Jefferson Laboratory LDRD Project Data Sheet Fiscal Year 2018

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

2. Project Identifier: PROJ: LD1805; PROJ ID: 000001.18.0P.001.003.003.11; 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:	10/01/2017
7. Expected Project Completion Date:	09/30/2018

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

The process "electron cooling" is an important feature of proposed designs of the nation's future Electron Ion Collider (EIC). Electron cooling is used to transfer unwanted transverse motion of individual ions within ion bunches to a sacrificial "cold" electron beam. When implemented, ion bunches occupy a smaller volume in space and time, resulting in improved luminosity when the ion bunches eventually collide with the electron bunches of a physics beam. Electron cooling has been implemented at a number of laboratories, such as Fermi Lab, but not under the extremely demanding conditions required by the EIC. An innovative cooling method promises to meet EIC cooling requirements by delivering an electron beam to a long solenoid magnet through which the ion beam passes. Inside the solenoidal field, the electrons would follow small helical trajectories thereby increasing the interaction time with ions and improving the cooling efficiency by up to two orders of magnitude over previously demonstrated cooling techniques. But delivering the electron beam into the cooling solenoid represents a significant challenge. The fringe field immediately upstream of the cooling solenoid "kicks" the electron beam, introducing a large deviation from the desired trajectory of the electron beam inside the solenoid. It is hoped the ill-effects of this fringe field can be cancelled if the electron beam is born in a similar field, and passing through a fringe field at the exit of the photogun that produces a beam motion "kick" in the opposite direction, such that the two "kicks" cancel.

This LDRD proposal aims to generate an electron beam from a photocathode immersed in a solenoidal field – so called "magnetized beam". This has been done inside an RF-gun but at low duty factor and low average current. No one has generated magnetized beam from a DC high voltage photogun, which could likely be the only type of electron gun that can meet the requirements of the Jefferson Lab IEC cooler design, related to beam current, bunch charge, bunch length and emittance.

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.

This project will benefit nuclear science by maximizing the scientific output of EIC as the future largescale DOE particle accelerator facility. The magnetized cooler will enable EIC to reach and maintain the required luminosity to successfully achieve its scientific mission and make best use of the resources invested. Future accelerator scientists (postdoc and graduate student) are working on the project.

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

We finished Year 1 (FY16) demonstrating non-magnetized beam at maximum current of 1 mA and started implementing a long list of improvements to the gun and diagnostic beamline. The cathode solenoid was mapped, installed and commissioned. Photocathode preparation chamber, gun HV chamber, cathode solenoid and fully instrumented beamline were all upgraded, commissioned and fully functional. Finally, we were ready to start the experimental measurements outlined in this project. **The highlight of Year 2 (FY17) was the demonstration of magnetized beam**. We delivered 4.5 mA magnetized beam for 6 hours with the gun HV at 300 kV and cathode solenoid magnetic field of 1511 Gauss on the photocathode. We also measured beam rotation using the slit and view screen method and these values were used to calculate beam magnetization. There is good agreement between prediction and measurement.

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

- 1. Replace the DC laser with one that provide RF-structure on the beam
- Generate very high current magnetized beam with RF structure and study beam transport vs electron bunch charge, at average current up to 5 mA/350 kV and 32 mA/225 kV using different high voltage power supplies attached to the gun
- 3. Measure beam magnetization vs bunch charge under the conditions explored in #2, compare measurements to predicted values obtained through simulation
- 4. Replace the drive laser with one capable of producing nanoCoulomb bunch charge but at low average current, repeat items 2 and 3
- 5. Evaluate a non-invasive technique to measure beam magnetization that relies on a TE₀₁₁ RF cavity
- 6. Install three skew quads and generate flat beam with skew quads and measure horizontal and vertical emittances

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 will 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.
- V. We will demonstrate experimentally many aspects of the magnetized bunched electron beam for the JLEIC cooler.

13. Project Funding Profile (burdened):

Fiscal Year Request	Amount (\$)
FY1 Budget (FY16)	\$339,211
FY2 Budget (FY17)	\$264,979
Current FY Budget Request (FY18)	\$211,449
Total Estimated Budget	\$815,639