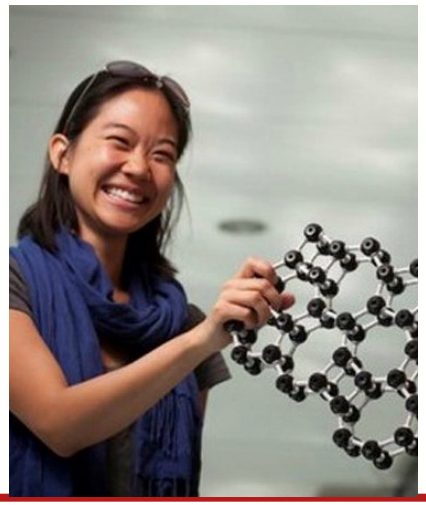
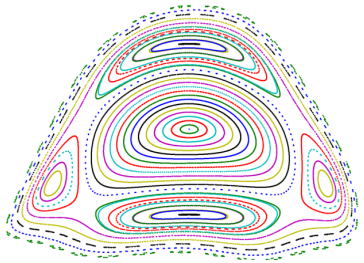
Center for
BRIGHT BEAMS
A National Science Foundation Science & Technology Center

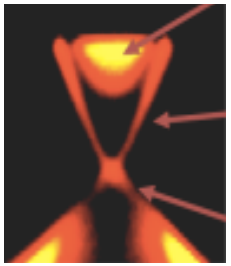
Center for Bright Beams Symposium 2018

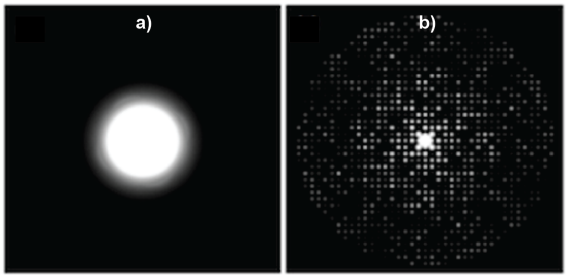
Center Overview

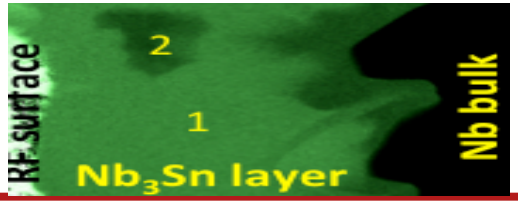
Ritchie Patterson, Director





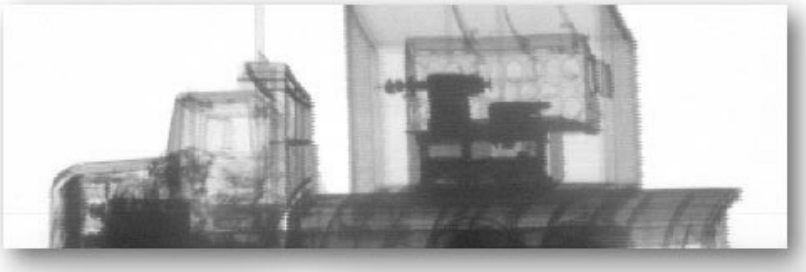


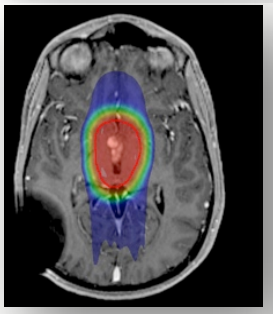




Why accelerators?

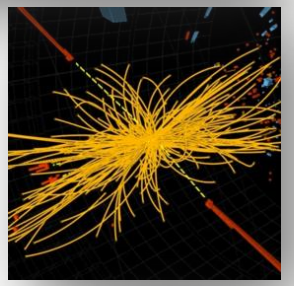
- Industry
  - Food & product safety
  - Contraband detection
  - Polymer cross-linking, eg tires
  - Semiconductor fabrication





- Medicine
  - Medical isotope production
  - Tumor treatment

~30,000 industrial and medical accelerators are in use, with annual sales of $3.5 B and 10% growth per year.



