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.

## Objectives for Phase II

### Objectives

<table>
<thead>
<tr>
<th>FY 22</th>
<th>FY 23</th>
<th>FY 24</th>
<th>FY 25</th>
<th>FY 26</th>
<th>Legacy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Probe the limits of brightness conservation in the presence of collective effects in low MTE photoinjectors (Conserve)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sources of emittance growth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cathode longevity testing capability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>List of parameters that determine emittance growth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Develop methods for cooling beams using optical stochastic cooling to increase beam luminosity in next-generation colliders (Cool)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proof of principle demonstrations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Configurations capable of very high cooling rates for future colliders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Investigate advanced optimization schemes for precision phase-space control of particle accelerator systems (Control)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methods for efficiently tuning accelerators</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Summary of the boundaries of applicability of ML in accelerators</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Deliverables

- Single-pass correction of beam distortion
- Increased scientific reach in X-ray FELs
- Higher luminosity electron-ion collider
- Active accelerator tuning and aberration control in electron microscopes

**Oct. 28th, 2021**
Current projects/personnel snapshot

Project Titles (PI / Postdoc or Grad Student):
- Advanced beam manipulations enabled by novel computational techniques in 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, UCL
- Afnan Al Marzouk, NIU
- Chenyu Zhang, Cornell

Oct. 28th, 2021
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).
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)
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 techniques in 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)