The Center for BRIGHTBEAMS

A NATIONAL SCIENCE FOUNDATION SCIENCE & TECHNOLOGY CENTER

NEWSLETTER

SPRING 2020

As we hunker down under the threat of COVID-19, I'm pleased to bring you news of CBB accomplishments. For sure, CBB has felt COVID-19's impact. Hardest hit are our experimenters, and because our research is highly interdependent we are all affected by the loss of their observations. Nevertheless, I am impressed by CBB drive during this time - we are making progress and our discussions are as lively as ever. Indeed, if there are future health crises, CBB discoveries may help find a cure.

Ritchie

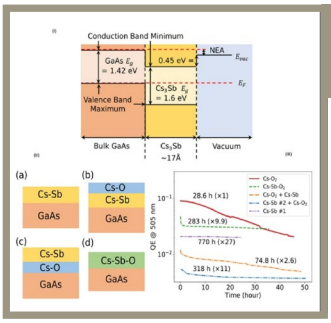
Ritchie Patterson
Director of the Center for Bright Beams

Gaining the fundamental understanding needed to transform the brightness of electron beams available to science, medicine and industry.

We recently created a video originally meant to air at the APS March meeting. The video showcases how important accelerator technology is to the advancement of technology and research. You can watch the video on our YouTube channel.

In This Issue

Research Highlights



Improved lifetime for GaAs based photocathodes

Jai Kwan Bae, Alice Galdi, Luca Cultrera, Frank Ikponmwen, Jared Maxson, Ivan Bazarov

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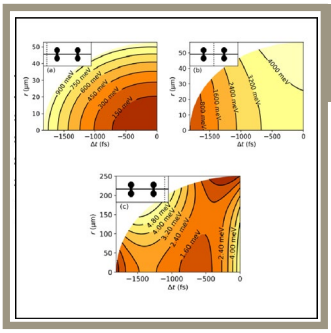
Image: (I) With a proper material choiche the hetero-structure junction forming with another semiconductor can result in the NEA formation; (II) different recipes for the hetro-junction were studied; (III) lifetimes measured at 505 nm indicating that up to a factor 10 larger lifetime can be achieved with minimal efficiency losses.



Lossless Monochromation for Electron Microscopy with Pulsed Photoemission Sources and Rf Cavities

C. J. R. Duncan, D. A. Muller, J. M. Maxson

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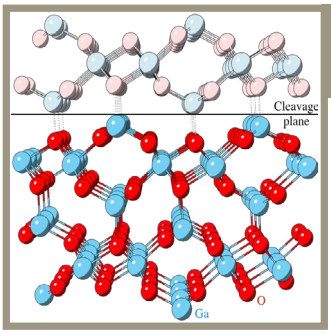
Image: simulated evolution of energy spread in an electron beam as it travels through our microwave monochromator; contours in panel (a) indicate the relative energy of particles before they enter the monochromator, which comprises the two rf cavities shown in the inset; (b) transiting the first cavity redistributes particle energy in time and space without reducing energy spread; (c) transiting the second cavity reduces the final energy spread to less than five percent the initial value.



Computational Synthesis of Substrates by Crystal Cleavage

Joshua T. Paul, Alice Galdi, and Richard G. Hennig

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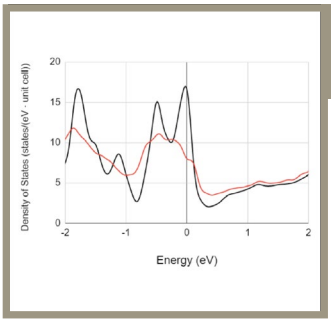
The readily cleavable material, Ga_2O_3, illustrates the core idea of our algorithm to search for crystal planes with a low density of bonds to identify candidate substrate materials.



