Technical Advisory Committee (TAC)

Report 2: February 11-12, 2000 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) SASE Experiments VISA, LANL, LEUTL, and DUV/SDL, (C) the injector, (D) the accelerator and compressor, (E) the undulator, (F) x-ray optics. (G) FEL parameters and simulation.

A. General Comments

We thank the collaboration for outstanding, focussed presentations. The collaboration has made use of limited funding to achieve excellent "bang for the buck". High praise goes to APS, BNL, LANL, LLNL, SLAC, and UCLA for continued support. Future support depends on this continued effort. Hard choices have been made and will need to be made again.

There needs to be close contact between the LCLS TAC and Scientific Advisory Committees (SAC), so that we all have an understanding of the LCLS capabilities and flexibilities. Three presentations were given at the March 2000 SAC meeting describing several flexible LCLS capabilities, including shorter x-ray pulses (10 femtoseconds), tunable wavelength ranges, and seeding the x-ray pulse. Continued communication between the TAC and SAC is important to build the LCLS scientific case.

Time is critical for organization and preparation of the Conceptual Design Report (CDR). The collaboration must make milestones to keep on schedule for the current funding cycle. In the short term, early experimental results from VISA, AFEL, and LEUTL are important. Engineering cost estimates are needed and the SLAC injector program should be evaluated.

B. SASE Experiments (Bill Colson, Naval Postgraduate School)

It is emphasized that the current SASE experiments must be used to feed new information to the LCLS CDR.

VISA is a key experiment which expects to have results by late May 2000 in time to contribute to the CDR. Important issues to be addressed are SASE saturation and the effect of slice emittance on high gain. The FEL will make use of an electron gun with low emittance of approximately 1 micron (1 mm-mrad) emittance, the kind of beam quality needed for the LCLS. It is important to establish that the relevant emittance for a high gain SASE FEL with small slippage is actually the slice emittance. The extensive VISA diagnostics are crucial for understanding the effect of slice emittance. The results may be ready for the next TAC meeting in May.

The LANL SASE experiment is expected to have results in the next few months and also contribute to the CDR, but with fewer diagnostics than VISA. Results will confirm the statistics of fluctuations at saturation at a longer 18 micrometer wavelength, and will increase FEL experience with another low emittance gun operating at ~1 micron.

The LEUTL experiment will explore SASE, bunch compression, and saturation at 530 nm wavelength this summer (July 2000 is proposed), and may be able to include some results in the

CDR. Bunch compression experience is crucial to the LCLS operation at x-ray wavelengths, and LEUTL will operate at shorter wavelength than either VISA or LANL.

The DUV/SDL is planned to be a dedicated SASE facility with 0.3 ps pulses. While commissioning is scheduled soon, results are longer term and probably will not influence the CDR. The development of diagnostic techniques for sub-picosecond pulses, and bunch compression experiments will be important long-term contributions to the LCLS project. We believe that the DUVFEL is now producing beam.

C. The LCLS Injector (Pat O'Shea, University of Maryland)

We see from the presentations made at the review, that a considerable amount of work is being done at the collaborating laboratories. There have been some good developments during the past six months in the area of simulation and theory. The new low-emittance physics designs look promising. Experimental results from both LANL and BNL show that sub-bunch or slice emittances of approximately 1 micron have been achieved. All indications are that drive-laser pulse shaping will result in total bunch emittance close to 1 micron.

In the cathode area, the work on Mg at BNL and Cs_2Te at LANL both appear to offer promising alternatives to Cu as a cathode material.

We note that the primary goal of the LCLS injector program should be the development of a system design for an injector that will satisfy all of the LCLS requirements. By system design, we mean a complete device that not only meets the design goals in a physics sense, but also in terms of robust reliability.

Our main concern in regard to the photoinjector development work is that it lacks focus on the primary photoinjector LCLS goal stated above. This was the primary concern of the last TAC review, and little improvement has occurred in the past six months. In many ways our recommendations on this topic are similar to the last TAC report.

Summary of injector recommendations:

General issues:

- Improve the focus to the R&D program to the primary LCLS design goal.
- Minimize the diffusion of effort among the collaborators with experimental photoinjector programs.
- Make clear how developments at each lab feed to the design effort.

To help focus on the primary goal we have developed the following plan:

- Start with the photoinjector performance goals
- Evaluate the state of the art for each subsystem (laser, cathode, gun cavity etc.) for its ability to meet these goals
- Down-select those elements that appear to meet the goals
- Focus the R&D program on specific unresolved issues in a timely fashion.

Take the cathode choice as an example of some confusion and lack of focus. We have heard about Cu, Mg and Cs_2Te. One of these should be chosen in an unambiguous manner as the mainline approach. At present, we have heard no clearly stated plan for how and when the choice will be made.

