % B_2O_3. To see whether the amount of modifier changed the structure of the glass, Raman spectra were compared for the doped samples and the pure TeO_2 sample. Spectra from the pure TeO_2 glass were compared to that of 0.25-mol % B_2O_3 as well. No discernable difference was noticed between them; all were glassy and similar to Figure 3, which shows pure TeO_2 glass and the alpha phase TeO_2 crystal. The peaks in the spectrum from the crystal are sharp and narrow, which we would expect, and the peaks from the glass are broader due to the disordered nature of the amorphous sample.

TABLE 1. Glass transition and crystallization temperature results from tellurites studied in this paper. All results were obtained from DSC measurements.

Sample	Tg ± 3 °C	Tx ± 3 °C
Pure TeO_2 (yellow)	305	348
	307	348
Pure TeO_2 (orange)	310	327
$0.03K_2O$-$0.97TeO_2$	302	x
	302	335
	302	346
$0.02K_2O$-$0.98TeO_2$	302	339
	302	339
	303	333
$0.01K_2O$-$0.99TeO_2$	304	323
	304	323
	304	332
$0.03B_2O_3$-$0.97TeO_2$	315	358
	312	354
	313	361
	314	351
$0.02B_2O_3$-$0.98TeO_2$	311	360
	311	359
$0.01B_2O_3$-$0.99TeO_2$	308	342
	309	346
$0.005B_2O_3$-$0.995TeO_2$	307	343
	307	337

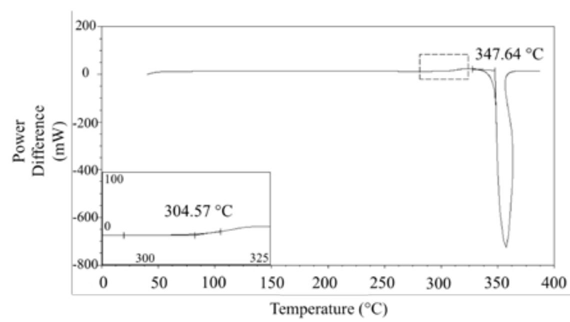

FIGURE 2. DSC curve from a sample of pure TeO_2. The T_g is shown to be 305 °C (see insert) and the T_x is 348 °C.

Figure 4 shows the T_gs and T_xs of boron tellurites with 3, 2, 1, 0.5, and 0 -mol % B_2O_3. By applying a linear fit to the extrapolated data, the T_g and T_x of pure amorphous TeO_2 were estimated to be around 306 °C and 340 °C, respectively. The T_g extrapolated was within error of the measured TeO_2 T_g of 305 ± 3 °C, while the T_x was a little farther away from 348 ± 3 °C, as seen in Figure 2. The T_g and T_x are fairly close, meaning that very high cooling rates need to be reached for glass formation.

CONCLUSIONS

While it is possible to produce small amounts of pure TeO_2 glass via the roller quencher, it is not a feasible method for large-scale fabrication. Instead, a water quenching technique has been used to create 0.6 to up to 3 gram samples.[4,6] This larger sample size will allow for a greater variety of structural tests to be run.

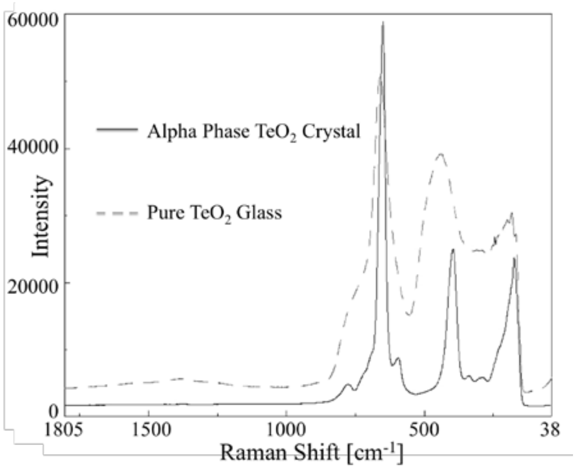

FIGURE 3. Overlaid Raman spectra from pure TeO_2 glass and the alpha phase TeO_2 crystal. The glass spectrum has broad peaks, which are indicative of a disordered structure, compared to the sharp peaks of the crystal.

DSC results for pure TeO_2 place the T_g at approximately 305 °C, which is consistent with the extrapolation of trends from the families of borate, potassium, and barium tellurites and other literature values. In addition to thermal measurements, coordination numbers of TeO_2 for the barium and strontium tellurite systems were calculated using Raman data (not included in this paper). The barium tellurites show a decreasing trend in Te coordination as the modifier is added, which is believed to occur because the increase in barium content adds non-bridging oxygens in the tellurite system. The strontium tellurite system shows a similar behavior. The most interesting result to notice, however, is that most of the trends of both families point to the coordination number of pure TeO_2 being approximately 3.7, which is consistent from values found in the literature.[1,5] Looking at the coordination number of pure SiO_2 glass, which is 4, this could explain why pure tellurium glass is so difficult to produce. Instead of having an even number of similarly sized bonds, as in SiO_2, TeO_2 most likely has bonds that are asymmetrical in length, thus making a cohesive short-range order harder to achieve.

One possible route to better study the amorphous TeO_2 structure is to use the gamma phase crystal, as preliminary work suggests it matches the structure of the glass better than the alpha phase crystal.[7] For further study of this, gamma phase crystal must be produced by heat-treating small samples of pure TeO_2 glass, as those are the conditions where this crystal has been formed.[1,7] There are also more glasses in the alkaline earth tellurite families that may be studied by roller quenching, specifically the calcium and magnesium systems.

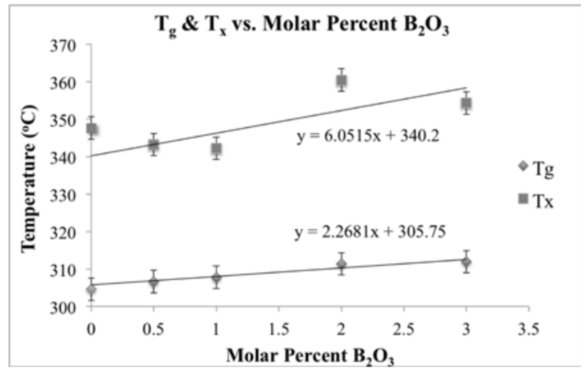

FIGURE 4. T_gs and T_xs of doped B_2O_3 tellurite glasses. The trend extrapolated from this data was used to predict the T_g of pure amorphous TeO_2. The measured T_g and T_x of pure TeO_2 have since been added.

ACKNOWLEDGEMENTS

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In Vitro Visualization of Ultrasonic Wave Fronts Interacting with Heel Bones Using Refracto-Vibrometry

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Abstract. Ultrasonic measurements of the heel bone (calcaneus) are used commonly for osteoporosis screening. Pulses emitted by an ultrasound transducer are incident on the calcaneus, and the transmitted wave fronts are detected with a separate transducer. In the current study, full field videos were obtained using refracto-vibrometry of ultrasonic pulses interacting human calcaneus samples in an in vitro environment. Pulses were emitted by a 500 kHz Panametrics V303 transducer. The measurement beam from a Polytec PSV-400 scanning laser Doppler vibrometer laser was directed through a water tank towards a stationary retroreflective surface. Acoustic wave fronts (density variations) which pass through the measurement laser cause variations in the integrated optical path length. The time-varying signals detected by the vibrometer at numerous scan points were used to determine the time evolution of ultrasonic wave fronts. The resulting videos enable visualization of the propagating wave fronts and the backscattered and transmitted wave fronts. These videos enable direct investigation of wave front distortion due to reflection, refraction and diffraction effects.

Keywords: Ultrasound, Sonometry, Refracto-vibrometery
PACS: 87.63.dh

INTRODUCTION

Osteoporosis is a degenerative bone disease afflicting millions, especially those of advanced age.[1] Osteoporotic bone is of lower density than healthy bone. This weakens the bone's structure, leading to an increased risk of fractures. Clinical diagnosis of osteoporosis is based on measurements of hip and spine bone mineral density (BMD) using a technique called dual-energy x-ray absorptiometry (DXA). Because x-ray absorption is dependent on the medium the x-rays travel through, measuring the absorption of x-rays through the bone provides indicators of their mineral composition and health. While DXA has found use as an osteoporosis diagnostic tool, BMD is only a proxy for bone strength, not completely describing fracture risk. Additionally, a DXA scan results in exposure to x-ray radiation.

Ultrasound shows great promise as an alternative for determining bone health because the propagation of ultrasonic waves in bone depends on the physical and mechanical properties of the tissue. Currently, ultrasonic heel bone sonometry has achieved clinical relevance as an economical method to pre-screen patients for osteoporosis. It functions by measuring the speed and attenuation of ultrasonic pulses propagated through the heel bone (calcaneus).[2] The heel bone is chosen because both sides of the bone are readily accessible, allowing for ultrasound transmission and reception. While deployed in clinics and health services around the world, there are still fundamental physical questions remaining regarding how ultrasound interacts with the complex geometry of the heel bone. Resolving these questions requires visualization of ultrasound waves reflecting and transmitting through the heel bone.

Refracto-Vibrometry for Ultrasound Visualization

Refracto-vibrometery is an emerging optical technique for creating full acoustic field visualizations. A scanning laser Doppler vibrometer is the instrument utilized for this technique. A vibrometer is designed to measure the Doppler shift of laser light after it is reflected from a vibrating surface.[3] However, in refracto-vibrometry the vibrometer is directed towards a motionless retroreflective surface. Acoustic (pressure) waves cause fluctuations in the density of a medium, changing its index of refraction. Therefore, as an ultrasound pulse traverses through the laser, the optical path length of the laser continuously changes. The time varying modulation of the laser detected by the vibrometer relates directly to the acoustic pulse passing through the laser, providing a method for noninvasively sampling a localized region of an acoustic field.[4] By repeatedly emitting ultrasound pulses from a transducer and compiling time-series data at numerous sampling locations, the vibrometer software can reconstruct an image of the traveling wavefront, display how this wavefront evolves over time, and show how it interacts with its environment.

METHODS

The aim of the current study is to visualize ultrasound interacting with a human calcaneus heel bone, mimicking the setup of a clinical ultrasound heel bone scanner. An excised calcaneus was suspended in a water tank. A 0.5 MHz ultrasound transducer, placed one focal length away from the surface of the bone, ensonified this specimen. On the back side of the water tank a retroreflector was placed, and a Polytec PSV-400 scanning laser Doppler vibrometer laser faced the heel sample from the other side of the tank. An image of this setup is shown in Figure 1. Figure 2 presents a depiction of the experimental configure from different perspectives. In Figure 2a, the setup is shown as seen from above. By sweeping the laser back and forth, locations across the entire acoustic field could be sampled. Figure 2b shows this sampling grid pattern from the vibrometer perspective. In all, 15000 different locations were sampled to reconstruct the sound field map. At each location, 100 pulsing cycles took place, and the time series were averaged.

RESULTS

An initial comparison was performed between the signal received by the vibrometer and a traditional piezo-electric transducer. Figure 3 presents a time trace obtained using the refracto-vibrometery technique (a) and piezo transducer (b) for a location on the other side of the bone from the transmitting transducer. Therefore, these traces capture the sound after it has propagated through the bone itself. The two traces are in general agreement with one another, offset only by the slight difference in location of the vibrometer beam and receiving transducer.

While each individual refracto-vibrometry measurement is limited to sampling over the small cross-section of the laser path, by interpolating between points, and combining each sampling location in the region surrounding the heel, a video of the time evolution of the acoustic field in the area is found.[5] This helps show the interactions between the ultrasound pulse and the bone structure. Figure 4 represents a single frame taken from this video. On the left of the image is the transmitting transducer. The image shows some of the wave having passed through the bone to the right side of the image, while a significant portion of the original outbound signal has been reflected off the bone back towards the transducer. Each band in the image represents the variation in index of refraction of the water medium caused by the wave's pressure fluctuations.

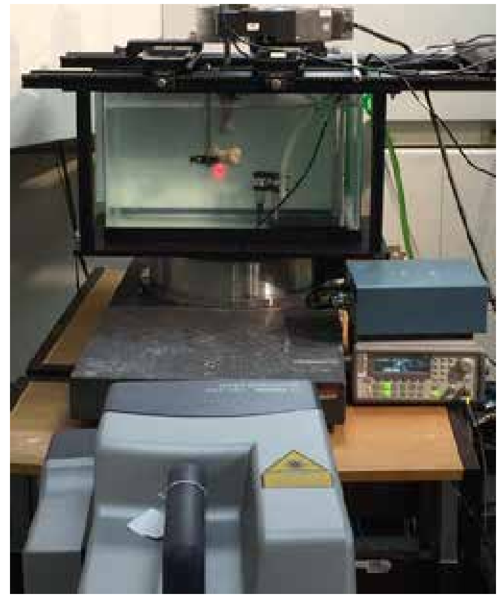

FIGURE 1. The experimental configuration, as pictured from the scanning laser Doppler vibrometer.

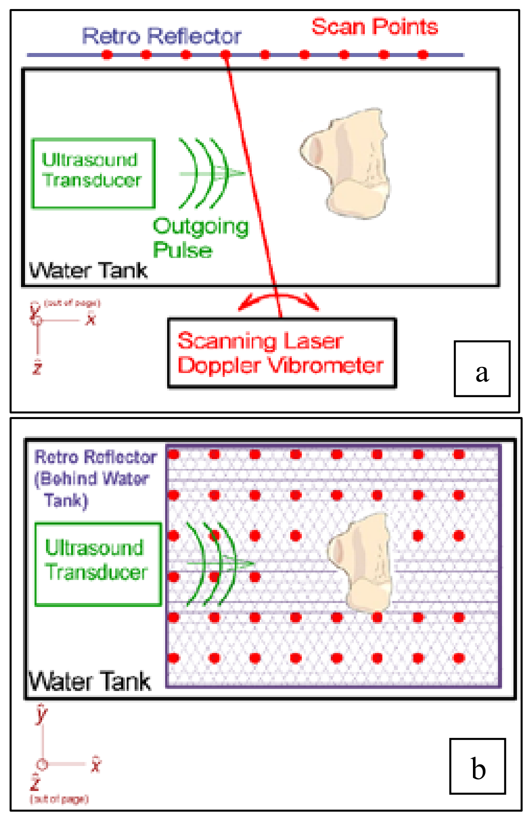

FIGURE 2. a) A top-down view of the experimental configuration. b) The view of the experimental setup from the vibrometer. The dots represent individual scan points. This depiction is simplified to show only the general layout of the scanning grid. In the experiment, 15000 data points were scanned.

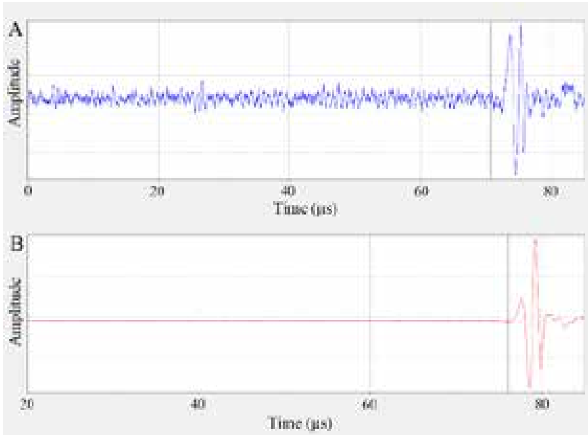

FIGURE 3. Time-series readouts of the a) vibrometer's and b) transducer's time-series measurement. In these graphs, amplitude corresponds to the voltage output of each instrument and has not been scaled to acoustic intensity.

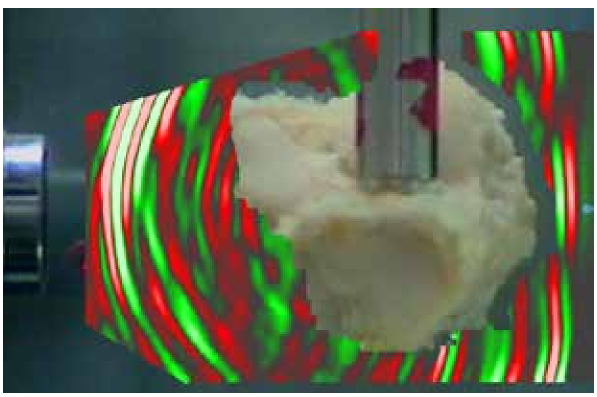

FIGURE 4. Still frame from a video of the ultrasound wave interacting with the heel bone. Green and red regions correspond to areas of increased and decreased pressure, respectively. The pulse originated from the transducer at the left of the image. In this image, the original wave pulse is being both transmitted through and reflected from the bone. For scale, the vertical metal support rod is 1cm in diameter.

