LCLS Newsletter 24-January-2000

This newsletter is relatively truncated, as a lot of people were very busy preparing for the TAC meeting.

Project Management *Lowell Klaisner, Max Cornacchia*

The TAC meeting took place on February 11th and 12th. The meeting was successful and the Committee showed their draft conclusions on Saturday afternoon (the final TAC report will be included in the Newsletter when it is available). The Committee showed its appreciation for the amount work being done and the limited funding for LCLS R&D.

LCLS General Seminar

There will be a LCLS seminar on "schemes to generate femtosecond pulses of spontaneous radiation at SLAC". The seminar will take place on Monday, February 28, in the 2nd floor conference room of Bldg. 137 (SSRL), starting at 3:00 pm. The speakers (15 min. each) are Joe Frisch, Patrick Krejcik and Pantaleo Raimondi. A discussion will follow, with Art Toor and Roman Tatchyn commenting on possible applications for the LCLS x-ray optics.

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

Slice Emittance Task Force

Introduction

A new LCLS Task Force has been formed to produce a better prediction for the slice emittance of the electron beam as a function of the position within the beam.

Expected by-products of the study are a complete description of the predicted six-dimensional phase space distribution within the electron beam at the entrance to the undulator.

This information is essential for producing accurate performance predictions with FEL computer simulations.

Background

Until now, most LCLS FEL computer simulations have been using a “Nominal Emittance” value of 1.5 mm mrad, which is close to the value of the projected emittance at the end of the LINAC as derived from computer simulations through the photo-injector and the linac. Parmela simulations through the photo-injector predict an emittance of 1 mm mrad or less at the end of the photo-injector.

The increase of the projected emittance is due to space charge, wakefields and CSR in the gun, the linac and the bunch compressors, respectively. This increase does not effect the intrinsic qualities of the bunch but chirps the average value of the transverse positions and momenta of the particle in slices along the bunch. Linac simulation codes predict that the slice emittance at the entrance of the undulator will be as small as that at the end of the photo-injector.

Slice emittance measurements for 10 % of the bunch length done at the ATF in Brookhaven resulted in values of 1.2 mm mrad for a beam with a total charge of 0.8 nC before slicing. Recent results of the HGHG experiment confirm this: The SASE gain measured in the experiment was much larger than expected from the projected ATF emittance of 2 mm mrad. Actually, in order to explain the measured gain, a slice emittance of less than 1 mm mrad needs to be assumed.

Slice Emittance Definition

For the FEL interaction in the undulator at a given moment, the emittance over one optical wavelength is important. It determines the transverse electron phase space density and, together with beam focusing, the beam-size. These quantities directly effect FEL gain. At this point in the process there is no interaction between different regions within the beam. As particles and fields move through the undulator, slippage occurs, i.e., for every undulator period that the electron beam travels it stays behind the radiation field by one optical wavelength. It is important that the center of the particle distributions for successive slices at the scale of the optical wavelength are lined up to much better than the radius of the optical mode. It is therefore reasonable to average the distribution in those successive slices when calculating emittance. This projection interval needs only to cover slices in which the x-ray beam, that slips across them, is of comparable intensity, i.e. is the same within one of two orders of magnitude. The light produced in earlier slices can be neglected and the relative transverse position of those slices becomes unimportant for further gain development.

The number of optical wavelengths that need to be included in slice emittance calculations will depend on the instantaneous gain and will be largest before the exponential gain regime at the entrance of the undulator. There, it is expected to be as long as the slippage that occurs while the beam travels over 4-6 gain lengths.

The relevant beam-slice to be used for specifying slice emittance and slice energy spread are therefore shorter that the slippage length over the entire undulator, which has values between 500 nm (15 GeV) and 5000 nm (5 GeV). This compares to 70000 nm of FWHM length of the entire LCLS electron bunch. A suitable choice of slice length will be investigated by the Task Force.

It is expected that the smallest slice lengths for which the emittance can be measured might be about 10 % of the total LCLS bunch length.

Effect on Slice Emittance on the LCLS

Using the slice emittance values has strong effects on the performance predictions. First, the saturation length becomes significantly shorter, as can be seen in **Figure 1**. This will enable to establish a clear Engineering Safety Margin that has been buried in the parameters until now.

Not all of the electron beam slices will be matched to the undulator, it is likely that only a small number in fact will. The expected mismatch is very small, because of the small ration between projected emittance and slice emittance. Earlier simulations have shown that small mismatches at the expected level will not effect the FEL gain, significantly. It is expected that the actual details of the distribution, i.e., its deviation from an ideal distribution might have a more significant effect.

Second, the fact that not all electron slices are lined up will express itself in a chirp of the X-Ray field distribution. This will also lead to a slight reduction in Brightness. Using a reduced slice emittance will not increase the overall Brightness prediction in the presence of a larger projected emittance.

Third, the field distribution of the X-Ray beam continues to change after saturation. To produce a good prediction of the fields, a reasonable prediction of the saturation point is important. An accurate description of the far field distribution of the x-ray field is essential for the R&D efforts of the X-Ray Optics group.

