LCLS Newsletter 08-May-2000

Project Management *Lowell Klaisner, Max Cornacchia*

There will be an LCLS TAC meeting May 19-20. The tentative agenda is as follows ..

Friday May 19, 2000

8:00 AM	8:30 AM	0:30 Continental Breakfast	
8:30 AM	9:00 AM	0:30 TAC Executive Session	W. Colson
9:00 AM	9:05 AM	0:05 Welcome and Charge to the Committee	K. Hodgson
9:05 AM	9:30 AM	0:25 Project Overview	M. Cornacchia
9:30 AM	10:00 AM	0:30 Summary of SAC Meeting	I. Lindau
10:00 AM	10:15 AM	0:15 Coffee Break	
10:15 AM	10:45 AM	0:30 Injector -- Overview	J. Clendenin
10:45 AM	11:15 AM	0:30 Injector -- Gun	J. Schmerge
11:15 AM	11:45 AM	0:30 Injector -- Laser	A. Fisher
11:45 AM	12:15 PM	0:30 Injector -- Beamline and Diagnostics	M. Woodley
12:15 PM	1:15 PM	1:00 Lunch	
1:15 PM	1:35 PM	0:20 Undulator -- Introduction and Overview	E. Gluskin
1:35 PM	1:55 PM	0:20 Undulator -- Tolerances	N. Vinokurov
1:55 PM	2:25 PM	0:30 Undulator -- Magnetic and Mech Design	E. R. Moog
2:25 PM	2:45 PM	0:20 Undulator -- Magnet Meas. And Tuning	I. Vasserman
2:45 PM	3:00 PM	0:15 Coffee Break	
3:00 PM	3:30 PM	0:30 Linac -- Overview	V. Bharadwaj
3:30 PM	4:00 PM	0:30 Linac -- Design	P. Emma
4:00 PM	5:00 PM	1:00 X-Ray Optics	A. Toor
5:00 PM	5:30 PM	0:30 TAC Executive Session	W. Colson

Saturday May 20, 2000

8:00 AM	8:30 AM	0:30 Continental Breakfast	
8:30 AM	8:45 AM	0:15 LCLS Parameter Control	H.-D. Nuhn
8:45 AM	9:00 AM	0:15 End to End Simulations	H.-D. Nuhn
9:00 AM	9:30 AM	0:30 FEL Physics and VISA experiment	C. Pellegrini
9:30 AM	10:00 AM	0:30 Summary	E. Paterson
10:00 AM	10:15 AM	0:15 Coffee Break	
10:15 AM	12:00 PM	1:45 Executive Session and report writing	W. Colson
12:00 PM	1:00 PM	1:00 Lunch	
1:00 PM	2:00 PM	1:00 Executive Session and report writing	W. Colson
2:00 PM	3:00 PM	1:00 Closeout	W. Colson

<u>LCLS General Seminar</u>

There will a seminar on Monday, May 8, 3:00 pm, LOS 2nd floor conference room. Paul Emma will report on the status of "end-to-end" tracking.

FEL Physics Section Report *C. Pellegrini, H-D Nuhn*

SLICE EMITTANCE TASK FORCE

- Overview

The fourth meeting of the Slice Emittance Task Force group took place on March 30, 2000 with contributions by S. Gierman ("Measurement of the Core Emittance at the GTF"), G. Stupakov ("Collimator Impedance Calculations") and by D. Walz (Collimator Design).

The objective of the Slice Emittance Task Force is to develop a realistic estimate for the 6 D phase space distributions of electron beam slices at the entrance of the LCLS undulator and to evaluate their effect on the generation for FEL radiation inside the undulator.

The main tool will be a system of simulation codes that will be used to track the electron distribution through the LCLS system. The major components are coming together:

- Linac Simulations

The electron optics for the main part of the linac, from end of L-0 to the entrance of the undulator has been developed by M. Woodley and an input file for M. Borland's code ELEGANT has been produced. P. Emma has tested the ELEGANT code and did the first simulations of a model 6 D phase space distribution from L-0 to the entrance of the undulator. This initial model phase space distribution was not yet based on Parmela runs. It was generated for optimum performance in the Linac and Bunch-Compressor system. In this run, the projected emittances increased on average by about 50 % but the slice emittance of 10 % of the bunch length increased by as little as 3 %. This is the first verification by simulation that a small slice emittance can survive the transport through linac and bunch compressors up to the entrance of the undulator. This is very good news.

- Parmela Simulations

The next step will be to use the Parmela code to transport an electron distribution from the cathode to the end of L-0. The simulation needs to include a realistic estimate for the thermal emittance and the injector components need to be tuned so that the simulated electron distribution at the end of L-0 closely approaches the optimum model emittance described, above. This step is very important and it is hoped that D. Palmer and P. Krejcik will help with these simulations.

