Steering Algorithms and Mover Step Size in the NLC Linac

PT
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1. The “canonical” NLC linac steering algorithm

In this algorithm, the linac is broken into $K$ regions, each of which contains $N_{\text{qtot}}/K = N_{\text{quad}}$ quadrupoles, $N_{\text{bpm}}$ “Q” BPMs (where $N_{\text{bpm}} \geq N_{\text{quad}}$)

The set of quad moves which minimizes the BPM readings is determined in a least-squares $Ax = B$ fashion, where :

- $B =$ vector of BPM readings
- $x =$ vector of quad moves
- $A =$ response matrix
- $A_{ij} = (k_qR_{12} \text{ or -1 or 0})$

**Refinements:**

There is also a “soft constraint” on movers to get a solution which minimizes RMS of the moves (suppress long-wavelength “bowing”); the last quad is not moved, but a corrector at the start of each section is adjusted to zero the beam in the BPM in the last quad.

For, each section of linac, the algorithm above is repeated several times; after each repetition the structures are aligned via “S” BPMs; all repetitions of a particular section are completed before the next section is started.
2. Simulations of the “Canonical” algorithm

The canonical algorithm is implemented in the code LIAR (Assmann et al); Simulated the results of this algorithm using the following parameters:

- “Classical” NLC-II-B params (1.1 x $10^{10}$ particles per bunch, 2 DDS l-type structures per girder, 1-5 girders per quad, 3.6 x 0.04 mm.mrad $\gamma$’s, 1.5% initial energy spread, 3 BNS phase regions)
- Single bunch; “Q” BPM resolution = 1 $\mu$m, “Q” BPM offset = 2 $\mu$m, “S” BPM resolution = 5 $\mu$m, RMS quad misalign = 50 $\mu$m (y only)
- Mover “resolution” ranging from 0 nm to 300 nm
- 5 iterations per linac region, 14 regions (~ 50 quads each)
Parameters versus z -- 50 nm mover steps (avg over 10 seeds)

\[ <\text{BPM}_y, \text{microns}> \]

\[ \text{BPM}_y \text{ RMS, microns} \]

\[ x \times 10^{-7} \]
Parameters vs $z$ -- 250 nm mover steps (avg over 10 seeds)
3. MICADO “Afterburner”

For “large” (ie, 200 nm or larger) mover resolution, linac emittance degradation is unacceptable!

T. Raubenheimer’s suggestion: implement an alignment “afterburner” which uses a subset of quadrupoles to flatten the BPM orbit

After examining some possible “afterburner” algorithms, MICADO was selected.

**MICADO algorithm:**
- Find single corrector which best minimizes RMS orbit
- Latch best corrector
- Find corrector which best minimizes RMS orbit in conjunction with latched
- Iterate until RMS orbit is below some tolerance, or maximum allowed number of correctors is in use
4. Simulations with “Afterburner”

Same parameters as before, however now perform 4 iterations of “canonical” algorithm followed by 3 iterations of MICADO

Max number of quads moved per section in MICADO: 7
RMS orbit tolerance for MICADO: 1 μm

Each iteration of MICADO followed by structure alignment
Emittance Dilution due to Mover Resolution, with and without MICADO (100 seeds each)

Final Luminosity with and without MICADO
Parameters vs $z$ -- 250 nm mover steps, with MICADO (avg over 10 seeds)

- BPM$_y$, microns
  - $-3$ to $3$
  - $0$ to $10000$

- BPM$_y$ RMS, microns
  - $0$ to $8$
  - $0$ to $10000$

- Normalized emittance, m.rad
  - $0$ to $1.5 	imes 10^{-7}$
  - $0$ to $10000$
5. Conclusions and Further Directions

- Use of MICADO “afterburner” improves resulting orbit, beam quality
- Tolerance on quad mover step size can possibly be relaxed

- Need to determine equilibrium points for “canonical” and “afterburner” algorithms (esp. equilibrium number of iterations)
- Examine model of “Mover Trim Error” in LIAR -- implications?
- Repeat simulations with new (3 structure/girder) ILC lattice
- How often will alignment be needed after initial alignment? How invasive? How time consuming? Improved resolution with full bunch train?
References:

“Canonical” Steering Algorithm:

LIAR

MICADO

Burn me afire in the reptile house
In the colour and the carnage fall me down
My face in the fire in the reptile house
And the kissing and the colour come crashing down

-The Sisters of Mercy
“Bum”