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

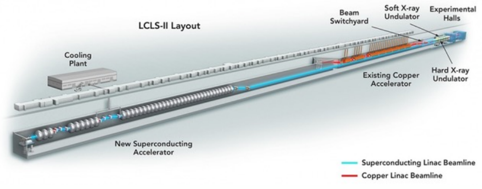
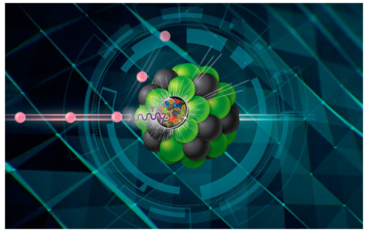
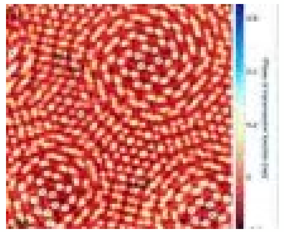
Beam Dynamics & Control (BDC) Discussion of Objectives & Prioritization (part I)

Optimal Outcome: *Methods for* ***beam transport*** *that preserve beam quality of* ***x100 brighter beams*** *in* ***linear accelerators*** *and electron microscopes and* ***x10 brighter*** *beams in* ***storage rings****.*

https://cbb.cornell.edu/research/beam-dynamics-and-control/beam-dynamics-and-control-team-and-projects

Objectives for Phase II

FY 22 | FY 23 | FY 24 | FY 25 | **FY 26**

Objectives	Deliverables	Legacy
Probe the limits of brightness conservation in the presence of collective effects in low MTE photoinjectors *(Conserve)*	Sources of emittance growth Cathode longevity testing capability List of parameters that determine emittance growth	 Increased scientific reach in X-ray FELs
Develop methods for cooling beams using optical stochastic cooling to increase beam luminosity in next-generation colliders *(Cool)*	Proof of principle demonstrations Configurations capable of very high cooling rates for future colliders Single-pass correction of beam distortion	 Higher luminosity electron-ion collider
Investigate advanced optimization schemes for precision phase-space control of particle accelerator systems *(Control)*	Methods for efficiently tuning accelerators **Summary of the boundaries of applicability of ML in accelerators**	 Active accelerator tuning and aberration control in electron microscopes

Current projects/personnel snapshot

Beam Dynamics and Control Team and Projects

Project Titles (PI / Postdoc or Grad Student):

- Advanced beam manipulations enabled by novel computational techniquesin beam physics (Musumeci / Cropp, Isen, Guo)
- Application of Machine Learning in Compact Photoinjectors (Biedron / Aslam)
- Brightness limiting effects of point to point space charge (Kim / Gordon)
- Demonstrating Emittance Preservation in Ultrafast Electron Micro-Diffraction (Maxson / Duncan)
- Development of the ASU-DC cryogun (Karkare / Gevorkyan)
- Exploring the Impact of Radiation Field on Brightness (Piot / Al Marzouk)
- Feedback System and Isochronous Lattice Development towards an Optical Stochastic Cooling Stability Experiment (Bazarov / Levenson)
- Microscope Tuning by ML and Emittance Optimization (Muller / Zhang)
- Operating hadron coolers with Machine Learning (Hoffstaetter / Lin)
- Optical Transport and Beam Manipulation for Optical Stochastic Cooling (Piot / Dick)
- Optimization of ultra-compact free-electron laser performance with very low MTE photocathodes (Rosenzweig / Majernik, Lawler)
- Strongly nonlinear space-charge in photoinjectors with collimating apertures (Maxson / Li)

Our Team:

Theme Leaders:

Young-Kee Kim, U Chicago

David Muller, Cornell

Philippe Piot, NIU

Senior Investigators:

Ivan Bazarov, Cornell

Sandra Biedron, UNM

Georg Hoffstaetter, Cornell

Siddharth Karkare, ASU

Young-Kee Kim, U Chicago

Jared Maxson, Cornell

David Muller, Cornell

Pietro Musumeci, UCLA

Philippe Piot, NIU

James Rosenzweig, UCLA

Graduate Students:

Aasma Aslam, UNM

Eric Cropp, UCLA

Cameron Duncan, Cornell

Austin (AJ) Dick, NIU

Gevork Gevorkyan, ASU

Matt Gordon, U Chicago

Jack Isen, UCLA

Gerard Lawler, UCLA

Samuel Levenson, Cornell

William Li, Cornell

Lucy Lin, Cornell

Post Docs:

Nathan Majernik, UCLA

Afnan Al Marzouk, NIU

Chenyu Zhang, Cornell

Current projects

- **Objective 1 (Conserve): Probe the ultimate limits of brightness conservation in the presence of collective effects in low MTE photoinjector beamlines.**
  - Deliverable: The sources of residual emittance growth in select optimized beam lines (to be completed by Spring 2022).
    - Brightness limiting effects of point to point space charge (Kim / Gordon)
    - Demonstrating Emittance Preservation in Ultrafast Electron Micro-Diffraction (Maxson / Duncan)
    - Development of the ASU-DC cryogun (Karkare / Gevorkyan)
  - Deliverable: Cathode longevity testing capability with beam to support Theme 1 developments (to complete by Fall 2023).
    - No work on this?
  - Deliverable: A list of the parameters that determine emittance growth in low MTE photoinjector beam lines (to be completed by Fall 2024).

Current projects

- **Objective 2 (Cool):** Develop methods for cooling beams using optical stochastic cooling to increase beam luminosity in next-generation colliders.
  - Deliverable: Proof of principle demonstrations of key elements of optical stochastic cooling at IOTA and CESR (to be completed by Spring 2023)
    - Feedback System and Isochronous Lattice Development towards an Optical Stochastic Cooling Stability Experiment (Bazarov / Levenson)
    - Optical Transport and Beam Manipulation for Optical Stochastic Cooling (Piot / Dick)
  - Deliverable: Configurations capable of the very high cooling rates needed for use in a future colliders. (to to be completed by Fall 2025)
    - Same as above – techniques developed will be applied to novel configurations
  - Deliverable: Single-pass correction of beam distortions and beam diagnostics using techniques developed for OSC (to be completed by Summer 2026)

Current projects

- **Objective 3 (Control):** Investigate advanced optimization schemes, including Machine Learning and parameter reduction techniques, for precision phase-space control of particle accelerator systems.
    - Deliverable: Methods for efficiently tuning an accelerator (to be completed by Summer 2026)
        - Exploring the Impact of Radiation Field on Brightness (Piot / Al Marzouk)
        - Advanced beam manipulations enabled by novel computational techniquesin beam physics (Musumeci / Cropp, Isen, Guo)
        - Optimization of ultra-compact free-electron laser performance with very low MTE photocathodes (Rosenzweig / Majernik, Lawler)
        - Strongly nonlinear space-charge in photoinjectors with collimating apertures (Maxson / Li)

Current projects

- **Objective 3 (Control):** Investigate advanced optimization schemes, including Machine Learning and parameter reduction techniques, for precision phase-space control of particle accelerator systems.
  - Deliverable: Summary of the boundaries of applicability of ML in accelerators with varying noise types and data availability (to be completed by Summer 2026).
    - Microscope Tuning by ML and Emittance Optimization (Muller / Zhang)
    - Operating hadron coolers with Machine Learning (Hoffstaetter / Lin)
    - Application of Machine Learning in Compact Photoinjectors (Biedron / Aslam)