ILC Damping Rings Lattices Evaluation
GDE Sendai Meeting
Revision: March 6, 2008

I. Summary of the Lattice Evaluation

Four lattices were compared as part of the March 4th meeting of the damping rings group at the ILC GDE meeting in Sendai. These lattices were the OCS8, FODO4, FODO5, and DCO lattices. The lattice evaluations were guided by the updated lattice specifications that were developed as part of the ILC Damping Rings Workshop held at KEK during December 2007. A particularly significant conclusion of that workshop was that the momentum compaction requirement for the damping rings could be lowered by approximately a factor of 2, thus opening up the possibility of employing a lattice with a 6 mm bunch length and a reasonable total RF voltage. The lattice specifications that came out of the December meeting can be found at: https://wiki.lepp.cornell.edu/ilc/pub/Public/DampingRings/LatEvalPage/EDRLatticeSpecifications.pdf.

In evaluating the various lattice designs, a small number of distinguishing criteria became apparent. In particular, work to pursue a lower momentum compaction factor was available for only 2 of the lattice designs (FODO5 and DCO). Implementation of the ability to flexibly adjust the momentum compaction factor was only possible for 3 of the lattice designs (work to implement this feature for the OCS8 design was not possible due to funding constraints). Concentrating as many specialty systems as possible near the main access shafts was deemed to be an important issue which the DCO lattice took specific steps to achieve. Finally, the number of magnets required to implement the designs was noticeably different between the various lattices. While the overall ratings among the 4 proposed lattices were amazingly close (this outcome was not unexpected given that each design had been demonstrated to meet a large fraction of the DR lattice specifications and also because the designs shared a number of key features), the DCO lattice appears to most closely match the specifications and capabilities desired for the present DR configuration. The ratings obtained for the four lattices were:

- OCS8 - 27.0
- FODO4 - 27.2
- FODO5 - 28.4
- DCO - 29.3

out of a possible 40 points overall score. Based this evaluation, the present recommendation is that the DCO lattice be specified as the ILC DR Baseline Lattice and that the FODO5 be specified as the alternate.

Baseline Lattice: DCO
Alternative Lattice: FODO5

II. Lattice Evaluation Criteria

The following 8 criteria were used to compare the lattices under consideration:

1. **Lattice design and dynamical properties.**
   a) Is the design complete? Does it include all necessary systems, such as injection/extraction optics, RF, wiggler, circumference chicane, tune trombone, etc?
   b) Is there sufficient margin in general dynamical parameters (damping times, equilibrium emittance and energy spread, etc.)?
   c) Does the momentum compaction factor provide a good compromise between RF requirements (at 6 mm and 9 mm bunch length) and instability thresholds?
   d) How does the lattice compare with others in terms of sensitivity to collective effects (such as impedance-driven instabilities, intrabeam scattering, space charge, ion effects, and electron cloud)?
   e) How much flexibility is there in tuning the momentum compaction factor?
   f) Is the dynamic aperture sufficient?
   g) Are there any particular benefits or concerns with the dynamics, specific to the lattice?

2. **Conventional facilities and services.**
   a) Is the layout technically feasible from point of view of:
      i) civil construction;
      ii) distribution of services, including air, water, cryogenics, power;
      iii) installation;
      iv) access for maintenance and repair.
   b) How would the cost for construction and installation compare with other lattices?
   c) Are there any particular benefits or concerns with the conventional facilities, distribution of services, or installation, specific to the lattice?

3. **Magnets, supports and power supplies.**
   a) How does the number of magnets, and the number of different styles of magnet, compare with the other lattices?
   b) Are the magnet parameters (length, field strength or gradient, spacing) reasonable?
   c) Compare the degree of magnet optimization required for the various lattices?
   d) How do the alignment and stability sensitivities compare with other lattices? In particular, what is the sensitivity of emittance dilution due to these effects.
   e) How do the numbers and types of supports required for the magnets compare with other lattices?

f) How do the numbers and types of individually powered magnets compare with other lattic

f) Are there any particular benefits or concerns with the magnets, supports and power supplies, specific to the lattice?

4. Vacuum system and radiation handling.

a) How do the aperture requirements compare with other lattice designs?

b) How does the difficulty of handling the radiation from the dipoles and wigglers compare with other lattice designs?

c) Are there any particular benefits or concerns with the vacuum system, specific to the lattice?

5. RF system.

a) How feasible is the RF voltage required, over the range of possible momentum compaction factors, to provide bunch lengths of 6 mm and 9 mm?

b) Is there sufficient space in the lattice for all required RF cavities (allowing some margin for klystron failure)?

6. Injection and extraction systems.

a) Do the injection/extraction optics meet the requirements?

b) Is there sufficient space for the number of required components (stripline kickers, septa…) and can they be clustered suitably to minimize the impact on the layout?

c) Are there any particular benefits or concerns with the injection/extraction systems, specific to the lattice?

7. Instrumentation and diagnostics.

a) Can the BPMs and other instrumentation and diagnostics be readily accommodated?

8. Control system, availability and reliability, other.

a) How does the complexity and cost of the control system compare with other lattices?

b) How would the availability and reliability compare with other lattices?

c) Are there any other particular benefits or concerns, specific to the lattice?

