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The working assumption for LCLS experimental halls is that the original construction will include two halls. The near hall will be like the large hall described recently (approximately 70 meters in the beam direction and 34 meters across the beam). That will be followed by a 10 foot by 10 foot tunnel that goes across the back of the research yard and then through the hill. The far hall will be east of the hill and west of the existing ring road. This allows for a far hall of approximately 55 meters by 35 meters. The electron beam will be bent up to level (the linac beam is going down at .2727 degrees) at the east end of the muon shield. The x-ray beam will be approximately 15 feet below grade at the far hall. The far experimental hall will be underground with a ceiling at about grade level. A lab and office area will be built on top of this hall for the LCLS users. The undulator will be described in the CDR as the design 120-meter length. The contingency on this length will be to expand to the west into the electron diagnostics area if required. If a major increase is required, the electron dump could be moved to the east and part of the near hall would be used for undulator. Both of these are considered contingency and not part of the baseline design. At any rate, we want to preserve the ability to do some experiments close to the end of the undulator. The details of the implementation of this plan depend on more analysis of the beam dynamics of the vertical bend, and on survey data on the level of the ground at both halls.

Report on the Workshop on "The Physics of, and the Science with, X-Ray Free-Electron Lasers" Arcidosso, Italy, September 10-15, 2000.

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The 20th Advanced ICFA Beam Dynamics Workshop on "The Physics of, and the Science with, X-Ray Free-Electron Lasers" took place in Arcidosso (Italy) from September 10 to September 15th, 2000. The Workshop was sponsored by the International Committee on Future Accelerators, the US Department of Energy, the University of California at Los Angeles, the Stanford Linear Accelerator Center, Deutsches Elektronen-Synchrotron and Lawrence Berkeley National Laboratory, together with local authorities of the Tuscany, Grosseto and Arcidosso areas. The Workshop's chairmen were M. Cornacchia (SLAC), I. Lindau (SLAC/Lund. Univ.), and C. Pellegrini (UCLA). Seventy-five scientists, of which 50 are involved in the physics and technology of accelerators, free-electron lasers and x-ray optics, and 25 in the science that can be pursued with x-ray free-electron lasers, attended the workshop. There were plenary and parallel sessions and many lively discussions, during and after the regular workshop schedule.

Arcidosso is a medieval town in southern Tuscany, close to the city of Sienna. The meeting took place in the historically evocative scenario of an 11th century castle atop a hill dominating the nearby valley. The castle was restored in 1989, and preserves the atmosphere and raggedness of medieval times.

There were two invited lectures on Monday, September 11, to open the subjects and two summary talks in the afternoon of Friday, September 15. All the other presentations were either informal or in the form of posters.

The Group on “Physics and Technology of the XFEL” with introductory talks by Kwang-Je Kim (ANL) and Jamie Rosenzweig (UCLA), was coordinated by Alberto Renieri (ENEA-Frascati).

The Group on “Science with the XFEL” was coordinated by Mark Sutton (McGill Univ.) with introductory talks by Andreas Freund (ESRF) and Ingolf Lindau (SLAC/Lund. Univ.)

These notes reflect the summary talks of the coordinators and the impressions and recollections of the organizers. The American Institute of Physics will publish the proceedings of the Workshop.

1. Summary of discussions and conclusions of Group 1: Physics and Technology of the XFEL

The main issues that were discussed by the 50 participants in this group were the photo-injector, the production of ultra-short pulses, the effects of wake-fields induced by the electron bunch, the operation at lower charge and emittance, the possibility of harmonic generation and the diagnostics in the undulator. The following is a short summary of the discussions and their conclusions.

It is important to measure the electron bunch emittance, length and energy spread as a function of charge and not focus exclusively on the standard photo-injector parameters (1 nC charge, 1 π mm-mrad emittance). The low charge option (about 0.2 nC charge, 0.6 π mm-mrad emittance) appears as feasible as the standard case used in the LCLS design, and offers the clear advantage of being less vulnerable to the effects of wake-fields. It has not been studied as much as the standard case and requires more work.

One should follow the progress with the new guns being studied, like the pulsed gun being developed at BNL and Eindhoven, and the Van der Wiel plasma gun.

The studies of the feasibility of electron bunch compression and/or x-ray pulse slicing and compression must be continued, given the importance of this option for the experimental program. In particular one should study the possibility of bunch compression when operating at low charge, and the effect of wake-fields in the two-undulator (seeding) scheme.