Ab Initio Study of Antisite Defects in Nb_3Sn: Phase Diagram and Impact on Superconductivity

Nathan S. Sitaraman, Michelle M. Kelley, Ryan D. Porter, Matthias U. Liepe, Tomás A. Arias, Jared Carlson, Alden R. Pack, Mark K. Transtrum, and Ravishankar Sundararaman

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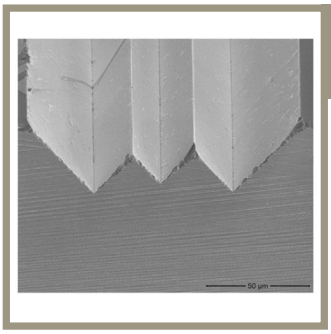
Image: Density of states versus energy difference from Fermi level in pure Nb_3Sn (black) and in grain boundary calculation(red).



Electron Diagnostics for Extreme High Brightness Nano-Blade Field Emission Cathodes

Lawler, G.; Sanwalka, K.; Zhuang, Y.; Yu, V.; Paschen, T.; Robles, R.; Williams, O.; Sakai, Y.; Naranjo, B.; Rosenzweig, J.

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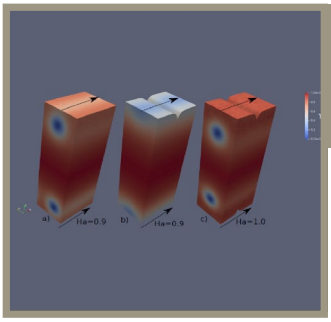
Image: Wet-etched gold-coated nano-blade cathodes using scanning electron microscopy (SEM). Note the double-blade geometry. Photo at 100 micron scale and 45 degrees relative to surface normal.

Research Highlights cont'd



Role of surface defects and material inhomogeneities for vortex nucleation in superconductors within time-dependent Ginzburg-Landau theory in 2 and 3 dimensions

Alden R. Pack, Jared Carlson, Spencer Wadsworth, Mark K. Transtrum

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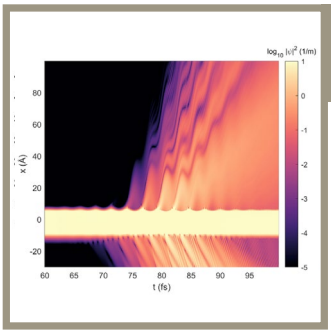
Image: Here we plot the norm squared of the superconducting order parameter on a 3D film. The norm squared of the order parameter is a measure of how superconducting the material is, zero being nonsuperconducting and 1 being the typical superconducting state.



1D Quantum Simulations of Electron Rescattering with Metallic Nanoblades

J. Mann, G. Lawler, and J. Rosenzweig

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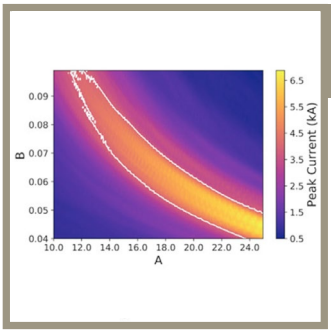
Image: A focused view of the electron probability density in space over time. The electron begins at its ground state in the metal towards the left. As the external field is applied, the electron may be excited and/or tunnel out of the metal. Once outside the metal, it may propagate and either return to the metal or escape permanently. Various energy bands may be seen just from this image from the different slopes of electron probability density bunches.



Compression of Ultra-High Brightness Beams for a Compact X-ray Free-Electron Laser

R. Robles and J. Rosenzweig

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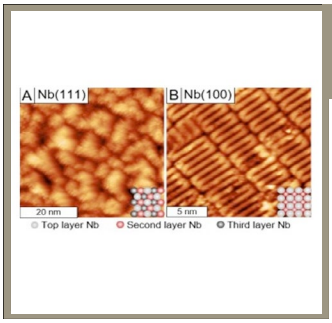
Image: Peak current of the microbunches as a function of normalized modulation amplitude and chicane compression. The white contour line denotes 4 kA current.



Oxygen dissolution and surface oxide reconstructions on Nb(100)

R. D. Veit, N. A. Kautz, R. G. Farber, and S. J. Sibener

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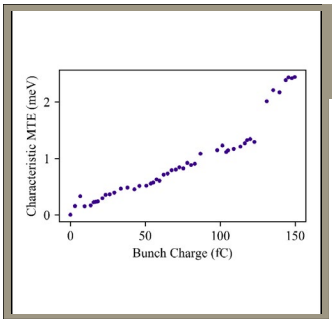
Image: STM images show surface crystallographic orientation effects on NbO surface structure. A) V = - 0.5 V, I = - 0.1 nA. Nb(111) presents disordered oxide domains with no long-range order due to the open nature of the Nb(111) plane; B) V = -0.5 V, I = -19 pA. Nb(100) presents highly-ordered (nx1)-O superlattices due to the closely-packed Nb(100) plane.