III. Ranking System

A ranking system with values 1-5, 5 being the best, was applied to each key question in each topic. For questions where absolute evaluations were required, the following scoring criteria were used:

5 – Item has been addressed in the lattice design and fully meets the DR specifications. In cases where lattice flexibility is required, the range of parameters has been thoroughly explored and meets the DR specifications for the entire parameter range. In cases where technical systems impact is being evaluated, the lattice design results in a technically feasible design with minimum cost.
4 – Item has been addressed in the lattice design but some refinement is still required to meet the DR specifications. In cases where lattice flexibility is desired, work remains to ensure that the DR specifications can be met for the entire parameter range. In cases where technical systems impact is being evaluated, the lattice design results in a technically feasible design, but technical issues remain and/or cost is not the minimum. In all cases, there is a high expectation that a successful design can be completed.
3 – Item has only been partially addressed. Significant work remains in order to meet the DR specifications. In cases where technical systems impact is being evaluated, significant technical issues remain and/or significant cost optimization is required. In all cases, there is a reasonable expectation that a successful design can be completed.
2 – Item has not been directly addressed in the lattice design. There is a reasonable expectation that a successful design can be achieved which meets DR specifications. In cases where technical systems impact is being evaluated, there is a reasonable expectation that technical and/or cost issues can be successfully addressed.
1 – Item has not been directly addressed in the lattice design. Significant questions exist about achieving a successful design which meets DR specifications. In cases where technical systems impact is being evaluated, there are significant uncertainties that technical and/or cost issues can be successfully addressed.

For questions where relative rankings were required, the ranking of the *best* lattice was calibrated with the above absolute rating scale. For cases where insufficient information existed to make an evaluation, an entry of "Ins." was recorded.

Within each major evaluation item, a weighted average of the rankings for each sub-item was used to generate the overall ranking for that item. Setting the weights of each sub-item was carried out as part of the evaluation process. In order to obtain an overall score for each lattice, the 8 item rankings were summed.

Special note: for entries labelled "Particular benefits/concerns", no value was entered in cases where no particular issues were identified during the course of the lattice discussions.

IV. Evaluation Table

Evaluation Item	**Weight**	**OCS8**	**FODO4**	**FODO5**	**DCO**
1. Lattice design and dynamical properties.					
Completeness	1.0	4	4	4?	4
Margin - general parameters	1.0	5	5	5	5

α_p choice	1.0	4	4	5	5
Compare lattice sensitivities to collective effects	1.0	Ins.	Ins.	Ins.	Ins.
α_p flexibility	1.0	4	5	5	5
Dynamic aperture	1.0	4	4	4	3
Particular benefits/concerns	1.0	-	-	-	-
Overall		4.2	4.4	4.6	4.4
2. Conventional facilities and services.					
Technical feasibility	1.0	4	4	4	4
Compare costs	1.0	Ins.	Ins.	Ins.	Ins.
Particular benefits/concerns[1]	1.0	3	3	3	4
Overall		3.5	3.5	3.5	4
3. Magnets, supports and power supplies.					
Compare magnet counts and types	1.0	3	4	4	4
Reasonableness of magnet parameters	1.0	5	5	5	5
Compare degree of optimization needed	1.0	5	4	4	5
Compare alignment & stability sensitivities	1.0	Ins.	Ins.	Ins.	Ins.
Compare support counts and types	1.0	3	4	4	4
Compare individual PS counts and types	1.0	3	4	4	4
Particular benefits/concerns	1.0	-	-	-	-
Overall		3.8	4.2	4.2	4.4
4. Vacuum system and radiation handling.					
Compare aperture requirements	1.0	Ins.	Ins.	Ins.	Ins.
Compare radiation load issues (dipole/wiggler regions)	1.0	Ins.	Ins.	Ins.	Ins.
Particular benefits/concerns	1.0	-	-	-	-
Overall		0	0	0	0
5. RF system.					
RF voltage requirements	1.0	2	2	4	4
Space in lattice for RF cavities	1.0	5	5	5	5
Overall		3.5	3.5	4.5	4.5
6. Injection and extraction systems.					
Suitability of inj/ext optics	1.0	5	4	4	4
Space in lattice for inj/ext components	1.0	4	4	4	4
Particular benefits/concerns[2]	0.5	3	3	3	4
Overall		4.2	3.8	3.8	4
7. Instrumentation and diagnostics.					

[1] A particular benefit was identified which was the ability to cluster all major components residing in alcoves within a few hundred meters of the two main access shafts. This is a distinguishing feature of the DCO design

[2] A particular benefit that was identified was the ability in the lattice to cluster the entire complement of injection or extraction kickers in a single location in the lattice, thus easing the injection/extraction region design.

Accommodation of diagnostics	1.0	4	4	4	4
Overall		4	4	4	4
8. Control system, availability and reliability, other.					
Compare cost and complexity	1.0	4	4	4	4
Compare availability and reliability	1.0	4	4	4	4
Particular benefits/concerns[3]	0.5	3	3	3	4
Overall		3.8	3.8	3.8	4
Grand Total		**27.0**	**27.2**	**28.4**	**29.3**

[3] The ability to concentrate control nodes at locations near the main access shafts is expected to improve the overall machine availability as well as to simplify maintenance.