Much attention was given to the wake fields in the undulator vacuum pipe. Comparative estimates were made using different models proposed by A. Agafonov (Levedev Physical Institute, Moscow), A. Novokatsky (Darmstadt Un.), Palumbo (Rome University) and G. Stupakov (SLAC). The effects have been calculated for the following situation: 15 GeV, undulator length of 100 m, a pipe radius of 2.5 mm, 1 nC charge, 230 fs long bunch. The maximum energy changes along the undulator length, according to different models and regimes are:

Agafonov model:	2×10^{-6} (roughness height: 100 nm, roughness period: 100 μm)
Novokatsky:	2×10^{-3} (roughness height: 100 nm, roughness period: 0.1 μm)
Palumbo:	3×10^{-6} (roughness height: 500 nm, roughness period: <10 μm)
Stupakov:	10^{-4} (roughness height: 500 nm, roughness period: 100 μm)

In addition, the contribution of the resistive wall effect is about 1.5×10^{-4} .

Additional contribution will come from vacuum ports, instrumentation, and discontinuities.

Since this energy change is of the order of the FEL parameter, it can have a serious and deleterious effect on the LCLS performance. The message from the workshop is that one should be aware of these effects, in particular for the LCLS small gap undulator. Notice that the minimum undulator gap considered for the TESLA X-ray FEL is 12 mm, compared to the present 6 mm of the LCLS.

Possible strategies to reduce the undulator wake-fields effects include reducing the bunch charge, increasing the undulator gap and reducing the undulator length.

The list of recommendations from the workshop on the surface roughness problem include the enhancement of the analytical models to predict realistic surface roughness conditions and of the numerical simulations to model realistic randomly distributed surfaces roughness. Experiments should be performed to measure the effect under controlled conditions of surface roughness.

The possibility of operation at a charge different and lower than 1 nC should be studied in all its implications. Different modes of controlling the bunch charge and emittance should also be investigated.

Once the wake-fields and the injector operation at different charges are understood, the system should be re-optimized, including considerations of various types of undulators, planar or helical, and with a gap chosen to minimize the wake-fields to an acceptable level.

The sub-group on undulator diagnostics reviewed the issues related to the electron and photon beams. The centroid of the electron beam can be measured to μm resolution with rf Beam Position Monitors (BPMs) or Optical Transition Radiators (OTR). One of the issues is whether the latter can survive the intense electron beam and how the surface quality of the OTR might affect the emitted light. Both questions should be soon be answered by experiments. On the measurements of the beam profile, there was consensus that saturation makes the scintillators not usable, while OTRs might be useful. It is also important to measure the longitudinal characteristics (bunch length and momentum spread) and the time-resolved slice measurements of emittance and momentum spread. A very promising technique for measuring very short bunch lengths uses an rf deflector that rotates the beam onto a screen. It was suggested that it might be possible to measure photon pulses down to 10 fs using grating Michelson interferometers.

One of the outstanding questions concerning the measurements of the x-ray beam is whether one can separate the spontaneous from the FEL radiation and whether the diagnostics can survive the x-ray and electron fluxes. It was recommended to estimate the damage mechanism with ionization and the dominant mechanism.

Crystalline materials directly impacted by the electron beam may see the space charge field and be subject to damage. It was suggested that an experiment be done at SLAC using the FFTB beam to create a high field gradient on a crystal similar to that that would occur in the LCLS.

It is very important to have a diagnostic system capable of measuring low charge beams in the linac and undulator.

More detailed studies of the survivability of the detectors and the information they provide are needed.

Some other noteworthy discussions included the following:

1. The wake fields in the undulator could have a strong effect on the harmonics; we need more experimental and simulation work on this possibility.
2. The same wake-fields could limit the possibility of reducing the line width or the pulse length.
3. The X-ray FEL must be optimized including collective effects.
4. A proof of principle of a seeded scheme using High Gain Harmonic Generation has been done at Brookhaven; the studies of an X-ray FEL using this approach should be continued.

2. Summary of discussions and conclusions of Group 2: Science with the XFEL

About 25 people attended sessions to discuss the possible scientific applications of a x-ray FEL. Because of the recent focus on the first experiments with the proposed Linac Coherent Light Source at Stanford, the discussions were mainly focussed on these proposals. The extension of the characteristics beyond the initial stage and the further developments of the source were also part of the program.