DISCUSSION

Comparing the vibrometer trace and transducer trace shown in Figure 3, the vibrometer measurement has a significantly lower signal to noise ratio. With repeated measurements and averaging, some of this noise can be reduced, albeit at the expense of longer sampling times. Despite the higher noise, the vibrometer measurement offers several advantages to traditional transducer measurement. First, the vibrometer measurement is non-invasive. Additionally, the vibrometer is sensitive to all frequencies, while transducers are more constrained in their bandwidth. The vibrometer beam can also be scanned anywhere in the acoustic field, as long as it has an unobstructed path to the retroreflector and back. The transducer requires moving the detector to a new location, constrained by where it can be physically located. An additional major difference is that the vibrometer samples a single line of data running through the field, while the transducer integrates over its entire face area.

The resultant waves seen from the video produced by refracto-vibrometry indicate a complex backscatter pattern contained in the reflection from the heel. However, the transmitted waveform is nearly planar. Therefore, the attenuation and time-of-flight speed of sound measurements traditionally done in ultrasound heel scanners are likely quite robust, with interference at the face of the receiving transducer not having a major impact on the resultant measurement.

CONCLUSIONS

Refracto-vibrometery provides a method for noninvasively sampling an acoustic field. The signals obtained by this measurement, while noisier than the traditional transducer measurements, are advantageous when mapping a complete sound field, as in this study. Applying refracto-vibrometer to the geometry used in a heel-bone ultrasound scanner provides the opportunity to better understand the wave dynamics in this complex system, offering the potential to improve the measurements done by these systems, or increase confidence in their results.

ACKNOWLEDGMENTS

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On Secure Specifications for Large-Scale Quantum Key Distribution Implementations

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Abstract. This paper addresses several security issues facing large scale or distributed implementations of the BB84 quantum key distribution protocol. Firstly, two simulations address how close the tolerated error and the actual error in the hardware must be. These results are quantified in the graphs below.

Keywords: Quantum Key Distribution, Security, Cryptography, BB84
PACS: 03.67.Dd

INTRODUCTION

Computer security is approaching a paradigm shift due to developments in quantum technologies. Many public key cryptosystems like RSA will be rendered obsolete in the coming years by quantum computers and Shor's Algorithm.[1] This major issue has led to many different developments in post-quantum cryptographic systems. One possible mitigation for the threat posed by quantum computers is the implementation of a quantum key distribution system.[2] While standard cryptographic schemes rely on the computational difficulty of solving certain mathematical problems (like the factoring problem for RSA), the security of quantum key distribution is ensured by quantum uncertainty of measuring certain systems.[3] This is preferable because continued increases in computational power can eventually render standard mathematical cryptographic schemes obsolete, while the security of quantum key distribution systems is not dependent on an attacker's computational power.[2]

This paper assesses the security of a large scale, photon polarization based implementation of the BB84 quantum key distribution (QKD) protocol.[3] The BB84 protocol attempts to leverage the quantum uncertainty of measuring photon polarization to ensure that a theoretical attacker, henceforth named Eve, cannot intercept the data without some statistical chance of altering the states in a detectable way.

Verified Bit Count and Hardware Noise

In the standard BB84 protocol implementation, for every photon measured by Eve, there is a 25% chance her measurement will be detectable to Alice (a sender) and Bob (a receiver), and a 50% chance she will be able to recover the correct bit.[3] The compounding of this detection chance over potentially thousands of bits in conjunction with privacy amplification algorithms ensures that Eve cannot intercept a significant portion of the data without being detected. However, a large-scale implementation of this protocol could face certain issues that a standard implementation does not. For example, if Eve had access to a high traffic central node, she could potentially have thousands or even millions of measurement attempts if she isn't targeting a specific victim. In this scenario, her key recovery rate could be much higher than the expected value, given a sufficient number of attempts. These statistics must be fully understood in order to identify the appropriate number of bits that the sender and receiver should compare in order to identify signs that the data has been intercepted.

Another important practical implementation issue to take into account is the error present in the hardware. To Alice and Bob a discrepancy caused by hardware uncertainty and a discrepancy caused by Eve performing an intercept-resend attack are indistinguishable.[3] Due to the inevitable lack of hardware reliability it is necessary that the protocol allows for a certain amount of error. If this error bound is too high, then it leaves room for Eve to intercept a certain percentage of the exchanged information, but if it is too low, it will result in a false positive.

I decided to address these issues using a series of simulations. The first step was to simulate the error variances in a hypothetical quantum channel. Greater error variance would lead to a greater range between the actual channel error and the error bounds allowed by the protocol. A second simulation is used to show what bit percentage is recoverable by Eve given a certain error range. Combining the data from these two simulations enabled me to identify constraints on a secure protocol.

Key Recovery Rate Simulation

To accomplish the first simulation, I created a Python program to show how the base hardware error rate and the verified bit length would affect the error variance, by directly stimulating photon measurement test cases with the relevant statistics from related literature. As would have been intuitively presupposed, greater base hardware error rate also led to greater error variance, while increasing the verified bit length helped mitigate this issue. Again, greater hardware error variance creates more space for Eve to potentially measure the photons undetected.

We then found the best fit plane for the data set visualized in Figure 1. This would enable us to estimate the potential error variance for any verified bit length and initial hardware error rate combination. It is important to emphasize that this simulation focuses on the feasible, statistical improbabilities. This is because in a distributed system Eve could have thousands or millions of attempts against different clients, and thus it is important to consider the worst case when assessing the security of the cryptographic system.

Recoverable Key Percentage Simulation

The second simulation shows how much of the key Eve could recover given a certain amount of allowed error. To do this I wrote a Python simulation for the BB84 protocol for a variety of error ranges and key lengths. To account for the distributed system scenario, I used the highest recovery percent given 1000 independent simulations. I found that the possible recovery rates could differ significantly from the expected values.

The results are visualized in Figure 2. Each line denotes the percent of key recovered (y-axis) given a certain key length and error rate. For example, the orange line corresponds to an 11% allowed error while the grey line corresponds to the 9% allowed error case. The chart shows the degree to which increasing the key length and decreasing the allowed error amount would decrease the key percentage recoverable by Eve.

As can be seen from the chart, while given a 10% allowed error, it is possible for Eve to recover around 30% of the exchanged information. This shows how while it is expected that Eve would recover 20% of the key information at a 10% detection rate,[2] in a distributed system with multiple attempts Eve could recover significantly more information.

Protocol Specification Restraints

The final step is to compile the results of our two simulations in order to formulate recommended hardware and software specifications. Most quantum key distribution systems implement a privacy amplification algorithm, so that even if Eve does recover a small amount of the exchanged information, it can be rendered useless. Usually, any recovery percent less than 11% can be rendered irrelevant by privacy amplification.[2] For this reason I wanted to choose specifications that would keep Eve's recoverable data percent below 11%.

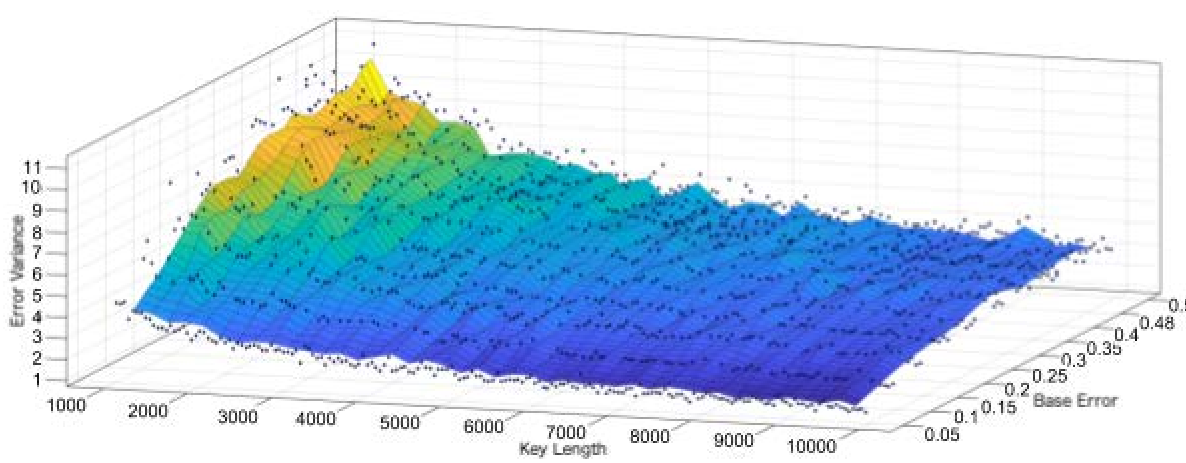

FIGURE 1. Visualization of how the key length and noise in cable affect the measured error variance

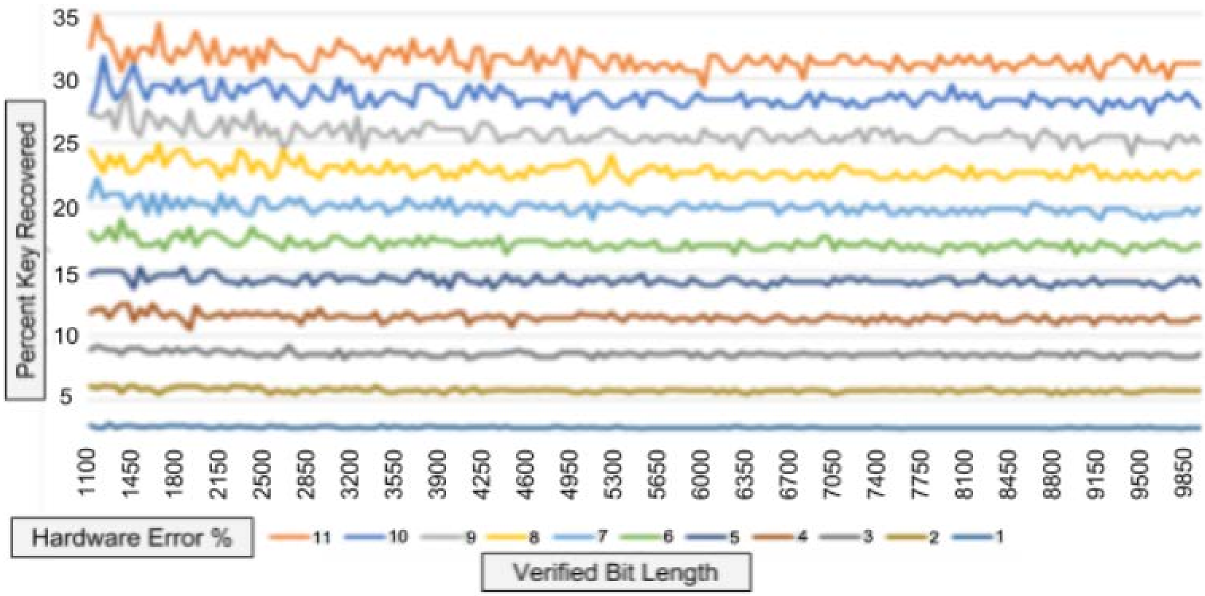

FIGURE 2. Visualization of the percent key recovered given measure rate and verified bit length

From our second simulation it can be seen that it is possible for Eve to recover just below 11% of the exchanged information with a detection rate of around 3.2%. This means that for privacy amplification to ensure any data Eve intercepts is useless, the error variance would ideally be less than 3.2%. Given x and y as the verified bit count and base hardware error, respectively, the equation must be less than 3.2%. For example, based on the graph shown, and a given hardware error rate of 10%, a 5000 bit verification would be sufficient while a 3000 bit verification would not. To make these results widely available I created an online calculator that would estimate the sufficiency of a user's proposed hardware error rate and verified bid count. This online calculator can be found at *http://chasekanipe.com/qkd.html.*

Error Bounds Calculations

One issue that arises from a distributed QKD system is the hardware noise variance. For example, if a large QKD network was implemented it is inevitable that the error bounds will vary from client to client due to the simple fact that error should initially increase linearly with distance. As I showed above, the protocol is most effective when the error bound is within around 3.2% of the actual error (because privacy amplification algorithms can reduce the usable bits to 0). For this reason, it would be necessary that the clients would have previously exchanged expected error information or highly reliable hardware.

CONCLUSION

Unless changes are made to the protocol, I conclude that it is impractical and insecure for distributed implementations. This insecurity is heightened by the fact that authentication difficulties leave QKD systems vulnerable to traditional MITM attacks. However, for dedicated use on high security data lines, it could be invaluable, especially with the incoming quantum computation threat to security and the necessity for long term data integrity. It could also be highly effective to encapsulate a classical scheme like RSA, or a post-quantum scheme so that even manipulation of the quantum channel could not immediately lead to data compromise.

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A Brief Introduction to Plasma Accelerators

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Abstract. This work describes the physics of plasma waves and plasma accelerators. The superiority of plasma accelerators over conventional accelerators has generated renewed interest in these devices with the advent of ultra-fast laser technology. The ponderomotive force produced by ultra short laser pulses interacting with the plasma is considered and the resulting acceleration gradient is derived from first principles. Electron injection is described. Beam driven, including electron beam and proton beam, plasma waves are proposed as the future of high energy plasma accelerators.

Keywords: Plasma Physics, Plasma Waves, Ponderomotive Force, Ultrashort Lasers, Plasma Accelerators, Laser Plasma Accelerator, Electron injection
PACS: 52.75.-d; 52.35.-g

INTRODUCTION

The primary limit of the current acceleration technology is the small accelerating gradient per meter which compounds the length and material cost of building more powerful accelerators.[1] The small accelerating gradient is due mainly to the maximum RF energy which can be tolerated by the accelerating structure before the structure degrades due to field emission.[1] Field emission happens when strong electromagnetic fields overcome the chemical potential of materials and rip off electrons from the surface, slowly degrading the material over time. However, plasma accelerators have the advantage that the electric field is immersed in a plasma, which significantly mitigates this effect. Plasma is the state of matter in which an ionized gas interacts with an equal number of free electrons in a confined space. The plasma accelerator's limits will be introduced later in this paper. The general idea of conventional particle accelerators is to accelerate charged particles by attracting and repelling them by a changing electromagnetic field. The current conventional accelerating gradient is about 100 MeV/m.[1] (The accelerating gradient is defined as the energy gained by the particle per unit length.) In a plasma accelerator the plasma acts as an energy transformer, where energy is transferred from the driver (the ultrashort pulse laser or high energy charged beam) to the accelerated particles. Using this regime plasma acceleration can achieve the acceleration gradient of 1 GeV/cm.

Laser-driven plasma accelerator was originally proposed three decades ago by Tajima and Dawson.[2] The basic design of a laser-driven plasma accelerator is applying an ultrashort laser pulse into plasma, creating a plasma wave. By injecting electrons onto the plasma wave, the electrons are accelerated.

In this paper, plasma acceleration, ponderomotive force, electron injection, beam-driven method, and some important milestones will be introduced.

