Technical Advisory Committee (TAC)
Report 5: December 10-11, 2001 Meeting

TAC Committee Members:
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The purpose of the Technical Advisory Committee (TAC) is to provide expert advice with regard to the R&D program of the Linac Coherent Light Source (LCLS). The report contains (A) general comments and sections on (B) the injector, (C) the accelerator and compressor, (D) the undulator, (E) x-ray optics, (F) FEL physics, and a new section on (G) system issues.

A. General Comments

The TAC compliments the continued drive and enthusiasm of the LCLS R&D collaboration. The collaboration as a whole is working well.

Highlights of the meeting were discovery of electron pulse microbunching, and the continued use of start-to-end simulations.

After reviewing the general comments of the first TAC report, we suggested that "a workshop with members of the table-top laser community may be technically fruitful. Collaboration between these communities is a key point of the Leone Panel on Novel Coherent Light Sources for DOE/BESAC in February 1999."

B. Injector

The Committee is delighted to see substantial improvements in both injector experiments and simulations. There now appears to be excellent coordination between the two efforts. The addition of new personnel to the injector effort is a major step forward.

Experiments:

The improved measured emittance values offer hope of achieving design goals. There are however, still some issues to be resolved

- YAG screen resolution - easy check planned
- Solenoid quad moment – planned fix
- Anomalous correlated energy spread, not just GTF issue
  - no clear answer yet
- Thermal emittance – still some debate as to the correct value to use in simulations

Simulations:

- The simulation effort is now very comprehensive, use PARMELA and

PIC codes now are supplementing HOMDYN.
- o The use of real field maps and drive laser profiles in simulation is an important step forward.
- o The details of the sensitivity studies were quite impressive.

Important things to do:

- o Upgrade drive-laser to get 1 nC reliably.
- o Resolve energy spread issue
  - Need to include gun wakefields in simulations
  - Measure longitudinal phase space
  - Measure gun field balance
- o Check YAG resolution
- o Measure "thermal emittance" - include results from other labs with similar guns
- o Implement drive-laser pulse shaping
- o Cross check numerical results with ASTRA code

The team should not wait until 2004 to begin work on the LCLS gun design. Therefore, it is important to fund further R&D, including design of an LCLS gun prototype immediately, and not wait until 2004. Therefore, the injector should be given earlier funding priority in FY 03. In addition, the reliability of injector components should be addressed soon.

C. Accelerator and Compress

Linac

- Overall we heard about a lot of progress
- Great job this past year.
- Need to adapt to new operational models
- Team is working well together
- New issue: CSR microbunching
- Inclusion of a compression scheme using a superconducting wiggler

CSR Micro bunching

- Continue efforts on simulation and comparison with experiments
- Theory of bunching and transient CSR wake
- Modeling of microbunching
- Adaptations of design to reduce the effect
- Critical to compare calculations with experiments
  - o Run simulation of SDL and compare data
  - o Simulate TTF and compare with their data
  - o Very critical to benchmark soon
  - o Slice diagnostics may be critical to optimize system.

Start to End Simulation

- Jitter simulations going well

- Comparison of CSR effects with APS data
- VISA experiment comparison with simulation
- Gaining confidence in tools
- Need to continue with microbunching comparisons
- Benchmarking with the SPPS will also be critical
- Run SPPS as soon as possible!!!

D. Undulator

- The strategy of bulk buying of reasonably specified permanent magnet (PM) blocks to minimize costs is a good one. There is no need to over specify PM block mechanical or magnetic tolerances. The obtainable PM block quality is very much improved and is good news for the LCLS undulator magnetic performance and quality.
- That said, error fields depend, among many other things, on:
  "which pole the PM is up against"
  "orientation and strength of minor magnetization components"
  "strength or major magnetization component"
  "etc"

