

Jefferson Laboratory  
LDRD Project Data Sheet  
Fiscal Year 2016

1. Project Title: Generation and Characterization of Magnetized Bunched Electron Beam from DC Photogun for MEIC Cooler

2. Project Identifier: PROJ: **LD1602**; PROJ ID: **000001.18.0P.001.003.003.06**; B&R: **LDRD**

3. Principal Investigator: Riad Suleiman

4. Phone Number of Principal Investigator: 757-269-7159

5. Responsible Project/Line Manager: Matthew Poelker

6. Project Start Date: 10/02/2015

7. Expected Project Completion Date: 09/30/2016

8. Type of Work: (basic research, applied research, or development) Basis Research

a. *Basic*= the systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind.

b. *Applied*= the systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.

c. *Development*= the systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development and improvement of prototypes and new processes to meet specific requirements.

9. Project Description: Include a short description of the project and an explanation of the cutting edge, high-risk, high-potential science or engineering.

To achieve the required luminosity at the Medium energy Electron Ion Collider (MEIC), ion beams must be cooled. In general, this is accomplished when an electron beam co-propagates with an ion beam moving at the same average velocity, but different temperatures, where the energy of chaotic motion of the ion beam is transferred to the cold electron beam. The cooling rate can be improved by about two orders of magnitude if the process occurs inside a solenoidal field that forces the electrons to follow small helical trajectories thereby increasing the interaction time with ions and improving the cooling efficiency. This cyclotron motion also provides suppression of electron-ion recombination. Cooling rates with magnetized electron beam are ultimately determined by electron longitudinal energy spread rather than the electron beam transverse emittance as the transverse motion of the electrons is quenched by the magnetic field.

The envisioned MEIC magnetized cooler is part of the Collider ring and aims to counteract emittance degradation induced by intra-beam scattering, to maintain emittance during collisions and extend the

luminosity lifetime. To implement cooling at relatively high energy (electron beam energy 55 MeV), the electron beam must be bunched and accelerated in an SRF linac. The MEIC cooling solenoid is 30 m long providing a 2 T field. Two requirements on the electron beam with noteworthy challenges are related to bunch charge and average current, 420 pC and 200 mA, respectively.

One challenge associated with implementing cooling inside the long solenoid of the Collider, is the fringe field immediately upstream of the cooling solenoid. The field lines outside the solenoid magnet introduce very large beam rotation. The ill-effects of this fringe field could be cancelled if the electron beam was born in a similar field, but producing beam rotation in the opposite direction, such that the two cancel.

Although, electron cooling with DC electron beams at low energy has been implemented at many labs, no one has yet demonstrated electron cooling with bunched electron beams, or magnetized cooling. Fermi Lab successfully demonstrated non-magnetized relativistic DC cooling at high energy (4.3 MeV). For Low Energy RHIC Electron Cooling non-magnetized bunched electron beam will be used and eRHIC is planning to use Coherent Electron Cooling.

We plan to demonstrate experimentally many aspects of the magnetized bunched electron beam for the MEIC cooler, with the notable exception of 200 mA average beam current (limited by the in-house high voltage supplies to 32 mA):

- I. Demonstrate 32 mA magnetized beam
- II. Quantify any difference in lifetime of  $K_2CsSb$  photocathode between magnetized and non-magnetized beam
- III. Measure magnetization for a variety of charge, bunch dimensions and solenoid strength guided by MEIC specifications.
- IV. Quantify the quality of round-to-flat beam transform for a variety of charge, bunch dimensions and solenoid strength.
- V. Demonstrate reliable simulation tools and methods.
- VI. Improve experimental techniques with new machine operation interface.

10. Tie to Mission: Explain the project's relevance or anticipated benefits to DOE's national security missions (energy resources, nuclear security, environmental quality, and science), and to the extent required by law, the mission of other federal agencies.

The goal of this project is to generate a magnetized beam and measure its properties. The impact of the cathode solenoid on the operation of the photogun will be explored. The planned simulations and measurements will provide insights on ways to optimize the MEIC electron cooler, and help us design the appropriate electron source.

The anticipated benefits are:

- I. Jefferson Laboratory will have direct experience magnetizing a high current electron beam.
- II. We will learn how the applied magnetic field influences the photocathode lifetime.
- III. We learn about challenges associated with round-to-flat beam transformations at high bunch charge.
- IV. We will benchmark our simulation tools in this new space-charge dominated, magnetized regime.

11. Prior FY Accomplishments and Results: (if applicable) NA

12. Work Proposed for the Current FY and Anticipated /Desired Results:

The electron beam parameters from the injector required to meet the MEIC cooling specification are unique. Producing low energy, magnetized beam that is space charge dominated has not been previously investigated in depth by the accelerator community. We will use simulation tools to create a physics design for the beamline so we can locate magnets and diagnostics at their optimum positions. Simulation of different operating scenarios of bunch charge, magnetization and bunch shape will be benchmarked against measurements of emittance and other beam parameters. As the beams will be space charge dominated, there will be some limit to the aspect ratio that can be achieved with the round-to-flat beam transform. Simulation will allow us to quantify how good or complete this can be made for different settings. These results will guide the design of the MEIC injector in the future.

The proposed measurements are:

- I. Generate magnetized beam and measure magnetization for different laser spot sizes, bunch charges, bunch lengths and gun solenoid fields.
- II. Use three skew quads to generate a flat beam with very large transverse emittance ratios.
- III. Generate very high currents magnetized beam and study beam transport and round-to-flat beam transformation versus electron bunch charge.
- IV. Measure magnetized photocathode lifetime at high currents (up to 32 mA) and high voltages.
- V. Study beam halo and beam loss versus magnetization.

For the current FY16, the proposed work and anticipated results are:

1. High-voltage condition the gun at 350 kV and commission  $k_2\text{CsSb}$  photocathode preparation chamber.
2. Design the beamline to locate magnets and diagnostics at optimum positions.
3. Design gun solenoid magnet or Helmholtz coil-pair to provide 0.2 T magnetic field at the photocathode.
4. Design skew quad magnets and slits.
5. Connect existing beamline to gun and complete hot checkout.
6. Relocate old arc dipole power supply to Gun Test Stand.
7. Procure gun solenoid magnet or Helmholtz coil-pair.
8. Procure skew quad magnets and slits.
9. Commission exiting beamline with beam.
10. Measure photocathode lifetime at 5 mA and 350 kV (not magnetized).
11. Assemble new beamline and commission with beam.
12. Install gun solenoid magnet or Helmholtz coil-pair.

13. Project Funding Profile (burdened):

| Fiscal Year Request               | Amount (\$) |
|-----------------------------------|-------------|
| FY15 (prior-year costs)           | \$0         |
| FY16 Budget (current year budget) | \$339,211   |
| FY17 Budget (next year's budget)  | \$265,850   |
| FY18 Projected Budget             | \$212,025   |
| FY19 Projected Budget             | \$0         |
|                                   |             |
| Total Estimated Budget            | \$817,086   |