Working Group 4 Accelerator Physics
Summary Report

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(Reported by Alex Chao)

Charges to the group

- Review the design to date.
- Identify calculations and experiments that are important for improving the design.

Working group schedule

Wednesday, 10:55 - 14:30
Longitudinal issues (Paul Emma)

Wednesday, 15:00 - 17:00
Optics issues (Yuri Nosochkov)

Thursday, 8:30 - 10:30
Operation issues (Marc Ross)

Thursday 11:00 - 12:30
Discussions, summary

Thanks

- Roger Erickson led the white paper study and reported at workshop.
- Roger Erickson, Paul Emma, Karl Bane, Yuri Nosochkov, Marc Ross, Tim Barklow worked in preparation for the workshop in spite of their extremely busy schedules!
- Paul Emma, Yuri Nosochkov, Marc Ross led the discussion sessions during the workshop.

Overall comments

- Saber accelerator design is based on solid experiences with SLC and SPPS. It has demonstrated feasibility of the Saber project. It is unlikely that surprises beyond SLC and SPPS are waiting around the corner.
- Design is sufficiently progressed to proceed to an engineering design together with its first cost estimate.
- One message is very clear: Saber is a facility for a wide range of user requirements. Jonathan Dorfan emphasized "spontaneity" of its use. Jo Stoehr asked for possibly much shorter pulse. Paul Emma pointed out the desirability of bringing the LCLS beam to Saber. All participants were excited about the wide range of possibilities of Saber. Let us keep it flexible and versatile! Users should not hesitate asking for flexibility. Accelerator physicists will be happy to (and are good at) thinking out of the box.
- Many issues were raised and discussed in three lively sessions. Lots of good ideas were suggested. Thanks to all!
- But don't rest. There remains lots of work to do…

White paper design as it stands

	Design nominal	Simulations (without errors)
E	28.5 GeV	
Species	both e+ and e-	
N	3.4 nC	
sigma_x	10 microns	5 microns
sigma_y	10 microns	5 microns
sigma_z	30 microns	20 microns
full mom. Spread	4%	4%
eta at IP	0	
eta' at IP	0	

The simulations listed above include wakefields, incoherent and coherent synchrotron radiation, and 2nd order optical nonlinearities. They do not include errors! Errors can change the results quickly.

[small print: CSR is notoriously difficult to calculate when one has to consider its transient effect and/or shielding effect.]

Sensitivity studies

Sensitivity to slight errors is expected of a highly optimized system in a multi-dimensional parameter space like SLC, SPPS, and Saber. In fact, the sensitivity to errors is a sign of how much we have pushed the system toward its optimization. It is not a sign of a defective design!

Sensitivity to various RF phase and beam intensity jitters was studied. Tolerances are tight, but not much beyond the SLC and SPPS level. Two to three feedback systems with 1 sec time scale should bring them into control. [Users: note that timing jitter at IP is likely to be 300 fs as it stands.]

Sensitivity to misalignments, field errors, 3rd order nonlinearities should be completed for the South Arc. Experience of SLC should come in handy.

Another view of the sensitivity is by looking at the trade-offs available. For example, by relaxing sigma_z from 25 to 41 microns, the (ugly) transverse beam tail clears. There are other trade-offs. [Users: just name your game! Explain which parameters are crucial to you, and also very importantly, which ones are not.]

Effects of magnet position vibration were studied. Users sensitive to beam position jitters at the IP should announce themselves.

Sawtooth instability in the damping ring

So far the nominal operation considers a beam intensity of 3.4 nC, which is above the sawtooth instability threshold. Although this is a relatively weak instability and we have lived with it in SLC, its effect on Saber should be examined more carefully. Is it advisable to operate at a slight reduced beam intensity? Also, for a 5 nC beam (specified for a noncompressed beam), this issue needs a closer examination.

Chicane magnets

$\Delta E/E$ in the chicane is 2% for Saber, compared with 1.6% for SPPS. This should be OK for magnet aperture.