Recently, Parmela simulation output has been provided by J. Rosenzweig. The distribution did not include a thermal emittance and the energy chirp along the bunch was not optimized. P. Emma analyzed the distribution and found the slice emittance to be small and constant along the undulator, even though there was still a misalignment of individual slices, with respect to each other, left. This slice misalignment expresses itself as a variation of the beta-function. P. Emma has tracked the distribution with ELEGANT and found that the variations of the beta-function survive the transport. We are now studying its effect on FEL performance. It is hoped that the addition of thermal emittance will reduce the overall beta-function variations.

- Bunch Collimator

C. Pellegrini proposes a beam collimator to reduce beam charge and beam emittance after the L-0 point. This concept would allow to manipulate the transverse beam dimensions without the need of retuning of the injector.

C. Schroeder has worked out an electron optics that increases the rms beam size to about 0.6 mm at two x, y collimator locations that are separated by 90 degrees in betatron phase advance. The total required length for that beamline is 10 m. The large beta-functions are required in order to minimize the bore aperture required for the collimator.

D. Walz estimated that for the collimator a cylinder made from Tungsten-Rhenium of 3.8 to 4 cm length would be sufficient. The diameter of the cylinder would be about 5 cm. A total length of 9 cm would be required for the whole structure. The required bore aperture of less than 0.5 mm is a problem that would need to be studied.

G. Stupakov presented rough impedance estimates for the round collimator bore in a metal surface, according to which the emittance increase could be as large as 1 mm mrad. More precise estimates require considerable amounts of work.

The next meeting with a topic related to the slice emittance question will be the LCLS Seminar on Monday May 8, 2000, where P. Emma will discuss his recent work on tracking Parmela output with ELEGANT.

VISA TRAJECTORY ANALYSIS

The last run on VISA before the shut down took place on Thursday, April 27, 2000. During that run a set of trajectory readings for the both the horizontal and vertical planes was taken for a variety of settings of the two upstream correctors. The analysis of this data, which is of much greater quality than what was taken in previous shifts, shows that the vertical trajectories can fairly well be described by betatron oscillations caused by launch errors. The same is true for horizontal difference trajectories. This indicates that the VISA quadrupole lattice has no major errors. The horizontal trajectories don't fit well to a single betatron oscillation. The data indicates that the beam receives a horizontal kick somewhere in the middle of undulator segment #3. A undulator misalignment has been considered as a a possible source for such a kick, but the results are not conclusive.

Undulator *Efim Gluskin/Liz Moog*

Further testing was done to determine the effect on the gain length of changing the transverse beam distribution in the RON simulations. When the approximation used for a Gaussian distribution is a distribution where the product of the particle density at the center of the beam and the rms beam emittance is the same as for a Gaussian, the resulting calculated gain length agreed with the results of other calculations. Other approximations to a Gaussian distribution resulted in a variety of other values being calculated for the gain length. This highlights the sensitivity of the gain length to the particle distribution in the beam.

Using the distribution that gives results that agree with other codes, the 'average' gain length was determined as a function of the length of the undulator section, for beam energies of both 14.35 GeV and 4.5 GeV. (The 'average' gain length takes into account the space between undulators, getting longer as more physical length is taken up by quadrupoles and inter-undulator drift spaces.) An undulator length of 3.36 m was found to be acceptable at both energies. It was assumed that every third space between undulators would be longer in order to accommodate more elaborate diagnostics. The shorter spaces would include, tentatively, only quadrupoles and beam position monitor pickups.

The quadrupole positions achieved after P. Emma's beam-based alignment simulation were used to determine the increase in the gain length due to the non-ideal trajectory. The decrease in intensity of the output signal at the end of the line of undulators was found to be a factor of e, meaning that the saturation length would be longer by about a gain length, or about 7 m. The simulation assumed 1.92-m-long undulators. Similar beam-based alignment simulations and intensity calculations are planned for 3.36-m-long undulators.

Experimental Program *Ingolf Lindau*

<u>Summary of the SAC mtg March 30-31, 2000</u>.

On February 28, 2000, the SSRL Director Keith Hodgson gave a status report of the LCLS project for BESAC.The outcome was that we have been asked by DOE to produce a document describing the first 5-6 experiments on LCLS and deliver this document to DOE not later than September 1, 2000.A broader class of experiments and their scientific impact may be discussed but should also be narrowed down to describe a specific experiment or sets of experiments, including a description of the technical feasibility to carry through the experiments. It is anticipated that some of these experiments can be considered as high-risk and with forward-looking and novel ideas. The total length of the document should be about 50 pages. This document will be reviewed by DOE and if the evaluation is positive it will provide the basis for Justification of Mission Need (CD1). It is thus extremely important that LCLS is successful in achieving this milestone. The LCLS Scientific Advisory Committee (SAC) has been charged to develop this document and this was the focus of the meeting March 30-31. SAC was successful in defining six classes of experiments and appoint spokespersons for all these working groups, except for one. It is further noteworthy that SAC considered it very important that one of these groups addresses the development of LCLS performance characteristics beyond what is in the baseline design. A draft report should be ready by the next SAC meeting July 14. Below is the list of the selected research areas with a short description of the research. The composition of the working groups are not fixed and you are all encouraged to contact the spokespersons for the different working groups directly for your inputs and suggestions.

