LCLS Newsletter AUGUST-2001

Project Management *John Galayda*

LCLS was on the agenda at the last meeting of the Basic Energy Sciences Advisory Committee in Gaithersburg, MD, 2-3 August. Eric Rohlfing reported on the Ultra-Short Bunch Workshop held in Washington, DC in May. Galayda gave an update on the status of LCLS R&D. Both presentations got a good reception. The BESAC Committee has accepted the scientific justification for LCLS at this point - with the clear understanding that it is important to produce light pulses of shorter duration than the initial performance specification of 230 fs. It is now up to the LCLS team to pull together the prerequisites for the next two stages in the DOE approval process - Critical Decisions 1 and 2.

Photoinjector R&D News *J. Clendenin*

During the month of July, GTF activity was dominated by what appears to be a new problem with the glass-laser regen system: debris of unknown origin is found to be coating the rod faces at an alarming rate, sometimes after only a few hours of operation. The glass structure itself does not always appear to be damaged. A thorough examination of the regen is underway. Meanwhile, contaminated rods are being examined in the surface sciences lab (Kirby).

Nonetheless, some additional emittance data at 2 ps FWHM and 4 ps has been accumulated as well as some additional longitudinal emittance data. The new data is consistent with data reported earlier. We now have a fairly good data set up to 350 pC at 2 ps, but need more at 4 ps. What data we have at 4 ps indicates emittances very similar to that at 2 ps. Dave Dowell participated in the experimental program at the GTF for half the month

The calibration of the camera/optics for the YAG screen used in the GTF emittance measurements was found to be wrong. The correction will increase the emittance values by ~10%. In addition, the camera was found to be out of focus by ~3 mm. The correction will decrease emittance values by ~10%.

PARMELA simulations for the present GTF experimental conditions are presently underway. The results are persistent in showing the emittance for 4 ps higher than for 2 ps. This result is counterintuitive. The emittance for 4 stacked 2-ps pulses is by comparison lower than for a single 2-ps pulse as expected.

Comparison of simulation codes for the LCLS injector has resumed under direction of Eric Colby. Said problems are being examined with 3 codes: MAXWELL, a 2D PIC (V. Ivanov), LANL-PARMELA with 2D rf fields (C. Limborg) and UCLA-PARMELA with 3D rf fields (E. Colby).

To determine the length of the laser pulse, we are depending on streak camera data taken almost a year ago. The camera's streak tube was replaced last winter, but there has been an ongoing problem with the software that is needed to control the camera in focus mode, which in turn is essential to making a measurement. Wai Chan, who is the Hadland software expert, is now at SLAC working on this problem.

We get some information on the length of the electron bunch from the longitudinal emittance data.

What's next? The parts for implementing the glass-laser SHG "afterburner" are in hand. Installation starts later in August. Parts for the add-on amplifier stage are due in soon.

Upgrade of the GTF control system starts in September.

Detailed design of the moveable pepper-pot is underway.

The 120 Hz gun review will be September 11-12 at SLAC.

No decision yet on the modulator for the upgrade to a 5045 klystron for the booster.

