Simulations of Optics Tuning in the NLC Final Focus System

Y. Nosochkov

Collimation Task Force Workshop
SLAC, December 16-17, 2002
Enlargement of beam size at IP caused by field and tilt errors in BDS quadrupoles
Enlargement of beam size at IP caused by field and tilt errors in FFS sextupoles
Enlargement of beam size at IP caused by field and tilt errors in FFS octupoles
Sextupoles, octupoles and decapoles in the Final Focus System

Beam parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{\text{cms}}, \text{GeV}$</td>
<td>500</td>
</tr>
<tr>
<td>$\gamma_{\varepsilon_x}, 10^{-8} \text{m}$</td>
<td>360</td>
</tr>
<tr>
<td>$\gamma_{\varepsilon_y}, 10^{-8} \text{m}$</td>
<td>4</td>
</tr>
<tr>
<td>$\beta_x^*, \text{mm}$</td>
<td>8</td>
</tr>
<tr>
<td>$\beta_y^*, \text{mm}$</td>
<td>0.11</td>
</tr>
<tr>
<td>$\sigma_x^*, \text{nm}$</td>
<td>243</td>
</tr>
<tr>
<td>$\sigma_y^*, \text{nm}$</td>
<td>3</td>
</tr>
<tr>
<td>$\delta, %$</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Characteristic “90°-to-IP” phase at most magnets in the FFS
5 linear knobs:

<table>
<thead>
<tr>
<th>Effect at IP</th>
<th>Correcting parameter</th>
<th>Magnets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal beta waist</td>
<td></td>
<td>SD0, SF1, SF6</td>
</tr>
<tr>
<td>Vertical beta waist</td>
<td>Horizontal sextupole offset</td>
<td>SD0, SF1</td>
</tr>
<tr>
<td>Horizontal dispersion</td>
<td>Vertical sextupole offset</td>
<td>SF5, SF6</td>
</tr>
<tr>
<td>Vertical dispersion</td>
<td></td>
<td>SF5, SF6</td>
</tr>
<tr>
<td>Coupling</td>
<td></td>
<td>SD0, SD4</td>
</tr>
</tbody>
</table>

Beta waist at IP: \( \Delta s_x = -3122 \Delta x_{SD0} \), \( \Delta s_y = -60.36 \Delta x_{SD0} \).

Dispersion at IP: \( \Delta \eta_x = -0.498 \Delta x_{SF5} \), \( \Delta \eta_y = 0.0692 \Delta y_{SF5} \).

2nd order orbit from sextupole offsets is compensated by orbit correction.

12 non-linear knobs:

<table>
<thead>
<tr>
<th>Effect at IP</th>
<th>Correcting parameter</th>
<th>Magnets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal sextupole terms: T122, T162, T166, T342, T364 (5 knobs)</td>
<td>Sextupole field</td>
<td>SD0, SF1, SD4, SF5, SF6, SOC10</td>
</tr>
<tr>
<td>Skew sextupole terms: T322, T344, T362, T366 (4 knobs)</td>
<td>Sextupole rotation</td>
<td>SD0, SF1, SD4, SF5, SF6</td>
</tr>
<tr>
<td>Dominant geometric octupole term U3422</td>
<td>Octupole field</td>
<td>OC7B</td>
</tr>
<tr>
<td>Dominant geometric decapole term V34222</td>
<td>Decapole field</td>
<td>DEC6</td>
</tr>
<tr>
<td>Dominant chromo-geometric decapole term V36422</td>
<td></td>
<td>DEC6, DEC4</td>
</tr>
</tbody>
</table>

Example: \( \Delta x^* = T_{162} x^{*'} \delta \), \( \Delta y^* = T_{342} x^{*'} y^{*'} \), \( \Delta y^* = V_{36422}(x^{*'} y^{*'})^2 \delta \).

Besides the main term, octupole and decapole knobs also create a few other minor terms.
Test of the knobs for 2nd order dispersion: T166, T366

- Circles - Mat-LIAR calculation of $\Delta \sigma^2 = \sigma^2(T) - \sigma^2(0)$ versus energy spread.
- Line - polynomial fit $\Delta \sigma^2 = a T^2 \sigma^4_\delta$.

Knob: $T166 = 10^{-2}$

Knob: $T366 = 2 \times 10^{-4}$
Test correction of random field errors in the FFS sextupoles with rms $\Delta k/k = 0.05$ using normal sextupole knobs T342, T364, T122, T162, T166.

- Dash line - rms beam size without errors.
- Red bin - rms size of full beam before correction.
- Blue and green - 3 iterations of 5 knobs.
- x symbol - gaussian fit sigma of beam core.
Horizontal distribution before correction (from previous page) has non-gaussian tails

Corrected distribution is close to gaussian
Test correction of random tilt errors in the FFS sextupoles with rms $\Delta \theta = 1$ mrad using 4 iterations of skew sextupole knobs T322, T362, T366, T344.

Test correction of random field errors in the FFS octupoles with rms $\Delta k/k = 0.5$ using one iteration of octupole knob U3422.

Test correction of random field errors in the FFS decapoles with rms $\Delta k/k = 1.0$ using 2 iterations of decapole knobs V36422, V34222.
BDS tuning simulation with random field and tilt errors without misalignment

<table>
<thead>
<tr>
<th></th>
<th>rms error</th>
<th>quads</th>
<th>QF1, QD0</th>
<th>sextupoles</th>
<th>octupoles</th>
<th>decapoles</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta k/k$, %</td>
<td>0.25</td>
<td>0.05</td>
<td>1.0</td>
<td>2.5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>tilt, mrad</td>
<td>0.1</td>
<td>0.05</td>
<td>0.3</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

2 iterations of 17 knobs: coupling, y-waist, x-waist, $\eta_y$, $\eta_x$, T322, T362, T366, T342, T364, T344, T122, T162, T166, U3422, V34222, V36422.
Orbit correction is performed after each knob.
BDS tuning simulation with random field, tilt and “large” alignment errors (without BBA)

<table>
<thead>
<tr>
<th>rms error</th>
<th>quads</th>
<th>QF1, QD0</th>
<th>sextupoles</th>
<th>octupoles</th>
<th>decapoles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δk/k, %</td>
<td>0.25</td>
<td>0.05</td>
<td>1.0</td>
<td>2.5</td>
<td>5</td>
</tr>
<tr>
<td>tilt, mrad</td>
<td>0.1</td>
<td>0.05</td>
<td>0.3</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>x / y, µm</td>
<td></td>
<td>150 / 50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Orbit correction consisted of 18 horizontal and 20 vertical quadrupole movers and BPMs.
BDS tuning simulation with random field, tilt and “small” alignment errors

<table>
<thead>
<tr>
<th></th>
<th>rms error</th>
<th>quads</th>
<th>QF1, QD0</th>
<th>sextupoles</th>
<th>octupoles</th>
<th>decapoles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δk/k, %</td>
<td>0.25</td>
<td>0.05</td>
<td>1.0</td>
<td>2.5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>tilt, mrad</td>
<td>0.1</td>
<td>0.05</td>
<td>0.3</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>x / y, µm</td>
<td></td>
<td></td>
<td></td>
<td>15 / 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusion so far

The FFS tuning knobs can provide significant compensation of beam size growth at IP caused by field and rotation errors in the BDS magnets. For maximum tuning performance, alignment errors need to be reduced to a minimum by means of a beam based alignment.