Effect of Negative Momentum Compaction Operation on the Current-Dependent Bunch Length

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Summary and Outlook
- Future low emittance rings could benefit from negative momentum compaction operation
- Reduced sextupoles possible and result in higher dynamic aperture
- Understanding of involved effects is necessary
- KARA as test facility allows studies in this regime

Status of Operation
- Injection into different optics with negative values of $\alpha_c$ has been established at 0.5 GeV [1]
- Maximum beam and bunch current is limited, highest achieved current is 22 mA distributed over 120 bunches and 1 mA for single bunch operation at 0.5 GeV
- High orbit deviations seem to be beneficial for the injection
- Reduced sextupole strengths and therefore reduced chromaticities seemed beneficial
- Ramping storage ring energy up to 0.9 GeV and 1.3 GeV has been established
- Orbit has been corrected at 0.9 GeV and 1.3 GeV
- Beam lifetime is greatly increased at higher energies

Bunch Length Simulations
- Simulations parameters equivalent to measurements
- Simulations performed with Inovesa [2]
- Purely longitudinal CSR Parallel Plates impedance considered

Bunch Length Measurements
- Bunch length measured using a streak camera setup [4, 5]
- Current decreased naturally during measurement
- Measurement during single bunch 1.3 GeV operation

Comparison
- Bunch lengthening with current for positive $\alpha_c$ and shortening for low currents at negative $\alpha_c$
- Simulations show roughly the same zero current bunch length in both cases as expected
- Measured $\beta_x$ at low currents suggests offset between positive $\alpha_c$ and negative $\alpha_c$
- Roughly gaussian bunches at low currents result in expected shortening for negative $\alpha_c$
- Simulations show bunch deformations at higher currents resulting in bunch lengthening for negative $\alpha_c$, not clearly visible in measurements due to limited measurement range

Operation Modes
- Bunch length influenced by effective longitudinal potential $V_{eff}$
- $V_{eff}$ is sum of RF potential and longitudinal wake potential
- Wake potential derived from bunch shape and impedance
- RF potential reversed for $\alpha_c < 0$ operation
- Difference in current-dependent bunch length expected

Lattice and Optics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>0.5 - 2.5 GeV</td>
</tr>
<tr>
<td>Circumference</td>
<td>110.4 m</td>
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<tr>
<td>RF frequency</td>
<td>500 MHz</td>
</tr>
<tr>
<td>Revolution frequency</td>
<td>2.715 MHz</td>
</tr>
<tr>
<td>$\alpha_c$ (standard operation, 2.5 GeV)</td>
<td>45 ps</td>
</tr>
<tr>
<td>$\alpha_c$ (short bunch mode, 1.3 GeV)</td>
<td>few ps</td>
</tr>
</tbody>
</table>

Motivation

$\alpha_c = \frac{\Delta L/L}{\Delta \rho/p} = \frac{1}{L} \int \frac{D(s)}{\rho(s)} ds$

Bunch Length Fluctuations arise at currents where the micro-bunching instability occurs [3]

Bunch length fluctuations at 5 GeV were limited during measurements

References

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