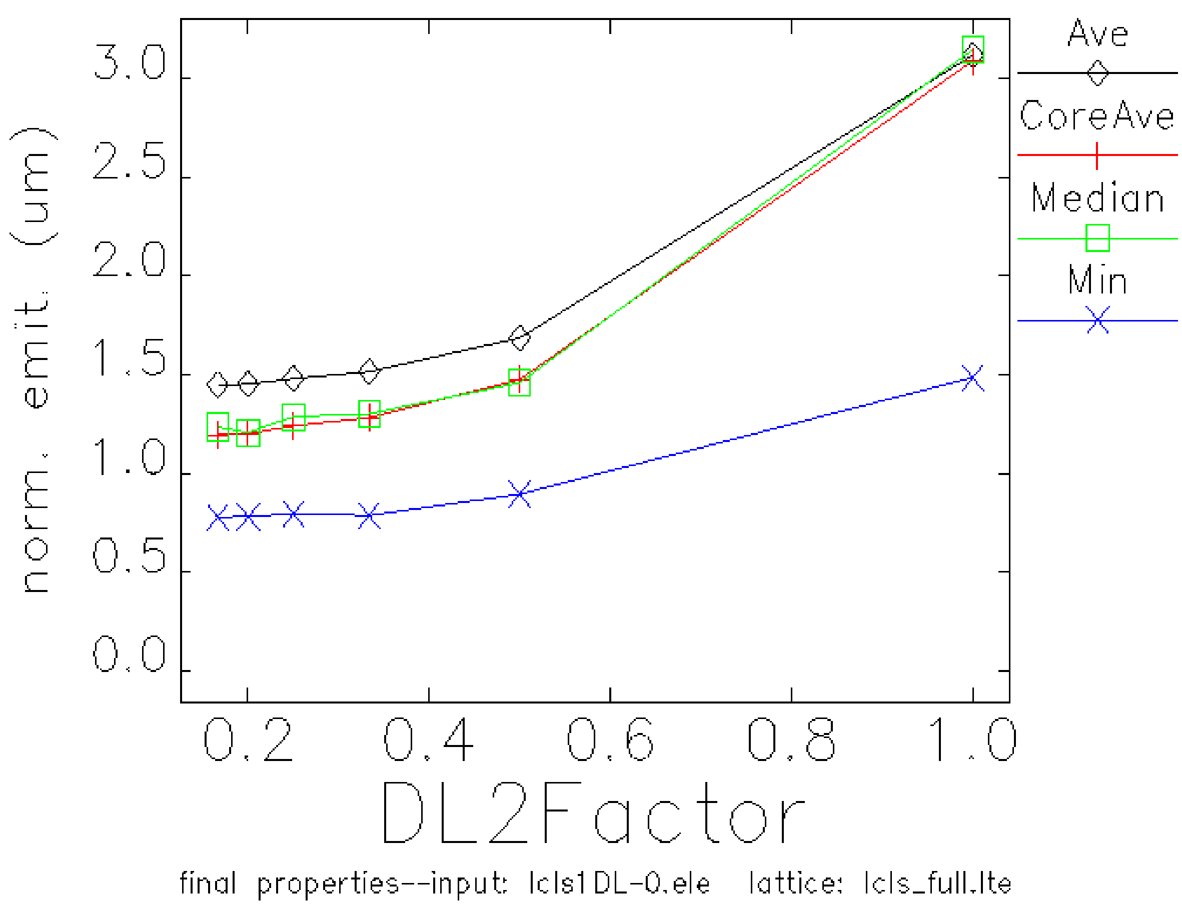
Linac *Vinod Bharadwaj*

The Accelerator chapter (Chapter 7) of the LCLS CDR is in good shape. The figures have been processed by Tech Pubs and are being re-inserted into the chapter. Once this is done, the chapter will be placed on the LCLS CDR "public web" for comments and corrections.

Paul Emma and Michael Borland have been working on "fixing" the emittance growth that Michael had calculated with his simulation code ELEGANT when using finer binning and when adding the CSR effects in drifts after the bends (reported in PAC2001). Paul proposed weakening the DL2 bends to overcome the problem. Michael's calculation of emittance versus DL2 strength (1.0=nominal) are shown in the following figure. It is planned to have a workshop to discuss CSR effects in the next few months.

During the last ROD (Repair Opportunity Day), the RF waveguide for the transverse RF cavity, that is planned to be tested for use as a bunch length diagnostic, was installed from the linac gallery to the tunnel. During the next ROD this waveguide will be connected to the cavity. It is hoped that the diagnostic can be tested by the end of this year.

The SPPS "white paper" is finished and will appear as an LCLS Technical Note, shortly. It is proposed to implement a "simple SPPS". Money to install the sector 11 chicane has been identified and there are plans to borrow undulators from APS. The schedule is very tight and this project will need high priority if it is to be finished on the required time scale.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Undulator *Liz Moog*

Work on the undulator prototype is progressing:

The titanium strongback has now been mounted on pedestals, with the eccentric cam movers all assembled and in place.

The comb bases that the poles and magnets will fit into are in the lab and all assembled. One base section needs some repair to a screw thread that got mangled, but otherwise they are ready to go.

We have received all the magnet blocks for the prototype now, and magnetic measurements of them have started. So far we have been measuring and remeasuring just a few magnets, getting the technique down and working on improving the speed and convenience with which we can swap magnets. We are also working on improving the fixtures mechanically so that they aren't significant contributors to scatter in the measurements.

