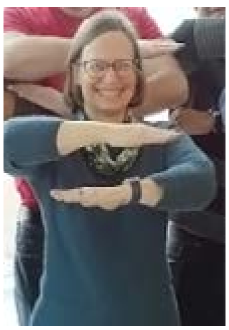
The Center for **BRIGHT**BEAMS

A NATIONAL SCIENCE FOUNDATION SCIENCE & TECHNOLOGY CENTER

NEWSLETTER

FALL 2021



Dear Friends of CBB,

As life becomes a bit more normal, CBB has begun to plan its next Symposium, which will take place on June 3, 2022 at UCLA. The focus will be Compact Light Sources with a program of expert talks on their capabilities, approach and technical challenges. If conditions allow it, the Symposium will be an in-person event, and I hope you'll join us.

A regular feature of the Symposium is a poster session by CBB students and postdocs. I'm always impressed by the accomplishments of CBB students and postdocs, and as illustrated on p. 5 of this Newsletter, they are taking their scientific and collaborative skills to national labs, industry, and universities. Many current students would like to learn more about career opportunities, especially in industry or at labs. If you can host a visit or offer an internship, please let us know.

CBB is now beginning its second five year term, and since Science and Technology Centers are limited to ten years of NSF funding, we have begun to plan with CBB's legacy in mind. On the one hand, CBB will continue to pursue high risk/high reward science while at the same time, we will bring our most promising technologies to the demonstration stage, working closely with partners in industry and at national labs to ensure that the technologies meet the needs of future accelerators.

Whether you're at a national lab, in industry, an educator, a CBB alum, or a current member of the Beam Team, CBB values your involvement, and I hope you'll stay in touch.

Ritchie

J. Ritchie Patterson
Director of the Center for Bright Beams

In case you missed the CBB screening of Picture a Scientist you can still catch it on Amazon, Netflix, iTunes, and PBS Nova.

"The film documents a reckoning both within the field and in our own brains with its fascinating and frightening examination of bias." -WGBH Radio

More on p. 6

In This Issue

The Center for Bright Beams Begins Its Second Five Years

The CBB Team at our 2019 Annual Meeting

The Center for Bright Beams (CBB), an NSF Science and Technology Center has begun its second and final five-year phase. CBB was created in November 2016 with an initial $23 million award to Cornell and partner institutions. The center integrates accelerator science with condensed matter physics, materials science and surface science for the advancement of particle accelerator technologies. It strives to gain the fundamental understanding needed to transform the brightness of electron beams available to science, medicine and industry.

These insights will help improve the performance and reduce the cost of accelerator technologies around the world and develop new research instruments that transform the frontiers of biology, materials science, condensed matter physics, particle physics and nuclear physics, as well as new manufacturing tools that enable chip makers to continue shrinking the features of integrated circuits.

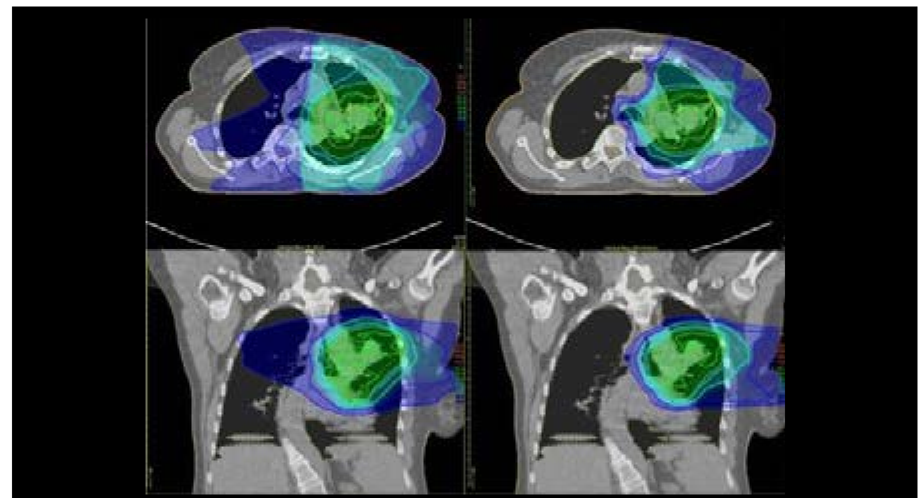
"Currently, all of these scientific and industrial instruments are limited by the brightness of their beams," said Ritchie Patterson, director of the Center for Bright Beams. "CBB is the only center in the world that brings together an interdisciplinary approach to address critical challenges limiting accelerator science. This renewed funding will help us build on our successes to date, which have benefited enormously from our collaborative approach."

The center is based at Cornell's Laboratory for Accelerator-based ScienceS and Education (CLASSE), and includes scientists from seven other universities and three national labs. CBB is organized into three interdependent research themes related to beam production, acceleration, and dynamics and control. These themes combine to focus on the creation of smaller, brighter electron beams.

Since 2016, CBB's research has resulted in an electron source with ten times smaller size and divergence than common sources in use today. This will open new pathways for drug design by allowing biologists who study the structure and dynamics of single molecules to reduce their data collection time by 90%.

The center has also created new methods for beam acceleration that match today's performance but are vastly simpler to operate. CBB's high-field Superconducting Radio Frequency (SRF) cavities will cut the construction costs of the largest accelerators by up to billions of dollars by reducing the length of tunnels and the number of cavities. Relaxed cavity operating temperatures will simplify cryogenics, making beams more accessible to universities and industry, or "a beam in every basement."

During Phase II CBB will focus on its most promising research directions with the aim of bringing key advances to fruition so that they can be put to use in future accelerators.



Traditional radiation therapy (top and bottom left) delivers radiation to the tumor and to healthy tissues around the tumor. With proton therapy (top and bottom right), the majority of the radiation is delivered to the tumor. Credit

Although particle accelerators are commonly associated with "Big Science," they are actually extremely pervasive in society - to the tune of more than 70.000 in total around the globe. For example, they are used in medical and industrial applications for radiation treatments and isotope production for medical procedures as well as in non destructive testing of manufactured components and radiation hardness and materials properties of space electronics.