Initial LCLS experiments, team leader (underlined) and teams
as recommended by the LCLS SAC (not in priority order):

A. Structural Studies on Single Biomolecules and Particles
Janos Hajdu
John Miao
Keith Hodgson
Richard Neutze
Gerd Materlik
Edgar Weckert

B. Warm Dense Matter
Dick Lee
Robert Cauble
Justin Wark
B. Remington

C. High Field Physics
Phil Bucksbaum
Rick Freeman
K. Kulander
Roger Falcone
Linda Young

D. Nanoscale Dynamics in Condensed Matter
Brian Stephenson
Simon Mochrie
Mark Sutton
Steve Dierker
Keith Nelson
Sunni Sinha
Francesco Sette
Dieter Schneider

E. High Field X-ray Laser Physics
Jerrv Hastings

Optics team:
Andreas Freund
Denny Mills
Art Toor

Seeding team:
Li-Hua Yu

Ultra-short electron pulse team:
Paul Emma

F. Femtosecond Chemistry

To be determined

Scientific Case for Initial Experiments at LCLS

A. Structural Studies on Single Biomolecules and Particles

LCLS has the potential to ultimately realize imaging of single biomolecules with atomic resolution, and in a more general sense to determine the structure of non-crystalline materials. This would open up a new avenue for structure determinations with a broad impact. Detailed simulations have provided convincing evidence that the LCLS x-ray pulse in the femtosecond time-domain can produce a diffraction pattern before the molecule explodes. Furthermore, LCLS can greatly alleviate the crystallization problem by extending x-ray crystallography for micrometer protein crystals. Such measurements, if successful, would truly revolutionize structural molecular biology.

B. Warm Dense Matter

Warm dense matter is a high energy density plasma, which is defined from a plasma physics point of view by strong coupling between the particles and from a condensed matter physics point of view by a temperature comparable to the Fermi energy. The basic physical properties of warm dense matter are not well-known. The LCLS x-ray beam is ideally suited to create, in a controlled fashion, this plasma which can then be probed with a number of experimental techniques. Of interest for study are, for instance, the kinetics behavior (important for x-ray laser schemes), the plasma coupling (dynamic structure factor), the bound-bound transition formation (plasma coupling for an ion), and profiles of plasma formation. This research field is of interest for high-power x-ray laser generation, laser plasma production, inertial fusion and astrophysics.

C. High Field Physics

The LCLS allows totally new atomic physics because photoionization is saturated in the unfocussed LCLS beam and Compton scattering is saturated in the focused LCLS beam. All material in the LCLS beam is affected by this new physics. The experimental program is based on the measurement of photoelectron energies, ion charge states and time resolved fluorescence from gases and solids. With the LCLS beam it will be possible to study so-called hollow atoms, *i.e.* atomic systems where inner core-levels have been removed with outer electrons still in place. The high degeneracy, 10^9, of the LCLS beam also makes it possible to study nonlinear x-ray interactions: parametric down-conversion, two-photon absorption and two-photon mixing. This is a virgin research field. Not even basic physical parameters, *e.g.* the cross-sections for two-photon absorption involving inner core-levels, are known experimentally.

D. Nanoscale Dynamics in Condensed Matter

Collective excitations in matter have associated time and length scales. Examples of such excitations are phonons, magnetic excitations, or the appearance of charge and spin ordering phenomena in correlated materials. In condensed matter physics the length scales of interest vary from microns to atomic dimensions and the time scales of interest cover the seconds to femtoseconds range. In a space-time correlation plot within these boundaries optical methods cover the length region down to a fraction of a micron, while inelastic x-ray scattering and neutron scattering cover a small part of the remaining phase space. The LCLS provides the unique capability to study length scales below those attainable with optical radiation with time resolution spanning from seconds into the femtosecond regime, *i.e.* phase space that is presently unexplored. The phenomena to be studied cover a broad range, *e.g.* structural relaxation in polymers, structural phase transitions, domain switching in ferromagnetic and ferroelectric materials, *etc*.

E. High Field X-ray Laser Physics

This experimental program is concerned with the beam line optics underlying all other programs and improving the LCLS parameters to meet future requirements. The technical design of LCLS provides a baseline of performance parameters for the first round of experimental programs. Novel scientific opportunities wilbecome available if the baseline parameters are improved. These efforts include the production of ultra-short pulses of 50 fs or below, seeding of the x-ray photon pulse to improve the characteristics of the x-ray pulses, and the implementation of x-ray pulses with a specified pulse train structure. The interaction of the LCLS x-ray pulse with optics and detection schemes for femtoscond x-ray pulses are also important research topics.

F. Femtosecond Chemistry

Chemical bonds are formed and broken on the femtosecond time-scale. Conventional femtosecond lasers in combination with molecular structural simulations are presently providing a wealth of information on bond breaking/formation and chemical reaction paths. In principle, electron diffraction experiments can provide structural information but they cannot reach the desired femtosecond time scale. The time-structure of the LCLS pulse is ideally suited to provide structural information of the dynamical processes on the femtosecond time-scale.