- Research
  - X ray sources and colliders for nuclear & particle physics
  - Electron microscopes

Since 1943, a Nobel Prize in **Physics** has been awarded to research benefiting from accelerators every 3 years.

Since 1997, the same has been true of **Chemistry**.

Center for Bright Beams - CBB

An NSF Science and Technology Center

Center Vision:
Revolutionize the brilliance of beams available to science, medicine and industry.

Center Mission:
Transform the reach of electron beams by

increasing brightness x100 and

reducing the cost and size of key technologies.

Transfer the best of these technologies to national labs and industry.

Prepare a diverse generation of students for a broad set of career paths.

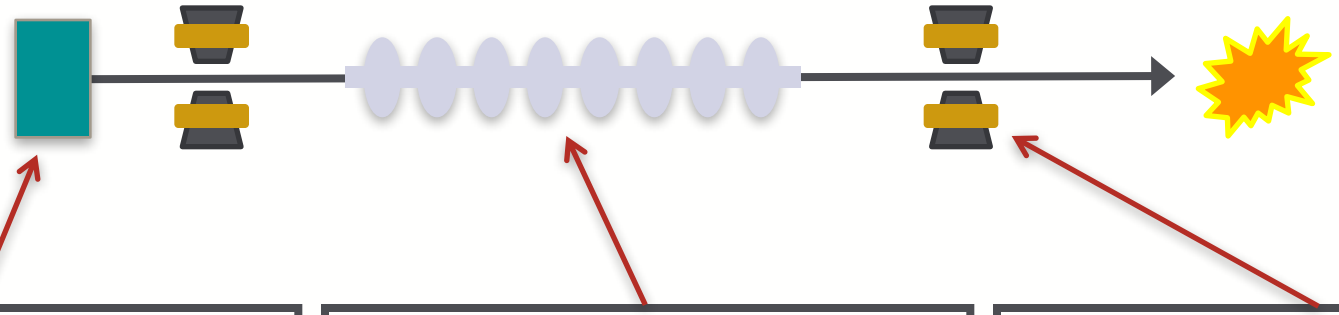
Cornell University
THE UNIVERSITY OF CHICAGO
UCLA
BYU
UF UNIVERSITY of FLORIDA
CLARK ATLANTA UNIVERSITY
UNIVERSITY OF TORONTO
MOREHOUSE COLLEGE
CHICAGO STATE UNIVERSITY
Fermilab
BERKELEY LAB
TRIUMF

LOW BRIGHTNESS
High emittance

HIGH BRIGHTNESS
Low emittance

Emittance =
Size x angular spread

CBB Research Themes



Beam Production

Methods for x100 brighter photocathodes

Beam Acceleration

Methods for superconducting RF accelerating cavities with x10 lower losses and x2 higher gradient

Beam Transport and Storage

Methods for beam transport that preserve x10 brighter beams

Integration of these methods in order to optimize high performance accelerator systems.