"If we look only to medical applications for photon radiation, to meet the need to treat the number of cancer patients worldwide, we need today another 5,000 particle accelerators of just this genre. Accelerators will continue to grow in number as the technology advances in terms of reliability, enhanced control, and packaging to smaller footprints," says Sandra Biedron, CBB's director of knowledge transfer." CBB is at the front and center of these advancements. This new funding will allow us to directly impact chip manufacturers, industrial leaders, and smaller research institutions, providing them with improved accelerators and associated capabilities."

For more than a century, major advances in physics, chemistry and biology have resulted from scattering, imaging, spectroscopy and colliding beam experiments. But in order to see something new you must do something new, and these experiments are now becoming increasingly dependent on time-resolved information which allows for such things as true movies of molecular machines at work. Examples of other cutting-edge methods dependent on advances in particle beams include beams for tumor treatment, electron microscopes capable of imaging individual atoms, instruments for wafer metrology, and the Large Hadron Collider.

While CBB is making significant advances in the particle accelerator frontier, its greatest impact may be the result of educating future scientists in electron beam technology.

"These large-scale colliders, intense X-ray sources, and electron microscopes are essential tools for science and industry, but the U.S. educates few students to understand the bright electron beams on which they depend for success," said Melissa Hines, associate director of CBB. "Our graduate students are helping to bridge this gap, and approximately half of CBB's students are in areas that the Department of Energy has identified as areas of critical need. Our most important output is almost certainly going to be the large number of graduate students and postdocs, most of whom will go off to have a big impact in a variety of different fields."

CBB also includes Arizona State University, Brigham Young University, Northern Illinois University, University of California, Los Angeles, University of Chicago, University of Florida, University of New Mexico, Fermi National Accelerator Laboratory, Lawrence Berkeley National Laboratory, SLAC National Accelerator Laboratory, and affiliates at other institutions.

The NSF Science and Technology Centers: Integrative Partnerships program provides grants for up to 10 years to support innovative, potentially transformative research and education projects that require large-scale, long-term awards. The centers foster cutting-edge research, education of the next generations of scientists and broad distribution of the knowledge and technology produced.

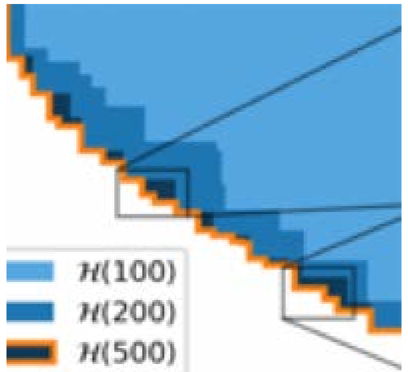
Rachael Farber, University of Chicago Postdoc, Surface Chemist, inspecting a vacuum chamber used for SRF cavity production.

Research Highlights

Learn more about CBB research at cbb.cornell.edu

Multiobjective Bayesian optimization for online accelerator tuning

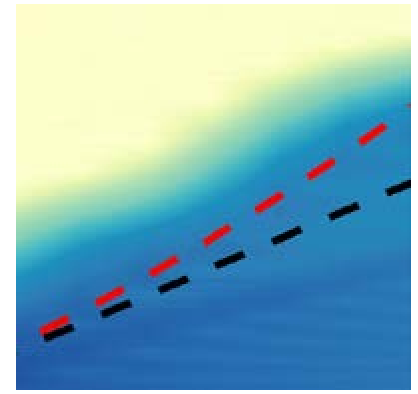
R. Roussel, A. Hanuka, A. Edelen



Currently online tuning of accelerator parameters to improve performance is limited to solving single objective problems, ie. minimizing the beam brightness or bunch length from a photoinjector. These objectives often are in competition with one another, where minimizing one objective comes at a deleterious cost to another. We wish to experimentally identify the ideal trade-off between competing objectives when it is expensive or time-consuming to perform an objective measurement, known as solving the multi-objective optimization problem.

Semi-Classical Cutoff Energies for Electron Emission & Scattering at Field-Enhancing Nanostructures with Large Ponderomotive Amplitudes

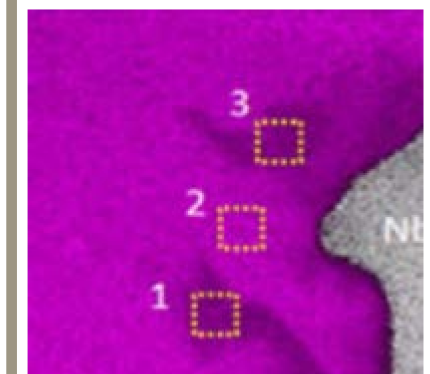
J. Mann, J. Rosenzweig



This work is another step towards our understanding of nanostructured cathodes, which may be an avenue for high brightness electron emissions. Potential applications for these cathodes include ultrafast electron diffraction (UED) and electron guns in general. These results allow us to quickly consider the spectral properties of regimes we have not yet explored, such as with extremely high wavelengths.

Effect of the density of states at the Fermi level on defect free energies and superconductivity: A case study of Nb$_3$Sn

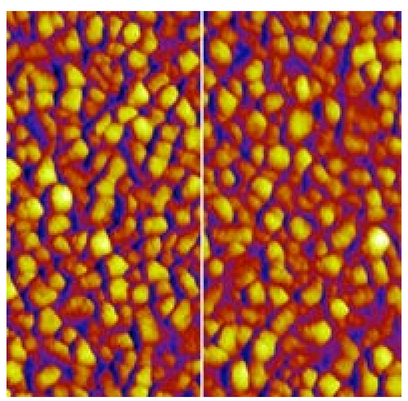
N. S. Sitaraman, M. M. Kelley, R. D. Porter, M. U. Liepe, T. A. Arias, J. Carlson, A. R. Pack, M. K. Transtrum, R. Sundararaman



This paper seeks to understand the behavior of defects in Nb$_3$Sn superconducting radiofrequency (SRF) cavities, in particular "antisite" defects where a niobium atom occupies the usual position for tin in the Nb$_3$Sn crystal and vice versa. We use the computational technique density functional theory (DFT) to calculate the effect of antisite defects on the electronic structure of Nb$_3$Sn.