PLASMA ACCELERATION GRADIENT

To evaluate the plasma acceleration gradient, evaluating the maximum electric field that can be created in plasma is the first step. According to Maxwell's equations,

$$\int E \cdot ds = \int \frac{\rho}{\varepsilon_o} dV \tag{1}$$

where ρ is the charge density and $\varepsilon_o$is the vacuum permittivity. In plasma, an electric field created by a charge that moved by distance x in a space of the charge density *n* is

$$E = \frac{nex}{\varepsilon_o} \tag{2}$$

Plasma frequency[3] is one of the most important parameters of the plasma, which is defined as the oscillation frequency of the plasma electrons, is given by

$$\omega_p^2 = \frac{ne^2}{\varepsilon_o m_e} => \frac{ne}{\varepsilon_o} = \frac{\omega_p^2 m_e}{e} \tag{3}$$

Now replace ne/ε_o in Eq. 2 by Eq. 3

$$E = \frac{\omega_p^2 m_e x}{e} \tag{4}$$

The displacement of the electrons in the plasma cannot be larger than a plasma wavelength, because the plasma wavelength is the maximum displacement that plasma electrons can oscillate. The maximum field will happen when $x \sim \lambda_p$ (λ_p is the plasma wavelength).

$$x \sim \lambda_p = \frac{c}{\omega_p} \tag{5}$$

Thus, Eq. 4 becomes

$$E = \frac{\omega_p^2 m_e \left(\frac{c}{\omega_p}\right)}{e} \tag{6}$$

Therefore,

$$eE_{max} = m_e c^2 \frac{\omega_p}{c} \quad (7)$$

By dimensional analysis, eE can be understood as the accelerating gradient, both of which have the unit of energy per length. Recall the plasma frequency (3), when evaluated is approximately 9000 $n^{1/2}$ Hz (where n is the units of cm^{-3}) the maximum accelerating gradient then only depends on the plasma density.[3]

$$eE_{max} = 1 \frac{eV}{cm} \cdot n^{1/2} \quad (8)$$

One numerical understanding of this result is that 1 GeV/cm accelerating gradient will be achieved by plasma density $n = 10^{18}\ cm^{-3}$, corresponding to plasma wavelength $\lambda_p = 30\ \mu m$ (around 100 fs). The result of the required laser pulse width to create the plasma acceleration was published before pure femtosecond lasers were invented. Therefore, back in the early 1980s, laser pulse amplitude modulation (Figure 1) was utilized to create the shorter pulse widths associated with plasma wavelength.

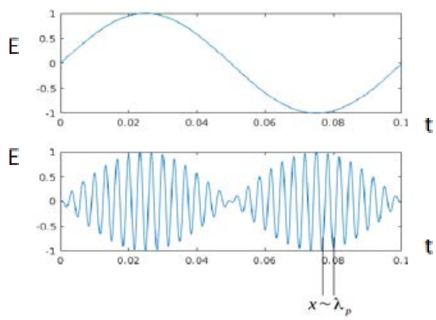

FIGURE 1. (a) Example of normalized laser pulse envelope without modulation. (b) Example of normalized amplitude modulated laser pulse and the associated where distance between the fast oscillation represents the plasma wavelength λ_p, such that the pulse is able to accelerate the plasma as shown in Figure 2.

PONDEROMOTIVE FORCE

Light is able to exert a small amount of radiation pressure on an object proportional to the intensity of the incoming electromagnetic radiation. Electro-magnetic radiation that is used to heat plasma can also be coupled to particles in a non-linear fashion and the resulting force is called the ponderomotive force.[4]

Chen derives this force in the following fashion.[5] Consider an electron in an oscillating E and B field of an electromagnetic wave. The electron motion can be described by (9), where m_e is the mass of a single electron.

$$m_e \frac{dv}{dt} = -e[E(r) + v \times B(r)] \quad (9)$$

The electric field will contain a spatial dependence that can be expanded to the second order about r_0 and time averaged. For a step by step description see Reference 5.

$$\mathrm{E} = E_s(r) \cos \omega t \quad (10)$$

Thus, substituting (10) into (9), expanding and time averaging the nonlinear force acting on the electrons by the pulse can be written as

$$f_{NL} = m_e \frac{dv_2}{dt}$$
$$= \frac{-e^2}{m_e \omega^2} \frac{1}{2} [(E_s \cdot \nabla) E_s + E_s \times (\nabla \times E_s)] \quad (11)$$

where v_2 is the second order velocity and E_s is the amplitude of E in which contains the spatial dependence. Furthermore, (11) can be simplified by using the vector triple product as $E_s \times (\nabla \times E_s) = \nabla (E_s \cdot E_s) - E_s (E_s \cdot \nabla)$, canceling out the $E_s (E_s \cdot \nabla)$ terms.

We find that effective ponderomotive force on a single electron is:

$$f_{NL} = \frac{-1}{4} \frac{e^2}{(m_e \omega^2)} \nabla E_s^2 \quad (12)$$

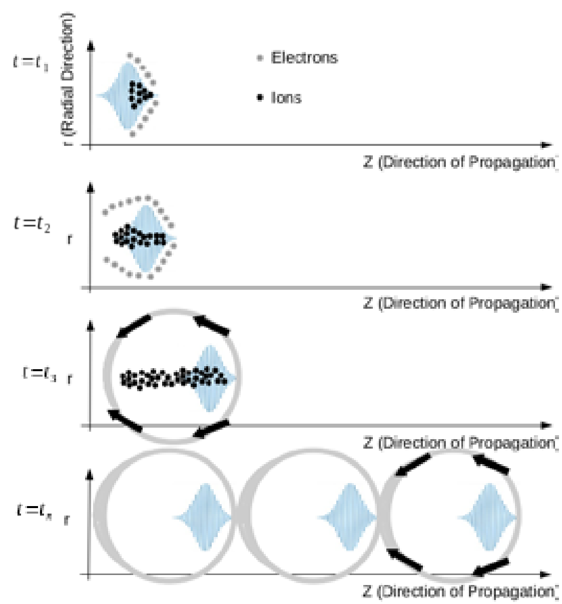

FIGURE 2. Plasma density altered by the massive EM field. At $t = t_1$, the electrons are repelled by the pulse and the ion at the center created a local positive region. At $t = t_2$, the electrons are attracted by the local positive region while the pulse is traveling. At $t = t_3$, the electron density form a bubble leaded by the pulse. At $t = t_n$, multiple bubbles are formed as a bubble train with multiple pulses.

By multiplying the force in (12) by the electron density, the ponderomotive force can be written in terms of plasma frequency. Plasma frequency ω_p is the rate at which electrons oscillate when they are displaced by a uniform background of ions generating a restoring force. The plasma frequency is therefore directly proportional to the density of the plasma and (3) can be rearranged and substituted into (12) to obtain the full ponderomotive force F_{NL} as:

$$F_{NL} = \frac{-\omega_p^2}{\omega^2} \nabla \frac{\langle \epsilon_0 E^2 \rangle}{2} \quad (13)$$

Electrons in a uniform field would oscillate purely in the direction of E but the magnetic field distorts their orbit. The Lorentz force acts in the direction of the wave number k which is in the direction of propagation, and if the amplitude of the electrical field varies, electrons will tend to bunch together or "pile up" in regions of smaller amplitude which becomes a local saddle point. The ponderomotive force acts directly upon electrons but the force is ultimately transmitted to ions due to charge separation field created by the space charge accumulated in the saddle points. The ions tend to flow toward the intensity minimum of the incoming radiation.

ELECTRON INJECTION

As previously described, the plasma electrons are the medium of the plasma wave. These electrons only oscillate in the plasma instead of propagating. To accelerate these electrons, they need to be accurately injected into the plasma wave. There are two ways of injecting electrons, self-injection and external injection. Self-injection occurs through the wave breaking phenomenon. Some plasma electrons at the plasma wave front break out from the plasma wave during plasma wave propagation. These electrons are stuck in the region in between two bubbles and start traveling with the plasma wave (bubble train). Note that only the trapped electrons are accelerated; other plasma electrons are the wave medium which oscillate in the surrounding plasma. External injection is inserting electrons externally into the bubble train. This is experimentally challenging because the electron bunches must be placed in the right place and at the right time.[3]

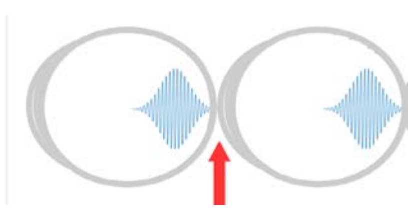

FIGURE 3. Position that electrons are injected with respect to the plasma wave is indicated by the red arrow.

PARTICLE BEAM DRIVEN

As the laser pulse propagates through a plasma, several competing effects work against acceleration. Diffraction of light as it interacts with the plasma matter and dephasing between the laser pulse and the accelerated plasma are the two notable problems in laser-plasma acceleration. All of the above mentioned cause an overall depletion in laser energy. Particle beam driven solutions solve this problem since more energy can be carried by the particle beam. Others have proposed mitigating this effect by "staging" the accelerator into 10 GeV stages.[6] Experiments by the UCLA plasma accelerator group at SLAC (Stanford Linear Accelerator Center) showed that using an input electron beam of 42 GeV to drive the plasma acceleration was using to obtain energy doubling in a record breaking experiment.[7] Greater acceleration gradients are expected from the AWAKE (The Proton Driven Plasma Wakefield Acceleration Experiment) group in CERN.[8]

CONCLUSION

Plasma acceleration utilizes the plasma as the energy transformer to transfer energy from the driver to the particle. Theoretically, it has a large acceleration gradient ~1 GeV/cm. The ponderomotive force creates the plasma wave. It is a non-linear radially decreasing distribution. One of the challenges in plasma acceleration is electron injection. Beam-driven plasma accelerators potentially will be the next generation accelerator due to the massive theoretical gradients possible, and its superiority over laser driven systems.

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Diffusion and Conformational Dynamics of Single DNA Molecules Crowded by Cytoskeletal Proteins

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Abstract. The high concentrations of proteins crowding cells greatly influence intracellular DNA dynamics. These crowders, ranging from small mobile proteins to large cytoskeletal filaments such as semiflexible actin and rigid microtubules, can hinder diffusion and induce conformational changes in DNA. While previous studies have mainly focused on the effect of small mobile crowders on DNA transport, we examine the impact of crowding by actin filaments and microtubules. Further, because actin filaments and microtubules are formed by polymerization of actin monomers and tubulin dimers, respectively, we also investigate the role that the polymerization state of each protein plays in DNA transport and in the time-varying conformational changes of single DNA molecules diffusing in *in vitro* networks of polymerized and monomeric actin and tubulin. We find that crowding by actin monomers slows DNA diffusion while tubulin crowding actually increases diffusion coefficients. Monomeric actin crowding DNA diffusion, more than when actin is polymerized, while crowding by tubulin dimers increases DNA diffusion more than when tubulin is polymerized (microtubules). Further, we find unexpected relationships between DNA coil size and diffusion when crowded. All crowding conditions lead to some degree of DNA compaction, but less compaction enables faster dynamics.

Keywords: DNA dynamics, Single-molecule Particle Tracking, Polymer Dynamics, Cytoskeletal Crowding
PACS: 87.14.gk, 87.16.Ln, 87.80.Nj

INTRODUCTION

The biological cell is a highly crowded environment comprised of a wide variety of molecules that effectively crowd a molecule and prevent random intracellular movement.[1] The proteins that comprise the cytoskeleton are among the most important of these crowding macromolecules. The cytoskeleton, which supports cell shape, structure, and mobility, is composed primarily of thick, rigid microtubules (~10 µm x 25 nm), polymerized from tubulin dimers (10 nm), as well as thinner, semiflexible actin filaments (~10 µm x 10 nm) comprised of globular actin monomers (~5 nm).[2,3] These proteins can greatly influence the mobility of nucleic acids as they traverse the cytoplasm and can induce conformational changes that impact that stability of DNA.[1]

Indeed, cytoskeletal crowding has been identified as a key barrier to cytoplasmic transport of DNA[3,4] and influences important biological processes, including replication and transcription as well as gene expression and delivery.[1-6] Though research has been done on how to introduce DNA into a target cell for gene therapy[7], little is known of how cytoskeleton crowding impacts the DNA dynamics and conformational stability needed for efficient gene delivery.

Here, we investigate the diffusion and conformational dynamics of DNA crowded by the cytoskeletal proteins actin and tubulin. We track single DNA molecules diffusing in varying crowded solutions of actin and tubulin, in both monomeric and polymerized states. We find that cytoskeleton crowding compacts DNA and plays a complex role in DNA transport. Specifically, actin monomers slow DNA

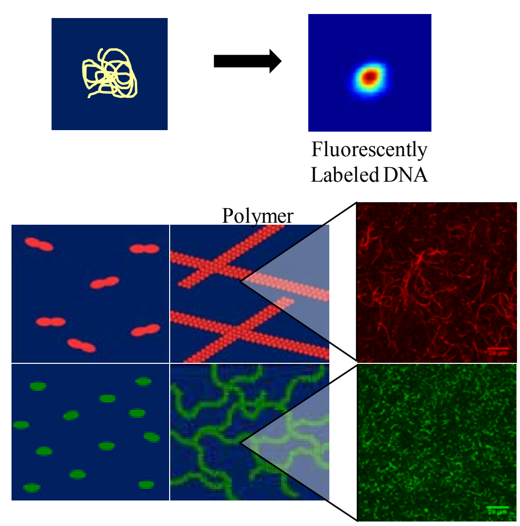

FIGURE 1. Experimental Schematic. (A) DNA molecules assume a random coil configuration in solution. When labeled with fluorescent dye, higher intensities denote higher mass density. (B) Cytoskeletal proteins exist in either monomer or polymer form. Polymerized proteins exhibit unique structural composition, as evident from confocal microscope images.

diffusion while tubulin aids DNA transport. Further, monomeric actin hinders DNA diffusion more than polymerized actin, while tubulin dimers increase DNA diffusion more than microtubules.

METHODS & MATERIALS

Double-stranded linear 115 kbp DNA molecules are prepared through replication of bacterial artificial chromosomes (BACs) in *Escherichia coli*, following established protocols.[8,9] DNA molecules are then labeled with YOYO-I dye (Invitrogen) at a 4:1 ratio of base pairs to dye molecules (Figure 1A). 0.5 ng/µl of labeled DNA is added to 11.4 µM solutions of either rabbit skeletal actin or porcine brain tubulin (Cytoskeleton) suspended in 100 mM PIPES, 2 mM $MgCl_2$, and 2 mM EGTA (Figure 1B).[3] 0.05% Tween, 4% β-mercaptoethanol, 0.43 µg/µl glucose, and 72 ng/µl glucose oxidase are added to prevent surface interactions and photobleaching. Solutions are pipetted using a wide-bore pipette tip into a flow chamber consisting of a glass slide and coverslip separated by ~100 µm of double sided tape to accommodate ~15 µl of solution. To polymerize cytoskeleton proteins, 2 mM ATP (actin) or GTP (tubulin) is also added, and samples are incubated at 37 ºC for 30 minutes.

To measure the transport and conformations of diffusing DNA molecules, we image single diffusing DNA molecules for 30 seconds at 10 frames per second using a 60x objective and high-speed CCD camera on a Nikon A1R Epifluorescence microscope. We track >50 molecules for each condition. We measure and track the center of mass (COM) position as well as the lengths of the major and minor axes (R_{max}, R_{min}) of each molecule

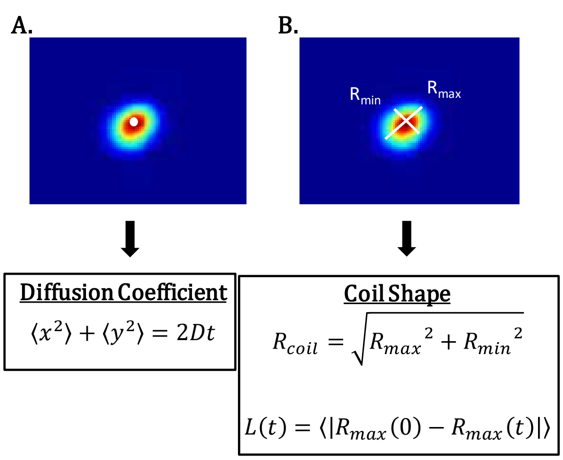

FIGURE 2. Measurements of interest. (A) Center-of-mass is tracked through center-of-intensity in order to calculate diffusion coefficients through mean-squared displacements. (B) Major and minor axis lengths are tracked in time *t* to quantify a conformational size and fluctuation length via the displayed equations.

in each frame using custom-written software (Matlab) (Figure 2).[10]

We calculate the COM mean-squared displacement in the *x* and *y* directions ($<\Delta x^2>$, $<\Delta y^2>$) to determine the diffusion coefficient *D* via $<\Delta x^2> + <\Delta y^2> = 2Dt$. Error bars are calculated using the bootstrap method for 1000 sub-ensembles. We quantify the conformational size of the DNA (R_{coil}) from the major and minor axis length measurements via $R_{coil} = (R_{max}{}^2 + R_{min}{}^2)^{1/2}$. Finally, we characterize the time-dependence and length scales of conformational fluctuations by examining the extent to which R_{max} varies from its initial value over time. Specifically, we define a fluctuation length *L* calculated as $L(t) = \langle |R_{\max}(0) - R_{max}(t)| \rangle$. The time over which this quantity reaches a steady-state value can be understood as the rate of conformational fluctuations. The steady-state length scale reached can be understood as the length scale over which a molecule fluctuates, or the range of different conformational states it accesses.