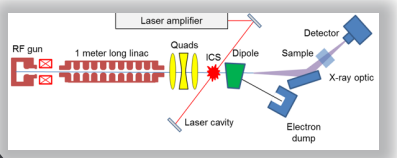
Impact of Brighter Beams

Bright Electron Beams

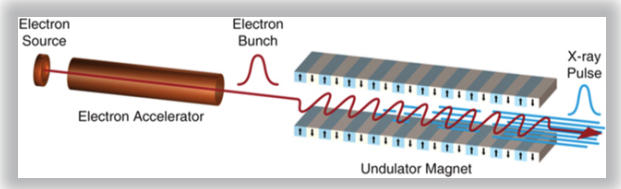
X-Ray Sources

Inverse Compton Scattering

W. Graves *et al.* PRSTAB, 17, 120701 (2014)



C. Pelligrini *et al.* Rev. Mod. Phys. 88 015006 (2015)

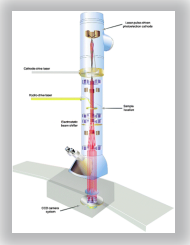


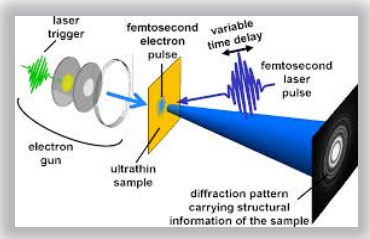
X-FELs

Time Resolved Electron Microscopy

Dynamic Transmission Electron Microscope (DTEM)

Armstrong *et al* Ultramicroscopy, 4, 356 (2007)

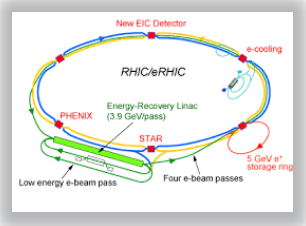




Ultrafast electron diffraction

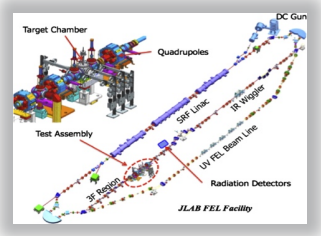
Particle Colliders

https://www.bnl.gov/rhic/news/081407/story1.asp



Electron-ion collider

Tschalär et al, NIMA, 729, 69 (2013)



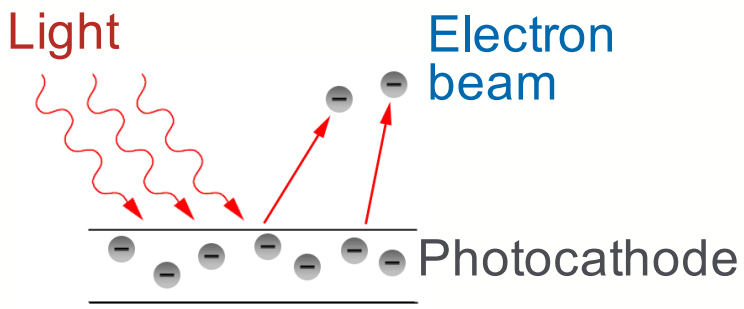
Dark Photon searches

Theme: Beam production

Goal:

Methods for x100 brighter electron beams through better photocathodes.

For brighter beams for X-ray sources, colliders and electron imaging.



Areas of investigation:

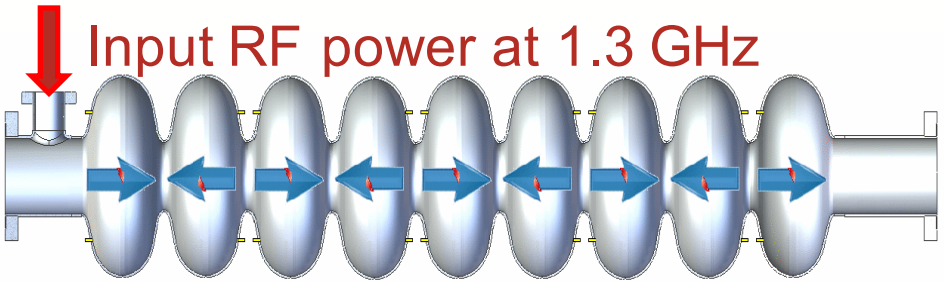
- Band structure, phonon scattering
- Ultrafast heating
- Surface roughness
- Multiphoton emission
- Tip arrays (eventually)

Sample discoveries:

- Two-photon emission dominates in copper photocathodes at the emission threshold for high laser fluence, and results in high transverse energy.