The Role of Low Intrinsic Emittance in Modern Photoinjector Brightness

Christopher M. Pierce, Matthew B. Andorf, Edmond Lu, Matthew Gordon, Young-Kee Kim, Colwyn Gulliford, Ivan V. Bazarov, Jared M. Maxson, Nora P. Norvell, Bruce M. Dunham, Tor O. Raubenheimer

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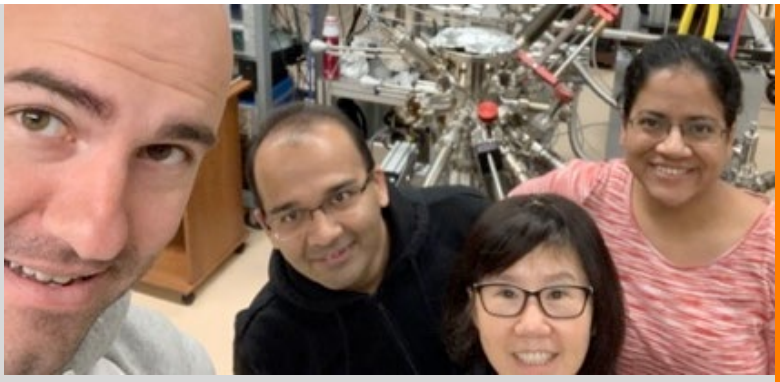
Image: The characteristic mean transverse energy (characteristic MTE) is a newly developed metric that sets the scale down to which photocathode improvements can make a difference in photoinjector brightness. The characteristic MTEs of the three systems we studied were well below the MTE of currently used photocathodes. This means that photocathode improvements are still a viable route to increase beam brightness.

Team Science! It's all about the team.

The CBB team, or "The Beam Team" is intellectually diverse, combining the expertise of accelerator scientists, condensed matter physicists, chemists, computer scientists and electron microscopists.

Often, these researchers lack common language for the same phenomena, and they bring varied expectations about publication practices, sharing early results, and even the frequency with which graduate students should attend conferences. CBB engages in numerous activities focused on overcoming these barriers and building a cohesive team. We have published our best practices in the CBB Handbook, which is now publicly available at the National Cancer Institue Team Science Toolkit and through the Cornell Library.



Collabrative Research: Prof. Young-Kee Kim (U. Chicago) of Beam Dynamics and Control collaborates with Prof. Sid Karkare and his graduate students Chris Knill and Pallavi Saha of Beam Production (Arizona St. U.)

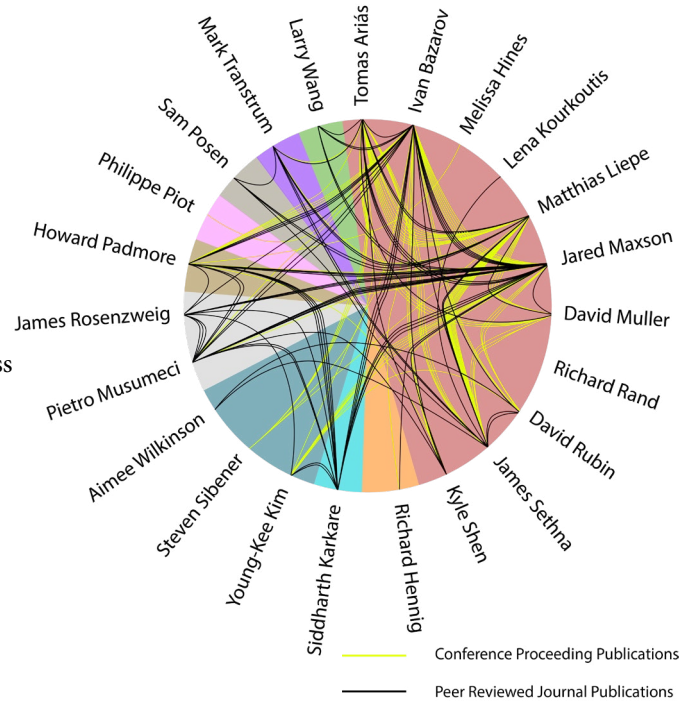
Team Science Success = Shared Goals + Collaboration across disciplines & institutions.