It may happen that a complete injector design that meets all LCLS criteria may not emerge prior to CDR. This is not necessarily bad, so long as there is a well defined program to solve the remaining problems.

In terms of a near-term experimental goal, we recommend that drive laser pulse shaping as a path to 1 micron emittance be emphasized:

- Perform direct measurement of electron beam phase space at exit of the gun using a streak camera or other technique.
- Perform detailed experiments from low to high charge.
- Study robustness/reliability of gun performance.

In the long run, robustness and reliability are key attributes of the injector. An injector that produced 1.5 micron, 1 nC beams reliably would be preferable to one that produced 1 micron beams occasionally.

D. Accelerator and Compressor (Ron Ruth, SLAC)

The LCLS group working on linac and compression has made excellent progress over the past few months. They are exploring a new capability of providing even shorter bunch lengths, down to 50 fs and are addressing the associated technical specifications and problems such as phase stability. One important new development is the progress with the design of the linac and bunch compressors. The new proposed design seems more robust and yields less emittance blowup. Start-to-end simulations are moving forward. To address bunch compressors and linac problems the group plans to use the LEUTL facility. It should be an excellent test bed, since it will have a near prototype for bunch compressor one in the LCLS design. Important initial experimental results will include measurements of CSR.

Overall there is excellent progress in this area. The new design appears more tolerant to inadvertent errors and might allow the very short bunches with retuning only. We encourage the group to pursue these lines of development.

E. Undulator (Ross Schlueter, LBL)

At the time of the last TAC meeting (July 1999), the Argonne team had recently joined the LCLS collaboration. Argonne took charge of the development of the undulator and associated components.

A significant (and somewhat contentious) issue at the time of the July 1999 TAC meeting was agreement on the choice of undulator technology, which would greatly affect the radiation characteristics and the projects technological risks. This issue has since been resolved, with Argonne concentrating development efforts towards a hybrid-based undulator technology producing linearly polarized light on-axis.

At the first meeting, the TAC committee suggested that it would be appropriate to hear about:

(1) the Argonne team's views on the baseline design details (as presented in the 1998 LCLS design study), and any proposed modifications,
(2) the baseline (hybrid) prototype development and test plan,
(3) LEUTL design and results and,
(4) the superconducting helical strawman option conceptual design and prototype plan.

The TAC committee is happy to report that all four of these issues have received the attention of the Argonne team over the past 7 months and were adequately addressed in the second TAC review.

In particular, the TAC committee was impressed with the quantity and quality of work completed during this period. A baseline undulator design is fully developed, with thought put into the difficult job of alignment of undulator sections, and lattice modifications that may make alignment of the undulator sections simpler.

The LEUTL experiment has progressed significantly, and results and developments made on this experiment bear directly on LCLS.

The TAC committee looks forward to hearing details about alignment and magnetic measurements at the next TAC meeting. Effect of alignment on radiation output and schemes to make such adjustments in a reasonable period of time are appropriate topics for continued work and discussion at the next TAC.

Likewise magnetic tolerances are very tight, so schemes for meeting, fiducializing, and measuring these tolerances are appropriate topics for continued work and discussion at the next TAC.

F. X-ray Optics (Dave Attwood, LBL)

The TAC is very pleased with progress at Lawrence Livermore in forming a team for high intensity optics, and for addressing recommendations of the previous meeting.

A layout of the LCLS experimental hall has been developed, which addresses upstream requirements for the first optical elements that experience the highest intensities and power loads.

Progress has been made on the definition of diagnostics for both coherent and spontaneous undulator radiation, including intensity, divergence, spatial and temporal coherence, temporal structure, and harmonic content.

Attenuation cells that will permit measurement with large dynamic range performance have been addressed.

Calculational tools for understanding surface dose and the performance of optical elements is underway.

X-ray optical techniques for pulse compression and control are being addressed.

G. Simulations (Bill Colson, Naval Postgraduate School)

Simulations have been used well in support of design decisions. The simulation codes appear reasonably mature and appear poised to contribute to the CDR. The code workshop held earlier this year showed confidence in the existing code methods, and new improvements to the codes is proceeding well.

The formal parameter list is important and developing well.

Simulations predicted the LCLS drop in performance with increasing emittance, and showed no real “cliff” as emittance is increased beyond the design specifications. This is encouraging and indicates robust performance over a range of emittance values.

A task force has been formed to develop a clearer understanding of slice emittance and its role in the high gain, small slippage LCLS. This understanding, supported by theory and code development, should play an important role in the upcoming CDR, and the relevance of the VISA experiments that explore aspect of slice emittance.