- Surface roughness drives transverse energy for alkali antimonide photocathodes.

Theme: Beam acceleration



Slowed down by factor of approximately 4x10⁹

Goals: Methods for

x10 lower power losses.

For lower costs, simpler refrigeration and wider access to high-power beams.

x2 accelerating gradient

Compound superconductors promise cheaper, more compact acceleration.

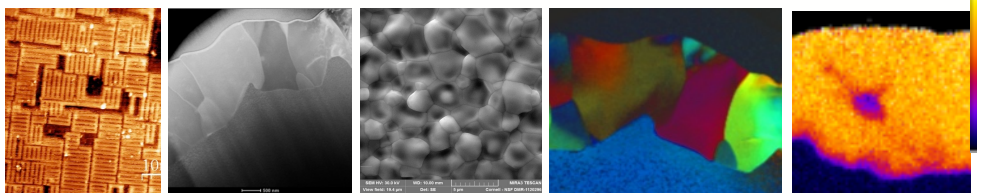
Areas of investigation:

- Doping effects in niobium
- Vortex nucleation & flux trapping
- Nb_3Sn growth, grain orientation and superconducting properties

Sample discoveries:

- The field in Nb_3Sn cavities is limited tin-depleted pockets

  .
- At high fields, viscous losses from trapped flux drive heating in niobium.

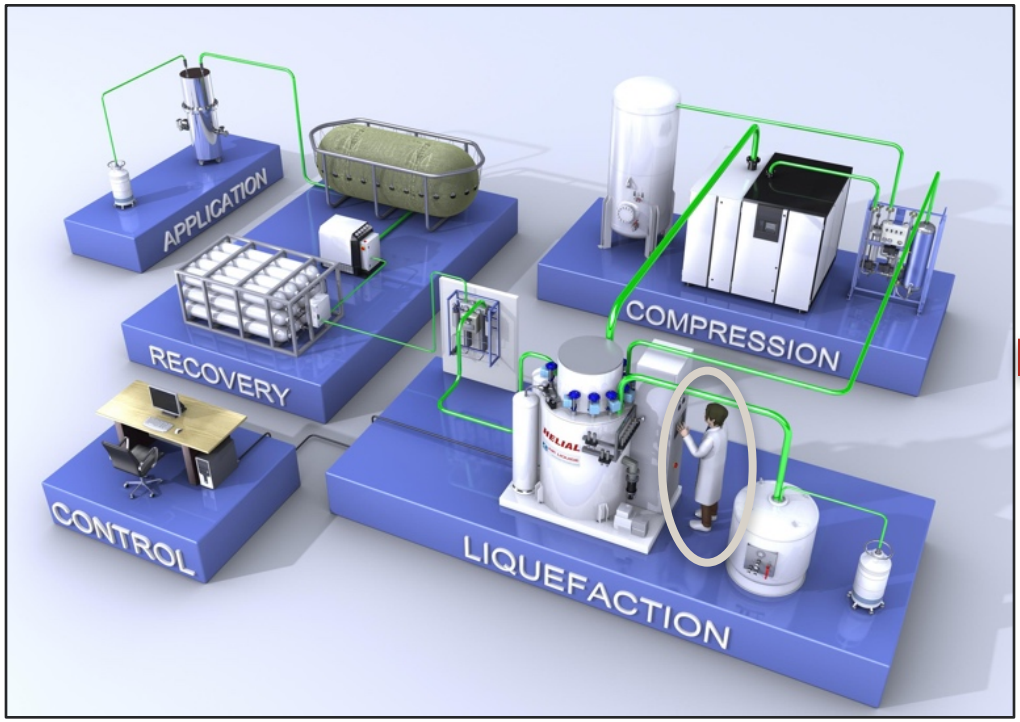


NbO on (100) Nb | *TEM cross section* | *Nb_3Sn grains* | *Grain Orientation in Nb_3Sn* | *Sn conc.*