Reduction of surface roughness emittance of Cs$_3$Sb photocathodes grown via codeposition on single crystal substrates

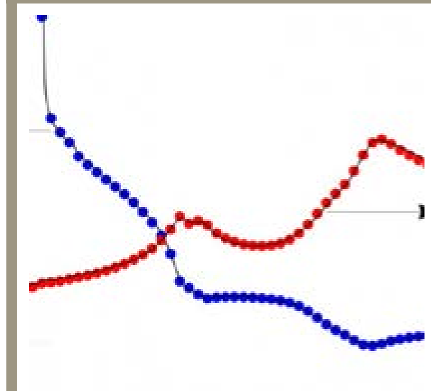
A. Galdi, J. Balajka, W. J. I. DeBenedetti, L. Cultrera, I. V. Bazarov, M. A. Hines, J. M. Maxson



Cs$_3$Sb and related compounds have been used for a long time without a real study of the growth mechanisms and how they affect the nanostructure of the photocathode materials. This study brings us closer to synthesizing these technologically important compounds in ordered form. This would allow better performances, more controlled properties and the opportunity to achieve a better theoretical understanding of the photoemission process.

Monte Carlo modeling of spin-polarized photoemission from p-doped bulk GaAs

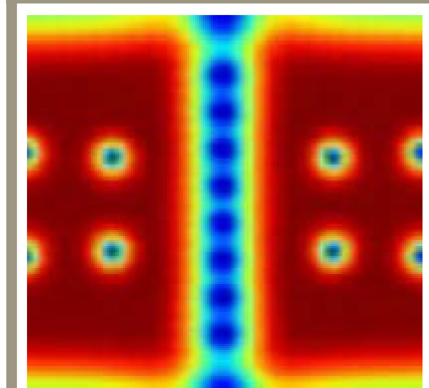
O. Chubenko, S. Karkare, D. A. Dimitrov, J. K. Bae, L. Cultrera, I. Bazarov, A. Afanasev



In this work we provide first-to-date Monte Carlo investigation of spin-polarized photoemission from bulk GaAs. We study in detail the influence of the photoexcitation energy, doping density, and electron affinity level on QE and electron spin polarization (ESP) simultaneously. We show that the behavior of both QE and ESP at room temperature can be fully explained by the bulk relaxation mechanisms and the time which electrons spend in the material before being emitted.

New simulations of magnetic vortex entry at grain boundaries Primary tabs

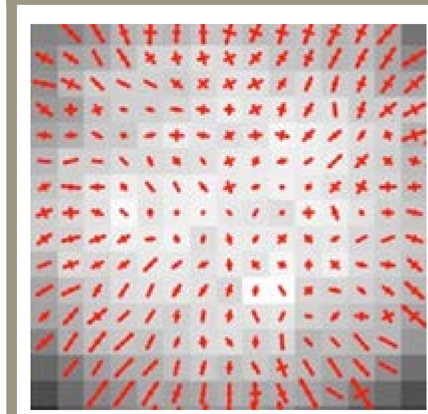
J. Carlson, A. Pack, M. K. Transtrum, J. Lee, D. N. Seidman, D. B. Liarte, N. S. Sitaraman, A. Senanian, M. M. Kelley, J. P. Sethna, T. Arias, S. Posen



Grain boundary defects in Nb$_3$Sn SRF cavities may limit the maximum magnetic field they optimally perform in. Using a finite element method, we computationally simulate these defects by mimicking surface roughness and Sn segregation. We find even small defects reduce the maximum magnetic field.

Robust Strain Mapping at Subnanometer Resolution & Subpicometer Precision

E. Padgett, M. E. Holtz, P. Cueva, Y.-T. Shao, E. Langenberg, D. G. Schlom, D. A. Muller



This project enhances the CBB's capabilities for the SRF thrust, especially for studying the polycrystalline Nb$_3$Sn coatings used in the superconducting RF cavities. The EWPC method provides a robust way to study the local strain distribution in polycrystalline Nb$_3$Sn coatings, providing materials insights into designing better SRF cavities.

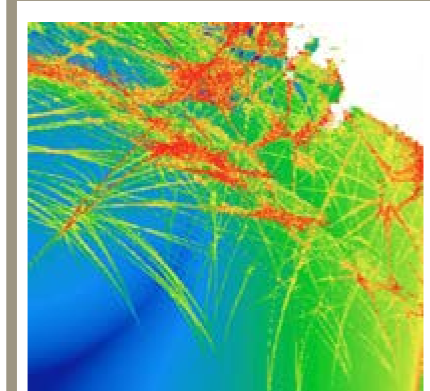
Multileaf Collimator for Real-Time Beam Shaping using Emittance Exchange

N. Majernik, G. Andonian, R. Roussel, S. Doran, G. Ha, J. Power, E. Wisniewski, J. Rosenzweig

We introduce the concept of using a multileaf collimator (MLC) in conjunction with an emittance exchange beamline to allow for finely resolved, real-time control over a beam's current profile. Prior to this advancement, the beam's profile was defined using laser cut masks which were installed into the UHV beamline, requiring days to change masks. However, by using a MLC, real-time iteration is possible; this new approach is highly synergistic with machine learning and should enable very high transformer ratio wakefield acceleration.

