Magnetized-Beam Formation and Beam-Beam Kicker for Electron Cooling

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Outline

• Introduction

• Formation & manipulation of magnetized beam

• Beam-beam kicker

• Outlook & plans
Introduction

• This talk discusses interests from our group to carry work related to JLEIC electron cooling

• Over the last 3 years we have submitted five proposals
  • 3 STTRs (1 reviewed but denied funding, 2 returned without review – deemed unresponsive...)
  • 2 unfunded university proposals to DOE NP

• The following slides are essentially exploratory work done in preparation of these proposals and related to synergistic work funded by other sources.
High-Current Magnetized-beam R&D

• Two directions

• Simulations:
  • Beam dynamics
  • Emission process

• Experiments:
  • At Fermilab FAST/IOTA facility, Argonne Wakefield Accelerator (AWA), and using a standalone DC gun at NIU.

• Photoemission sources:
  • Demonstrate single-bunch performance
  • Explore scaling,
  • Investigate new concept,
  • Develop relevant diagnostics
  • Temporal shaping for flat-top e- beam

• Development of a high-current gun based on alternative emission mechanism:
  • Thermionic emission
  • Field-emission
Magnetized beam formation: basics

- electrons born in an axial B field $B_z \rightarrow$ CAM

\[ L(r) = er A_\theta \approx \frac{er^2}{2} B_{z,0} + \mathcal{O}(r^4) \]

- upon exit of solenoid field ($A_\theta = 0$): CAM becomes purely kinetic.

\[ p_\theta(r, z > z_{sol}) = P_\theta(r, z = 0) \]
Previous work in an RF photoinjector (A0PI)

- Weak $Q$ dependence,
- quadratic scaling with laser spot size $\sigma_c$ on photocathode.

On-going work in collaboration w. AWA (Argonne)

- Generation of very uniform laser spots on photocathode using a microlens array (MLA)
  
  - Production of multi-beam pattern at AWA witness beamline → could help understand the non-paraxial dependence of the CAM

Planned experiment at FAST/IOTA

~300-MeV e- injector section

- RF gun
- cryomodule
- test beamlines
- IOTA
- beam dumps

- SRF cavities
- Bunch compressor
- 2.5 MeV p source
- cathode
  \[ B_{\text{max}} \approx 0.3 \text{T} \] on cathode

- FAST-IOTA facility complex includes:
  - IOTA (integrable-optics test accelerator) ring,
  - An electron linear accelerator (that nominally serves as an electron injector to IOTA),
  - A proton source & injector for IOTA
Planned experiments at FAST/IOTA (Summer 17)

- Experiment to focus on flat beam generation (after decoupling of magnetized beam with a skew-quad channel)
- Characterization of magnetized beams will be a byproduct
Flat-to-round beam transformation

- Reverse of flat beam transform:
  - Illuminate photocathode with ribbon laser
  - Transform into a magnetized beam

- Preliminary simulations (IMPACT-T)

- At FAST/IOTA produced magnetized beam could be injected in IOTA (R. Li)

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High-current sources

- use field emission by placing cathode in an RF gun ($f=1.3$ GHz)
- different cathodes tested (here CNT)

![Graphs and charts]

D. Mihalcea et al., APL 107, 033502 (2015)
High-current sources (cnt’d)

• Main issue is proper bunching. Currently working with Fermilab on a 1+1/2 cell gated SCRF gun operating at 650 MHz with gate at 1.3 GHz.

• Field emission cathode lifetime and contamination is also an open issue
  • activity at NIU to test potential cathode in a DC gap over long period of time
  • Simulation of field emission (WARP)

[A. Lueangaramwong et al., AIP Conf.Proc. 1812 (2017) no.1, 080009]
Interests in the Beam-Beam kicker

• Simulations:
  • Beam dynamics: degradation of the cooling e- beam, optimization of kicker e-beam parameters

• Experiments:
  • At AWA using the two-injector configuration currently used for two-beam acceleration in DWFA

[V. Shiltsev, NIM AA, vol. 374, 137 (1996)]
Beam-beam kicker design

• Preliminary simulations using WARP
  • 1 MeV kicking beam to kick a 50-MeV cooling beam
  • 0.4-ns rise time
• Cooling beam possibly flat so that kicking beam would also need to be flat (+t-shaping?)
• Design/test of kicking e-beam could leverage on e-cooling beam electron source
Beam-beam kicker experiment (proposed)

• use the witness beam to kick the drive beam

Drive beam < 50 MeV

witness beam < 5 MeV

sub-MeV magnetized electron source
matching quadrupoles
compensating dipoles
skew quadrupoles (round-to-flat beam transformer)
chicane beamline for kicking beam translation
beam dump
cooling beam
Summary

• We are interested in collaborating on JLEIC with primary focus on magnetized-beam formation and beam-beam kicker
• So far our work is exploratory and tied to other projects in progress
• Several facilities available at Argonne and Fermilab with parameters relevant to the JLEIC e-cooler could be ideal testbeds:
  • **FAST linac**: magnetized beam, longitudinal manipulation of magnetized beam, round-to-flat and flat-to-round beam transformation
  • **AWA**: two beam setup readily available could support test of beam-beam kicker, work on magnetized beam has also been carried out there, also emittance exchanger used for temporal shaping.
  • **IOTA ring**: recirculation of magnetized beam produced in the FAST linac (suggested by R. Li)
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