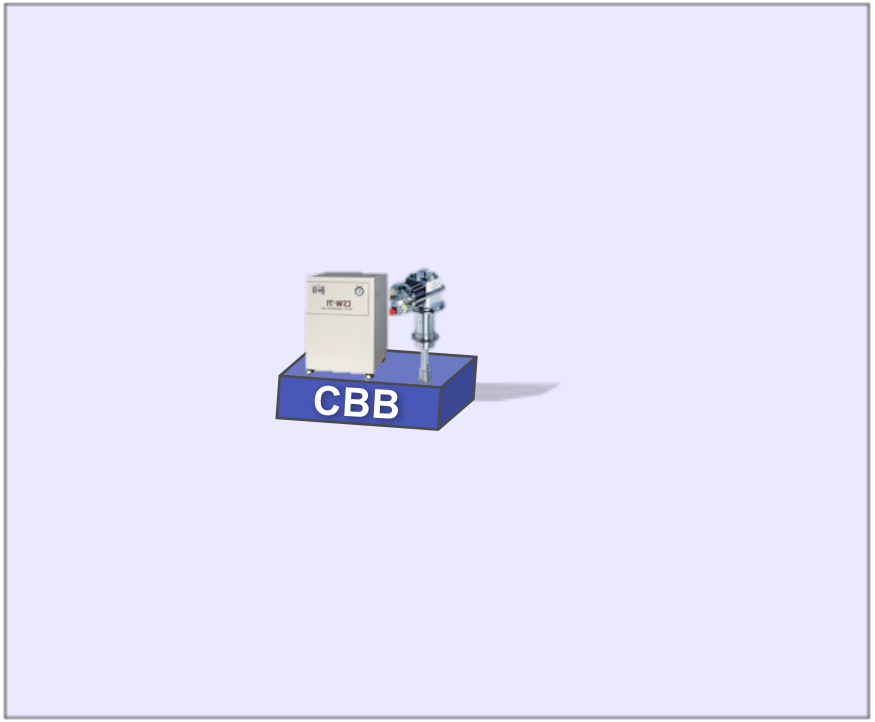
Impact for SRF operations

Superconducting RF refrigeration systems, for one cavity.

2K (Today) Cost: ~$1M

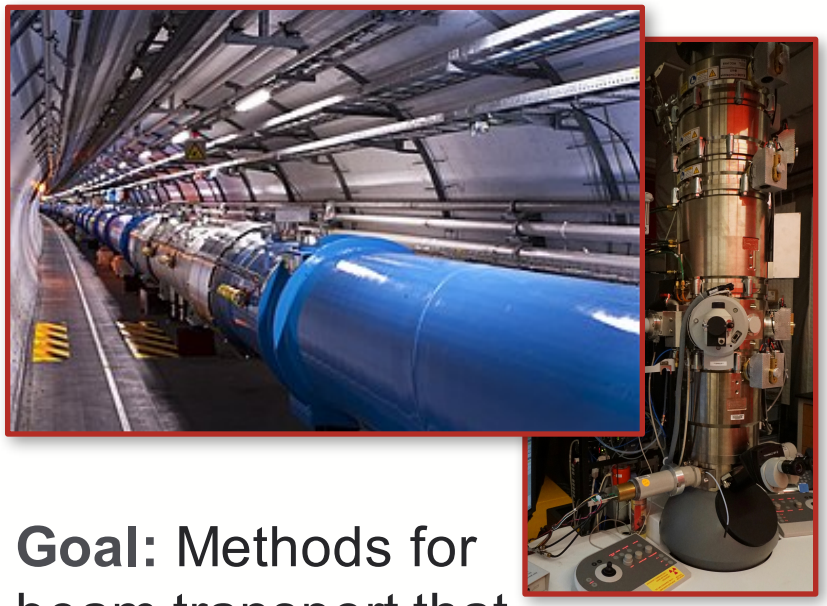


4.2K Cost: $50k



4.2K operation will make Superconducting RF vastly more accessible, enabling widespread use of high power beams in science and industry.