RESULTS

Actin Crowding

We first examine the diffusion coefficients of DNA molecules crowded by monomeric or polymerized actin compared to the case of no crowding. Crowding by actin inhibits DNA diffusion, with monomers slowing diffusion more than filaments. Normalizing by the dilute diffusion coefficient reveals a ~50% and ~25% decrease in diffusion coefficients when crowded by actin monomers or filaments, respectively (Figure 3A) Reduction in diffusion coefficients is coupled with a modest decrease in average coil size, from R_{coil} = 2.175 µm with no crowding to R_{coil} = 1.925 µm and R_{coil} = 1.875 µm in actin monomers and filaments, respectively (Figure 3A).

Figure 3B shows the reduced length scales as well as reduced rates at which conformational fluctuations are taking place: a higher length scale here denotes more conformational states being accessed. Conformational fluctuation rates are greatly hindered by the presence of actin, regardless of polymerization state. Molecular conformational states fluctuate on larger length scales at significantly slower rates (Figure 3B), accessing more conformational states over time.

Tubulin Crowding

Figure 3A shows that crowding by either tubulin dimers or microtubules speeds up DNA diffusion. While crowding by microtubules results in only a 4% increase in diffusion coefficient compared to the case without crowders, tubulin dimers induce a 47% increase in DNA diffusion coefficients. Despite this large

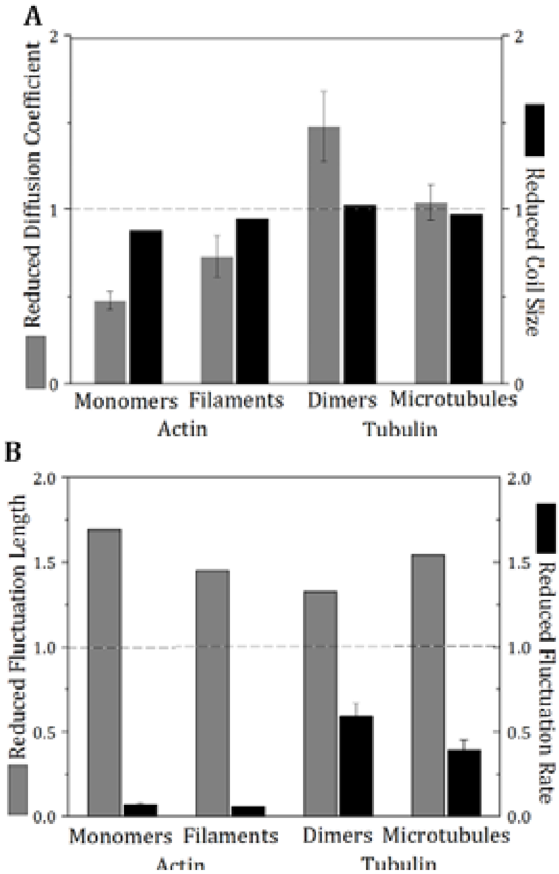

FIGURE 3. DNA transport and conformational dynamics when crowded by cytoskeleton proteins. (A) Tracking COM mean-squared displacement results in DNA diffusion coefficients (grey) Tracking of major and minor axis lengths results in average DNA coil sizes (black). Both quantities are normalized (reduced) by the corresponding value with no crowding (dotted line). Results show less compaction leads to faster dynamics. (B) Steady-state conformational fluctuation lengths (grey) and fluctuation rates (black) reduced by the corresponding value with no crowding (dotted line). Results show crowding increases the number of accessed conformational states, but at timescales much lower than without crowding.

increase in diffusion coefficient, there is no evident change in coil size for either case (Figure 3A).

However, as shown in Figure 3B, both tubulin and microtubule crowding allow DNA molecules to access a wider range of conformational states compared to the case of no crowding. While DNA fluctuates over large length scales, the rate of fluctuations is reduced by a factor of ~2 in each case.

DISCUSSION

Crowding by actin reduces DNA diffusion, following expected crowded behavior. Actin filaments suppress conformational fluctuations of DNA more than actin monomers, possibly enabling DNA to undergo faster COM diffusion when crowded by the actin filaments compared to monomers.

However, crowding by tubulin enhances DNA diffusion, with tubulin dimers inducing significantly faster DNA diffusion microtubules. This increase in diffusion coefficient runs counter to most accepted crowding models, since diffusion is quicker than in even the dilute condition. Furthermore, quicker diffusion rates D are normally coupled with smaller coil sizes R_{coil}, as described by the Stokes-Einstein diffusion relation between viscosity η, thermal energy k_BT, and molecule radius r

$$D = \frac{k_B T}{6\pi\eta r}$$

Overall, we find that less compaction leads to faster dynamics and that all cytoskeletal crowding leads to slower conformational changes but access to a broader range of conformational states.

CONCLUSION

We investigate the role of cytoskeleton crowding on the diffusion and conformational dynamics of DNA molecules. We show that actin and microtubules have highly different effects on DNA diffusion, with actin slowing DNA transport while tubulin surprisingly speeds up diffusive transport. Further, while crowding by polymerized actin filaments hinders DNA diffusion less than when actin is monomeric, we find the opposite effect with tubulin. Namely, crowding by tubulin dimers increases DNA diffusion more than polymerized microtubules. Unlike the impact on DNA diffusion, crowding by all cytoskeleton proteins has similar effects on DNA conformational dynamics. All crowding conditions induced modest DNA compaction, slower conformational fluctuation rates, and a wider range of conformational states accessed.

Future work will examine how crowding by composite systems of both actin and microtubules impacts DNA dynamics and the role that DNA topology plays in crowding-induced dynamics.

ACKNOWLEDGMENTS

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Radiation Shielding Using Magnetic Fields

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Abstract. Radiation shielding is essential to future space exploration missions with longer exposure to space radiation. High Atomic Number and Energy particles (HZE) in Galactic Cosmic Radiation (GCR) presents one of the most difficult types of radiation to shield. We propose a combination of active and passive shielding to maximize deflection of radiation and minimize production of secondary radiation, while creating a possibility of usable power. The focus of this paper is on the 7687 kg wire design and the 0.57 T magnetic field created, with less than 2 G in the crew area, and its ability to deflect a 2800 GeV iron ion. Estimates of trapped plasma reducing the iron ion to 140 GeV, as well as thrust production of 34 N are presented.

Keywords: Space Travel, Galactic Radiation Shielding
Pacs: 07.87.+v, 96.50.-e

INTRODUCTION

Radiation shielding is essential for all future space exploration. Interplanetary space is full of ionizing radiation that can interfere with sensors, on-board computers, and cause severe harm to astronauts.[1] It is imperative that a method be developed to limit all types of ionizing radiation. Many ideas have been proposed using passive shielding, wire loops, and plasma, but none have been demonstrated to adequately shield against high energy Galactic Cosmic Radiation (GCR) on their own while accounting for secondary effects.[2-5]

We propose a method for radiation shielding using a combination of confined magnetic fields, unconfined magnetic fields, and passive shielding to protect against radiation.

SR2S Project

The SR2S project began in 2013 by a team of seven European organizations. The program reevaluated active shielding based on the fact that space is not a vacuum as all previously proposed concepts assumed it was, but rather a diffuse plasma of charged particles. This can increase the effectiveness of active shielding due to trapped plasma, which induces another magnetic field and can deflect charged radiation with Coulomb interactions.

The SR2S project released several articles including an analysis on superconducting material, the effectiveness of unconfined magnetic fields in space, and a sun-shield to keep a superconductor below its critical temperature. One SR2S experiment showed that a B-field in space will induce a plasma, and predicts how the results enhance the active shield.[6]

Materials and Methods

To create large magnetic fields, superconductors must be used. The SR2S project analyzed the effectiveness of Ti-MgB_2 superconductors, which is easily produced and has a critical temperature of 39 K. A 360 m spool of Ti-MgB_2 superconducting wire has a weight of 4000 kg/m^3, a current density of 80 A/mm^2, and operates well in a 1 T field at 29 K.[7]

The most dangerous ionizing radiation particle is not the highest energy particle ever recorded, but rather a high energy particle with a significant flux through space. Schimmerling describes recent data of the kinetic energy and flux of GCR radiation which enters the solar system.[8] From these values of GCR particles our target particle is an iron ion, Fe^{+26}, moving at 0.9998c, having a relativistic energy of 2800 GeV with an atomic mass of 55.85 u or 52024 MeV/c^2 and a charge of +26 e.[8]

Proposed Method

No one method of shielding appears to be sufficient in the literature, and hence we propose a combination of active magnetic and passive mass shielding. The design, shown in Figure 1, consists of a large deployable 100 m radius wire loop (in blue), a smaller loop with current opposite that of the larger loop in black of 15 m radius, and a split toroid in blue with an inner radius of 10 m, outer radius of 15 m, and a height of 10 m. The structural components (ship habitat) design has mass shielding of Boron Nitrogen Nanotubes (BNNT), which is a promising material for reducing secondary radiation, however, BNNTs are still being studied.

The split toroid design is advantageous due to the configuration of the magnetic fields. Since two B-fields of opposite direction are produced, small amounts of thrust can be generated and focused in one direction.

The key to this method's shielding ability is the large deployable loop. The SR2S project demonstrated that a magnetic field in a diffuse plasma will trap charged particles, creating an induced plasma and an

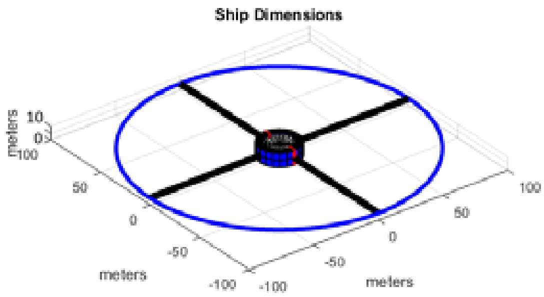

FIGURE 1. Proposed Shielding Structure

induced magnetic field.[6] In our method, the outer loop will create a magnetic field that will induce radiation belts to surround the ship and decrease the kinetic energy of radiation particles that pass through. One potential problem is that the magnetic poles tend to direct particles into a spiral down the magnetic field lines similar to Earth's magnetic poles. This collection of radiation particles at the magnetic poles can be redirected by adjustable magnetic field caps as seen in Figure 2.

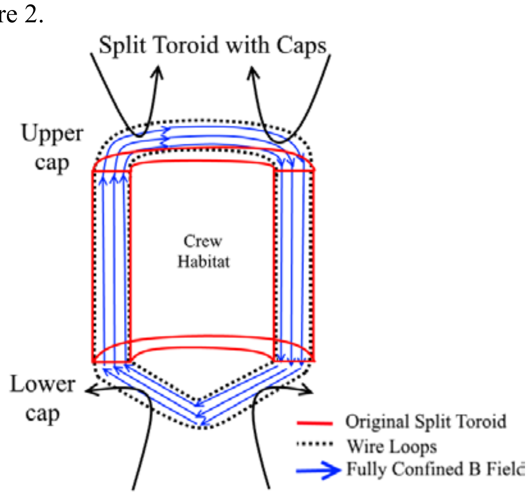

FIGURE 2. Particle deflection at top and bottom of design (Toroidal caps)

To control how much thrust is produced at any time, the toroid caps must be adjustable by some mechanism which can bend the orientation of the toroidal cap wire loops. Since our proposed method produces electromagnetic radiation (bremsstrahlung and synchrotron), there is a potential for power production using silicon solar cells. A recent experiment by Hirota, Tarusawa, Kudo, and Uchida demonstrated that power can be produced from incident X-rays and gamma rays using amorphous silicon.[10] The ability to create power from a shielding method would be extremely useful for many applications in future space flights.

Calculations

The SR2S project has shown that a magnetic field in space will induce a plasma. The calculations to find how much shielding ability this plasma creates are so complex and variable that the SR2S project did not develop an equation to use. They explain the equations they provide should only be used as a guide for a rough estimate as the plasma effect has so many variables.[11] Calculating the additional shielding effect exactly is not done here; however, we know that any additions from the plasma will be positive additions to the shielding ability.

We do a rough estimate of the plasma effect using knowledge of the Van Allen belts which provide substantial shielding from GCR. One example where shielding is known is for the ISS that orbits below the Van Allen belts, but above the atmosphere. We assume that a wire loop creating a B-field of the same magnitude of Earth's will create radiation belts that shield as much as Earth's Van Allen belts. If this assumption is false, our method can be easily altered to create stronger or more spread-out fields. To calculate how much current is required, we assume Earth's outer core acts as a wire loop and scale the radiation belts and B-field to a 100 m radius wire loop. Using the National Centers for Environmental Information on the NOAA website,[12] we calculate a current loop of 100 m radius to require 7.14×10^4 A with a standard deviation of 2.26×10^4 A using the Biot-Savart law. The reasonably large uncertainty is due to the Earth not being a perfect magnetic dipole. In our calculations, we assumed the high end of this current range and propose a needed current of 7.14×10^4 A. Since one Ti-MgB_2 superconducting wire can carry 8000 A, 9 wires are needed for the outer loop to produce the magnetic field.

Strong B-fields can cause health risks to a crew over long missions. Therefore, we calculate the small wire loop's current to be -10800 A, creating a maximum B-field no greater than 1.14 Gauss in the crew habitat.

A NASA presentation from the Space Radiation Analysis Group presents collected data from low Earth orbit.[13] The average proton kinetic energy is 8.4 to 27 MeV. According to Schimmerling, GCR protons with the highest flux have an energy level of around 3.33×10^2 MeV.[9] If we take the middle of the average energy range of the low Earth orbit data (17.7 MeV) and compare it to the average kinetic energy from Schimmerling's GCR data, we find that radiation particles in low Earth orbit are about 5% of the average GCR proton. This means if energy is reasonably accounted for within the belts, the Van Allen belts decrease the incident radiation to approximately 5% their initial kinetic energy. Our qualitative ballpark estimate of shielding effectiveness of an induced plasma in a similar magnetic field to Earth's is a decrease in kinetic energy of about 20 times the initial kinetic energy. If our target particle (Fe^{+26}) enters this induced plasma at 2800 GeV, it will slow down to an energy of 140 GeV.

A 3D simulation of the field with an outer loop of 9 wires, an inner loop of 2 wires, and a partially confined split toroid of 60 wires per meter created a *B*-field of about 0.57 T inside the split toroid and a maximum *B*-field of about 2 Gauss inside the crew area. This can be seen in Figure 3. The approximate weight of the wires is 7687 kg. Assuming this is implemented on a ship the size of the space shuttle, this is a total weight of 82,500 kg. This weight includes the weight of a method to keep the superconductors cool such as liquid helium or a sun shield.[14] Assuming the induced plasma can be redirected at the poles, we calculated a maximum thrust of 34.4 N, creating a constant acceleration of 4.17×10^{-4} m/s^2.

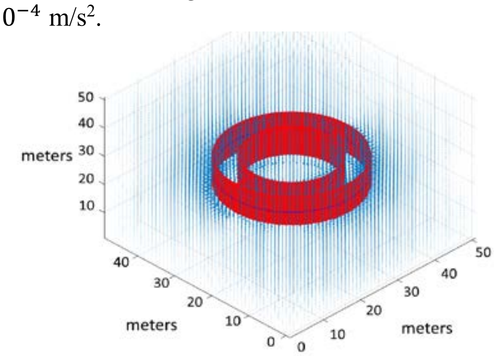

FIGURE 3. Simulation of ***B***-field in blue created by wire configuration. The walls of the toroid are in red.

Our proposed method has produced the *B*-field strengths and characteristics we expected, however, they should not be used as exact specifications for a working design, but rather an explanation of a proposed shielding method. More analysis on the proposed design is required. We are currently working on a simulation sending in relativistic particles of varied energies from various directions. Initial findings look promising even without plasma effects considered, however we have not yet included secondary radiation effects. Our next step will be to include the synchrotron radiation produced and calculations of the minimum effect the plasma must have to fully shield the crew area from our test particle. More research must be done to find the full range of BNNT shielding capabilities. The implications of this concept could decrease the travel time to Mars and open greater possibilities for space exploration due to the constant thrust.

Acknowledgments

We thank Dr. Schmelzenbach, Dr. Chen, Dr. Gabler, and Dr. Delap for being on this project's committee.