Six scientific areas were discussed: Atomic Physics, Warm Dense Matter, Femtosecond Chemistry, Imaging/Holography, Bio-molecular Structures and X-Ray Fluctuations Spectroscopy.

New phenomena can be studied in atomic physics. Hollow atoms, where inner core electrons have been removed with outer valence electrons still in place, appear especially interesting. Non-linear x-ray interactions are of interest, i.e. parametric down-conversion, two-photon absorption and two-photon mixing. Even with an unfocussed LCLS-type beam it is possible to achieve saturation for photo-ionization. With a focussed beam the Compton scattering will saturate.

Warm dense matter (WDM) is a new form of matter, between highly ionized plasma and condensed matter. Though W

DM is of great importance in many fields, i.e. laser plasma production, inertial fusion and astrophysics, its basic properties are still basically unknown. With a x-ray FEL beam, WDM can both be created and probed.

In femtosecond chemistry it is of great interest to study bond changes on the time scale characteristic for breaking and forming bonds. This would involve pump-probe experiments where the system is excited with a conventional laser and the structure changes are probed dynamically with the x-ray FEL beam.

The workshop addressed the possibility of imaging and holography of non-crystalline samples and small nano-structures. Bio-fragments and bio-molecules are also an extension of this work. The radiation damage and the amount of structural information that can be extracted before the molecules fly apart are key issues. For small structures, great advances have been made in computer modeling. It would be desirable to extend the models to bulk samples.

X-ray intensity fluctuation spectroscopy is already being pioneered at third generation light sources and its extension to x-ray FELs, in terms of the time-scales and length-scales, were discussed, together with the possibility of studying a broad range of materials.

There were intense discussions trying to define the most important radiation characteristics. This will of course in many cases depend on the specific experiments, but in general terms the following order was established, in de-creasing order of importance:

1. Beam position stability
2. Beam focusing
3. Synchronization for pump-probe
4. Shorter pulses
5. Smoother pulses
6. Reduced pulse to pulse intensity fluctuations

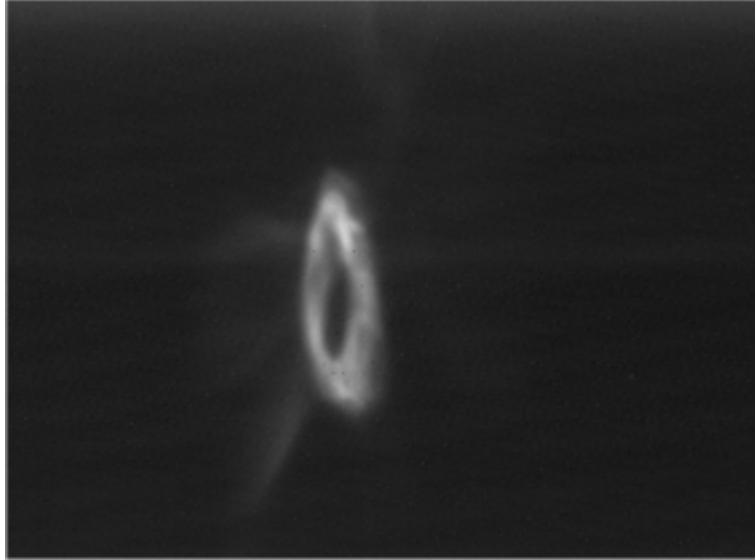
Photoinjector R&D News

J. Clendenin

1. Analysis of emittance measurements at GTF.

Emittance values at the GTF are derived from a set of beamwidth measurements for a range of quadrupole field strengths, the so-called "quad scan" technique. The beamwidth measurements are obtained by analyzing digital images of the beam crossing a screen intercept downstream from the variable quad focusing element. A review of methods used to characterize "beamwidth" is now underway at the GTF. The problem is straightforward in the case of ideal beams, but in the case of non-uniform beams with "hot" spots and other defects, a simple "lineout" through a local hot spot may not lead to meaningful emittance values. In the past, most GTF beams have exhibited hot spots that are presumably linked to some combination of variations in cathode emissivity and drive-laser flux. This past summer, using a cathode installed a year ago, we observed gross topological disorders of a new sort that we believe resulted from a machining defect at the cathode center. We have recently installed a new cathode that was carefully chosen to have a smooth and uniform surface.