Conceptual Design Report: Optical Stochastic Cooling at IOTA

V. Lebedev, J. Jarvis, H. Piekarz, A. Romanov, J. Ruan, M. Andorf



Exploring methods of beam cooling with OSC to improve brightness in next generation particle colliders is a thrust of the Beam Dynamics and Cooling theme. This is the conceptual design report for the OSC experiment taking place in IOTA this year. The experiment aims to make the first ever experimental demonstration of OSC with electrons. The demonstration will be a major breakthrough in particle beam cooling and a critical step towards strong hadron cooling with OSC.

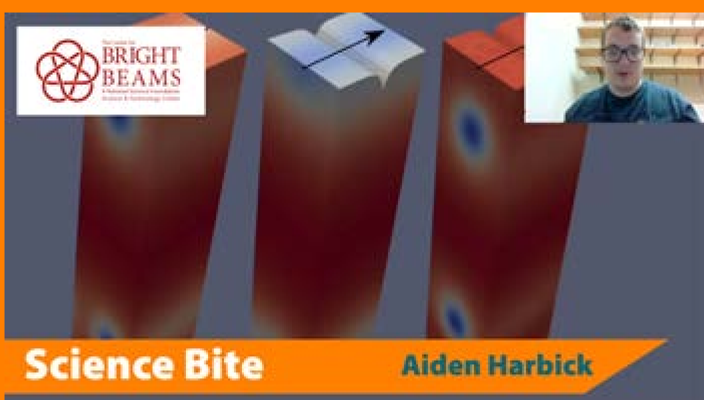
The COVID Impact

The early days of COVID-19 restrictions, which included significant lab occupancy reductions, resulted in a slowdown of CBB's experimental activities and an inability to provide hands-on lab training to our students who typically work side-by-side with their mentors. Additionally, supply chain interruptions led to further delays in research progress. Through creative scheduling and smart use of time outside of the lab we were able to significantly lessen the impact of these disruptions.

We are pleased that CBB research activities have resumed full force, moderated in particular instances by current national and international supply-chain and personnel issues that are still occurring due to COVID-19. While progress continues we still face the most important challenge of all - integrating our new team members into the center. We rely upon our in-person annual meetings to bring together our team from all corners of the U.S. for three full days of workshops, team building exercises, and research talks. While we've continued to host activities in a fully remote manner since 2020, it cannot replace the value that comes from meeting in person, especially for those who have joined us since the pandemic began. As we look to the future, we are excited to plan for our 2022 Annual Meeting that will take place at UCLA in the summer of 2022, bringing our team together, in person, once more.

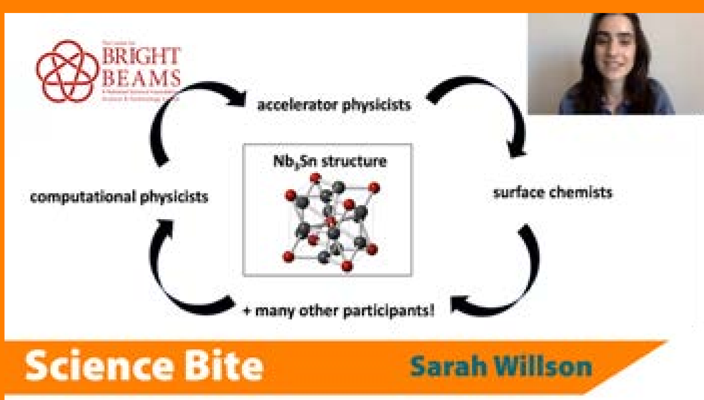
Science Bites

Short videos by our graduate students that explain how their work can lead to brighter beams and may make accelerators less expensive and more efficient. Check out the growing collection of science videos on the CBB YouTube Channel.

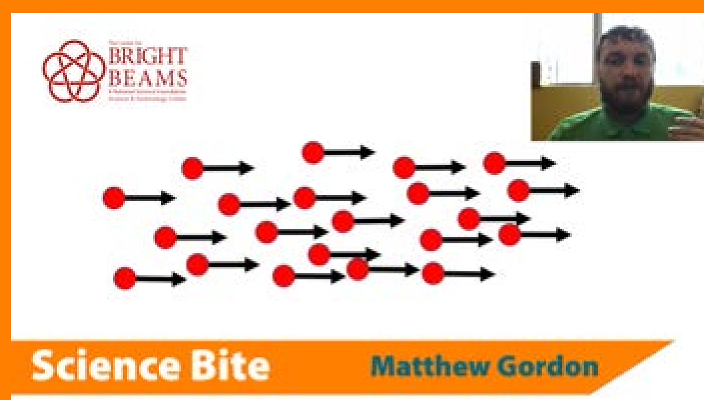


Aiden Harbick, Brigham Young University, explains how he conducts numerical simulations of superconductors to understand what the effects of various surface structures have on field enhancement.

Nathan Sitaraman, Cornell University, explains how he uses density functional theory (DFT) to understand chemical reactions at the atomic level.



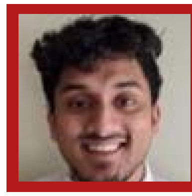
Sarah Willson, University of Chicago, explains how she uses surface chemistry studies to examine how individual Nb and Sn atoms interact to form Nb_3Sn with minimal defects.



Matt Gordon, University of Chicago, uses simulations to determine how bright beams can get in photocathodes.

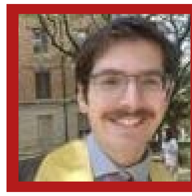
Welcome New CBB Members

We are delighted to welcome a number of new and returning members to CBB.

