Generation and Characterization of Magnetized Bunched Electron Beam from a DC High Voltage Photogun

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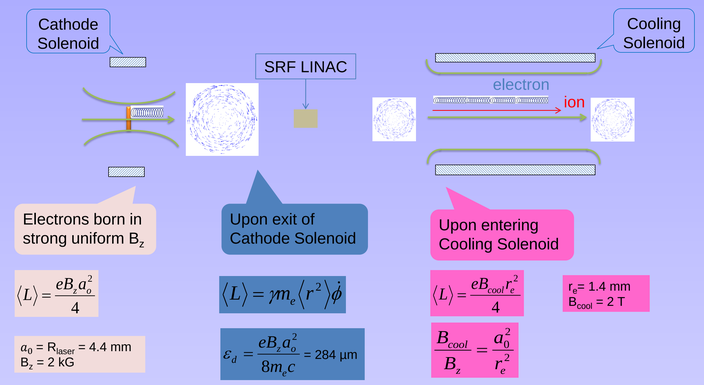
Motivation

Jefferson Lab Electron Ion Collider (JLEIC) bunched magnetized electron cooler is part of Collider Ring and aims to counteract emittance degradation induced by intra-beam scattering, to maintain ion beam emittance during collisions and extend luminosity lifetime

Magnetized Cooling

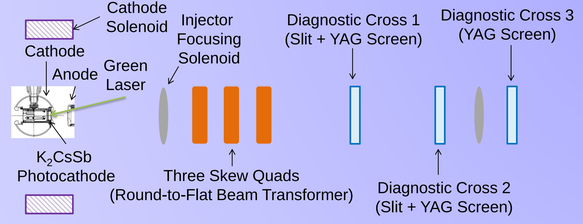
- Electrons helical motion in strong magnetic field increases electron-ion interaction time, thereby significantly improving cooling efficiency. Electron-ion collisions that occur over many cyclotron oscillations and at distances larger than cyclotron radius are insensitive to electrons transverse velocity.
- Cooling rates are determined by electron longitudinal energy spread rather than electron beam transverse emittance as transverse motion of electrons is quenched by magnetic field.
- This cyclotron motion also provides suppression of electron-ion recombination.

Electron beam is being used inside cooling solenoid where it suffers an azimuthal kick when it enters. This kick is cancelled by an earlier kick at exit of cathode solenoid.

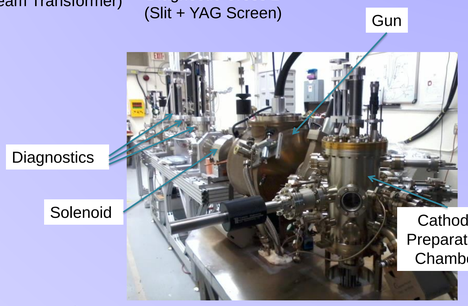


Bunch length	60 ps (2 cm)
Repetition rate	476.3 MHz
Bunch charge	420 pC
Peak current	7.0 A
Average current	200 mA
Transverse normalized emittance	10s mm mrad
Cathode spot radius – top-hat (a_0)	4.4 mm
Solenoid field at cathode (B_z)	2 kG

Experimental Overview



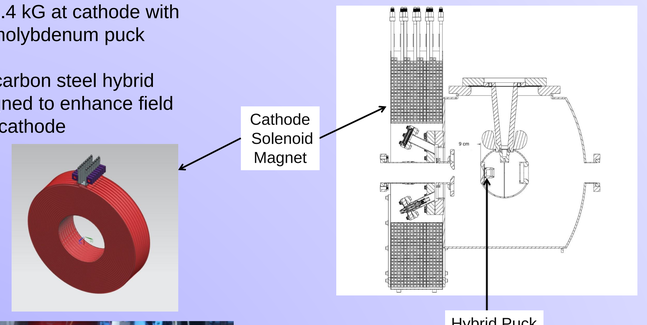
- Generate magnetized beam:
  - a_0 = 1 – 5 mm, B_z = 0 – 2 kG
  - Bunch charge: 1 – 500 pC
  - Frequency: 15 Hz – 476.3 MHz
  - Bunch length: 10 – 100 ps
  - Average currents up to 32 mA
  - Gun high voltage: 200 – 350 kV



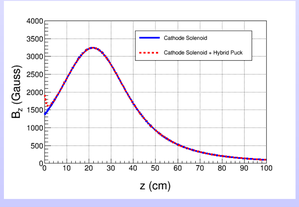
1. Measure mechanical angular momentum
2. Measure photocathode lifetime versus solenoid field at high currents (up to 32 mA) and high voltages (200 – 350 kV) limited by in-house HV supplies
3. Study beam halo and beam loss versus magnetization
4. Use skew quads – Round-to-Flat Beam (RTFB) Transformer – to generate flat beam and measure horizontal and vertical emittances using slit method
5. Generate very high currents magnetized beam and study beam transport and RTFB versus electron bunch charge

Cathode Solenoid

- Provides 1.4 kG at cathode with standard molybdenum puck
- Moly and carbon steel hybrid puck designed to enhance field to 2 kG at cathode



Simulations

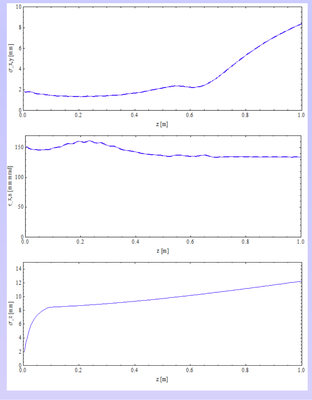


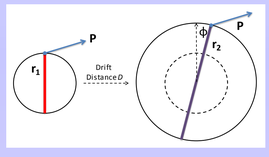
- Insert slit into beamline to select an emittance-dominated beamlet
- Let beamlet drift to screen and image it

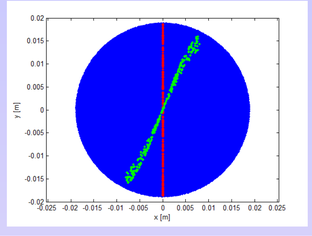
$$\langle L \rangle = p_z \frac{a_1 a_2 \sin\phi}{2D} = \frac{eB_z a_o^2}{4}$$

a_1 beam radius measured at Diagnostic Cross 1
a_2 beam radius measured at Diagnostic Cross 2
D drift between two crosses
p_z beam longitudinal momentum

Parameter	
Cathode B_z	2 kG
Radius, top-hat (a_0)	3 mm
t rms, Gaussian	23 ps
Bunch Charge	420 pC
Gun HV	350 kV







Plans and Summary

- Generate magnetized electron beam and measure its properties starting fall 2016
- Explore impact of cathode solenoid on photogun operation
- Simulations and measurements will provide insights on ways to optimize JLEIC electron cooler and help design appropriate source
- Jefferson Lab will have direct experience magnetizing high current electron beam

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