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Programs

2017–18 SPS and Sigma Pi Sigma Year in Review

by SPS and Sigma Pi Sigma Staff

From research to outreach, fellowship to scholarship, and leadership to advocacy, the Society of Physics Students and Sigma Pi Sigma made big strides in 2017–18 toward providing opportunities for all students interested in physics and astronomy. As the only organization dedicated to undergraduate students interested in physics and astronomy, SPS and Sigma Pi Sigma seek to encourage the diverse interests of our community and find ways to channel the energy and enthusiasm into programs and resources that are impactful.

We kicked off the year with a new National Council, inspired by the success of the 2016 Physics Congress and eager to sustain the momentum for a larger conference in Providence, RI, November 14–16, 2019. The council formed committees to focus on topics including professional community engagement, governance, PhysCon 2019, career pathways, zones, and chapter health and outreach. The committees met throughout the year and developed useful tools such as an effective practices for chapters guide and an alumni engagement website among other resources.

The council also welcomed several new chapters:

SPS

#1523 Del Mar College (Zone 13)
#6101 Saint Anselm College (Zone 1)
#7059 University of Tampa (Zone 6)

Sigma Pi Sigma

#577 University of Nevada, Las Vegas (Zone 18)
#578 Wofford College (Zone 5)
#579 High Point University (Zone 5)
#580 Saint Anselm College (Zone 1)

As of June 4, 2018, we have 4,127 national members in over 527 chapters or in at-large status.

Programmatically, the year got off to a strong start with the Great American Eclipse. SPS provided over 6,000 pairs of viewing glasses to 37 chapters to host outreach events in their local communities and/or the path of totality. Chapters submitted 43 applications for Fall Awards, including Marsh White, Future Faces of Physics, Chapter Research, and Sigma Pi Sigma, and we distributed 31 grants.

A record 79 students applied for the SPS Summer Internship program, with 15 students accepted for placements with AIP, NASA, NIST, Member Societies, and on Capitol Hill. The National Office also expanded the SPS Congressional Visits Day program to chapter officers and accepted five students for a rigorous two-day program of training and meetings with senators, representatives, and their staffers.

Spring brought applications for scholarships (38), Outstanding Undergraduate Research Awards (15), and the Outstanding Chapter Advisor Award (9), as well as zone meetings in all 18 zones. Many chapters took advantage of new funding offered by the National Office to ensure that as many chapters as possible have the opportunity to travel to their zone meeting and connect with their peers.

Sigma Pi Sigma had another strong year of inductions, with 1,691 inductees at 286 chapters. Lifelong members continued their commitment to honor, scholarship, fellowship, and service through participation in opportunities like Adopt-a-Physicist, Hidden Physicist profiles, and induction ceremonies at their alma maters or local chapters.

Outreach was a theme throughout the year with the resurgence of the Science Outreach Catalyst Kit (SOCK) as developed by the Summer 2017 SPS Interns. In a dramatic expansion from past years, SPS distributed 77 of these kits to allow more chapters to share the wonders of the *Fabric of the Universe*[1] demonstration. The support of interns also allowed the creation of 20 new demonstration guides to support chapters providing outreach to their local communities. SPS also supported the coordination of the Everyday Physics booths at the USA Science and Engineering Festival held in Washington, DC, April 7–8.

SPS and Sigma Pi Sigma continue to support the career aspirations of all students through the Careers Toolbox, SPS Jobs website, and, as of Fall 2017, the GradSchoolShopper printed guide and website. These resources provide a comprehensive suite of tools for students considering industry or graduate study after completing their bachelor's degrees. SPS released a newly revised Toolbox in early 2018, including updated statistics from the AIP Statistical Research Center and additional tools to support students with their job search. The SPS Jobs website (http://jobs.spsnational.org) grew in scope in 2017–18 and is quickly becoming the home for universities and other organizations to post internships and research opportunities of interest to undergraduates.

SPS staff, leaders, and members also made themselves known at national and regional physics meetings with exhibits or sessions at SACNAS, CU²MiP, NSBP Annual Conference, AMS Student Conference, AAS Winter Meeting, AAPT Winter Meeting, CUWiPs, APS March Meeting, APS April Meeting, PhysTEC, Building Thriving Undergraduate Programs, ACA, AAPM, AAPT Summer Meeting, SOR, and the Emerging Researchers National Conference. Students received over $19,700 in financial support to attend these meetings and present their research or write about their experience. Much of that support came directly from the generous contributions of Sigma Pi Sigma alumni and SPS supporters through our donation campaigns.

Publications were another high note for the year, with four issues of *The SPS Observer* (including JURP) and two issues of Sigma Pi Sigma's *Radiations*. This year the editorial staff intentionally sought out a broader range of student voices for these magazines and shared relevant topics for our members:

The SPS Observer

Fall 2017: Building Community
Winter 2018: Career Pathways
Spring 2018: Communicating Science
Summer 2018: Journal of Undergraduate Reports in Physics

Radiations

Fall 2017: Today's Physics Education
Spring 2018: Science Tourism

Administratively, SPS and Sigma Pi Sigma staff continue to work behind the scenes to ensure that systems and processes are efficient and effective in meeting the needs of our members and chapters. Highlights in this area from the year include the launching of our new Single Sign-On (SSO) for the awards application system, partnering with a fulfillment provider for Sigma Pi Sigma who reduced turnaround times and provided improved shipment tracking data, providing Google Group mailing lists for all chapter officers and advisors by zone, streamlining the chapter report submission process, and developing the ability to accept automatically recurring donations through http://donate.aip.org.

The staff and volunteer leadership of SPS and Sigma Pi Sigma are proud of what we have accomplished this year and are eager to take on the new challenges that 2018–19 will bring. We look forward to continuing to work in partnership with our members, advisors, and chapters to achieve our collective goals. Together we are building a stronger physical sciences community. //

1. See https://www.spsnational.org/programs/outreach/fabric-universe and https://www.spsnational.org/programs/outreach/fabric-universe-part-2.

ABOVE: 2018– 2019 SPS Executive Committee.

Meeting Notes are SPS member reflections on their experiences attending professional scientific meetings. Professional meetings offer undergraduate students a unique opportunity to network amongst their peers, gain valuable skills and connections, present their research, and expand their knowledge within the field. Many of these students received funding to support their travel through the SPS reporter award.

You can find out how to apply for a reporter award here: http://www.spsnational.org/awards/reporter.

HAVING A BLAST AT AAS

231st Meeting of the American Astronomical Society

by Talha Rehman, SPS Member, Berea College

I had a blast during the 231st Meeting of the American Astronomical Society, which was the best conference I have attended to date.

This meeting took place just outside Washington, DC, at the Gaylord National Resort & Convention Center January 8–12, 2018.

In addition to attending various panels and events, I also served as a volunteer, mostly helping coordinate the Q&A sessions following the plenary talks. I also helped out at the registration table. As a result, I exchanged pleasantries with people who had traveled from all around the world to attend this meeting.

Many aspects of this conference were different from other conferences I have attended. At other conferences, attendees mostly dressed in suits. Here, some participants dressed in colorful clothing depicting astronomy-inspired artwork. You could even buy astronomy-inspired clothing and jewelry in the exhibition hall. Believe me, it was very hard to resist the beautiful merchandise!

I was encouraged that many participants were passionate about addressing the issues of diversity and low participation of women in astrophysics. There were special meet and greet sessions by the Committee on the Status of Minorities in Astronomy and the Committee on the Status of Women in Astronomy. There was also an education and outreach event for local high school students. It was very inspiring for me to see these young people showing immense interest in science.

On the first evening of the conference, I attended the student reception and Graduate School Fair. Since I am applying to grad school this year, I was excited to see so many institutions represented by both professors and graduate students. I visited most of the booths and learned about ongoing research at the different institutions. I also got an opportunity to network with some of the most notable names in astrophysics at the opening reception.

Another night I attended the SPS Evening of Undergraduate Science where Kerry Kidwell-Slak of SPS National talked about some of the resources available to students through SPS. Then we had a trivia contest, and my team was the runner-up. We got to choose our prizes. I had just taken a classical mechanics course in the fall, and rotational energy was still on my mind. Guess what I chose as my prize—a YO-YO! I could not resist it.

In between the networking and trivia, I attended plenaries and poster sessions! The plenary sessions were detailed talks that were easy to understand, which I greatly appreciated. Two of my favorites were "Unveiling the Low Surface Brightness Stellar Peripheries of Galaxies," by Annette Ferguson of the University of Edinburgh, and "Astro Data Science: The Next Generation," by Chris Mentzel of the Moore Foundation. By attending these sessions I was able to learn a great deal about various research areas. I would highly encourage any undergraduate attending professional conferences to try to attend all plenary sessions, if possible.

I am thankful to the Society of Physics Students, the internship office, and the president's office at Berea College for making it possible for me to become part of this wonderful experience. //

ABOVE: The author helping attendees with registration. Photo courtesy of CorporateEventImages/Todd Buchanan 2018.

FERROELECTRIC THEORY MEETS EXPERIMENT IN WASHINGTON, DC

Fundamental Physics of Ferroelectrics and Related Materials

by Yugan Sakthi, SPS Member,
Case Western Reserve University

Held at the beautiful Carnegie Institution for Science in the heart of Washington, DC, the 2018 Fundamental Physics of Ferroelectrics and Related Materials, or Ferro2018, was a gathering of the world's leading researchers in ferroelectric materials. Between the banquet dinners and croissant-laden coffee breaks, I experienced a sharing and developing of knowledge in which few, if any, undergraduate students usually get the chance to participate. My goal was to learn as much as possible.

The study of ferroelectrics involves materials that exhibit ferroelectric behavior—that is, they have a macroscopic nonzero polarization that can be reversed, or switched, with the application of an external electric field. It is a behavior that stems from off-center symmetries in materials, and the science involved is fundamentally interdisciplinary.

Related topics include multiferroics (which are materials that couple both ferroelectricity and ferromagnetism), relaxors (which display nanodomains of polarization even after the critical temperature is reached), antiferroelectrics (in which neighboring lines of ions are polarized in antiparallel directions), and more. Ferro2018 had experts in all these fields from around the world presenting their ongoing work and their findings.

The four-day workshop was divided into 12 sessions, each covering a specific topic, and one poster session. Following a short reception Sunday evening, the workshops started full-swing Monday morning with the first session of talks, this one titled "Domains and Domain Walls". I was particularly fascinated by Dr. Julia A. Mundy of Harvard University's talk, "Functional Electronic Inversion Layers at Ferroelectric Domain Walls."

The work Mundy and her group have done is pushing the boundaries of ferroelectrics as a field. In this part of their research, they sought to answer a central question: *How can we explain electronic transport jumps in ferroelectric ErMnO3?* The results produced in pursuit of answers could lead to insight into charged domain walls, which in turn holds great promise as the first truly two-dimensional functional materials.

Over dinner Monday, I sat down with Dr. Raffaele Resta of the University of Trieste in Italy. Resta has been involved with the conference since its inception in 1989 and had much to say about the workshop's history. At one point I asked Dr. Resta, "I heard earlier that the modern theory of polarization was developed at this conference in its early days. What do you know about that?" He replied with a smile on his face. "That was me," he began, much to my surprise (and awe).

He recounted how in one of the first years of the workshop, after a fellow attendee, David Vanderbilt, had heard his talk, they met to discuss some new ideas. Over the next few months, they developed one of the most fundamental theories of modern ferroelectric study, the theory of polarization.

Attending the talks, listening to conversations during breaks, and at the poster session, I witnessed glimpses of similar activity all around me. Attendees approached each other after talks, mentioning specifics of their presentations and setting up meetings over lunch or dinner to discuss new ideas and solutions to problems. In that way, Ferro2018 was rightly called a "workshop" and not a "conference"; it was abuzz with intellectual activity.

Around noon on Wednesday, after the last talks were over and most of the attendees had left, I stuck around to help clean up and catch any last bits of wisdom. Dr. Peter Gehring, a researcher at NIST, and I struck up a conversation. As one of the conference organizers, Dr. Gehring had also seen the conference—as well as the field of ferroelectrics itself—develop over time, and he had a lot to say about it.

With every new advancement in ferroelectrics, he said, researchers become more and more specialized, narrowing their spheres of knowledge. "When you only know how to use a hammer, every problem begins to look like a nail," he said. The best researchers are the ones who can not only perform effective research, but also contextualize that work in the larger field of ferroelectrics and physics in general. He said a growing challenge in the future will be to convince scientists to care about the field beyond their own work.

But Dr. Gehring was optimistic. "[The workshop] might seem sleepy at times, but these people here are some of the best around," he said.

I couldn't help but think what Ferro2019 will look like. From the outside, it will most likely be similar—the talks and posters will continue to be filled with equations and diagrams, and the coffee breaks will still have croissants. But with new attendees working side-by-side with familiar faces such as Dr. Resta and Dr. Cohen, the research shared and knowledge produced will be quite different. I'm looking forward to finding out.

Special thanks to Dr. Ronald Cohen of the Carnegie Institution for Science for his work in organizing Ferro2018 and allowing me the opportunity to attend it, as well as to the SPS for its continued support of physics education and the students who pursue it. //

TOP: Every attendee at Ferro2018.
Photo by Carnegie Institution for Science.

MY TIME AT THE WOMEN'S CONFERENCE FOR PLANETARY SCIENCE AND EXPLORATION—THROUGH HARDSHIP TO THE STARS

Women in Planetary Science and Exploration Conference

by Dahlia Baker, SPS Chapter President, Coe College

I'm currently a senior physics student at Coe College, and recently I had the opportunity to travel internationally to a conference in Toronto. I am Coe's current SPS chapter president, and in the past few years I have planned many of our outreach events and conference travels, including a trek to the 2016 PhysCon. I've found that conferences are pressure cookers for collaboration and professional growth, and I encourage all undergraduates to attend at least one conference.

In 2016, I was an SPS intern at NASA Goddard, working with Ed Wollack on infrared absorber coatings. It was this research experience that solidified my interest in the space world, and since then, I have worked at Planetary Resources, Inc., and applied for graduate studies in aerospace engineering and planetary sciences. At Coe, I have also led a movement creating a community for women in STEM fields, which has become a personal priority of mine alongside a career in space.

There are astronomy and space conferences, and there are conferences for women in STEM, but never have the two subjects been combined as they were at the first Women in Planetary Science and Exploration (WPSE) conference, held at the University of Toronto. People of all genders showed up to hear talks and give talks, which was encouraging and indicated the inclusivity of the conference. There were around 100 people, roughly evenly divided between American and Canadian scientists and engineers.

Dr. Tanya Harrison, Director of Research at Arizona State University and an organizer of WPSE, opened the conference. Her first slide set the tone for the rest of the two-day event, starting with the quote "Per aspera as astera," or "Through hardship to the stars." She also took a moment to recognize the indigenous culture of Toronto and the lands and people who lived there before European colonization.

The talk she gave focused on explaining what is meant when news reporters claim that we "found water on Mars," something that's more complicated than those reports often say. "Water on Mars" can mean ice, hydrated minerals, or leftovers from meteorite impacts. Or something else entirely—but it's often simplified to just "water."

Another notable keynote speaker was Dr. Cassandra Steer, an Australian citizen based in Canada who is an expert in international air and space law. She specializes in the regulation of military activities in space. Her talk was remotely given, and through Skype she explained the legal aspects of sending objects to space, putting satellites in orbit, and mining asteroids. Under space law, every country or private entity is responsible for the materials they put into space or orbit. As low-earth orbit becomes more crowded with satellites, space law is becoming increasingly relevant.

The talks were given by professionals, professors, graduate students, and many undergraduates whom had never spoken to such a large crowd about their work. There was even a surprise visit by citizen scientists Arushi Nath, 8, and her brother Artash, 11. Arushi spoke about her model Canad-arm, a robotic arm used on the Space Shuttle orbiter to deploy and capture payloads. Arushi recently was recognized in the Space Apps Challenge put on by the Canadian Space Agency with her recreation of the Canada 150 logo using RADARSAT-2 images of the country.

The panels were the meat of the conference and focused on crucial social issues such as outreach, LGBTQ+ issues in STEM, women of color in STEM, harassment in STEM, and nonacademic career options. During the LGBTQ+ panel, speakers explored the assumption that your personal identity is not supposed to affect your work as a scientist, but it always will; therefore scientists should strive to make room for personal diversity and embrace it in their institutions. In the harassment panel, the panelists addressed the four different types of harassment one can experience, which break down to earnest, hostile, paternalistic, and competitive. Paternalistic harassment gives a name to the situation where a young woman is treated less than capable by the harasser, who assumes they know best for the person. This harassment is difficult to address, as the harasser believes they are behaving benevolently. The panelists gave advice about addressing this harassment by hosting a social climate survey, creating a safe space for those who feel discriminated to speak their mind, or simply addressing the perpetrator one-on-one about his or her behavior.