CBB team members from Cornell and Brigham Young at the SRF'19 conference in Dresden, Germany.

HOW WE SUCCEED

- Every project depends on the **diverse expertise** of at least two team members, typically from distinct disciplines.
- Our **Ontology** creates a common language.
- **Pedagogy lectures**, on the CBB YouTube Channel, create common knowledge.
- Frequent **meetings**: via Zoom and in person.
  - » Theme meetings, grad only meetings, joint theme meetings.
  - » Symposia and special seminars, industry panel discussions.
- **Inclusiveness** – mentor training, implicit bias awareness training and talks, diversity and equity seminars.
- Weekly **newsletter** keeps everyone informed.
- **Onboarding** for all participants.
- Public and internal **web site** and Indico pages
- CBB **lounges**.
- Video displays of CBB **research highlights**.
- Annual **poster sessions and blitzes.**
- **Travel exchange** program brings collabtorators together.
- **Celebrate** awards, honors, graduations, successes.
- **Always Improving** based on feedback from external Team Science evaluators.

Connecting publication co-authors of peer reviewed journals and conference proceedings.



49 of the 126 CBB publications have multiple PI authors.

Awards & Honors

The Center for BRIGHT BEAMS

Jai Kwan Bae
North American Particle Accelerator Conference 2019 Student Poster Prize

Jan Balajka
Royal Society of Chemistry Loschmidt Prize 2019

Paul Cueva
Microscopy Society of America Student Scholar Award

Lipi Gupta
University of Chicago Chair's Award for Distinguished Service

Young-Kee Kim
Korean Scientist of the Year 2019 - Korean Scientists and Engineers Association (U.S.) and the Korean Federation of Science and Technology (Korea)

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Nikita Kuklev
Fermi National Accelerator Lab 52nd Users Meeting Best Poster Award

Matthias Liepe
American Physical Society Fellowship

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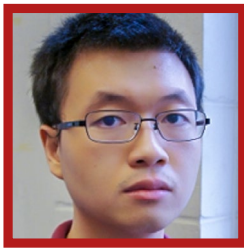
David Muller
Highly Cited Researcher (top 1% by citations in Physics) by Clarivate Analytics



Kevin Nangoi
CBB Symposium 2019 Best Poster Award

Joshua Paul
University of Florida Graduate School Preeminence Award

Ritchie Patterson
American Association for the Advancement of Science 2019 Fellow

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Jim Sethna
American Physical Society Fellowship

(more)

Sarah Willson
University of Chicago Nathan Sugarman Teaching Award in General Chemistry

Spotlight - Eric Cropp

ERIC CROPP - CBB Graduate Student @ UCLA

BERKELEY LAB

Eric is interning at the **Hi**gh **R**epetition Rate **E**lectron **S**cattering apparatus (HiRES) at Berkeley Lab. HiRES will function like an ultrafast electron camera, potentially producing images that can pinpoint defects and their effects, track electronic and superconducting properties in exotic materials, and detail chemical reactions in gases, liquids and biological samples that are difficult to study using more conventional, X-ray-based experiments.

We reached out to Eric to ask him a few questions.

What makes the program unique?