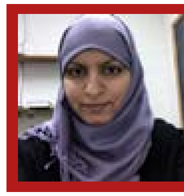


Vivek Anil
Graduate Student
Cornell University
Beam Production

Gabriel Gaitan
Graduate Student
Cornell University
Beam Acceleration



David Garcia
Graduate Student
UCLA
Beam Production



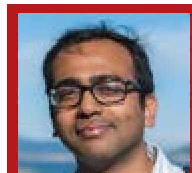
Afnan Al Marzouk
Theme Postdoctoral Fellow
Northern Illinois University
Beam Dynamics & Control

Alison McMillan
Graduate Student
University of Chicago
Beam Acceleration

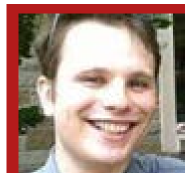
Liana Shpani
Graduate Student
Cornell University
Beam Acceleration

Recent Alumni

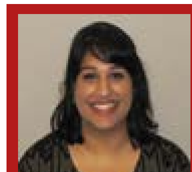
Recent Graduates



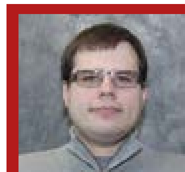
Nilanjan Banerjee
Postdoctoral Fellow
University of Chicago
Thesis: Towards More Efficient Accelerating Rf Systems: Superconducting Energy Recovery Linacs and Thermometry of High Q Cavities



Paul Cueva
Engineer
Corning Inc.
Thesis: Transforming 4D-Stem Data: Diffraction to Cepstra & Aberrations to Brightness

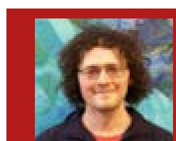


Lipi Gupta
Postdoctoral Fellow
Berkeley Lab
Thesis: Analytic and Machine Learning Methods for Controlling Nonlinearities in Particle Accelerators



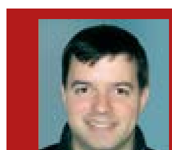
Nikita Kuklev
Postdoctoral Fellow
Argonne National Lab
Thesis: Experimental Studies of Nonlinear Integrable Optics

Departing Postdocs

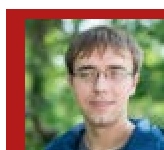


Matthew Andorf
Research Associate
Cornell University

Alice Galdi
Associate Professor
University of Salerno



Jacob Graham
Space Research Scientist
NASA



Ryan Roussel
Associate Scientist
SLAC

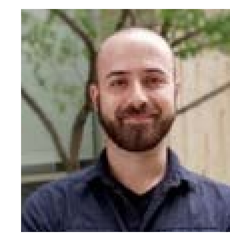
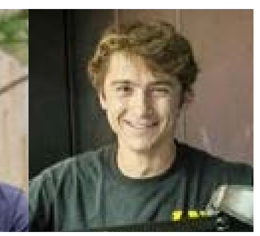
Good luck in your new positions!

Awards & Honors

Senior Investigator, Young-Kee Kim (University of Chicago), President Elect, American Physical Society

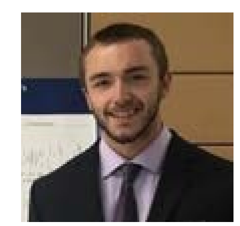
Professor Kim is a notable CBB scientist and key member of the leadership team. She leads initiatives in education and diversity and has shaped scientific direction.

"I am humbled by this moment and deeply grateful to my colleagues for their confidence and the opportunity to serve this amazing society. The mission of APS is to advance and diffuse the knowledge of physics for the benefit of humanity, promote physics, and serve the broader physics community. Never have these goals been more important than the present." Full Article

Graduate students AJ Dick (Northern Illinois University) and Chris Pierce (Cornell University)

Department of Energy Office of Science Graduate Student Research Program (SCGSR) Award. Chris Pierce is working on ultra-fast electron diffraction at Berkeley Lab and AJ Dick is working on IOTA at Fermilab.



Graduate student Jason Gibson (University of Florida)

- The Molecular Sciences Software Institute (MolSSI) Seed Software Fellowship

Graduate student Chris Knill (Arizona State University)

- The Arizona State College of Liberal Arts and Sciences (CLAS) Early Start Scholarship
- Steven Archer Scholarship Graduate Award
- CLAS Graduate Excellence Award

Graduate student Ryan Porter (Cornell University)

- Second place in the poster session at the 2021 International Conferences on RF Superconductivity (SRF'21)
- Douglas Fitchen Travel Award

Senior Investigator Kyle Shen (Cornell University), American Physical Society Fellow

For angle-resolved photoemission spectroscopy studies of quantum materials, and particularly for pioneering the investigation of thin films grown by molecular-beam epitaxy, enabling studies of new systems including heterostructures, materials under epitaxial strain, and atomically thin materials.

Diversity, Equity, and Inclusion

The Center for Bright Beams strives to have a measurable impact on the field of accelerator science and the pipelines that feed accelerator science. We work to recruit a diverse group of students and to create an environment in which all team members feel welcome and empowered.

CBB held a screening of Picture a Scientist, a film that chronicles the experiences of three women in science and provides new perspectives on how to make science itself more diverse, equitable, and open to all.

The film can be viewed on Netflix, Amazon, iTunes, and PBS Nova.

Following the screening, Adi Grabiner-Keinan, Ph.D., Executive Director for Academic DEI Education led an Intergroup Dialogue Project workshop. The exercises in this interactive workshop provided tools to help understand our privilege and how to communicate across differences. "I" Statements podcasts are available online (https://idp.cornell.edu/offerings/i-statements/).

Dr. Corrie Moreau, Professor of Arthropod Biosystematics and Biodiversity at Cornell University, led the CBB team in a presentation and dialogue on "Diversity in Science – An Everyone Issue."

The presentation can be viewed on YouTube

Mary James, A. A. Knowlton Professor of Physics & Dean for Institutional Diversity, Reed College and co-chair of the American Institute of Physics (AIP) TEAM-UP Task Force presented "What Does Access Really Mean? Findings from the AIP TEAM-UP Report."

