LHeC Final Focus System

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Thanks to: H. Garcia, R. Tomas, F. Zimmermann
Contents

• Round optics. $e^-$ FFS optics I: triplet
• Flat optics:
  – $e^-$ FFS optics II: Doublet, local chromatic correction
  – $e^-$ FFS optics III: Doublet, traditional chromatic correction

Introduced in the talk Interaction Region by R. Tomas (this workshop)
e⁻ FFS optics I: triplet

No chromatic correction
Bending magnets to compensate the dispersion created by the last dipole

Beam size by order computed with MAPCLASS

Chromatic aberration
Flat beam optics

Chromatic correction

• 4 Sextupoles to correct chromaticity in pairs
  1\textsuperscript{st} pair: correction in X. $\beta_x >> \beta_y$
  2\textsuperscript{nd} pair: correction in Y. $\beta_x << \beta_y$

\[ \beta_{x,y}^* = 0.1 \text{ m.} \]

\[ \begin{array}{l}
\beta_x^* = 0.2 \text{ m.} \\
\beta_y^* = 0.05 \text{ m.}
\end{array} \]

Separation of $\beta$-functions

• Each of the sextupoles of the pair must be spaced $\Delta \mu_{x,y} = \pi$
• 2 arrangements
  • Traditional, dedicated section
  • Compact, Local chromatic correction

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LheC workshop 2012

Length: 150 m

SR power of 83 kW

Beam size by order

\( \beta^*_x = 0.2 \text{ m.} \)

\( \beta^*_y = 0.05 \text{ m.} \)
e⁻ FFS optics III: Traditional

Length: 267 m (too long)
Modular construction:
Chromaticity compensated two dedicated sections.
Separated optics with strictly defined functions that makes the system relatively simple to design.
Chromaticity is not locally corrected.

**SR power** of 39 kW
e⁻ FFS optics III: Traditional

Beam size by order

Geometric aberration
Flat beams comparative

Bandwidth

e⁻ FFS optics II  e⁻ FFS optics III: Traditional

Much wider bandwidth for the local chromatic option → more stable for energy variations

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Flat beams comparative

Momentum spread $\sigma_\delta = 0.3 \times 10^{-3}$ without synchrotron radiation evaluated by tracking with PLACET

Synchrotron radiation effects due to emittance dilution in the horizontal plane.

<table>
<thead>
<tr>
<th></th>
<th>$\sigma_x$ [(\mu m)]</th>
<th>$\sigma_y$ [(\mu m)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>9.34</td>
<td>4.69</td>
</tr>
<tr>
<td>Traditional</td>
<td>9.75</td>
<td>4.97</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>$\sigma_y$ [(\mu m)]</th>
<th>$\sigma_x$ [(\mu m)]</th>
<th>$\sigma_x$ [(\mu m)]</th>
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</thead>
<tbody>
<tr>
<td>w/o SR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local</td>
<td>9.41</td>
<td>22.24</td>
<td>22.33</td>
</tr>
<tr>
<td>traditional</td>
<td>10.15</td>
<td>12.84</td>
<td>13.63</td>
</tr>
</tbody>
</table>

\[ \Delta \left( \frac{\sigma_x^*}{\beta_x^*} \right) = 4.13 \times 10^{-11} m^2 GeV^{-5} E^5 I \]

\[ I = \int_0^L \frac{H(s)}{|\rho(s)|^3} \cos^2 \phi(s) ds \]

\[ H = \frac{D_x^2 + (D'_x \beta_x + D_x \alpha_x)^2}{\beta_x} \]

## Magnet comparison

<table>
<thead>
<tr>
<th>Name</th>
<th>Gradient [T/m]</th>
<th>Length [m]</th>
<th>Radius [mm]</th>
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<th>Length [m]</th>
<th>Radius [mm]</th>
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<th>Length [m]</th>
<th>Radius [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>19.7</td>
<td>1.34</td>
<td>20</td>
<td>−19.1</td>
<td>1.1</td>
<td>36</td>
<td>−20.54</td>
<td>2.5</td>
<td>36</td>
</tr>
<tr>
<td>Q2</td>
<td>−38.8</td>
<td>1.18</td>
<td>32</td>
<td>17.7</td>
<td>1.1</td>
<td>37</td>
<td>20.31</td>
<td>2.5</td>
<td>35</td>
</tr>
<tr>
<td>Q3</td>
<td>−3.46</td>
<td>1.18</td>
<td>20</td>
<td>−14.7</td>
<td>1.1</td>
<td>41</td>
<td>−6.59</td>
<td>0.3</td>
<td>17</td>
</tr>
<tr>
<td>Q4</td>
<td>22.3</td>
<td>1.34</td>
<td>22</td>
<td>11.8</td>
<td>1.1</td>
<td>41</td>
<td>2.85</td>
<td>0.3</td>
<td>13</td>
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</table>
Conclusions

• A chromatic correction needs high dispersion regions in the sextupoles that introduce SR and emittance growth
• Restriction in length
• Restriction in L*
• Three different solutions have been studied and presented
Conclusions

Three different e- FFS optics

<table>
<thead>
<tr>
<th></th>
<th>Main advantages</th>
<th>Main disadvantages</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>optics I: Triplet</td>
<td>Simple and short</td>
<td>Chromaticity not corrected</td>
<td></td>
</tr>
<tr>
<td>optics II: Doublet, local chromatic correction</td>
<td>Short</td>
<td>Large emittance growth from synchrotron radiation</td>
<td>H-function optimization</td>
</tr>
<tr>
<td>optics III: Doublet, traditional modular chromatic correction</td>
<td>Chromaticity corrected with low emittance growth</td>
<td>Too Long?</td>
<td>If there is enough space</td>
</tr>
</tbody>
</table>
References

• J.L. Abelleira, H. Garcia, R. Tomas, F. Zimmermann; IPAC’12 New Orleans
Thank you for your attention