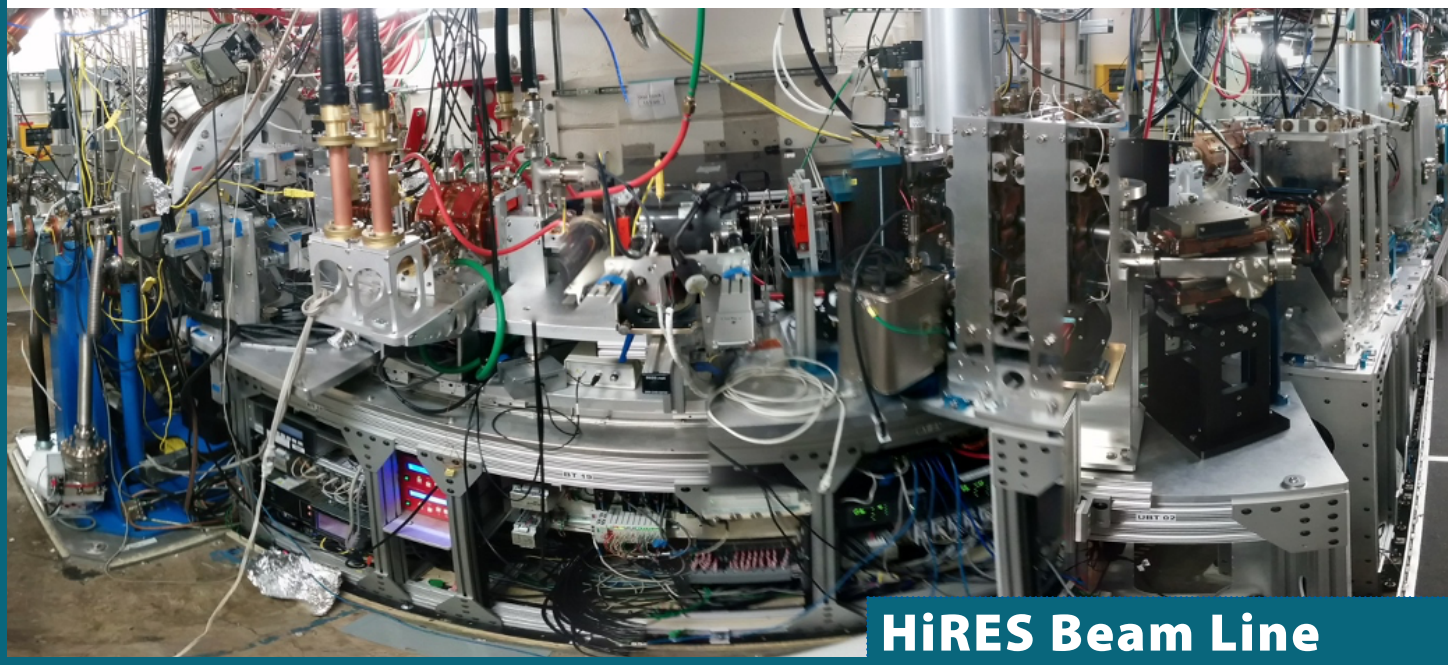
The **Hi**gh **R**epetition Rate **E**lectron **S**cattering apparatus (HiRES) is an electron beam line that is on the cutting edge of accelerator technology. Two unique points to the beam line are 1) it has the state-of-the-art electron gun (it was the prototype for LCLS-II), and 2) the capability of the HiRES gun to operate in continuous wave can allow for high repetition rate material studies, including Ultrafast Electron Diffraction (UED).

What is your project and why is it relevant to CBB?

My project is two-fold. The first part is to leverage my existing knowledge of beamline operations (that I learned at the PEGASUS laboratory at UCLA) to help with UED studies of 2-D materials. These materials are important to the future of solid-state science and potentially electronics and photovoltaics. The application of high brightness accelerators, in this case to UED, is central to CBB. The second part of my project is the study of the machine itself. In practice, this involves simulation, conventional optimization, and will involve machine learning, all in line directly with the goals of the third theme of CBB. The collaboration itself is also central to CBB's overarching objective, as the PEGASUS and HiRES laboratories are affiliated with CBB.

What milestones have you achieved and how will this prepare you for a career?

So far, studying HiRES and becoming a certified operator has been one milestone. Also, expanding the modeling tools for the beam line, especially the double bend achromat, has been a high point. Diversifying my experiences in graduate school and gaining experience at a national lab will help with my career.



HiRES Beam Line

US Particle Accelerator School

The U.S. Particle Accelerator School (USPAS) offers a graduate-level training and workforce development program in the science of particle beams and their associated accelerator technologies. USPAS hosts two sessions per year. The courses are intense and cover material not typically available at universities.