There are two types of measurements being made. One type is the Helmholtz coil measurements - put the magnet at the center of a pair of Helmholtz coils, rotate the magnet, and look at the induced current vs angular position to get M_y and M_z. Then turn the magnet 90 degrees in the holder and repeat to get M_x and M_z.. These measurements are the standard measurements of the components of the total moment of the magnet, and they were also made by the vendor, Shin Etsu. The measurements we have made so far agree very closely with the manufacturer's measurements. So closely, in fact, that we would consider relying only on their measurements if they had reported the sign of the M_y (vertical) component of the magnetic moment. Unfortunately, they only gave the magnitude of M_y.

The other type of measurement is showing us that M_y is an important contributor to the on-axis field of the undulator. This type of measurement uses a test fixture that holds two poles on each the top and bottom, with a single standard magnet always between the poles on the bottom and the test magnet between the poles on the top, so it is effectively a half-period-long section of undulator where we swap out one magnet and measure specifically the effect that the magnet has on the on-axis field. Measurements that were made with magnet blocks in a variety of orientations showed that the sign of the M_y component on the test magnet affects the on-axis field. It affects both the field integral and the calculated phase predicted for particles traveling through the undulator. We are examining these effects and working to determine a good scheme for deciding how to arrange and how to orient the magnet blocks in the undulator so as to make the undulator easy to tune. Orientation of the magnet blocks is a choice because the magnet blocks were designed to be symmetrical top to bottom, so we can turn them upside-down for installation if we need to reverse the M_y direction.

Judging from the manufacturer's measurements of the whole set of magnets, it looks like a good set. The magnets are very uniform in their total magnetic moment. They all fall within a range of +/- 0.5%. This is better than the specification, which called for +/- 1%. Another important requirement was that the direction of magnetization of the blocks be aligned with the geometric axis within 2 degrees. The measurements show that the magnets have a magnetic moment that is, on average, 1.0 degree vertically from the axis. The transverse (horizontal) component is negligible so there is no horizontal component to the angle. The range of angles is from 0.7 to 1.3 degrees, vertically. Since all the magnets have a vertical moment, we are especially interested in the results of the vertical moment effect measurements mentioned above.

Most of the poles have now been received, with the Ti ears attached. Of the group of about 400 that were received, 10% were held out for careful dimensional checking and the rest were sent for annealing. We are short a few poles, 1) because there were some problems in the initial slicing of the pole blanks from the bar of Vanadium Permendur that made some of the blanks not usable, and 2) because some of the poles cracked or broke during the annealing process. We are examining the annealed poles to determine how much of a problem the cracking is and how prevalent it is. So far, seven cracked or broken poles have been identified.

An initial result from the detailed dimensional checking is that the poles are very uniform. All the poles are the same height to about 10 µm, and the thicknesses are good. However, it was discovered that there was some confusion over drawings during the manufacture, with the result that the chamfering on the poles is not what was the first choice from the magnetic modeling. Instead of the 0.5-mm chamfer that was preferred, the poles have a 1-mm chamfer. It is expected that this will reduce the effective field of the undulator by ~1.7%, although no change is expected in the peak field. The field loss represents a gap change of ~0.16 mm. So, although the undulator won't be the ideal configuration, it won't be very different from the ideal, and we will keep the differences in mind when working with it.

X-Ray Optics *Alan Wootton*

Prototype focusing element for the LCLS Warm Dense Matter experiment.

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Physics and Technology Directorate
Lawrence Livermore National Laboratory

This work was performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under contracts No. W-7045-Eng-48 and DE-AC03-76SF00515.

