

# Single-pass vs Re-circulation studies for New Light Source

LCLS-II TN-14-02

# 3/3/2014

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During the design phase for UK New Light Source (2008-2010), detailed studies were carried to investigate whether the beam dynamics requirements to deliver FEL requirements can be met using a re-circulating Linac and to estimate associated cost reduction. Details of both these designs are published in the NLS CDR (available at <u>www.newlightsource.org</u>) and the re-circulation design was published in <u>http://journals.aps.org/prstab/abstract/10.1103/PhysRevSTAB.14.050704</u>). Other considerations of recirculation for an FEL are described in a note on the re-circulation design studies for WiFEL: <u>http://www.src.wisc.edu/users/src\_technotes/TechNotes\_2011/SRC-</u>227.pdf.





Re-circulation Linac: 10 cryomodules to reach 2.2 GeV



## **Overall facility layout differences**

The overall layout is dictated by length of collimation + switchyard take-off + switchyard + experimental stations and reduction in linear length is ~65m due to difference in number of cryomodules.

Additional beam transport is required to accommodate the injection line with merger, beam spreader/combiner (matching to/from arcs), two 180° arcs, beam transport elements (FODO) in the return leg and path length correction sections required: This needs more floor space, which makes the building wider.

The topology for the re-circulation with linac only in single leg was decided considering the cryogenic requirements as well as possibility of extraction at two energies at 1.2 GeV and 2.2 GeV.



The relative savings compared to 18 cryomodules:

Linac Relative Costs	
Relative RF Power Cost	0.56
Relative Total Cryomodule Cost	0.56
Relative Cryoplant Cost	0.72
Relative Tunnel and RF Gallery Cost	0.56
Relative Total Capital Cost	0.61
Relative Yearly Operating Cost	0.55
Relative Total Cost Over 10 years	0.60
Relative Total Cost Over 20 years	0.60

With cost of additional beam transport elements and cost of building (due to wider footprint), the overall saving is only ~10-15%. However, the operating cost can be significantly lower as it will be mainly dictated by the SCRF costs.

#### **Design constraints in re-circulation**

Several factors need to be considered in designing a re-circulating linac:

- Longitudinal space charge at injection energy and optimum number of cryomodules
  - the energy of the injector and first bunch compressor (BC) before merging with the main linac
- Emittance growth (due to CSR, ISR, chromatic terms)
  - o arc design and bunch length whilst passing through the arcs and BCs

- Sensitivity to chromatic and geometric aberrations due to additional transport specially the alignments of sextupoles in the arcs and combiners/spreaders
- Locations of other bunch compressors in the loop.
- Tuning and tolerances of large number of magnetic components

Even though we demonstrated that the requirements to achieve lasing could be met for NLS parameters, it is clear that the flexibility of design is somewhat limited by above constraints. For NLS parameters, with the chosen locations of BCs, it was impossible to take out the beam chirp as the final compression was done at full energy. Some options as suggested by the Technical Advisory Committee (see below) could be considered to reduce the chirp or some de-chirpers could be added.

Also to note that nearly all of the bunch compression in the recirculating design was done at BC1 and BC2, with only a final small compression at BC3. The simulations could have been changed to eliminate all compression at BC3 quite easily, allowing use of the second linac pass to de-chirp (it was on the correct side of crest to do this in any case).

The majority of work done on the recirculating design was to get a working solution for the transverse optics, in particular transporting the 1.2 and 2.2 GeV beams simultaneously through the linac optics, given the constraints of space, injection merger and exit optics from the arc. This was achieved.

There was always an option to combat microbunching instability through the insertion of a laser heater in the injection line, this was not done for the final simulations, but placeholder space existed for it. A detailed microbunching analysis was never completed for the recirculating design, so the need for this was not fully established.

#### Extract from NLS Technical Advisory Committee Report (December 2009) on the Recirculation linac option

(J. Rossbach (chair), H. Chapman, J. Corlett, M.-E. Couprie, P. Emma, J. Feldhaus, F. Parmigiani, R. Rimmer, T. Shintake, K. Ueda)

**Recirculation Option** 

A nice design was described for a possible recirculation scheme to cut the linac length in half, potentially reducing costs. The scheme described had located the BC3 compressor after the final linac pass, therefore losing the ability to cancel the energy chirp after BC3. Since the chirp flatness requirements were described as being extremely important, and this recirculation scheme provides no chirp control at all (either by RF phasing or structure wakefields), this particular recirculation scheme does not seem to meet the needs of the FEL. It may be possible to relocate the BC3 before the final linac pass (although the BC2 is already located here), or use the arcs as the BC3, but many problems will likely arise with this relocation (such as more CSR in the end-of-arc bends after relocating BC3). It appears (although with our narrow understanding of the issues) that the recirculation idea may be too limiting for the refined beam control required of this facility. Given limited resources, *the TAC suggests to bring the study on recirculation to a conclusion at an appropriate point and concentrate on the many other issues of the baseline design requiring attention unless a clear idea is available which still allows the fine chirp control needed (as well as control of the other slice parameters under various beam parameter conditions).* 

Finally, the apparent advantage of using the spontaneous energy spread generated in the recirculation arcs as an equivalent laser heater may not be real. An increased sliced energy spread (such as generated by a laser heater) is most effective in Landau damping only when it is generated before the BC1, where the  $\mu$ -bunching is smeared early, before it causes trouble. The spontaneous energy spread generated in the recirculation arcs may occur too 'late' in the beam transport to be effective, and rather than adding Landau damping it may simply reduce the FEL power with an increased slice energy spread. Such a conclusion might be reached after an extensive  $\mu$ -bunching study of the recirculation optics, but it may not be time well spent at this point, especially in light of the chirp control problem described above.