CBB's presence was strong at the January 2020 session.

CBB Students and faculty pictured alongside others

CBB Students and faculty pictured alongside others

SIX CBB members developed & taught courses based on research performed within the Center

Photocathode Physics
Instructors: Ivan Bazarov and Jared Maxson (Cornell U, CBB Faculty), Sid Karkare (Arizona State U, CBB Faculty). TA: Oksana Chubenko (Arizona State U, CBB Postdoc).

High Brightness Electron Injectors and Applications
Instructors: Daniele Filippetto (CBB affiliate) and Chad Mitchell of Lawrence Berkeley National Lab, Pietro Musumeci (UCLA, CBB faculty). TA: Oksana Chubenko (Arizona State U, CBB Postdoc).

Particle Driven Wakefield Accelerators
Instructors: James Rosenzweig (UCLA, CBB faculty), Michael Litos (U. of Colorado), Spencer Gessner (CERN).

12 CBB students attended

Jai Kwan Bae
Zhaslan Baraissov
Nathan Burger
Eric Cropp
AJ Dick
Cameron Duncan
Gevork Gevorkyan
Chris Knill
William Li
Chad Pennington
Chris Pierce
Pallavi Saha

CBB in USPAS Leadership

Matthias Liepe
Curriculum Sub-Committee

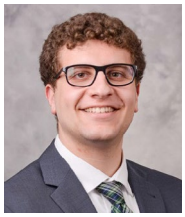
Young-Kee Kim
Directors Advisory Council

Georg Hoffstaetter
Directors Advisory Council

New CBB Members

Welcome to the Beam Team!

Zhaslan Baraissov
Graduate Student
Cornell University
David Muller



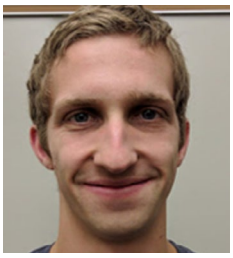
Sam Levenson
Graduate Student
Cornell University
Tomás Arias

Ryan Roussel
Postdoctoral Fellow
University of Chicago
Young-Kee Kim

Caleb Thompson
Graduate Student
University of Chicago
Steve Sibener

Sarah Willson
Graduate Student
University of Chicago
Steve Sibener

Recent Graduations



Alden Pack
Ph.D. Recipient
Brigham Young University
Thesis: Superconductivity
at its Limit: Simulating Superconductor Dynamics
Near the Superconducting Superheating Field in
Eilenberger and Ginzburg-Landau Theory

Aron Tesfamichael
Masters Recipient
Clark Atlanta University
Thesis: Adsorption And Decomposition Of
Organophosphorus Compounds On Metal Oxides

Happenings

CBB regularly hosts seminars and conferences. Stay up to date @ cbb.cornell.edu/

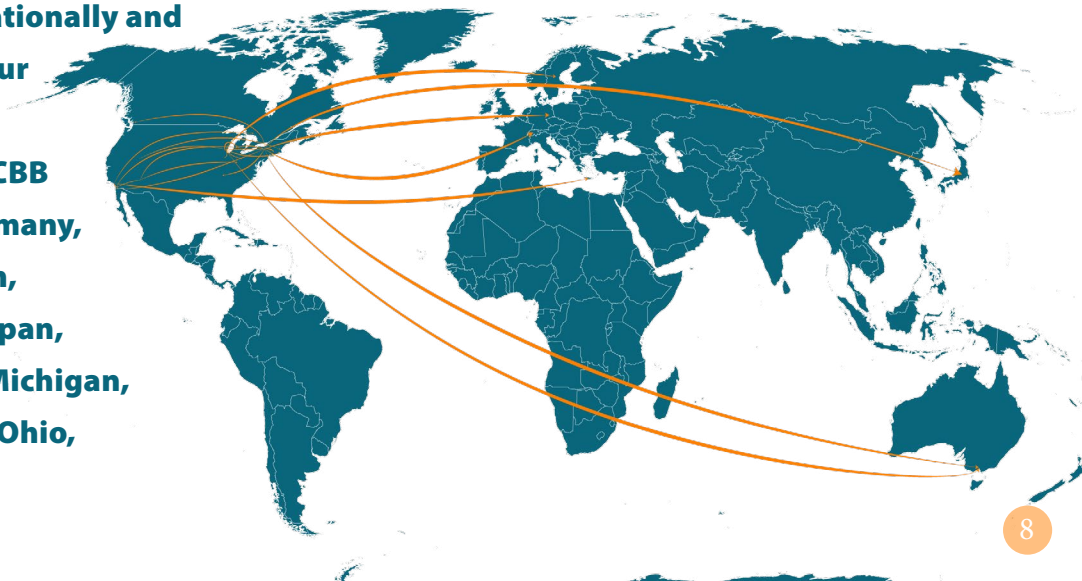
Fall, 2020:
- Nb3SnSRF'20 International Workshop: Niobium-3-Tin Superconducting Radio Frequency Science, Technology, and Applications, hosted at Cornell University Poster