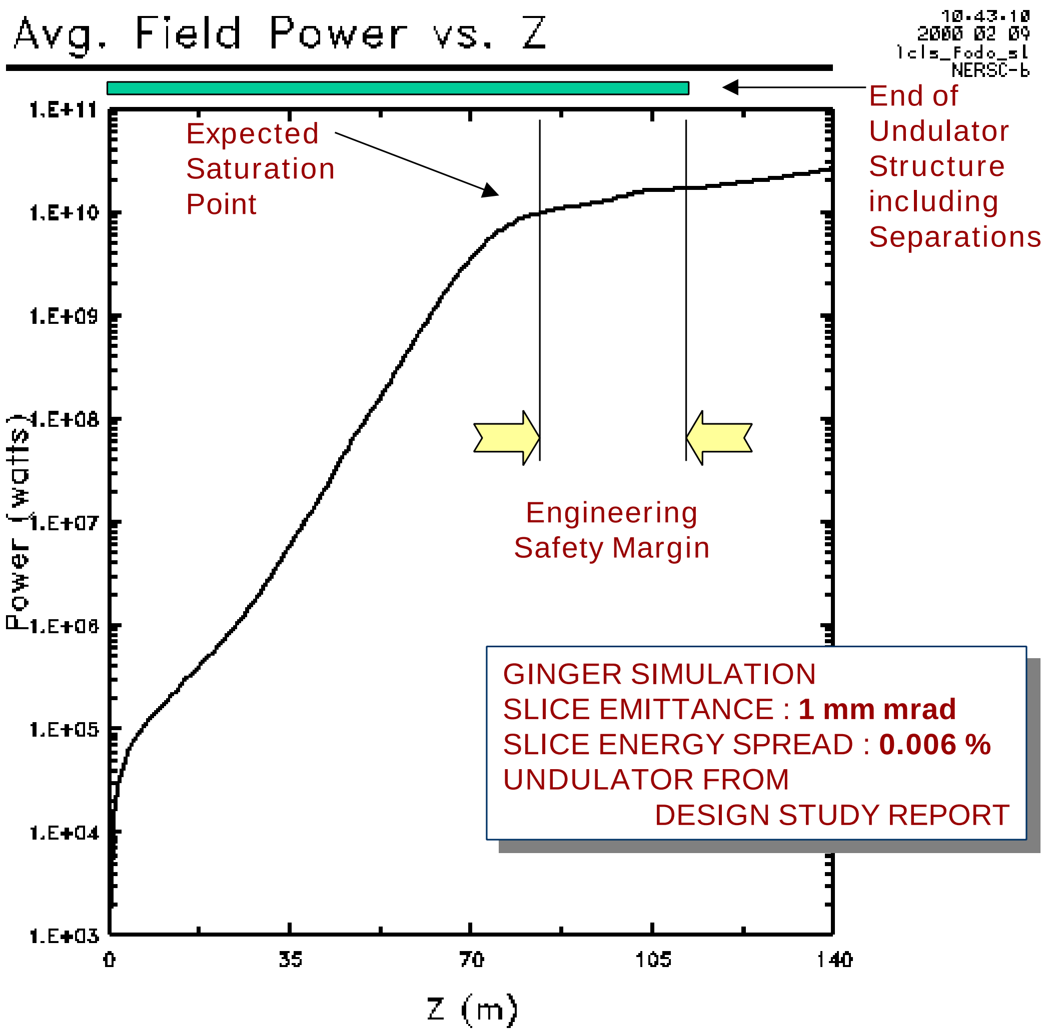

Figure 1: Ginger prediction for LCLS performance with a slice emittance of 1 mm mrad and 0.006 % slice energy spread. The simulation is based on the FODO lattice with 23.5 cm separations between undulator segments. The FEL is predicted to saturate a significant distance before the end of the undulator at 112 m is reached. This fact will give the project a clearly visible Engineering Safety margin.

Task Force Purpose

The purpose of the newly instated LCLS "Slice Emittance Task Force" is to

- better predict the FEL power development,
- produce a clearer Definition of Engineering Safety Margin, and
- deliver a more precise description of X-Ray fields.

Task Force Objective

The Slice Emittance Task Force will analyze theoretical and experimental information as well as computer simulations using the Start-To-End-Simulation codes PARMELA and ELEGANT to establish realistic predictions for the slice emittance, slice energy spread and 6D phase space distribution along the electron bunch at the entrance to the undulator. The study will also include the effects of beam collimators, which are being studied as tools for shaping the transverse phase space, to reduce the emittance. Presently, the following individuals are members of the Task Force.

Vinod Bharadwaj	Start-To-End Simulations
Jym Clendenin	Gun
Steve Gierman	Gun Parmela Simulations
Paul Emma	Elegant Simulations
Patrick Krejcik	Parmela Simulations
Heinz-Dieter Nuhn	Chair
Claudio Pellegrini	Beam Collimator
John Schmerge	Gun
Carl Schroeder	Beam Collimator
Mark Woodley	Beam Optics

The initial meeting took place on Monday February 7, 2000.