Theme: Beam transport and storage



Goal: Methods for beam transport that **preserve the quality** of

x100 brighter beams in linear accelerators and electron microscopes and

x10 brighter beams in storage rings.

For better, cheaper beam control.

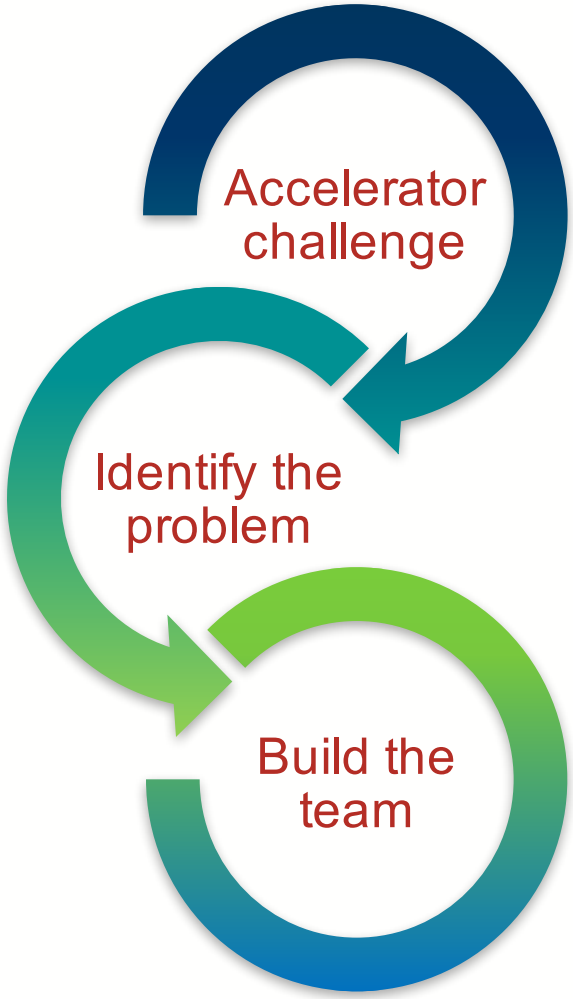
Areas of investigation:

- Emittance conservation of 100x brighter sources to the target.
- Real-time tuning of aberration correction in electron microscopes
- Nonlinearity optimization in storage rings
- Instability suppression via increased tune spread

Sample discoveries:

- Electron microscope tuning can be described with a sloppy model, reducing the number of tuning parameters from >100 to ~10.
- A new metric can identify sources of emittance dilution in UED setups.

CBB Team



- Accelerator science
- Surface chemistry
- Nonlinear dynamics
- Condensed matter physics
- Materials science
- Ultrafast electron microscopy
- Elementary particle physics

CBB success depends on teamwork.

Future Workforce

Grad student training

- Individual Development Plans
- Communications: Oral and written
- Mentoring training for all
- Entrepreneurship workshops
- Internships
- Improv workshop on teamwork
- Ethics education
- Implicit bias diagnostics