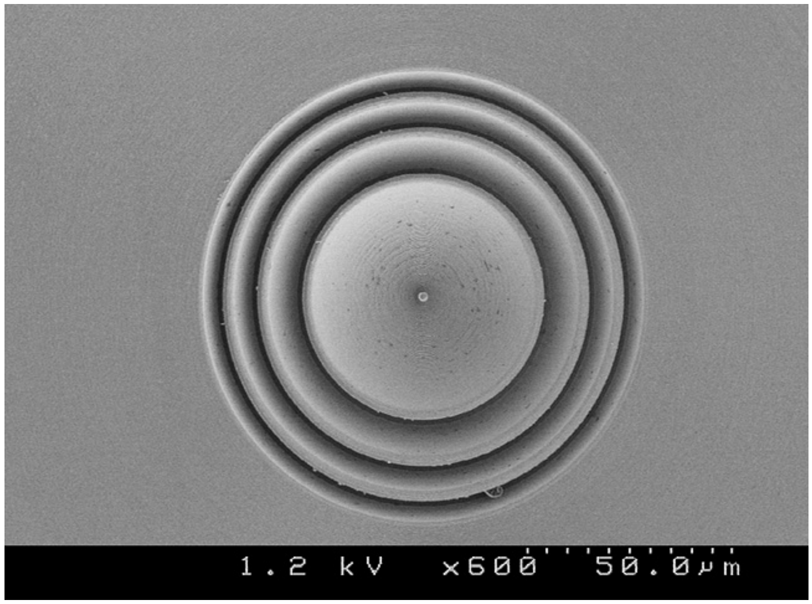

Figure 1: LLNL is developing focusing elements for the Warm Dense Matter experiment to be performed at the LCLS. This experiment studies the interesting properties of "warm dense matter", an energetic plasma at near-solid density. Thought to exist in the centers of large planets, the properties of this state of matter are important to astrophysics and relevant to the production of inertially confined fusion reactions. To create warm dense matter in the laboratory the 8 keV, 100 micron diameter LCLS x-ray FEL beam will be focused on to a spot 2 to 10 microns in diameter in the center of the sample of solid matter under study. The focusing element of choice for this experiment is a 200 micron diameter "blazed phase lens" made of Carbon, which is capable of withstanding the full, unfocused, LCLS beam without sustaining damage. This photograph shows a 100-micron diameter prototype of this lens made of Al, which has nearly the same phase-changing optical constant as Carbon for 8 keV light.

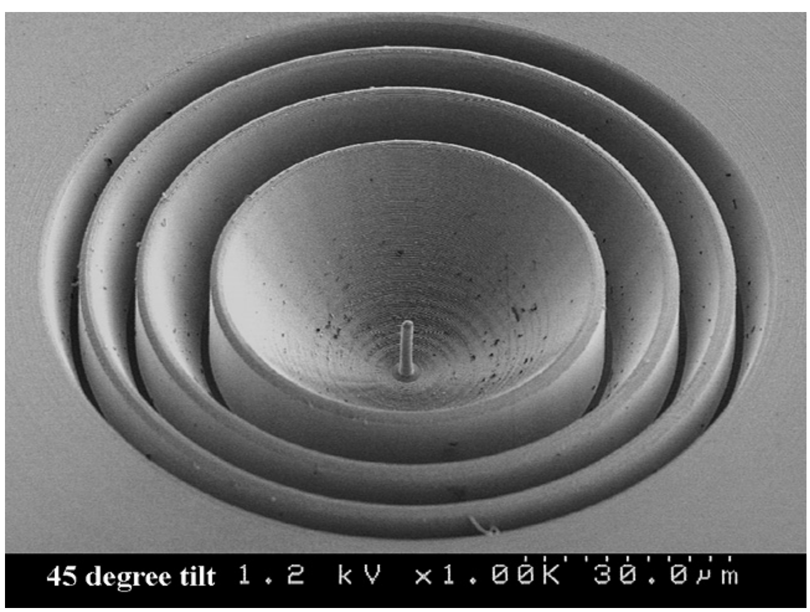

Figure 2: LLNL's Precision machine shop developed a specially shaped diamond tip to carve the lens pattern into the surface of a flat disk of pure Al. Each groove is 18.7 microns deep, which is the thickness in Al where 8 keV x-rays acquire an extra 2π radians of phase shift with respect to x-rays traveling the same distance in vacuum. The small pillar in the center is difficult to remove but has negligible effect on the performance of the lens. The carved disk was subsequently flipped over and thinned down from the backside to a final thickness of 79 microns.