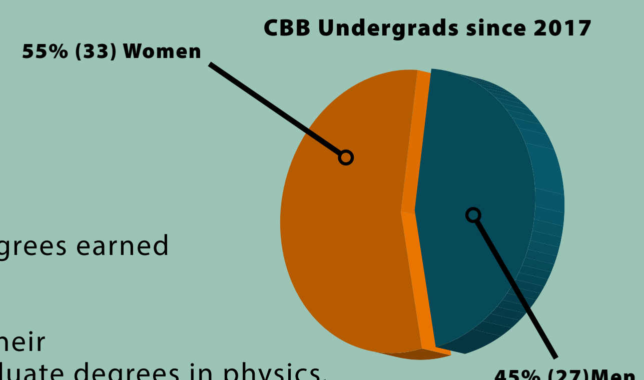
TEAM-UP identified five factors responsible for the success or failure of African American students in physics and astronomy: Belonging, Physics Identity, Academic Support, Personal Support, and Leadership and Structures.

Download the full report

To learn more about engaging young women in physics check out the APS STEP UP Program

STEP UP report states that only 20% of bachelor's degrees earned in 2015 were by women.

OF the forty men and women who have completed their bachelor's degrees, half have gone on to pursue graduate degrees in physics.



Summer Students - REU 2021

CBB strives to broaden the pipeline of accelerator scientists by increasing awareness of the discipline beyond the walls of national accelerator laboratories and by actively seeking out the participation of students and senior researchers from underrepresented groups. The Research Experience for Undergraduates (REU) has been a key component of this goal. Brigham Young University, University of Chicago, and Cornell University hosted CBB REU programs again this summer.

Contribute to cutting edge discovery.

Experience interdisciplinary research.

Learn alongside individuals from a wide range of nationalities, cultures, and educational backgrounds.

Explore unique areas of science.

Check out what a few of our 2021 REU students had to say!

Jael Lopez-Saucedo
Stanford University

"As I am reaching the end of this amazing experience, I have understood the benefit of different perspectives in a research team to fulfill goals. I was also reminded that researchers need self-motivation and self-learning methods to persist. Finally, I truly understood the importance of computational physics when analyzing complex phenomena. This program showed me that engaging in physics research is truly incredible. You use all your academic and personal tools to understand the world around you: your computational and communication skills, scientific abilities, and your identity. "

(more)

Zeinab Ismail
Saint John's University

"This experience has only reinvigorated my desire to earn a PhD in physics and become a researcher. Although in what I'm not sure yet. It also taught me that being a researcher is by no means easy. I always thought it was easier to study and work on an assignment when given ultimate freedom on how to work with it. However, after being given an assignment and having to navigate by myself to get the answer I realized it is not easy whatsoever. This realization means a lot to me."

(more)

Eva Guevara
University of Texas

"I have most enjoyed being a part of a larger research community and having such clarity about what the larger picture of my research is and where my project fits in. I have thoroughly enjoyed working with my smaller research group and participating in the larger CBB meetings."

(more)

CBB Advancing Superconducting Materials

A team of scientists at the Center for Bright Beams, a National Science Foundation Science and Technology Center, are working on the next generation of superconducting materials that will greatly reduce the costs associated with operating large particle accelerators.

Accelerators use superconducting radiofrequency (SRF) cavities, made from the element Niobium (Nb), to propel particles like electrons to nearly the speed of light. At superconducting temperatures, SRF cavities are nearly unencumbered by electrical resistance and contribute to areas such as medicine, industry, and basic research.

By making these cavities more efficient, researchers aim to lessen their environmental impact while also increasing the ability for smaller institutions and industry to use these critical research tools.

Particle accelerators are critical tools in the fight against climate change as they help strengthen new technologies such as lithium-ion storage capabilities and next-generation solar panels. However, the amount of energy required to operate some of these large machines is enormous, not only adding to the carbon footprint they seek to reduce, but also limiting their accessibility.

Their large consumption of power is a major hurdle for researchers, and is mostly due to one straightforward fact: the typical operating temperature of Niobium cavities is 2K, or - 456° F. In order to cool an accelerator cavity to these temperatures, it requires an intense amount of liquid helium based cooling (cryogenics), which is not readily available at smaller institutions.

At this rate, it is not feasible for industry, let alone smaller universities, to invest in SRF accelerator infrastructure needed for research and development. But imagine if they could.

Making accelerator technology more efficient can unleash a torrent of research. Higher operating temperatures could make an impact in not only energy development and storage but also medical treatments, large-scale sanitation, the semiconductor industry, as well as the critical endeavor of basic research.

"The current energy requirements of the world's largest particle accelerators are immense," explains Matthias Liepe, the head of the SRF cavity team at Cornell University, the lead institution of the Center for Bright Beams (CBB).

"Some of these really large machines that we're dreaming about—they're barely feasible with current technology," says Liepe. "You'd have to build a nuclear plant to run them, and that's certainly not within what's possible or [what] can be funded."

Liepe explains that the complexity, size, and power consumption of the cryogenics needed to operate these machines severely limits them to primarily large-scale, non-industrial accelerators. "Everything is reliant upon the performance and cost of the Niobium SRF cavities," says Liepe.

An interdisciplinary team of scientists at the Center for Bright Beams —from universities and national labs across the U.S. — are making significant strides in tackling this problem by revolutionizing SRF technology and employing next-generation materials, primarily Nb_3Sn.

The team is pursuing a more materials science-based approach to push RF performance of materials well-beyond the current level. CBB has already laid the foundation for further exploration of compound superconductors for SRF use, especially with Nb_3Sn, and has demonstrated that significant progress is achievable using its interdisciplinary skillset and tools.

"Niobium has been the state-of-the-art SRF material for decades due to its very good performance. And since it is a pure metal, it is fairly easy to make these cavities," says Sam Posen, former Cornell SRF graduate student and now Scientist and Deputy Division Head at Fermilab, and CBB affiliate. "While Nb_3Sn is a specific mixture of Niobium and Tin, it is somewhat harder to make cavities, but it can be very much worth the effort in a number of applications."

