EXPERIMENTAL STUDIES OF OPTICS SCHEMES AT CEBAF FOR SUPPRESSION OF COHERENT SYNCHROTRON RADIATION INDUCED EMITTANCE GROWTH

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Bunched Beam Electron Cooler

Baseline cooling requirements
- Emittance 0.5 to 1 mm-mrad -> reduce IBS effect
- Magnetized beam, up to 55 MeV energy, 200 mA current
- Linac for acceleration
- Must utilize energy-recovery-linac (beam power is 11 MW)

Solution: cooling by a bunched electron beam

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron energy</td>
<td>MeV</td>
</tr>
<tr>
<td></td>
<td>up to</td>
</tr>
<tr>
<td></td>
<td>55</td>
</tr>
<tr>
<td>Current and bunch charge</td>
<td>A / nC</td>
</tr>
<tr>
<td></td>
<td>0.2 /</td>
</tr>
<tr>
<td></td>
<td>0.42</td>
</tr>
<tr>
<td>Bunch repetition</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td>476</td>
</tr>
<tr>
<td>Cooling section length</td>
<td>m</td>
</tr>
<tr>
<td></td>
<td>60</td>
</tr>
<tr>
<td>RMS Bunch length</td>
<td>cm</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Electron energy spread</td>
<td>10^{-4}</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Cooling section solenoid field</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Beam radius in solenoid/cathode</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td>~1 / 3</td>
</tr>
<tr>
<td>Solenoid field at cathode</td>
<td>KG</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>
Goal of this LDRD

• Carry out studies to prepare a proposal for an actual experiment at CEBAF.

• Scope:
  – Design optics to enhance/suppress CSR in east ARC (ARC1 or ARC3)
  – Study transport from injector to ARC, optimize for high charge.
  – Determinate optimal injector setup
Experiment Layout
CSR Induced Emittance Growth

500 MeV/c (0.1 ps x 100 keV)

courtesy C. Tennant

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Preliminary Injector simulations

(courtesy A. Hofler)
Proposed location for new injector

Minimal modifications. Remove differential pump and diagnostic girder, add new injector.
Option 1: Use FEL Booster cavity

\[ \sigma_z = 2.5 - 3pS \]

\[ \epsilon_x = 0.2 \, \text{mm. mrad} \]
Option 2: Capture via 0L03

\[ \epsilon_x = 0.7 \text{ mm.mrad} \]

\[ \sigma_z = 0.25 \text{ mm} = 0.8 \text{ pS} \]
Longitudinal match

Entrance 0L04

Exit 0L04

Exit chicane

Exit North Linac

Entrance ARC3

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CSR suppression lattice

• Recipe:
  – 2\textsuperscript{nd} order achromat with achromatic and isochronous super periods to suppress CSR induced emittance growth in transverse emittance
  – Low M56 variations within the lattice to also reduce the microbunching gain.

CEBAF lattices can meet that requirement.
CSR ARC3 suppressed lattice (cont)

Small R56 variation, 2nd order achromat, 4 superperiods.
CSR Enhancing Lattice

Twiss parameters—input: csrbadv2optimized.ele  lattice: csrbadv2optimized.lte
CSR Enhancing Lattice

\[ \varepsilon_{x,n} \text{ (m)} \]

\[ s \text{ (m)} \]

5pC
10pC
20pC
40pC

sigma matrix -- input: csrbdv2optimized.ele  lattice: csrbdv2optimized.ltc
Emittance Growth in ARC3

Bunchlength fs, transverse emittance 0.2 mm.mrad

Sigma matrix—input: csrbadv2Soptimized.ele lattice: csrbadv2Soptimized.lte
Tomography at the FEL

- With similar phase coverage (157°) we were able to reconstruct horizontal phase space in the FEL Upgrade Driver (TN-09-021)

![Actual beam spots](image)

![Simulated beam spots](image)

MENT output

courtesy C. Tennant

Reconstructed (x,x’)

Simulated (x,x’)

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Conclusions

- Proof of principle CSR suppression experiment seems feasible at CEBAF
- Writing a proposal to the Program Advisory Committee
- Transporting high brilliance beam at CEBAF will also be needed for injection into MEIC
Insertable dump design

Located past 3R04 girder

17 kW dump
Insertable dump design (cont)

<table>
<thead>
<tr>
<th>Beam parameters at dump</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunch repetition rate</td>
<td>31 MHz</td>
</tr>
<tr>
<td>Transverse emittance</td>
<td>&lt; 1mm.mrad</td>
</tr>
<tr>
<td>Macro pulse</td>
<td>200 μs , 60 Hz</td>
</tr>
<tr>
<td>Charge</td>
<td>40 pC (15 μA average)</td>
</tr>
<tr>
<td>Bunch Length rms</td>
<td>&lt; 0.1 pS</td>
</tr>
<tr>
<td>Energy spreader rms</td>
<td>&lt; 10 KeV</td>
</tr>
<tr>
<td>Energy</td>
<td>500-600 Mev</td>
</tr>
<tr>
<td>Power deposited</td>
<td>7.5 kW (at 500 MeV)</td>
</tr>
</tbody>
</table>
Power density in dump

7.5 kW beam
7.1 kW deposited
0.4 escape as neutrons and gammas