This conference was educational, inclusive, and well balanced between scientific talks and panels. While the panelists shared their personal stories, the presenters shared current research results. By incorporating both the personal and professional into just one venue, WPSE has opened the doors to a more inclusive STEM environment in the future. This conference is planned to be hosted yearly, with the next one occurring in spring 2019 at Arizona State University. //

QUANTUM CAUSES, DOTS, AND CONNECTIONS

2018 APS March Meeting

by Marie T. Rioux, SPS Member, Benedictine College

The room was enormous, filled with rows of chairs and dimly lit by lamps dotting dark gray walls. A lone podium stood in a spotlight of reflected light from a looming projector screen, and Dr. Robert Spekkens from the Perimeter Institute for Theoretical Physics had just begun.

It was one of the opening talks for a morning session at the 2018 American Physical Society (APS) March Meeting in Los Angeles, California, and everyday notions of cause and effect were already being turned on their heads.

Spekkens laid out his principles first, explaining that two variables that are causally disconnected have no common cause, and so are statistically independent. “Learning the value of one is going to teaching you nothing about the other,” Spekkens said.

Similarly, if there’s a correlation between two variables, then there must be a common cause unless the common cause is conditional. Spekkens elaborated to say that if a common cause between two variables is conditioned on, then the two variables don’t need to be correlated and don’t have a common cause. Then Spekkens contrasted two kinds of causal systems: a classical one and a quantum one.

With only a smattering of undergraduate exposure to quantum mechanics, I was quickly lost beyond the discussion of his classical system, but this was my second day at the APS Meeting—after spending the previous day in the company of professional researchers, I was getting used to falling behind. Even so, I was determined to know more.

Spekkens was heavily engrossed in a discussion when I approached him, walking past me toward the door of the room. SPS director Brad Conrad would tell me later that same day, “Just put your hand out there, introduce yourself, and you’d be amazed at the connections and where those can lead.” I hadn’t heard that advice yet, but my curiosity was strong and I caught Spekkens’ attention with a soft “Excuse me.” He agreed to share his slides and volunteered extra links to his extended presentations on the same topic, along with a wealth of clarifying information which has continued to provide me with new insights on every reading.

Investigating the foundations of quantum mechanics was fascinating, but there was much more to see at the meeting, especially for an undergraduate student like myself.

ABOVE: A Nor-Cal Products representative explains the intricacies of a vacuum deposition chamber to undergraduate Nathaniel Strandquist, Benedictine College. Photo by Marie Rioux.

RIGHT: Advanced Research Systems representative Joe Bychowski discusses his displayed cryogenic systems to interested APS attendees. Photo by Marie Rioux.

The presentations were collected into sessions that lasted several hours and were focused on a single topic. I found myself using the program I’d been handed at check-in to narrow down interesting sessions by topic and title, and then using the APS Meeting app to read the individual abstracts. It was a surprisingly easy juggling act after the first few times.

Since I’m involved in solar energy research, I sought out sessions focused on that topic and found a few explicitly focused on quantum dots, nano-sized semiconductors that can absorb and reemit light. It wasn’t surprising that even in sessions in my general area, my understanding was quickly outstripped. Far from intimidating, though, it was inspiring.

One such presentation was by Professor Ted Sargent from the University of Toronto on quantum dot sensor development. A success from his team’s research was later used in certified devices. Without a sufficient background in quantum dots, his finer points were obscure to me, but it remained one of the most memorable presentations I attended.

Between sessions, I visited the graduate school and job fair. Each school and company had a booth, and the colorful displays sported pens, cards, and an assortment of trinkets with logos and contact information printed on them.

It was there that I met SPS director Brad Conrad. He was filled with infectious enthusiasm, telling me that the March Meeting is one of his favorite meetings of the year. “When you start coming year after year, you not only see your friends from undergrad but your friends from grad school, you see your colleagues, post-docs, and you get to see these people through a wide cross-section of the community. So, the nice thing about the March Meeting is that it’s like a family reunion,” Conrad said.

This piqued my curiosity—since he’d attended so many, I asked what he thought of the presentations this year. His reply was unhesitating. He explained he’d been at the undergraduate sessions previously. “They were the best yet,” Conrad said. It was an easy segue into a discussion about advice for undergraduates like myself attending the meeting without the level of expertise of so many other attendees.

"The most important thing you can do at the March APS Meeting is meet people," Conrad said, explaining that the meeting isn't just for learning new things in the presentations, but also for making connections.

It was advice that I quickly experienced firsthand. Within moments of admitting that I study journalism as well as physics, Conrad was introducing me to Julia Majors from the American Institute of Physics News and Media Services team, asking her to share some insight into the field of science communication with me. It was a delight to discuss a field that overlapped with my current studies and interests—especially since Majors was passionate about her work. When she invited me to observe a press conference I eagerly accepted.

It was little different from the staged press conferences in my tiny undergraduate classroom back home, with tripods, cameras, lights, and microphones scattered around a small, quiet room filled with chairs, a few tables, and a single podium. It was unassuming and simple, and I was wholly enamored with it. I watched silently as scientists presented featured research projects in a panel session. With only two minutes left to spare, I finally left to meet my friends for the final presentation of the day, where I proceeded to bombard them with details until the session began.

It was only the end of the second day, but from twisting my mind around cause and effect in a quantum world and nanomaterials exceeding my depth of experience, I was as exhausted as I was exhilarated—eager for whatever the next day might hold. //

APRIL SHOWERS BRING MAY FLOWERS

2018 APS April Meeting and Hope for the Future

by Stephanie Williams, SPS Chapter President, University of Maryland

I have a pretty busy schedule, but when I saw the advertisements for the APS April Meeting, I knew I had to find a way to go, even though the meeting started the same day I had to take the physics GRE. The tagline "Quarks to Cosmos" piqued my interest, and as I did more research I realized that this was the main professional conference for those in my field. I also learned that a new PhD who used to work on my research team, Jon Balajthy, would be presenting his work, among others in the field of dark matter detection. There were also multiple sections discussing physics education research (PER) and outreach, which intrigued me.

And so I was off to Columbus, Ohio. I arrived late Saturday evening and, after some sleep, checked in early Sunday, expecting a wonderful day. That is what I got! I met new people and learned about possible areas of research and jobs I had never considered before. There were talks aimed at undergraduates by people in industry jobs that were especially helpful to me. They cleared up a lot of anxiety I had had about my future, as they affirmed and explained different ways I could continue as a physicist even outside of academia. I went out to a local restaurant at the end of the evening with some people to talk more and just relax and it was amazing. These people had been coming to this conference for years and were catching up with each other as well as advising me on graduate school choices and explaining their research. It was a wonderful example of what my future in physics could be like. We exchanged contact information and have kept in contact since.

The next day, I had the polar opposite experience.

I started the day going to see some of the PER talks and met people from the Access Assembly Network, a university-based program working with graduate and undergraduate students across the country towards a diverse, equitable, inclusive, and accessible STEM community. I work in this network and will be going to their conference in Boulder, Colorado, soon. I spend a lot of time doing outreach, and increasing accessibility and inclusion in STEM is very important to me. These talks were interesting and seemed to set a nice tone for the day to come.

Next, I headed to a talk about Richard Feynman given by Virginia Trimble. I am a fan of the "Trimble Lectures" she endowed in honor of her father and was thrilled to have the opportunity to learn more about Virginia Trimble and Feynman. I do not know much more about Feynman after Dr. Trimble's talk, but I do know she is an explicit opponent of the "Me too" movement. She said that she thought it was a ridiculous movement and often empathized with the men who have been outed for their sexual harassment of women in the workplace. She went on to talk of her liaisons with physicists, including Feynman. She explained how during her time in graduate schools, women were not allowed to live on campus in the dorms, and the stipends they received were never enough to pay for a real apartment. She talked about how she used to model for Feynman, an amateur artist, in exchange for money and physics lessons to get by. Trimble explained, to paraphrase, "Every woman had to do things to get by then. It's just how it was. But we had a grand time."

It is impossible to say how each person in the room internalized this information, but the message was essentially that it is acceptable for a faculty member to exchange favors and have an affair with a grad student. What her remarks fail to acknowledge is that Trimble may not know of people who did not have a "grand time" back then because they have since left physics. This lack of acknowledgment of thousands of women's pain and trauma in such a public way from a position of power, and from another woman, felt invalidating and alienating in a room full of older men.

I tried to not let that single talk affect me and instead went to a talk about women in the history of astronomy, which, while interesting, was poorly coordinated, as every one of the speakers talked about the same woman.

Next, I went to a talk in a PER session titled "Privilege and Broadening Participation in Physics." The speaker was Dr. Lior Burko of Georgia Gwinnett College. Dr. Burko decided to use a public platform, at a nationally acclaimed conference and in a PER section focused on diversity issues, to claim that there were none.

In the talk, Dr. Burko responded to "Unveiling Privilege to Broaden Participation,"[1] an article published in the "Race and Physics Teaching" special collection of *The Physics Teacher.* The article attempted to explain why women do not pursue physics degrees or drop out before finishing graduate school. Dr. Burko's talk consisted of a rebuttal to that article, an article with multiple sources and authors. Burko's rebuttal, however, had only one source with six data points, used to derive a result that fit his world view. This is bad science. The evidence behind his assertion that women were not leaving the field was six data points from the AIP website detailing how many women had received a bachelor's degree and a doctoral degree for three different years. He argued that since the average number of women earning bachelor's degrees and doctorate degrees over these years was the same, women aren't leaving physics, and therefore we do not have a problem. However, this does not take into account how many women are leaving programs, how many are coming back to programs, how many are international, how many went into the physics workforce, or how many simply left physics altogether. At this point in the talk, women began to leave the room.

Dr. Burko then went on to explain how microaggressions were a fallacy, or at the very least, not enough of a problem that we should care about it as physicists, as it is not a physics issue. He seemed aggravated by the idea that this was even being discussed in a physics-based forum. All I could think about was how even today at my own school, the women have had to create our own study space to avoid disrespect from male students. We get together to study in the research building, which is not designed for collaborative study, late at night after the professors have left in order to learn in peace. Professors all over the country have been fired for harassing students, asking for explicit favors in exchange for granting the student better grades. But, Dr. Burko insisted, harassment isn't a problem in physics.

After these talks, I was so uncomfortable that I ended up leaving the conference a day early. I couldn't stomach being invalidated in my experiences, in the experiences of so many of my female peers, and I did not feel comfortable and welcome. The positive feelings I had from the night before had all but washed away.

Is physics really still this bad? Is this a field I want to be in? Will I have to deal with this kind of rhetoric the rest of my life if I stay? These are the things that cause people to leave. Fighting constantly to be even heard, let alone make a change, is draining, to say the least.

Both Dr. Burko and Dr. Trimble's[2] abstracts are posted online if you would like to explore them for yourself. Dr. Burko also shared his slides.[3]

I hope to use this avenue to change things for the better. To Dr. Burko and Dr. Trimble, I want to emphasize that just because you have not experienced transgressions does not mean they don't exist. And in fact, the actions you are taking are further alienating people in the field of physics, which is a physics issue. I urge you to think critically about the things you choose to say in positions of power and how you decide to spend your time on a public platform.

To everyone else who may be reading this, things are changing, and we are the change. People are speaking out against these attitudes and behaviors, including wonderful people I met at the conference, people who stayed behind after each of the talks to discuss and debate with the speakers, people who participate in and help plan inclusive events in physics.

For the first time, this year's APS April Meeting had a workshop focused on LGBT+ issues and entire seminar sections dedicated to discussing minority issues. People care, and they give me support and inspiration to stay in physics, along with a determination to make it better for the people who will come after me so that in 60 years when another 20-year-old undergrad walks into a conference, they don't leave thinking "How are things still like this?" Things are changing because people are talking about them and becoming more aware. Do not give up, stand up when you can, and when you don't have the strength, know that being here is more than support enough. Physics wants you, even if some physicists don't.

If you are interested in becoming involved in groups focused on increasing access to physics, some resources are listed below. You can also feel free to contact me at swillia7@terpmail.umd.edu.

1. Women in Physics (WiP): https://www.aps.org/programs/women/.
2. Society for the Advancement of Chicanos and Native Americans in Science (SACNAS): http://sacnas.org/.
3. Out in STEM (oSTEM) for LGBT+: https://www.ostem.org/.
4. National Society of Black Physicists (NSBP): https://www.nsbp.org/.
5. Access Assembly Network: http://accessnetwork.org/assembly/.

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1. Rachel E. Scherr and Amy D. Robertson, Unveiling Privilege to Broaden Participation, *The Physics Teacher* **55**, 394 (2017), https://aapt.scitation.org/doi/10.1119/1.5003737.
2. Dr. Virginia Trimble, "Richard Feynman in Song and Story," http://meetings.aps.org/Meeting/APR18/Session/S06.3.
3. Dr. Lior Burko, "Privilege and Broadening Participation in Physics," http://meetings.aps.org/Meeting/APR18/Session/U10.8.

ON LIGO, GENERAL RELATIVITY, AND PLANNING YOUR FUTURE: A WEEKEND OF PHYSICS IN COLUMBUS

APS April Meeting 2018

by Morgan Waddy, Levi Schult, and Matt Walker,
SPS Members, University of Virginia

We had the pleasure of attending the April American Physical Society (APS) Meeting and learning about cutting-edge research in particle physics, nuclear physics, astrophysics, and gravitation. We got to meet lots of professional scientists, professors, postdocs, and students, and talk to them about their research and what it's like to have a career in physics. Here are some highlights from the sessions we attended and the people that we met along the way.

One of the meeting highlights was a plenary talk by Dr. Rainer Weiss about his Nobel Prize–winning work on LIGO, the Laser Interferometer Gravitational-Wave Observatory. The Q&A session after his talk was illuminating. When asked, "When was a time you thought you might quit?" his answer was truly telling—Weiss said he never really thought of giving up because even though there were problems popping up every day and the work didn't always seem to be progressing the way his team had hoped, he loved his work. The problems were interesting and he knew that solving them would bring him closer to what he wanted to know.

After the talk, Weiss obliged us with autographs and a short interview. He told us that the most exciting result of the LIGO discoveries is that Einstein's field equations work over a wide range of field strengths. "They explain why you're standing on the ground," he said, "and they explain how the sun holds together, and they also work at the edge of a black hole… That's amazing, and it was all done by something in [Einstein's] head!"

We attended another gravitational waves session at the meeting called the "Third Generation of Gravitational Wave Detectors." There we met Dr. Matthew Evans, a physics professor at Massachusetts Institute of Technology. He chatted with us about how he chose his career path, his outreach plans for the Cosmic Explorer—a next-generation gravitational wave detector, and his advice to students. He told us that as an undergraduate, he didn't really give much thought to his major. "I wanted to understand everything by the time I got old, and to do that [I decided] I should start with physics," he told us. Then he decided to attend graduate school at Caltech because of its nice campus. Despite this nonchalance, he ended up finding LIGO, a project he loved. It was refreshing to hear that, like many of us, he didn't have it all figured out at our age. Evans thinks that it's ideal to plan your future, but he emphasized that it is likely your plans will change and you will end up just fine in the end.

Dr. Anne Archibald, a researcher at the Netherlands Institute for Radio Astronomy (ASTRON), went through such a change of plans in her research focus. Archibald gave a plenary talk at the meeting about an extreme triple-star system observed with pulsar timing. She talked with us about her evolution from being a mathematician, trained as a number theorist, to a pulsar astronomer. After receiving a master's in number theory, Archibald went to McGill University. She became interested in pulsars through a friend who was working under the same PhD advisor. Her friend was looking for pulsations in the X-ray signals of binaries and had tried several techniques, but Archibald suggested a better one. They ended up successfully implementing this technique. Following that experience, Archibald realized that while being a mathematician was great, as a scientist you can see how your ideas line up against the natural world.

"In mathematics you come up with a clever idea, you write it up, you put 'QED' on the end, and you publish and you hope you weren't wrong," she said. "You can be confident, a proof is a proof, but that's all that happens. In astronomy—in pulsar astronomy—you have a clever idea, you write the code, you run it over real data, and you find the pulsar, or you find the timing solution that lines up all the pulse arrival times. You take your clever idea and you bang it against nature, and if it was clever enough you find something new," she told us.