"The higher operating temperature will allow a company to cool their cavities with a small device called a cryocooler instead of a large, complex, and difficult-to-maintain cryogenic plant,"

Posen explains that Nb_3Sn turns superconducting at 18 Kelvin, allowing researchers to operate SRF cavities at much higher temperatures. This significant jump in operating temperatures can drastically alter the industrial landscape.

"The higher operating temperature will allow a company to cool their cavities with a small device called a cryocooler instead of a large, complex, and difficult-to-maintain cryogenic plant," says Posen. "This could enable new industrial particle accelerator applications, in domains like isotope production, wastewater treatment, and tools for the semiconductor industry."

High-efficiency SRF cavities employing CBB's next-generation surfaces will help overcome the cost barrier of future large-scale science accelerators and will make a critical contribution towards sustainable science, thereby advancing the energy and intensity frontier of science.

Within the first four years of the Center, CBB researchers have developed powerful theoretical and experimental tools for material screening and RF performance testing of samples and have used these tools to demonstrate promising material and growth options for further development including not only Nb_3Sn, but also NbN, and NbTiN.

CBB has made key contributions to reducing excess surface resistance of state-of-the-art, vapor-diffusion Nb_3Sn films and has demonstrated that vortex entry at grain boundaries, enhanced by overall surface roughness, is the likely source of premature failure of superconductivity (quench) of these films. Posen points to this cross-collaboration of CBB as a main reason for the Center's success, as CBB brings together experts in a range of fields, not just experimentalists, but also theorists who help better understand the results and guide improvements to the cavities. This collaboration between experiment and theory is not only applied to the acceleration of particles but also the production and transport of electron beams researched within CBB.

CBB has used this knowledge to develop improved Nb_3Sn nucleation (growth), coating, and post-processing procedures, which have already halved surface resistance. Nb_3Sn has now become the first-ever usable alternative to Nb for SRF cavities, enabling ~2x higher temperature operation and ~70% (~3x) lower cooling power needs, compared to clean bulk Nb.

Significant challenges remain in order to bring Nb_3Sn to full fruition. Energy losses must be reduced even further and higher accelerating fields would increase the range of applications. Other promising compound superconductors and structured layers should also be explored.

While these feats are being pursued, Posen says that CBB scientists and others will continue to build on the work that has come before them. Much of this research has been conducted over the past decade at Cornell University with funding provided by the Department of Energy (DOE). This funding allowed researchers Liepe and Posen to achieve a first ever demonstration of a high-performance Nb_3Sn coated SRF accelerator cavity.

In the longer term, the CBB team hopes that Nb_3Sn cavities could be used for high-energy linear colliders, as Nb_3Sn is predicted to withstand higher electromagnetic fields than niobium. "So far this hasn't been demonstrated yet," says Posen, "but we've been making steady progress towards this exciting goal."

Year 6 Projects

PI Name	Projects	Theme	Students & Post-docs
Arias	Ab initio theory of photoemission and of photomaterials	PHC	J. Kevin Nangoi (GRA)
Arias	Ab initio studies of lattice and electron excitations relevant to SRF performance and inverse-Q behavior	SRF	Michelle Kelley (GRA)
Arias	Ab initio study of Nb and Nb_3Sn surfaces and interfaces relevant to SRF performance	SRF	Nathan Sitaraman (GRA)
Bazarov	Cryogenic photocathode characterization in a low voltage electron gun	PHC/BDC	Chris Pierce (GRA)
Bazarov	Feedback systems and isochronus lattice developments for optical stochastic cooling stability	BDC	Samuel Levenson (GRA)
Biedron	Application of Machine Learning in Compact Photoinjectors	BDC	Aasma Aslam (GRA)
Hennig	Computational synthesis of photocathodes by epitaxial growth	PHC	Jason Gibson (GRA)
Hennig	Thermodynamics and superconducting properties of novel SRF superconductors	SRF	Ajinkya Hire (GRA)
Hines	Air-stable, high performance photocathodes	PHC	Amy Zhu (GRA), Dulanga Somaratne (PD)
Hoffstaetter	Operating hadron coolers with Machine Learning	BDC	Lucy Lin (GRA)
Karkare	Development of the ASU-DC cryogun	BDC	Gevork Gevorkyan (GRA)
Karkare	Optical and X-ray characterization of Alkali-antimonides	PHC	Pallavi Saha (GRA)
Karkare	Nano-scale photoemitters	PHC	Oksana Chubenko (PD)
Karkare	Measurements of low energy electron distributions	PHC	Chris Knill (GRA)
Kim	Brightness limiting effects of point to point space charge	BDC	Matt Gordon (GRA)
Liepe	Advanced Growth Methods for Next-Gen SRF Surfaces	SRF	Gabriel Gaitan (GRA)
Liepe	Electroplating based Growth and Surface Oxides	SRF	Zeming Sun (PD)
Liepe	High-field Nb_3Sn	SRF	Liana Shpani (GRA)
Liepe	SRF Surfaces by Design	SRF	Thomas Oseroff (GRA)
Maxson	MTE of easily oxidizable photocathodes both with and without protection coatings	PHC	William Li (GRA)
Maxson	Strongly nonlinear space-charge in photoinjectors with collimating apertures	BDC	William Li (GRA)
Maxson	High Gradient Testing and the Brightness of Epitaxial Alkali Antimonides	PHC	Chad Pennington (GRA)
Maxson	Growth and Characterization of the Epitaxial Alkali Antimonides: Exploring growth parameters, MET, QE, and robustness	PHC	TBD
Maxson	Demonstrating Emittance Preservation in Ultrafast Electron Micro-Diffraction	BDC	Cameron Duncan (GRA)
Muller	Microscope Tuning by ML and Emittance Optimization	BDC	Chenyu Zhang (PD)
Muller	Nb_3Sn Composition, Strain and Electronic Structure	SRF	Zhaslan Baraissov (GRA)
Musumeci	Advanced photocathodes testing in high gradient RF gun at the UCLA Pegasus Laboratory	PHC/BDC	David Garcia (GRA)
Musumeci	Advanced beam manipulations enabled by novel computational techniques in beam physics	BDC	Eric Cropp (GRA), Jack Isen (GRA), & Veronica Guo (UG)
Piot	Optical Transport and Beam Manipulation for Optical Stochastic Cooling	BDC	AJ Dick (GRA)
Piot	Exploring the Impact of Radiation Field on Brightness	BDC	Afnan Al Marzouk (PD)
Rosenzweig	Optimization of ultra-compact free-electron laser performance with very low MTE photocathodes	BDC	Nathan Majernik (PD), Lawler (GRA)
Rosenzweig	Extreme High Brightness Electron Source from Intense Laser Illumination of Nano-Blades	PHC/BDC	Joshua Mann (GRA), Gerard Lawler (GRA)
Shen	Atomically Ordered & Engineered Materials for Photocathodes	PHC	Vivek Anil (GRA)
Sibener	Surface scattering studies that Connect Atomic-Scale Structure and Dynamics to the Superconductivity of SRF Materials	SRF	Alison McMillan (GRA), Caleb Thompson (GRA)
Sibener	Investigating the Atomic and Micron-scale Morphological Development of Nb_3Sn Homogeneous Thin Films	SRF	Rachael Farber (PD), Sarah Willson (GRA)
Sibener	Detecting and Visualizing Alloy Growth Mechanisms of Next-Generation SRF Materials	SRF	Rachael Farber (PD), Sarah Willson (GRA)
Transtrum	Time-Dependent Ginzburg-Landau studies of realistic materials and surfaces	SRF	Aiden Harbick (GRA)
Transtrum	Optimizing surface layers for SRF Performance	SRF	Benjamin Francis (PD)