Photoinjector R&D News *J. Clendenin*

GTF Status.

The laser system is back up and running with nominal output: about 6 mJ in the IR. Repolished rods installed (new Kigre-glass rods received immediately afterwards), o-ring grove modified, new o-rings (for rods) installed, and new flow tubes installed. The new flow tubes did not reduce pump power (~35 J). Positive Light has ordered Schott-glass rods for future installation.

AFEL SASE Experiment.

The AFEL is being turned on for 2nd SASE run with the modified 2-m wiggler. J. Schmerge scheduled to go to LANL for 1 week beginning Feb. 14th.

Schedule of Photoinjector R&D Meetings.

Video Conference Meeting on alternate Thursdays (alternating with Linac Video Conference Meeting) at 11:00 PST. Agenda announcements emailed in advance. Minutes available from LCLS Photoinjector Home Page. SLAC contingent meets on the Ground Floor of Computer Building.

GTF/LCLS Photoinjector R&D Meeting on alternate Tuesdays (alternating with week of Photoinjector Video Conference Meeting) at 13:30 in Building 270 Conference Room by announcement only (sometimes Wednesday rather than Tuesday). No minutes.

GTF Weekly Status Meeting at 09:30 at the GTF Control Room in Building 140. No announcements or minutes.

Linac *Vinod Bharadwaj*

The LCLS collaboration meeting on "Short Bunch Length Measurement and Tomography" will take place at Brookhaven on March 3,4 2000. (contact Vinod Bharadwaj or Bill Graves for information).

X-Ray Optics *Art Toor*

One of the issues regarding the Attenuation Cell is the heat loading on the walls due to electron transport. Alberto Fasso has completed the first set of FLUKA simulations to study this issue. He has modeled the r-Z dependence of dose delivered by photoelectrons resulting from the interaction of an 8.5 keV x-ray beam in a xenon gas cell. The cell was 2-m long with a pressure of 27 Torr and an x-ray attenuation of 10^4. The simulations show the energy is contained near the axis of the cell and for our baseline design with 1-mm diameter baffles the energy loading on the baffles does not appear to be an issue. Single scattering and multiple scattering calculations gave similar results. FLUKA has a low energy cutoff for electrons at 1 keV. We will examine the details of the calculations to see if further simulations that transport electrons to lower energies will be necessary.

Applications of LCLS that study electric-field ionization and excitation, QED phenomena such as spontaneous pair production or two photon atomic ionization will require higher field strengths than those associated with the baseline design at 1.5Å. Focussing the beam to 2-10 µm could in principal provide such fields. Slava Shlyaptsev has modeled the temporal evolution of the plasma electron density and temperature for a prototype lens that looks promising. His magneto-hydrodynamic calculations for a LiH capillary show a 2kA pulse with ~3 µs duration provides a parabolic electron density profile for central density of 2x10^20 cm-3. Slava will present his results and discuss a design for a 20-cm focal length lens at our next X-ray Optics meeting (Feburary 24).

Rich London has run several hydrodynamic simulations near the damage threshold in beryllium with LASNEX. Runs bracketing the damage threshold have been completed. Other strength models are being evaluated before proceeding further.

Last week's X-ray Optics Meeting (February 10) focused on the issues associated with the mirror reflectivity experiment to be conducted at JanUSP. An experiment design review will be held at the March 9 X-ray Optics Meeting.

The next Radiation Safety meeting is scheduled for March 13.

VISA Report from ATF Newsletter *Ilan Ben-Zvi*

Only the VISA report (Aaron Tremaine) is excerpted from the ATF newsletter for the week ending February 4th 2000. There is other news in the ATF newsletter that may be of interest to the LCLS collaboration and you are encouraged to read it.

We saw good OTR signal through the BPM using the more sensitive COHU camera. The beam was propagated through the undulator and a reasonably shaped beam was seen at all pop-ins. Using polarizers and filters we were able to determine to our satisfaction what is seen in the cameras is OTR. 700pC of charge was sent into the undulator and we were getting transmissions of >90%. We were able to transport >90% of the beam without using the undulator correcting coils. Then a "transport matrix" was made. The position of the electron beam centroid RELATIVE to the alignment laser at each pop-in was measured. This tells us what the undulator is doing to the electron beam since we

know the alignment laser is a straight line and no correction is being used. One must keep in mind keep that the alignment laser is not at the magnetic center of the undulator.
There appears to be the betatron motion of the electron beam with large amplitude. We will get a good estimate after a calibration on the cameras (micron/pixel) is done (a fairly illuminating plot of the workings of our undulator on the e-beam at this time).
One inconsistency: We were not able to reproduce the signal seen from last time at the detector- 400mV. At most we saw 20mV. This is puzzling since we were getting through a lot more charge and using the same setup.