July, 2020:
- Annual Symposium

May 13, 2020
- CBB Seminar - Prof. Alex Gurevich: "High brightness CW electron beams from superconducting RF photoemission gun."

CBB research is shared both nationally and internationally. In fact, since our last reporting, CBB students and postdocs have presented CBB research at conferences in Germany, Australia, Switzerland, Sweden, Greece, Ontario, Vancouver, Japan, Massachusetts, Connecticut, Michigan, California, Tennessee, Illinois, Ohio, and Rhode Island.

cbb.cornell.edu



Recent Publications

2020

C. Hansel, W. An, W. Mori, and J. B. Rosenzweig, "Nonlinear equilibria and emittance growth in plasma wakefield accelerators with ion motion," arXiv:2003.12062 [physics], Mar. 2020 [Online].

J. Carlson, A. Pack, M. K. Transtrum, J. Lee, D. N. Seidman, D. B. Liarte, N. Sitaraman, A. Senanian, J. P. Sethna, T. Arias, and S. Posen, "Analysis of Magnetic Vortex Dissipation in Sn-Segregated Boundaries in Nb3Sn SRF Cavities," arXiv:2003.03362 [cond-mat, physics:physics], Mar. 2020 [Online].

J. B. Rosenzweig, N. Majernik, R. R. Robles, G. Andonian, O. Camacho, A. Fukasawa, A. Kogar, G. Lawler, J. Miao, P. Musumeci, B. Naranjo, Y. Sakai, R. Candler, B. Pound, C. Pellegrini, C. Emma, A. Halavanau, J. Hastings, Z. Li, M. Nasr, S. Tantawi, P. Anisimov, B. Carlsten, F. Krawczyk, E. Simakov, L. Faillace, M. Ferrario, B. Spataro, S. Karkare, J. Maxson, Y. Ma, J. Wurtele, A. Murokh, A. Zholents, A. Cianchi, and D. Cocco, "An Ultra-Compact X-Ray Free-Electron Laser," arXiv:2003.06083 *[cond-mat, physics:hep-ex, physics:physics]*, Mar. 2020 [Online].

P. Denham, F. Cropp, and P. Musumeci, "Analysis of Skew Quadrupole Compensation in RF-Photoinjectors," arXiv:2003.00049 *[physics]*, Feb. 2020 [Online].

S. Karkare, G. Adhikari, W. A. Schroeder, J. K. Nangoi, T. Arias, J. Maxson, and H. Padmore, "Ultracold electrons via Near-Threshold Photoemission from Single-Crystal Cu(100)," arXiv:2002.11579 *[physics]*, Feb. 2020 [Online].

C. J. R. Duncan, D. A. Muller, and J. M. Maxson, "Lossless monochromation for electron microscopy with pulsed photoemission sources and rf cavities," arXiv:2002.11235 *[cond-mat, physics:physics]*, Feb. 2020 [Online].

A. R. Pack, J. Carlson, S. Wadsworth, and M. K. Transtrum, "Role of surface defects and material inhomogeneities for vortex nucleation in superconductors within time-dependent Ginzburg-Landau theory in 2 and 3 dimensions," *arXiv:1911.02132 [physics]*, Feb. 2020 [Online].