However, to run both e+ and e-, the B1 and B4 magnets of the chicane are to be aligned straight instead of yawed. The corresponding cut in aperture needs to be addressed. If this cut is not tolerable, we need to evaluate the option of new wide-bore B1 and B4, to be operated in series with the B2+, B2-, B3+, B3- of the existing design.

Aside from the aperture issue, the straight configuration has different focusing to e+ and e- beams, requiring slightly different optics matching. When running e+, optimization is to be done for e+ beam, while the e- scavenging beam is estimated to be 30% mismatched, which should be OK.

Nonlinear optics issues

Optical design in the white paper was based on sound principles. As it stands, the beam maximum extensions are acceptable:

- 7 mm in the first dogleg of bypass
- 3 mm in the bypass straight section
- 12 mm in the second dogleg of bypass
- 4 mm in South Arc
- 13 mm in FFS quads

More simulations are needed to include various errors, and 3rd order perturbations. The impact of this study is most likely not on feasibility but on defining an optimal tuning procedure.

One concern is the correction of the nonlinear chromatic effects at the IP. These corrections are done by 8 sextupoles far upstream from the IP. Sensitivity to errors in the transport line between the sextupoles and the IP, including the South Arc, may play a role here. Studies are needed, both by simulation and experiments.

Sextupole alignments are likely to be important. Tolerance needs to be calculated.

The old arc components

Reuse as much of these components as possible.

It seems the old arc magnets, plumbing, magnet movers, vacuum, control all still work. It remains to be seen (by designed experiments) whether the SLC arc model developed for the SLC still applies.

Tracking of magnet fields has been performed for SLC, but it was at 50 GeV. Tracking over 14-28 GeV for Saber needs to be checked. Magnet quality with polarity reversal (for e- running) also needs to be checked.

Possibility of running a 5 GeV beam should be examined if there are users for it.

Experimental space

Users: Note that the IP has been moved downstream by 11 m compared with the white paper. Free space downstream of IP is therefore reduced from 23 m to 13 m. In addition to experimental requirements, this space should also accommodate beam diagnostics, separation of e+/e- beam and photons, possibly a spectrometer, and a beam dump.

Distance from last quad to IP is $L^* = 2$ m. This is a sensitive parameter. Need to re-examine this design parameter with users inputs. For some users, the IP location needs to be adjustable by FFS quads. Need to specify the range of L^* for these users and establish the optics (linear and nonlinear optics) capability to cover this range.

The transverse space around IP is approximately +- 3 ft 2π around. Space needed for a laser table, for example, in this limited space needs to be addressed.

Easy access is important for Saber users.

Arc3 magnets (the arc downstream of the IP) can be removed if more space is needed. The reverse bend region in the South Arc is not considered too useful at this point.

Diagnostics and corrections

Diagnostics will be needed in the chicane, the bypass, and the FFS. These diagnostics are used to (a) confirm the beam parameters at IP, (b) monitor the beam along the accelerator for tuning and feedback purposes.

Wire scanners should be provided for transverse beam measurements. Interferometer can be used for absolute bunch length measurement, and microwave spectrum can be used for pulse-to-pulse bunch length variation. These are considered straightforward. One can consider borrowing from FFTB.

A set of orthogonal correction knobs need to be defined. New correction magnets (correctors, skew quads, etc) may need to be added.

The diagnostic X-ray wiggler in the congested BSY region should be kept.

More options beyond the white paper

- Lower damping ring energy to lower the longitudinal emittance of the beam.
- Adding a short X-band section in the linac to optimize the longitudinal beam profile and therefore potentially shorter bunch length.
- Alternative bypass layout.
- Keep possibility of sending LCLS beam to Saber.
- Secondary beam possibilities.
- Moving chicane further upstream and/or an S-chicane.
- 50 GeV beam to Saber.

Due to lack of time, not all of these options were discussed in detail in the working sessions. Those discussed in detail are given below.