  These effects likely must be quantified in order to have a realistic chance of reaching the stated goal of undulator assembly followed by verification of magnetics performance, with the expectation of not having to do time consuming post-construction block shimming, tuning, etc.
- A plan was not presented for any specific undulator correction method, if undulator performance/field quality falls short of specs on the first pass. Has any necessary undulator measurement data post-processing software been written and tested?
- Is understanding of the undulator requirements sufficient and current? Are they fully translatable to magnet tolerances, magnetic tolerances, etc?
- The present design calls for undulator and quadrupole mechanically on the same support structure and thus their alignment is yoked. [Stepper motor] resolution is ~45 nm. Alignment repeatability capability of this undulator/quad structure has achieved 5 microns; the requirement for the quadrupole alignment is 1 micron. Further improvement is still needed. Why are common supports needed with undulator sections?
- Be prepared to defend the choice of PM technology for the quadrupoles. Is coping with the cooling-induced thermal expansion of electromagnet quads more difficult than dealing with the lack of tuning capability of the fixed strength PM quads? What are the benefits of permanent magnet concept versus difficulties? Revise permanent magnet quadrupole concept vs. operation simplicity of beam based alignment and flexibility.
- Repeating a small sampling of the PM block measurements on a second Helmholtz coil setup would be a truly independent verification measurement.
- Consider addition of spacers to fix PM relative to upstream block. Previous experience has demonstrated that a 0.020" PM 'slop', when

decreased via mylar spacers to 0.002” results in a significant decrease of dB/Bpeak rms (e.g., from 0.0065 to 0.0011).

- There is just one PM block per pole surface. It may be worthwhile to calculate expected variations in pole tip scalar potential. What on-axis field errors would arise from the known PM magnetization distribution? If a beam is off-magnetic axis by 30 microns does it matter, in view of these field errors?
- Perhaps it is worthwhile to intensify the R&D effort on tube roughness (longer pipes, larger samples for microscopy).

E. X-ray Optics

The definition of the project scope has been refined. The experiments per se are no longer part of the scope. However, under the definition of ‘tools to characterize and deliver the photon beam’ described in the baseline design most of the optical elements required by the first experiments are included in the project. It is very important that these optical elements remain as part of the project scope. They will provide important experimental capability during the early commissioning and first lasing. It should be emphasized that the experience at the Tesla Test facility was that having the ability to characterize the ‘first’ photons was critical.

The production of short pulses was presented. As part of the ‘sixth’ experiment the two undulator scheme, proposed by DESY to provide a transform limited FEL pulse in the UV-soft x-ray region, can be adapted to produce very short pulses (~10fs). The concept, which places a monochromator between two undulator sections, eliminates radiation damage issues on the optics, reduces fluctuations, and eliminates monochromator losses that would be present if the monochromator is placed downstream of the undulator. Finding for this idea should be pursued as well as support for other aspects of the ‘sixth’ experiment.

Finally the Sub picosecond Photon Source (SPPS) was presented. The SPPS provides opportunities for R&D associated with the experimental program: photon bunch length measurements, development of pump laser-x-ray probe time correlation methods, x-ray beam manipulation (splitting, delaying and recombining, and new science. The LCLS staff is encouraged to work with others in these activities to provide important tools needed for early success of the first experiments.

F. FEL Physics

Have potential implications for the FEL physics at 1 nC versus 0.2-0.3 nC been anticipated/explored? How confident are extrapolations? Is the 1 nC regime adequately explored/parameterized?

Continue to develop plans to deal with the microbunching and the newest emittance growth projections? Will the compensating factors presented (single chicances, superconducting wiggler, DL2 bend reduction, improved CSR calculations) be adequate.

G. System Issues

- Minimize risks wherever reasonably possible
  - Resistive wall and roughness wakes vs. undulator aperture: Increase aperture? Investigate radiation hazard.
  - Allow technically for large parameter space (Q, I, ε). It is too unsafe to restrict design to what is now considered the optimum; optimum may also be different for different users.
  - Plan for 50m more tunnel length than you presently believe you need.
  - Allow for costs to improve reliability by redundancy (e.g. rf gun laser)

- Make sure at least two pilot experiment groups are in the boat during construction and commissioning of the machine. You need their photon diagnostics hardware and their knowledge of user demands, they need to understand the machine.
- Allow for two times more electron beam diagnostics tools than you think are necessary.
- Investigate parameter sets which intentionally wastes 80% of beam and make possible they can be operated. See DESY experience at TTF FEL.
- What is the robustness of operating point, considering simultaneous perturbations in charge, spot size, solenoid field, laser phase, E-field, gun balance, etc? Is there any nonlinear response to this multivariable system? [Quantify the correlation between parameters.]

The two stage chirped beam requires a ~33m electron beam bypass and (?) additional undulator length. Have facilities plans been optimized to accommodate this potential upgrade?