Archibald also went more in-depth about her belief in cross-pollination between disciplines. That's how she got started in the field of pulsar astronomy, and throughout her career she's seen that this diversification of ideas has helped to bring lots of new and different things to the table.

Another person that reiterated the theme of not needing to have it all figured out was Osase Omoruyi, one of the students presenting a research poster. Omoruyi is a third-year undergraduate at Yale pursuing a degree in astrophysics. She presented a poster on interstellar bubbles and their relation to the inefficiency of molecular clouds in creating stars. Omoruyi's research is heavily dependent on citizen scientists searching for traces of bubbles in the interstellar medium. We asked her about choosing a research area to specialize in for her future, and Omoruyi said, "I'm very torn. I really don't know at this point, but I think it's okay because graduate school is where you're supposed to figure that out: I don't need to decide that now."

On the science side, Matt really enjoyed two talks in a session titled "Mathematical Aspects of General Relativity." The first was by Gautam Satishchandran, a graduate student at The University of Chicago. He talked about the memory effect in odd dimensions greater than four. In a recent paper that Satishchandran wrote with his PhD advisor Robert Wald, they proved that the memory effect doesn't exist in spacetime dimensions greater than four. It was previously known that the memory effect does not exist in even spacetime dimensions greater than four, but thanks to Satishchandran we now understand that it doesn't exist in any odd spacetime dimensions greater than four either. This begs the question "Why does it manifest itself in our four dimensions?" There is more research to be done on this topic and Satishchandran will continue investigating.

The second talk was by Dr. Leo Stein, a postdoc at Caltech. His talk was titled "Black Hole Scalar Charge from a Horizon Integral in Einstein-dilaton-Gauss-Bonnet Gravity." Matt was excited about Stein's talk the minute he read the title and abstract, as a huge fan of the Gauss-Bonnet theorem. It turns out that a large part of testing general relativity (GR) is studying theories that almost resemble it but are slightly different. In this case, the Gauss-Bonnet theorem adds an extra symmetry and allows researchers to explore the consequences.

Stein illustrated how in beyond-GR theories with a scalar field, a black hole's scalar charge is perfect for testing the theory. In the special case of Einstein-dilaton-Gauss-Bonnet theory, the scalar charge can be extracted from a horizon integral. Stein showed how he did this and his results. At some point he referenced an older paper he wrote with his colleague, Kento Yagi. Coincidently, Dr. Yagi is Matt's professor for GR.

This was the first APS meeting for all of us and overall it was an amazing experience. Matt got to present research that he has been working on the past year. Morgan enjoyed talking with Archibald because, like Archibald, Morgan decided to study physics because she was interested in the natural world and thought it would be best to stop wondering and start learning. That way, she could someday see if her ideas lined up with the truth of the natural world. Levi came away encouraged to explore many different fields within astrophysics, thankful that he doesn't have to have everything figured out right now. We met some awesome scientists and fellow students and look forward to attending future conferences. //

FROM THE LAUNCHPAD: WITNESSING EXOPLANET HISTORY IN THE MAKING

NASA TESS Launch

by Adina Feinstein, SPS Chapter President 2017–18, Tufts University

There have only been a few years in my life when there have been no humans in space. Sending and bringing home astronauts no longer awes the public as it once did—often major news outlets don't even cover it. But exoplanets, planets orbiting stars other than our sun, and prospects of finding life outside of our own system—that's newsworthy. Recently, NASA, the Massachusetts Institute of Technology (MIT), and SpaceX joined forces to launch the next planet-hunting mission, TESS, the Transiting Exoplanet Survey Satellite.

I'm no stranger to the question "Do you think there is other life in the universe?" Right now, we have no evidence to suggest that there is, but the exoplanet community is making progress on answering this question at an unprecedented speed. Just twenty years ago, we did not know exoplanets existed. Now over three thousand have been confirmed by the Kepler Space Telescope alone. The Kepler Space Telescope observed only a small portion (~10%) of the sky, while TESS will look at nearly all of it. Both Kepler and TESS search for planets by observing what is known as a transit, which is a slight dip in the brightness of a star as a planet passes in front of the star along our line of sight.

As an exoplanet enthusiast, I couldn't miss the opportunity to see TESS launch on SpaceX's Falcon 9 rocket. I applied and was selected to attend as part of the NASA Social program. The NASA Social program is an opportunity for anybody with social media accounts to learn and share information about NASA missions, people, and programs. I was truly honored to have been chosen for this competitive program.

NASA Social arranged two days of activities for its TESS launch participants. On the first day, we attended a NASA briefing and heard from exoplanet scientists, including Dr. Elisa Quintana and Dr. Jessie Christiansen. The event was live-streamed on NASA TV. Being a part of the NASA Social program was like being part of the press. As someone trained in astrophysics, I found it very difficult to ask not-too-technical questions when talking to our guest speakers. Most people in the group of participants I was with did not have scientific backgrounds so I felt it necessary to ask questions that everybody in the room would understand.

After the briefing, I visited the Kennedy Space Center (KSC) Visitors Complex. I walked around the center with a friend, whom I met at NASA over a summer internship, and her family. I had been to KSC before, but it was a lot of fun walking around with my friend's five-year-old daughter, watching her face light up as we saw the real Atlantis Space Shuttle and a life-size replica of the Hubble Space Telescope. "I've never seen her so excited about science before," my friend told me about her daughter. It is difficult to understand the scale of astronomy, especially as a child, but being able to see the Hubble Space Telescope replica and the actual retired Atlantis shuttle was clearly awe-inspiring.

ABOVE: The author standing in front of the Vehicle Assembly Building (VAB). This building is 526 feet tall and where the Apollo missions were and the future Space Launch System (SLS) will be assembled. This is one of the largest buildings by volume in the world. Photo by Ashley Muller.

The second day of the program, we were taken behind the scenes of KSC and toured Swamp Works, a robotics engineering lab that accelerates design innovations for tools that could be used in space, on the moon, and potentially even on Mars. There were giant pits of synthetic moon sand and little rovers scattered around the lab, and unfortunately we weren't allowed to take any photos. The lab is called Swamp Works because, like a lot of Florida, it is located right next to a swamp! Apparently employees have to check under their cars for gators before leaving for the day. We spotted a big one as we were leaving the building—who knew the hardest part of these engineering jobs was leaving safely at the end of the day!

After touring Swamp Works, we finally got to see the rocket! This was by far my favorite part of the entire experience (which shouldn't be of much surprise). As we were driving up to Launch Pad 40, the bus was going crazy; everybody was excited to see the rocket up close. In contrast, I became a lot quieter. I didn't want to talk or listen to other people. Exoplanets have always been a field I loved. I completed two research projects on them when I was in high school, and even though I took a break to study galaxy evolution during my undergraduate career, I want to get back to exoplanets in graduate school. As we approached the rocket, I was really looking at my future.

We stepped off the bus and turned around to see, not one hundred meters away, this magnificent, skinny rocket with the TESS mission stored in payload fairing. On the fairing itself were giant images of the NASA and TESS logos. Although the NASA Social program director warned us to watch our step in the grass, as there could be fire ants, I felt completely overwhelmed and sat down and just stared at the rocket. As a child, I wasn't interested in engineering. Building rockets, robots, and satellites never excited me as much as raw science. On that day, I sat and appreciated the amount of time, work, and energy that was needed to get us to this point. I felt so overwhelmingly lucky to be there.

After visiting Launch Pad 40, we drove to Launch Pad 39B. This historic launchpad is where the Apollo missions, the first manned rockets, were launched. I had been behind the scenes at KSC previously on a guided tour through the Visitors Complex, but this time we drove up to the launchpad, and then our bus driver actually drove us onto the launchpad! It was incredible to see the flame trenches and the ongoing construction to get ready for the next shuttles NASA is building, the Space Launch System (SLS). The SLS is being designed for deep space exploration and potentially sending humans to Mars. Although I'm sure fixing up an existing launchpad is cheaper than building a new one, I found it poetic that they chose to use 39B, the one that sent our men to the moon, to send our men and women farther than we ever thought possible.

We ate lunch at the employee cafeteria and toured the Vehicle Assembly Building (VAB), which is one of the world's largest buildings by volume, covering 129,428,000 cubic feet. Here, they are getting ready to start assembling the new SLS. The building also contains what I refer to as "testing toys." The toys are to-scale models of parts of the SLS, or the Apollo mission, that engineers use to make sure they are able to properly assemble the rocket. They have a mock-up of the Apollo capsule sitting on the floor of the building as an example.

Before the end of our tour, we learned that the TESS launch had been delayed for 48 hours. The weather was great, but the guidance and navigation systems of the Falcon 9 needed further analysis to be ready for launch. As disappointing as this news was, I knew there was a risk the rocket wouldn't launch the day I was there.

Unfortunately, due to classes, I was unable to stay for the delayed launch. It hurt more than I expected it to when I arrived at the airport Tuesday morning. Instead of watching the launch in person, I watched the launch as an anxiety-ridden mess in the comfort of a small blanket fort; I could only imagine what the viewers still at KSC must have been feeling. There has truly never been a better time to study exoplanet science. TESS is going to observe millions upon millions of stars. The amount of data that will be transmitted and the amount of follow-up observations that will need to be completed will be through the roof. In a few months, data will start flowing down from TESS and the community will be overwhelmed with new science and discoveries. I hope to be a part of this effort when I start graduate school this fall. //

LEFT: I was so excited about the TESS mission, I sewed the patch onto my jacket! This is an image of me, in the jacket, and the Falcon 9 rocket with TESS in the payload fairing on top. Photo by Trevor Anthony Woods.

The SPS Congressional Visits Day (SPS CVD) is a program that supports student engagement in science policy and advocacy on Capitol Hill. During the two-day program, SPS members come to Washington, DC, to meet with members of Capitol Hill and their staff to engage with them and advocate for science policy issues. These interactions are an important and effective opportunity for those members interested in science policy and communication. The following articles provide two of the 2018 SPS CVD participants' perspectives about their visits, the topics they discussed, and lessons learned.

You can find out more about the SPS Congressional Visits Day here: http://www.spsnational.org/programs/sps-cvd.

SCIENCE POLICY IN CONGRESS: A PHYSICS PROBLEM WHERE THE LAWS OF PHYSICS DON'T APPLY

by Laura Goodman, SPS Chapter Secretary,
North Carolina State University

Heisenberg's uncertainty principle states that position and momentum cannot be simultaneously known in a quantum system. On the other hand, members of the United States Congress have no problem telling you both their position AND momentum on an issue.

As a physics student, I am more comfortable studying the laws of physics than the laws of the United States government. If I wanted the path of least resistance, though, I wouldn't have gone into physics. When the opportunity came up through the Society of Physics Students Congressional Visits Day to go to Washington, DC, meet US representatives and their staff, and talk about science policy, as both a researcher and science advocate I had to go.

I am a double major in physics and applied mathematics who is minoring in international studies at North Carolina State University. As the secretary of the active SPS chapter at my school, I've helped my chapter grow and participate in events like the March for Science and outreach activities.

My goal in attending the SPS Congressional Visits Day (CVD) was to discuss US immigration policy as it relates to those I know in the sciences. I have had labmates and professors from all over the world. Scientists based in the United States collaborate with people in many different countries, and our science and innovation is better because of the mix of collaboration and competition.

SPS made sure we (the five of us students participating in SPS CVD) didn't just wander into congressional offices without any preparation. Beforehand, they connected us with professional advocates who had PhDs in physics and were working in Washington, trying to use their physics background to make change. The five of us were interested in discussing policy related to physics education, energy research, science funding, and immigration. Our interests were as varied as the places we came from (North Carolina to Alaska), so we had a lot to talk about. During the training, we learned about crafting our message, how laws are drafted, and all the factors congressional representatives need to keep in mind while making decisions.

RIGHT: Pheobe Sharp, Laura Goodman, and Guillermo Gutierrez in front of the United States Capitol Building. Photo by Danielle Weiland.

Then came the day we got to visit Congress! And it snowed… DC was shut down and many offices called in to cancel appointments. Needless to say, it wasn't a surprise to get a text

at 7:11 a.m. that North Carolina Senator Richard Burr and North Carolina House Representative Walter B. Jones had to cancel due to snow. We were lucky that a handful of offices stayed open to meet with us.

We started the morning with a Constituent Meet-and-Greet. At these events, representatives meet with voters in their states and announce what they are currently working on, list any big concerns, and listen to the concerns of everyone who made it there that morning. From there, we moved on to our meetings with different offices.

In most of the meetings, we weren't actually meeting with the senators or representatives themselves but their staffers. The staffers we met with were all pretty young, recently out of college and in charge of collecting information related to how bills should be written and what the congressional representatives should know before they vote. (Basically, Congress is being run by a bunch of people in their twenties!) These are people who have to keep up with dozens of different issues at the same time.

Our group of students attended the meetings together. In each meeting, we let the student whose state was represented run the meeting and choose the topic to discuss. As a physics student from eastern North Carolina, I've had my share of experiences related to lack of physics education at the K-12 level, the need for better energy research, and the need for science funding, so it was easy to give supporting evidence in the meetings run by other students.

My big meeting was with North Carolina Senator Thom Tillis's staffer Andrew Nam. As it turns out, Andrew attended both universities that I spend time at: North Carolina State University and University of North Carolina at Chapel Hill. Between this connection and the fact he wasn't much older than I am, we had a very comfortable conversation. It was Andrew's job to highlight what Senator Tillis is currently working toward accomplishing and both listen to me and present Senator Tillis's stances.

It was an interesting dynamic. I came to talk about how the complexities of immigration and visas were costing academic institutions and businesses millions and slowing down US advancement and innovation. It's impossible for someone to change visa status without the aid and expense of an immigration lawyer, regardless of the reason why. Senator Tillis is currently working on an immigration bill related to DACA called the Solution for Undocumented Children through Careers, Employment, Education and Defending our Nation (SUCCEED) Act (S. 1852). While this potential law provides a path for the currently uncertain future of DACA participants to attain permanent legal status, it's a 10–15-year path that, in its current form, is pretty strict. My friend David, who has been a part of DACA for the last five or so years, worries that he will be well into his thirties by the time he could change his immigration status. Such an uncertain future is pretty scary.

The experience of talking with Andrew helped me realize that regardless of what my goals may be, different offices will have different priorities. Thus, my message is one that will have to be repeated often.

Overall, through SPS CVD I learned that Congress is much more complicated than I've been taught, just as physics is much more complicated than a freshman physics class makes it seem. Advocating for the things we care about may not seem easy, but it is something we all can do. Science policy is something that needs to be talked about again and again for us to make a sustained difference, and all that talking sounds like great practice that will only make us better at sharing our message.

Physics students are not afraid of a challenge, so I dare you to take a step toward improving science policy. Start by doing some online research or talking about it with your fellow students and go from there. Good luck! //

Reflections on My Trek to Capitol Hill

by EliseAnne C. Koskelo, SPS Member, Pomona College

Although many of my meetings were cancelled due to snow, one of my favorite parts of the trip was being proactive and running from senate office to senate office, making impromptu pitches for renewable energy and diversity in science, technology, engineering, and math. I was fortunate to speak with the chiefs of staff for senators Heinrich and Udall of New Mexico (my home state). From them, I learned more about the different policies of New Mexico's senators and found myself leaving with more faith in the future as New Mexico makes strides in solar and wind energy. I also met fellow constituents from the salmon fishing and pharmaceuticals industries. This was a heart-warming experience, as I got to share my love for my home state with fellow New Mexicans while trying to make an impact on our future.

Another perk of the program was teaming up with fellow SPS CVD participants. I found that the most successful meetings were those where we, as students, related the issues for which we were advocating back to our own experiences—whether that be learning physics in high school or conducting research at a university or a national lab. I came away from this experience with a greater understanding of policy-making as well as the different pathways in physics that lead there. I plan to focus on a career in research and teaching, but I finished CVD with a reinforced appreciation for the importance of advocacy.

To read the full version of this report, visit http://www.spsnational.org/programs/sps-cvd/2018/eliseann-c-koskelo.

LEFT: SPS CVD participants meeting with Representative Jim Cooper to discuss our experiences with physics and science education in the United States. Photo by Danielle Weiland.

Zone meetings are an opportunity for SPS members and chapters to engage with other undergraduate students and advisors within their geographical region. These meetings often combine a fun and informal platform for students to network while also enabling students to present their research, interact with relevant speakers, visit local labs, and participate in other engaging activities. Each SPS zone meeting takes on a unique style and culture, shaped largely by the traditions of the schools in that region.