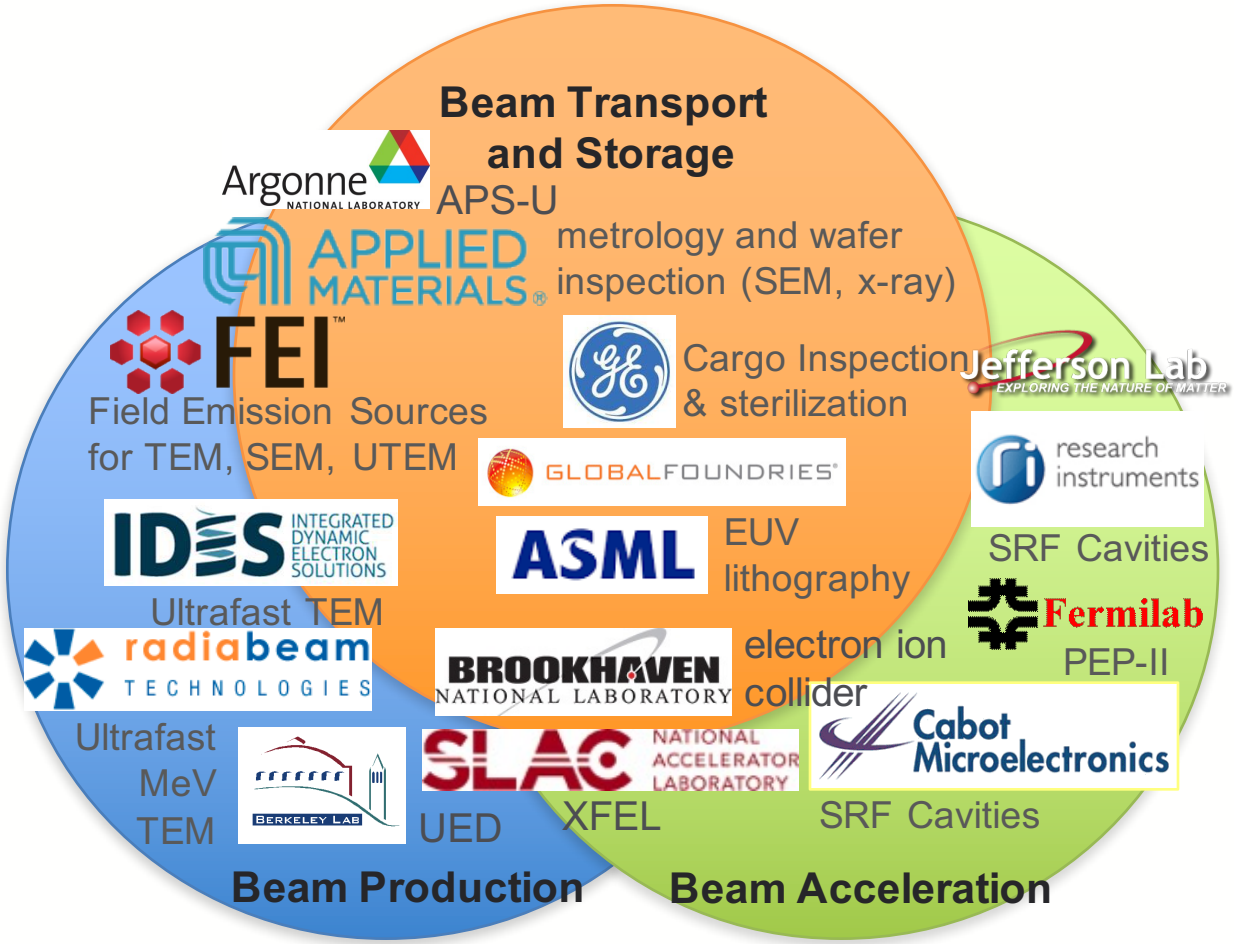
Building the STEM pipeline.

Science needs smart people.

- Close partnership with the Atlanta Consortium of minority-serving institutions
- Research Experience for Undergraduates from underrepresented groups
- *STEP UP!* and *Expanding Your Horizons* for middle school students and teachers.

Knowledge Transfer

- Transfer CBB approaches into new accelerators and commercial products.
- Prepare students for a broad range of career paths.