Recent Publications

Full publications list online at https://cbb.cornell.edu/publications

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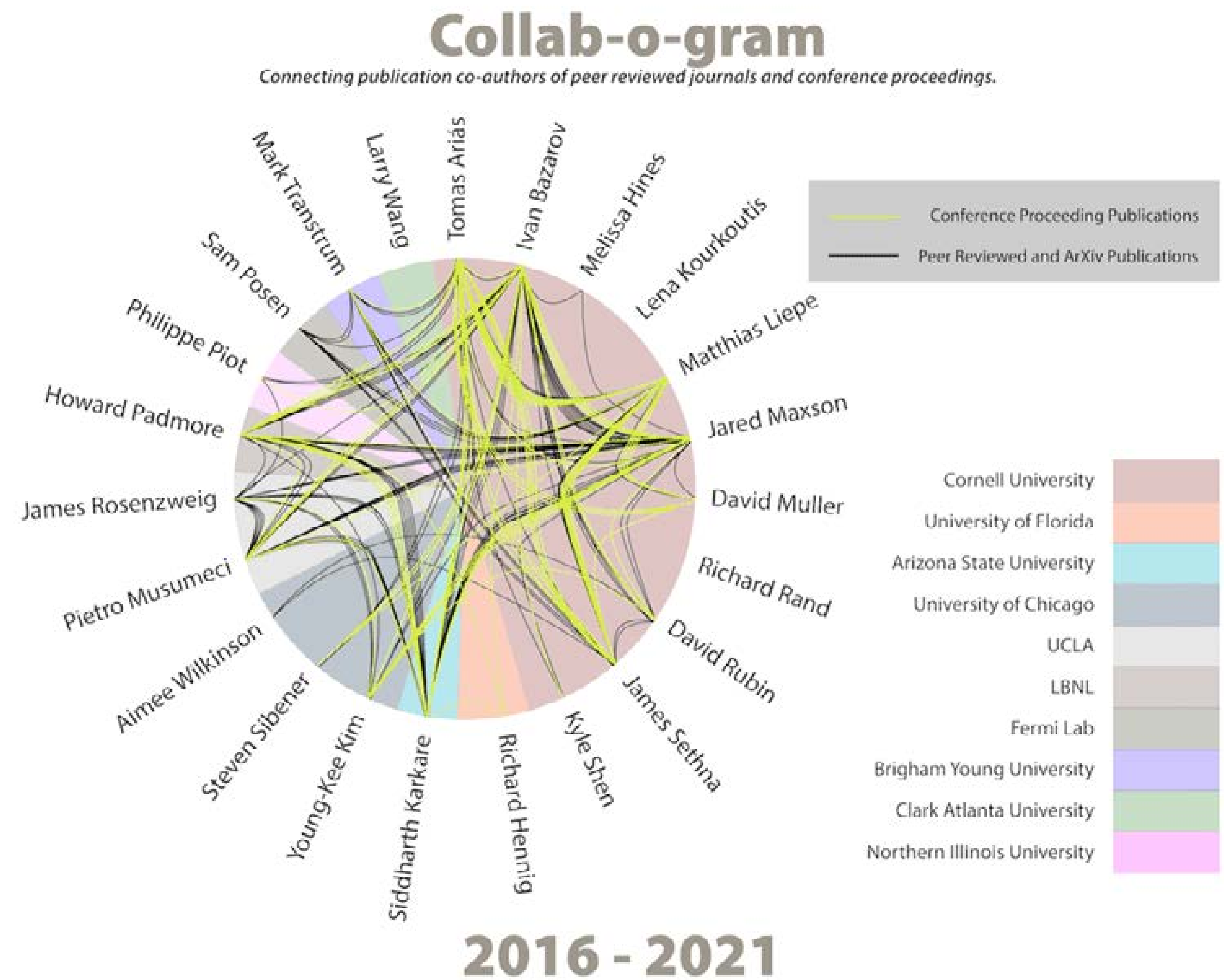
72 of 168 (43%) of CBB publications and conference presentations are authored by multiple center PIs



Co-authorship of CBB peer-reviewed or arXiv papers and conference proceedings. CBB senior investigators are shown around the circle, and the lines connecting them indicate co-authorship