To support the meeting agenda and enable student travel, SPS National offers zone meeting funding. Upon receipt of that funding, the zone must submit a report. The following reports highlight two zone meetings (zones 10 and 17) that occurred in the 2017–18 academic year.

To learn more about SPS zone meetings, visit http://www.spsnational.org/meetings/zone-meetings.

THE UNIVERSITY OF MISSISSIPPI HOSTS ZONE 10's 2018 MEETING

by Carolton Tippitt, SPS Member, University of Mississippi

The first day's events were very casual. The SPS groups from colleges in Mississippi, Louisiana, Arkansas, and some of Tennessee arrived around 4 p.m. We socialized, and a few hours later, dinner was ready. We ate some delicious hamburgers and veggie burgers as well as a variety of chips and sodas while continuing to get to know each other.

Around 7 p.m., the main event of the night was ready. The students filed into Lewis Hall's large lecture hall to watch a presentation on LIGO, the Laser Interferometer Gravitational-Wave Observatory. Dr. Marco Cavaglià, a member of the LIGO team and a professor at the university, led the presentation and held a short Q&A after the viewing. Afterward, some of the students returned to their hotels, but most stayed in Lewis Hall to play music and board games, most notably, Cards Against Humanity.

The next day, the students reunited to continue the meeting. During this day, they learned a lot about graduate school and life after graduate school.

A few panels were held throughout the day. In one of them students learned about what graduate schools look for in applicants. Others included representatives from universities within Zone 10 and talks on fundraising, outreach, and the importance of minorities in physics. There were also tours of the National Center for Physical Acoustics.

Dr. Breese Quinn gave the keynote speech around noon. Dr. Quinn, who has years of experience lobbying for grants and budget inclusion for physics study, explained the process of lobbying Congress. He also detailed the importance of lobbying, showing that it gets results. Afterward, some students and faculty members presented their research, and we had lunch.

Finally, each chapter presented their yearly events and progress. For many of us, this was a great way to improve our respective chapters. Many of the chapters had hosted unique events, but there were also reports of similar events, for example, witnessing the solar eclipse in August. We concluded by asking for nominations for zone counselors.

This year's Zone 10 meeting was very beneficial for all of those involved. It was a great opportunity for different schools to share what helped them through the year. Everyone is already excited for next year's zone meeting—it will be a blast! //

ABOVE: Ole Miss SPS officers Carolton Tippitt and Renee Sullivan-Gonzalez making liquid nitrogen frozen marshmallows during the Zone 10 meeting. Photo by William Slaton.

A BIOLOGY STUDENT GOES TO THE SPS ZONE 17 MEETING

Alexander Gloger, SPS Member,
University of Alaska Fairbanks

After a long, stressful, but eye-opening spring semester, I figured I ought to treat myself to a small trip to a part of the country that I'd never been to before: Oregon. I would accompany our chapter president, Riley Troyer, to the Zone 17 Meeting. We would fly to Seattle and then drive to Corvallis, Oregon, to confer with other SPS chapters at Oregon State University (OSU).

For Riley, traveling on official physics business was nothing new, but I had no idea what to expect from this trip, many leagues away from Fairbanks. And for that matter, it was only the second time anybody from Alaska had ever gone to a zone meeting.

We arrived in the afternoon, after a long car ride across a mixed landscape of mountains and plains saturated with countless evergreens. Upon our arrival in Corvallis, we were greeted by an Earth free of snow and beginning to blossom with the essence of spring.

We entered a large, intimidating building with various twists and turns where many brilliant young minds prepared to become scientists. It was nothing like the simple Reichardt building back in Fairbanks, Alaska. This place was big. Even for someone like myself, who comes from a giant metropolis, its size was truly remarkable.

For the first event that evening, we watched a presentation by the former APS president, Dr. Laura Greene, about superconductor magnets and how they might revolutionize the technological world. She demonstrated the effects of super-chilling by pouring liquid nitrogen on the ground and we watched it boil at room temperature. After all, superconductors need to be super-chilled to work properly. It's bewildering to discover how different branches of science such as physics and chemistry intertwine to bring us such advanced technology, a common and recurring theme we would see throughout the zone meeting.

The demonstration ended, and we met up with our Alaskan counterparts from the University of Alaska Anchorage, who had arrived earlier than us. Like me, none of them were actual physics majors, although they were pursuing degrees in STEM fields.

The keynote of the meeting, a presentation by an Italian physicist, Dr. Davide Lazzati, was a huge success. His explanation of gamma-ray bursts and his research into the many isotopes and chemical elements in the universe stretched across the furthest reaches of the galaxy. It is interesting how in some respects, we know more about the universe around us than our own planet.

The evening closed with a tour of campus from two OSU SPS members. On the tour we saw their SPS room, which was bigger than ours. We then left the physical science building and walked around the campus. We saw grand evergreen trees, historic brick buildings, and students going about their day in the warm-lit evening landscape that was the university. We quickly grabbed dinner and made our way to our rented room.

We started day 2 with a physics decathlon. For most bright minds like Riley, soon to be entering a PhD program, this was no problem. For me, with my biology background, many of the questions stumped me. However, my chemistry background helped greatly. Aside from the trivia questions, we also had to build a tower from spaghetti straw and masking tape and design an aerodynamically rigorous paper airplane.

Next, we spoke via video conference with the director of SPS and Sigma Pi Sigma, Dr. Brad Conrad, who shared lots of helpful information. We had a question-and-answer session and heard about his journey to SPS. He congratulated us on our turnout and reinvigorated us with words of encouragement, the very thing all STEM students need at the end of a stressful semester. We then proceeded to several other presentations by graduate students and alumni of OSU. We observed the many pathways in life they have taken or plan to take as well as learned about the many options available to STEM students. I think it's fair to say that we will rule the world, eventually.

The last event of the meeting was a tour of the OSU labs, which had various applied physics projects going on within. I toured the biophysics lab. Here the scientists studied the various shapes and geometries that cancer cells can assume. The hope is to expose vulnerabilities and ultimately help treat cancer. Physics, geometry, and biology intermeshed within the same project. Amazing.

We closed the meeting by taking a photo with attendees. After saying goodbye to our new friends, we departed back to Alaska a little tired, a little wiser, reassured, and a little more informed. Not bad for an overnight trip. //

LEFT: Attendees trying on SPS eclipse glasses during breakfast. Photo courtesy of Richelle Castro, SPS member, Oregon State University.

The SPS Summer Internship Program offers SPS members 10-week positions in the Washington, DC, area. Interns are able to participate in research, education, policy, and outreach and are placed in organizations such as the American Physical Society, American Association of Physics Teachers, Society of Physics Students, The Optical Society, Capitol Hill, NASA, and the National Institute for Standards and Technology, etc. Over the summer, students engage in a diverse set of activities and projects that collectively provide them with a unique learning and professional development opportunity.

As part of the internship requirements, each intern must maintain a weekly blog highlighting their work and/or a significant experience. The following articles are excerpts from a few of the 2017 SPS interns, including Justine Boeker (AAPT Teacher Professional Development Intern), Lisa McDonald (AIP FYI Science Policy Communications Intern), and Tori Eng (AIP Niels Bohr Library & Archives Intern).

You can find out more about the SPS Internship Program here: http://www.spsnational.org/programs/internships.

GAINING CONFIDENCE AND FINDING BALANCE

by Justine Boeker, 2017 AAPT Teacher Professional Development Intern

I can't believe I made it to this point. Friday was my last day of student teaching, Saturday I graduated, Sunday I packed, and Monday morning I left for DC. I had orientation on Tuesday and finally, my first day at the American Association of Physics Teachers (AAPT) on Wednesday. I am not even sure I have breathed the past week. Even though it was busy, I have found myself learning and experiencing things I didn't even realize I would. It has been a week of perspective switches.

My intern placement is at AAPT, working on teacher professional development programs. My first two days of work consisted mostly of getting to know my mentor, Rebecca Vieyra. The more I get to know her, the more I feel honored and blessed to be learning from her. As I started work, I learned about several initiatives that I will get to be a part of that address a range of issues in physics and physics education. Some, like the lack of women in physics, the lack of quality physics education in elementary education, and the negative perceptions of teaching, are issues I have experience with myself.

For example, I am designing a workshop for K-8 teachers to present at the AAPT conference in Cincinnati that includes lesson plans, light activities, and bio/physics interdisciplinary lessons. This workshop will provide elementary teachers with the necessary equipment and innovative methods and activities aligned with best practices and the science standards for their students to effectively explore sound.

I also am going to have the opportunity to work on a project that has affected me personally. Have you ever heard the phrase, "You're too smart to be a teacher?" I have. But teaching physics is just as intellectually stimulating as an engineering job. Being a good teacher is just as difficult, if not more, than being a good physicist. The group I will be working with aims to change negative perspectives on teachers and teaching.

One of the main myths we are discussing is the belief that teachers are poor when, in fact, teachers make a livable income. According to a report by the American Physical Society, most people believed that an average secondary teacher makes around $40,000. In reality, the average secondary teacher salary is $52,000 (although salaries vary depending on geographic location). Additionally, the benefits and retirement plans of a teacher are notably better than those of other STEM professionals, in general.

I am also working with Rebecca to advocate for a nationally funded program (the Albert Einstein Fellowship) that she passionately believes in. It is being eliminated after this coming year. This has been an interesting process. I took Government and Citizenship in ninth grade with Mr. Hartzberg, but that was a long time ago, so there are a lot of gaps in my understanding of my own government. I am learning more about government and policy than I did before. Additionally, and more importantly, through this process, I am developing even more respect and admiration for my mentor as I watch her take initiative on something she believes in. She is a strong and passionate woman who has the skills to initiate change.

When I look at the week as a whole, I have one last major insight. I am turning around to Rachel to say "I have no idea what I am doing!" a lot less. (Rachel is the high school student intern who works next to me a couple days a week.) If I were to have honestly spoken about those first couple of weeks here, you would have heard how vastly underqualified I felt for this job. *What does a politically conservative, 22-year-old recent college graduate have any business doing in an* experienced, *adult-driven, and generally liberal environment?* However, I am slowly gaining confidence. I am developing a healthy balance of seeing the value I bring and accepting that I am not supposed to know what I am doing. I am here primarily to learn and develop as an educator and an individual. It is okay for me to ask questions and process new information. It is okay for me to not know what I am doing, and because I don't have all the answers (and I probably never will when it comes to teaching), I have endless potential for growth.

This article was originally published as a series of blog posts. They have been lightly edited and condensed for publication. Read the originals at:

https://www.spsnational.org/programs/internships/blog/wider-perspectives-week-1

https://www.spsnational.org/programs/internships/blog/challenging-perspectives-week-2

https://www.spsnational.org/programs/internships/blog/endless-potential-week-4

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MY WASHINGTON, DC, INTERNSHIP

by Tori Eng, 2017 AIP Niels Bohr Library & Archives Intern

This past week of work has been exciting. Another intern—Lexxi—and I are creating an exhibit about the importance of the history of physics to be installed in the Niels Bohr Library & Archives. We finished all the work for the exhibit on Monday, now we just have to install it. Lexxi and I met with our mentor to discuss the next steps for the project. We had been knocking around ideas for social media and outreach projects. Our mentor loved some of our ideas, so Lexxi is now working on a series of newsletters to send out to SPS students and I am making a series of videos related to our exhibit. We will also work on an article to be released in *The SPS Observer*. I have never worked on a project this varied.

On Thursday, as an intern group, we toured Capitol Hill. We started the morning out by going to a subcommittee hearing on in-space propulsion. At that hearing, we were recognized by Congressman Ami Bera as being the future of science. He had us stand, and we were recognized by the whole room. I have done quite a few cool things in my life, including watching lava flow into the ocean from less than 100 feet away, and I can honestly say that this was the coolest thing that has ever happened to me. It was so encouraging and awe-inspiring. I was literally speechless for minutes afterward (and I talk a lot).

I am originally from the Sacramento area, in Rep. Bera's district, and I remember when he was elected. To see that we as human beings, as future scientists, could influence the policies that govern our world was eye-opening. It is hard to quantify the experience of being on Capitol Hill—it's like democracy is alive and there is so much possibility for change.

As you can imagine, it was hard to beat a Thursday like that, but on Friday we got to install our exhibit! I honestly thought it would only take a few hours to install, but it took all day. I am beyond happy that the exhibit is installed. It feels good to have our hard work on display and it looks awesome! You can check it out below!

This article was originally published as a blog post at https://www.spsnational.org/programs/internships/blog/week-5-installing. It has been lightly edited for publication. //

RIGHT: Lisa McDonald (Coe College '17) was the 2017 summer intern for FYI, the American Institute of Physics science policy news publication. Photo by Luis Alejandro Royo.

WHY HELIUM IS IMPORTANT

by Lisa McDonald, 2017 AIP FYI Science Policy Communications Intern

Halfway through the summer and I've set a new record for this internship position: publishing two articles with still five weeks to go.

To be fair, since I'm only the second person to participate in this particular internship, it's not a transformational feat, but I still feel a lot of pride.

The topic of interest this week is actually a topic that occurred last week: a House subcommittee hearing to discuss the draft legislation "Helium Extraction Act of 2017." Originally I attended the hearing with the intention of writing a short blurb for the weekly newsletter, but during our group meeting on Monday it was decided we would do a full-length Bulletin on the event as well.

The meeting, as Ranking Member Alan Lowenthal pointed out, was "unexpectedly timely." Earlier this month Saudi Arabia closed its borders with Qatar—cutting off Qatar's ability to ship overland transports—and Qatar subsequently shut down its two helium production plants. Qatar is second only to the United States in terms of world helium production, with Algeria and Russia ranked third and fourth, respectively. With the sell-off of the Federal Helium Reserve well underway, this means the United States government is lacking both domestic and international supplies of helium for federal agencies.

Though I found the hearing itself a bit dry—subcommittee members kept showing up late and asking the *exact same question*—I found the topic quite fascinating. People my own age likely remember a few years ago when there was a shortage of helium that prevented birthday parties from brimming with balloons, but helium shortages are so much more than a birthday party falling flat. Without helium, some of our well-known life-saving technologies, like magnetic resonance imaging (MRI), would not exist. To discover the Bureau of Land Management disregarded the government's request to leave three billion cubic feet of helium in the Federal Helium Reserve for federal users—the bureau instead sold *everything*—and then to brush over that fact during the hearing makes my blood boil. They should be taken to task for putting our research facilities at such risk of closing down.

However, I don't feel entirely hopeless. My mentor, Mitch, showed me this week how our email server keeps track of how many times a specific subscriber opens each email, and one of the top openers of my ARPA–E article was Ernest Moniz, the former secretary of energy under Barack Obama, who negotiated the Iran Nuclear Deal! Knowing that such an important person not only read my article, but forwarded it to others to read as well, fills me with optimism that reporting on these government acts can get the word out and can be an agent for change.

On a final note, the entire intern group spent Thursday on the Hill to tour the workplace of fellow interns Eleanor Hook and Riley Troyer. During the House Space Subcommittee hearing we attended, Ranking Member Ami Bera called us out! He said:

"Before I read my opening statement, I'm told that there's a group of students from the Society of Physics Students today, and I just want to recognize those students that are here in the audience because they are interning in a variety of places, including in our own House Science, Space, and Technology Committee. You guys represent the future, and that's why we do what we do."

This article was originally published as a blog post at https://www.spsnational.org/programs/internships/blog/week-five-%E2%80%9Cair%E2%80%9Ding-my-grievances-through-words. It has been lightly edited for publication. //

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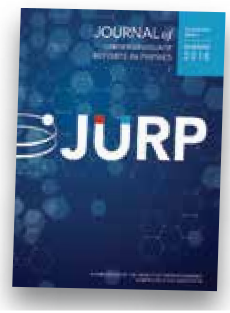

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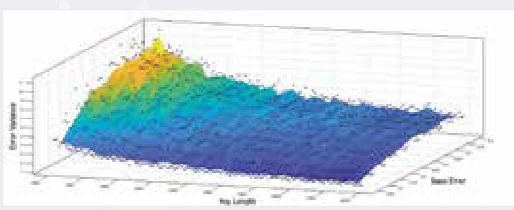

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- Conference reflections, SPS chapter award final reports, SPS intern blogs, and other special programs articles.

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