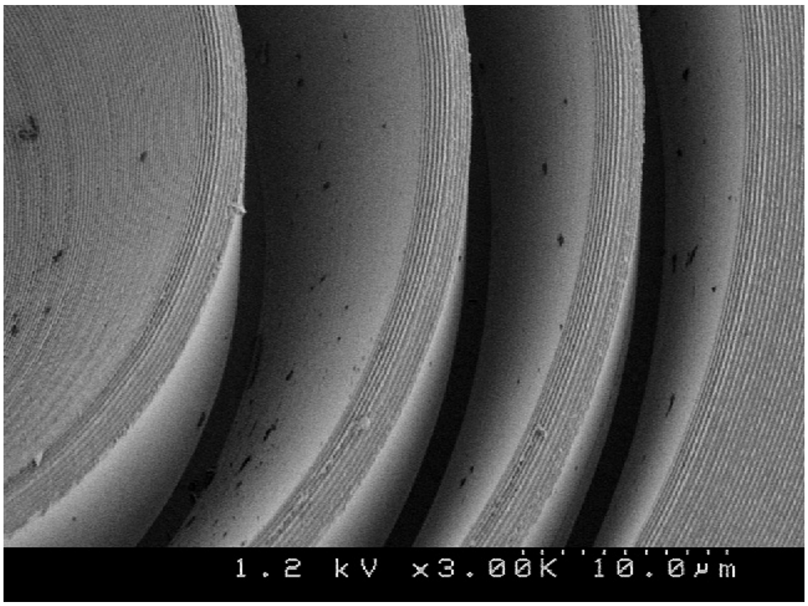

Figure 3: The lens profile changes the phase of the raw LCLS beam, converting it from an outgoing Gaussian beam whose waist is inside the undulator, to a converging Gaussian beam whose smaller waist is in the target foil. The required phase change as a function of radius is reset every 2π radians and converted to a material thickness using the optical constants of Al with respect to vacuum. Unlike conventional Fresnel zone plates, which only crudely approximate the needed phase profile, and as a result have a myriad of unwanted positive and negative foci, this lens imparts the correct phase shift across the entire wavefront (except at the rims of the grooves where the accuracy is limited by the finite size of the single point diamond tip.) LLNL expects to continue research into the manufacture of lenses of this type, and their testing at SSRL, with the goal of producing 200 micron diameter Carbon lenses over the next two years.

VISA *Claudio Pellegrini, Heinz-Dieter Nuhn*

A meeting to review and discuss the experimental results and data analysis of the VISA Free-Electron Laser experiment was held at the Stanford Linear Accelerator Center (SLAC) on Thursday, August 9, 2001 in the Training Center room C/D. At the core of the meeting were technical presentations describing the acquisition and analysis of data taken at the ATF VISA system after the last VISA meeting that took place on April 30,

2001. The initial measurements of gain above 10^7 and gain length on the order of 19 cm could be repeated and confirmed.

The ATF gun has not been able to produce the electron beam parameters proposed in the original VISA design. Data analysis shows that VISA achieved its design goal because of strong non-linear bunch compression (by a factor of 10) of the energy-chirped electron beam in the beam transport line from the linac to the undulator. The key measurement for confirming this result was based on the analysis of Optical Transition Radiation from the electron beam as it left the undulator using a Golay cell and submillimeter wavelengths filters. The chirping was achieved by off-crest acceleration in both ATF linac sections. The compression increased the peak current from 55 A at the end of the linac to 250 A at the entrance to the undulator. The beam dynamics was simulated from the cathode to the linac exit with UCLA-Parmela, and from the linac exit to the undulator entrance with M. Borland's code ELEGANT.

The simulations show that there is a rather strong effect from Coherent Synchrotron Radiation (CSR) that increases the horizontal emittance to about 7 mm mrad, with a core having about 4 mm mrad. The off-crest acceleration also changes the center energy of the beam and thus its horizontal position in the dispersive section, causing the longitudinal bunch tails to be scraped at the narrow aperture of +/- 1.5 cm at the location of one of the ATF beamline switching magnets. The combination of bunch rotation and scraping produces a compact beam distribution in longitudinal phase space at the entrance to the undulator. This kind of dispersive scraping caused the positive effect of correlating charge with beam energy (or linac phase), thus enabling filtering of the data with respect to linac phase, and allowing to combat one of the experimental problems, the linac phase fluctuations.

Using the particle distribution, created by the PARMELA and ELEGANT codes, one can reproduce the results of the Golay cell measurements. Using the same particle distribution, S. Reiche is able to predict, using his FEL simulation code GENESIS 1.3, the measured radiation intensity correctly without any free parameters. This is the first time that this kind of agreement of SASE-FEL experimental results and cathode-to-FEL simulation codes has been achieved.

These start-to-end simulations indicate that the slice emittance of the electron beam after the linac is 0.8 mm mrad in both planes, at a charge of about 200 pC. As mentioned above, the horizontal emittance is spoiled by CSR in the transport line while the vertical emittance stays more or less unchanged during beam transport. This result supports the notion that the parameters of the ATF gun are sufficient for LCLS operation.

Further analysis is required with regard to the spectral data. At the saturation point, the measured spectrum of the fundamental wavelength differs from simulation results, i.e., the simulated spectra are somewhat narrower and contain side bands, while the measured spectrum consists of a single broad peak, only. A large number of spectra have been taken at different ports and at different gain levels and these will be analyzed in the near future.