C. T. Parzyck, B. D. Faeth, G. N. Tam, G. R. Stewart, and K. M. Shen, "Enhanced surface superconductivity in Ba(Fe $_{0.95}$ Co $_{0.05}$) 2 As 2," *Applied Physics Letters*, vol. 116, no. 6, p. 062601, Feb. 2020, doi: 10.1063/1.5133647. [Online].

L. Cultrera, A. Galdi, J. K. Bae, F. Ikponmwen, J. Maxson, and I. Bazarov, "Long lifetime polarized electron beam production from negative electron affinity GaAs activated with Sb-Cs-O: Trade-offs between efficiency, spin polarization, and lifetime," *Physical Review Accelerators and Beams*, vol. 23, no. 2, Feb. 2020, doi: 10.1103/PhysRevAccelBeams.23.023401. [Online].

J. T. Paul, A. Galdi, and R. G. Hennig, "Computational Synthesis of Substrates and 2D Materials by Crystal Cleavage," arXiv:2002.00903 *[cond-mat]*, Feb. 2020 [Online].

2019

N. S. Sitaraman, J. Carlson, A. R. Pack, R. D. Porter, M. U. Liepe, M. K. Transtrum, and T. A. Arias, "Ab Initio Study of Antisite Defects in Nb3Sn: Phase Diagram and Impact on Superconductivity," *arXiv:1912.07576 [cond-mat, physics:physics]*, Dec. 2019 [Online].

J. Mann, G. Lawler, and J. Rosenzweig, "1D Quantum Simulations of Electron Rescattering with Metallic Nanoblades," *Instruments*, vol. 3, no. 4, p. 59, Dec. 2019, doi: 10.3390/instruments3040059. [Online].

N. Majernik and J. Rosenzweig, "Design of Comb Fabricated Halbach Undulators," *Instruments*, vol. 3, no. 4, p. 58, Dec. 2019, doi: 10.3390/instruments3040058. [Online].

G. Lawler, K. Sanwalka, Y. Zhuang, V. Yu, T. Paschen, R. Robles, O. Williams, Y. Sakai, B. Naranjo, and J. Rosenzweig, "Electron Diagnostics for Extreme High Brightness Nano-Blade Field Emission Cathodes," *Instruments,* vol. 3, no. 4, p. 57, Dec. 2019, doi: 10.3390/instruments3040057. [Online].

J. K. Bae, A. Galdi, L. Cultrera, F. Ikponmwen, J. Maxson, and I. Bazarov, "Improved lifetime of a high spin polarization superlattice photocathode," *arXiv:1911.09609 [physics]*, Nov. 2019 [Online].

S. R. Xie, G. R. Stewart, J. J. Hamlin, P. J. Hirschfeld, and R. G. Hennig, "Functional form of the superconducting critical temperature from machine learning," *Phys. Rev. B*, vol. 100, no. 17, p. 174513, Nov. 2019, doi: 10.1103/PhysRevB.100.174513. [Online].

E. Padgett, M. E. Holtz, P. Cueva, E. Langenberg, D. G. Schlom, and D. A. Muller, "The Exit-Wave Power-Cepstrum Transform for Scanning Nanobeam Electron Diffraction. Part 1: Robust Strain Mapping at Subnanometer Resolution and Subpicometer Precision," *arXiv:1911.00984 [cond-mat]*, Nov. 2019 [Online].

J. Rosenzweig, "Towards an ultra-compact x-ray free-electron laser (Conference Presentation)," in *Advances in Laboratory-based X-Ray Sources, Optics, and Applications VII, 2019*, vol. 11110, p. 1111006, doi: 10.1117/12.2531143 [Online].

A. Pack and M. Transtrum, "Numerical Calculations of the Superconducting Superheating Field within Eilenberger Theory," in *Bull. of the Am. Phys. Soc.*, Prescott, Arizona, 2019 [Online].

Y.-K. Kim, "Program at the center for bright beams to recruit and train the next generation of scientists in accelerator and related fields," *AIP Conference Proceedings*, vol. 2160, no. 1, p. 040008, Oct. 2019, doi: 10.1063/1.5127688. [Online].