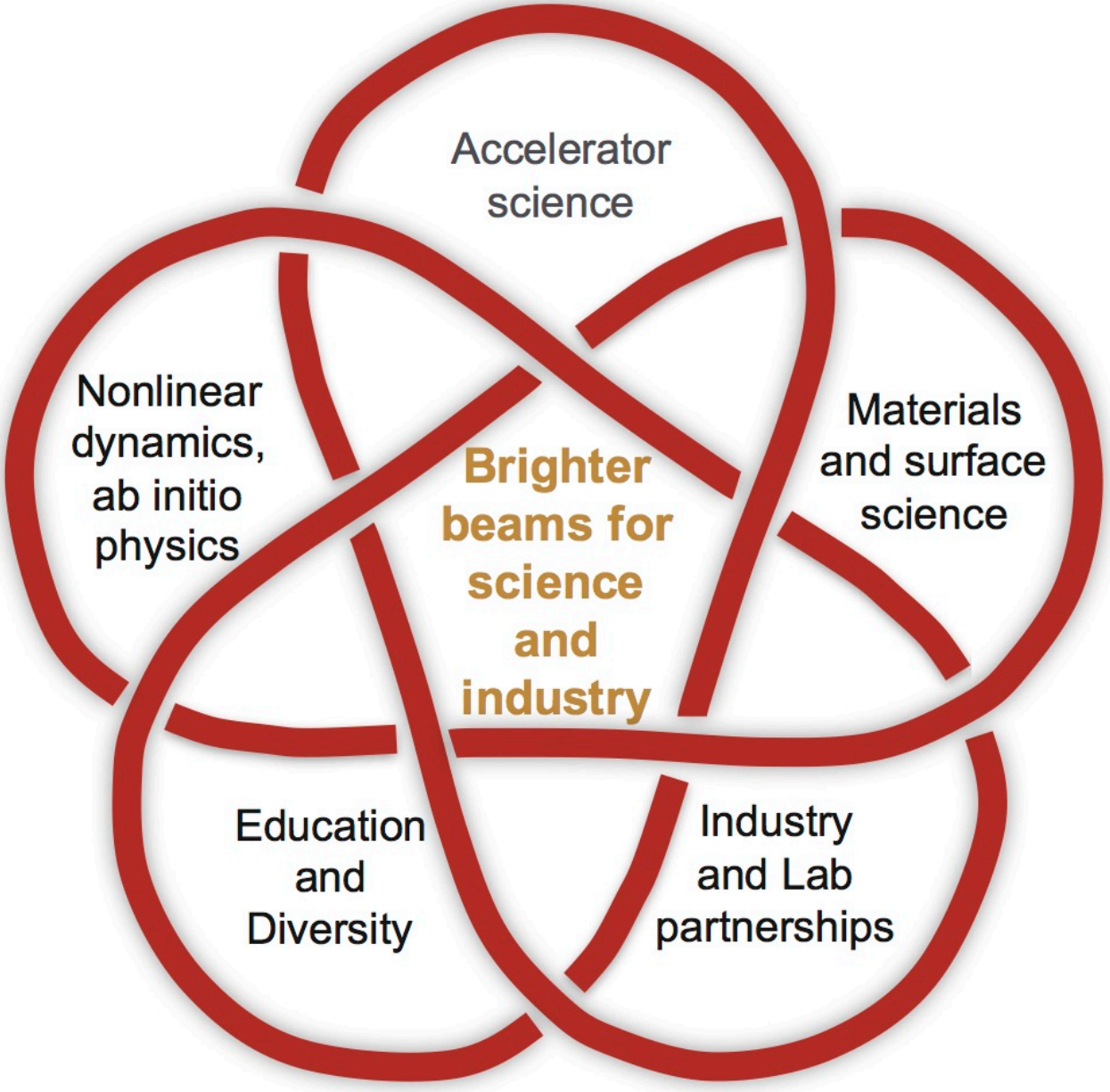


Get involved

- See an activity relevant to your lab or company?
  Tell us. We're eager to collaborate
  or transfer our know-how.

- Interested in connecting with our students and postdocs?
  Become a career mentor or offer an internship
  opportunity. Or spend a day with us,
  and tell us about your work and career.

Center for Bright Beams



Questions?