The standard analysis method that we have utilized for the past couple years determines the rms width of the beam from a single lineout that includes the hottest pixel. Applying this method of analysis to our data from summer 2000, we found minimum values of normalized rms emittances of about 2×10^{-6} m, which for our conditions is consistent with the predictions of PARMELA. See the August Newsletter. More recently however, using projections of all the background-subtracted data for a given pulse, we are finding much higher values of emittance. The difference in these results, if it persists, is almost surely due to the highly irregular shape of the beam at the screen. An image of the beam when it is focused as part of a quad scan is shown below. We believe that the cure for this problem is to produce a more uniform beam image using the new cathode. We will begin emittance measurements using the new cathode in a few weeks once the SPEAR ring is operating normally for its next experimental cycle.



2. GTF Immediate Plans.

The beam performance with the new cathode will be checked as soon as SPEAR is operating normally in a few weeks. A Laser Task Force headed by Paul Bolton is examining the question of what should be done with the glass laser. We discovered more damage to the rods at the end of the last experimental run. Any major changes to the laser will be delayed at least until after the next experimental run. Meanwhile, the pulse stacker will be tested, and we also expect to test the IR FROG soon. The streak camera has been returned to England to have a new streak tube installed and other improvements.

3. PARMELA.

PARMELA results for a beam having a temporal ramp at the cathode were reported by Limborg et al. at Arcidosso. The emittance out of the injector booster (L0) was very close to 1×10^{-6} m for the usual LCLS 1-nC conditions. However, the decision now is to use an X-band section in L1, which means the injector can use a temporally uniform pulse to produce the lowest possible emittance. A PARMELA study will now be made of how to minimize emittance growth in the matching section between L0 and L1.

4. LCLS Injector Vault.

The footprint for the LCLS laser shack has been laid out showing, among other things, the desired location for the laser beam penetration. A 20" ID penetration will be drilled at the end of October after a precision survey of the Vault is completed.

5. LANL

D. Nguyen will soon be ready for a low emittance measurement at the AFEL. The GTF pulse stacker and (if it is back in time) the SSRL streak camera will be used.

Undulator

Liz Moog/Efim Gluskin

The order for magnets for the undulator prototype is now in the hands of Procurement. One vendor has agreed to accept a requirement that all the magnets have the same total dipole moment to within +/- 1% with no impact on the price. The purchase of permanent magnets for the quadrupole prototype is in progress. A prototype of the quadrupole has been manufactured and assembled, though without the permanent magnets.

Robert Ruland visited for a day and we discussed alignment issues and tolerances with him.

First drafts of some sections of the undulator chapter of the CDR have been completed.

We are preparing for an internal design review of the mechanical aspects of the undulator prototype. The review will take place on November 2, which will coincide with a visit by Vinod Bharadwaj and Lowell Klaisner.

During the past week, there has been some serious SASE lasing going on at the APS FEL, both at 530 nm and at 380 nm, with enough light being produced to result in four dead CCD cameras. Data analysis is in progress and the theorists are evaluating the preliminary results.

VISA Report

Aaron Tremaine

The fiducialization of the magnets has been completed and the numbers agree well with the CMM data taken on the sections. Unfortunately, the data taken can not be compared with that done last year as the tooling balls were replaced. It was noticed that Section 1 had an asymmetrical mounted shimming magnet, which may cause a perturbation in the strong focussing. Sections 1 & 2 will be placed back on the pulse wire bench next week (the 1st week of October) and this potential problem will be corrected.

The new slides are still in the design and test phase and should hopefully have a prototype finished by early next week. Once this is done then they will go into production, which will take about 3 weeks. Simultaneously, the vertical adjusters are being designed. This is to allow vertical adjustment of the undulator while under vacuum. In order to satisfy other experimental run times and VISA installation we are thinking of holding off installation until late November. This will give VISA the most access time to the experimental hall and also continue smooth operation of ATF experiments.

Brendan will come out with the slides and head the installation of them. After the slides are installed then the undulator will be installed and pre-aligned with an optical survey. Robert Ruland thinks that it is best to install the vertical adjusters after the laser

interferometric system as aligned the undulator to within 100 μm . This whole process we think will take at least 1.5 weeks puts pump-down into the beginning of December.