Lower damping ring energy

Bunch length is proportional to E^3. Reducing the damping ring energy from 1.2 GeV to 0.75 GeV has been studied (Mark Woodley, Richard Iverson). In order to implement this option, one needs to rework the shunt boxes for the damping ring injection and extraction magnets.

A simulation (Karl Bane) for a 0.9-GeV damping ring gave an rms bunch length of 10 microns or less.

The sawtooth instability in the damping ring becomes more serious and needs to be evaluated. Furthermore, if the damping ring energy is lowered much beyond 0.9 GeV or so, it is estimated (Karl Bane) that threshold of the next, stronger instability will be crossed, and if so, that will impose a hard limit to Saber operation.

Intrabeam scattering is another possible issue. Damping time is OK however for a 10 Hz operation of Saber.

Alternative bypass layout

The bypass region is a very congested area. As it stands, the obvious magnet interferences have basically been resolved, but still needs to be confirmed carefully. This is believed to be a resolvable issue although lots of equipments for the LCLS-to-Sarc line have to be removed and possibility of LCLS beam to Saber is eliminated in the present design.

If an alternative line can be found, it may allow keeping many diagnostics and control components, and it may allow better nonlinear optics design. A possible alternative is found in this workshop (Roger Erickson) by moving the bypass-to-Sarc joint further downstream from the present point (51B2 magnet).

Bringing the LCLS beam to Saber

Another exciting possibility that substantially improves the outlook of Saber is to look for a solution that allows sending the LCLS beam to Saber. In the present design, after the bypass is installed, the LCLS beam can in principle be sent to Saber if the 50B1 and 51B2 dipoles are replaced by pulsed magnets. This remains a possibility.

However, an alternative idea from Ted Fieguth seems more exciting. In this possibility, the magnet 50B1 is simply turned off. The bypass line will go off the linac on the north side (instead of the south side as the white paper design). The bypass then approaches back toward the linac at the position of 50B1 at an angle of 1 deg from north. With 50B1 turned off, the beam enters directly the existing 51 line and go straight all the way to Saber. When one wants to send the LCLS beam to Saber, just turn 50B1 on!

In the above scenario, one can consider replacing 50B1 by a pulsed magnet to allow pulse-to-pulse operations for both LCLS and Saber (Franz-Josef Decker).

Secondary beams

Key of making the secondary beams at Saber is to provide a way to remove the primary beam after the secondary beam is produced.

Any one wants pions? Pions are a more substantial secondary beam requirement.

Double bunches

Is there a need to provide for a train of multiple bunches for Saber? In case of a two-bunch train, what range of spacing is needed?

Experiments for accelerator physics

Saber is presently considered to consist of 3 phases:

Phase 1: 30 GeV uncompressed e+ to South Arc, by end of 2006.
Re-establish the line as a system. Check beam losses, wire scanners, BPMs, and X-ray chicane. Important to confirm that the SLC optics model and the established tuning procedure of the SLC still apply. Measure energy pass band.
Time window: 9 months, parasitic to PEP-II running.

Phase 2: New chicane. Compress e+, September-November 2007.
Important to test this stage fully, particularly the ultra short bunch length.
Time window: 12 months, either parasitic to PEP-II or parasitic to LCLS running.

Phase 3: Add bypass, ready when the PEP-II program ends at end of FY2008.

Beam parameters:

	LCLS e-	DR e+	DR e-
Phase 1	0.3 nC	3 nC 600 micron z	3 nC 600 micron z
Phase 2	2.6 micron z ! 1 nC 13.6 GeV	30 micron 30 GeV	30 micron 30 GeV
Phase 3	???	white paper	white paper

All phases can accept users.

Most interesting accelerator physics is expected when/if the LCLS e- beam is available to Saber (most likely during Phase II). But there are two questions: (a) Will machine time be available when it runs parasitic to LCLS and/or PEP-II? (b) As it stands, this exciting option disappears in 2009 when Phase 3 starts. Let’s try to keep it!