1.0 Generation and Characterization of Magnetized Bunched Electron Beam from a DC Photogun for JLEIC Cooler

Principal Investigators: Riad Suleiman and Matt Poelker

Project Description

To maintain ion beam emittance and extend luminosity lifetime, the Jefferson Lab design of the Electron Ion Collider includes a bunched magnetized electron beam cooler as part of the Collider Ring. This 3-year (FY16/17/18) project aimed to generate and characterize magnetized electron beams using a 350 kV inverted-insulator DC high voltage photogun. Measurements of beam magnetization at different bunch charge as a function of laser beam size and magnetic field at the photocathode. Results were compared to particle tracking code simulations. A goal had was set to measure photocathode lifetime at beam currents up to 32 milliamperes and compare to beam lifetime with no magnetization, in order to explore the impact of the magnetic field on photogun operation. Combined, these measurements and simulations benchmarked our design tools and provide insights on ways to optimize the electron cooler and choose the appropriate electron source and injector layout. Originally, there had been a goal to perform "round-to-flat" beam transformations but this requirement was dropped from JLEIC cooler design, so we focused the effort on the magnetized beam studies.

Accomplishments

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 first demonstrations of magnetized beam and the assessment of beam magnetization using an invasive slit/viewer technique, with results accurately predicted by simulation.

In Year 3 (FY18), magnetized beam with rf-structure was produced at average currents up to 28 mA which is a factor of 370 more current than previously demonstrated, and exhibiting exceptionally long photocathode lifetime using a biased anode to repel ions generated in the beamline. The studies concluded with demonstrations of magnetized beam with high bunch charge, up to 700 pC. These demonstrations of magnetized beam – particularly at high average current – represent a major extension of the state-of-the-art and provide essential credibility for the JLEIC cooler design.

Additional details

- Learned that micro-arcing at the photogun cathode electrode was due to beam-induced ions entering the cathode/anode gap. This micro-arcing and associated QE decay could be eliminated by using a biased anode. The photogun magnetizing solenoid also serves to reduce micro-arcing activity.
- Photocathodes fabricated on molybdenum substrates provide very high QE and performed better than photocathodes fabricated on GaAs substrates.
- Delivered 14 mA beam with rf-structure for 90 hours with no noticeable photocathode QE decay.
- Photocathode QE observed to decrease slightly at 28 mA average current, perhaps a result of laser heating and associated bandgap shift.
- Magnetized beam could be produced with high bunch charge, i.e. up to 700 pC.
- A non-invasive TE011 cavity was designed to non-invasively detect beam magnetization. The cavity is under construction.

Publications

None

Workshops/Conferences

M. Poelker, P. Adderley, J. Benesch, B. Bullard, J. Grames, F. Hannon, J. Hansknecht, C. Hernandez-Garcia, R. Kazimi, G. Krafft, M. Mamun, R. Suleiman, M. Tiefenback, Y. Wang, S. Wijiethunga, J. Yoskovitz and S. Zhang, *Magnetized electron beam for the JLEIC re-circulator cooler ring*, 2017 International Workshop on Polarized Sources, Targets, and Polarimetry, Oct 16 - 20, 2017, Daejeon, Republic of Korea.

J. Guo, J. Henry, M. Poelker, R. A. Rimmer, R. Suleiman, H. Wang, *Using a TE011 Cavity as a Magnetic Momentum Monitor*, Poster presented at the 7th International Beam Instrumentation Conference (IBIC 2018), Shanghai, China, September 9 – 13, 2018.

M. A. Mamun, P. Adderley, J. Benesch, B. Bullard, J. Delayen, J. Grames, F. Hannon, J. Hansknecht, C. Hernandez-Garcia, R. Kazimi, G. Krafft, M. Poelker, R. Suleiman, M. Tiefenback, S. Zhang, Y. Wang, S. Wijiethunga and J. Yoskovitz, *Magnetized Electron Source for JLEIC Electron Cooler*, Invited Talk presented at Photocathode Physics for Photoinjectors (P3) Workshop, Santa Fe, New Mexico, October 15 – 17, 2018.

Questionnaire

Question	Answer
Will follow-on funding (post-LDRD project) be applied for?	Yes
Source of support for follow-on funding?	DOE SBIR *
Has follow-on funding been obtained?	Yes
Amount of follow-on funding ($K)?	970* + 970**
Number of Post Docs supported by LDRD project?	1
Number of students supported by LDRD project?	0
Number of scientific staff/technical staff hired with LDRD funding?	0
Number of copyrights filed (beyond publications)?	0
Number of invention disclosures filed?	1
Number of patent applications filed?	0

* *A Magnetized Electron Source for Ion Beam Cooling* - Xelera Research - Phase II Proposal DE-SC001518.

** *Resonant Polarimetry and Magnetometry* – Electrodynamic – Phase II Proposal DE-SC0017120.