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LCLS-II INJECTOR LASER SYSTEM

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Abstract

The Linac Coherent Light Source II (LCLS-II) is a new Free Electron Laser (FEL) facility being built as an upgrade to the existing LCLS-I and is planned for early commissioning this year (2017) and full operation in 2020. The injector laser, which hits the cathode to produce the electrons for this FEL source, is conceptually similar to LCLS-I but will utilize an upgraded controls architecture in order to be compatible with the faster repetition rate (1 MHz) of the beam. This includes moving to industrial PCs from VME and utilizing SLAC designed PCIe timing cards and camera framegrabbers.

BACKGROUND

The Linac Coherent Light Source II (Figure 1) at SLAC National Accelerator Laboratory is a high intensity, extremely tunable X-Ray Free Electron Laser (XFEL) facility. The light this facility uses for experiments is generated by a 1 km superconducting electron accelerator with a photocathode source [1].

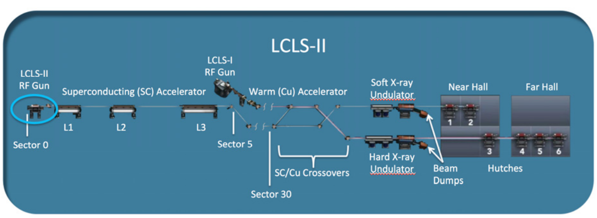

Figure 1: LCLS-II Full Beamline Schematic (Injector circled).

In order to generate these intense X-Rays, LCLS-II actually uses two different laser systems (Figure 2). For the first or these, high power 257 nm wavelength (UV) laser light (hereon referred to as the Drive Laser) is pulsed at up to 1 MHz onto a semi-conductor cathode to emit electrons that are then accelerated by RF through a series of superconducting cavities.

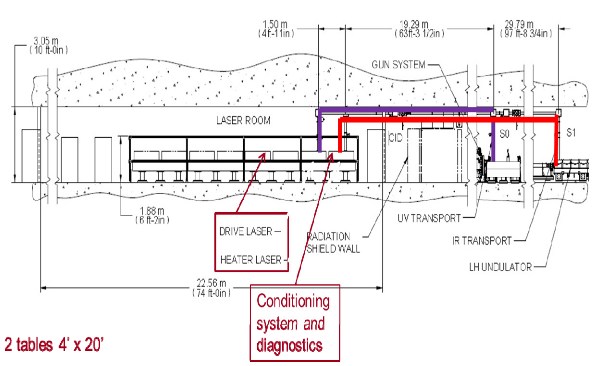

Figure 2: Laser Transport Lines.

Once these electrons are sent down the accelerator however, micro-bunching instabilities can develop which adversely affect the quality of the X-Ray beam generated further on. To counteract these instabilities there is a second 1030 nm (IR) laser (called the Heater Laser) that is aligned to co-propagate with the electron bunch through a small wiggler magnet in the center of a magnetic chicane. This laser is capable of running at 1 MHz as well and will be timed to overlap with the travel time of the electrons to the chicane.

REQUIREMENTS

Each of the two laser systems described above will be designed to function entirely independently [2]. They will each be generated from separate sources and synchronized with independent oscillators and feedbacks. This is a departure from LCLS-I where the Heater Laser was generated from the unconverted light left over after the UV conversion process for the Drive Laser. This allows for far more flexibility for using these systems as well as the ability for the laser physicists to manually reconfigure the Heater Laser to act as a hot spare for the Drive Laser in the case of a major failure (dedicated spare lasers are planned for both the Heater and Drive, but they will come at a later date).

Additionally, both lasers will have dual shutoff paths tied to the Machine Protection System (MPS) in the case of an interlock fault which endangers a piece of beamline equipment as well as the Beam Containment System (BCS) which will fault the Drive Laser in the event of a fault where the beam may cause a potential risk to personnel. The first of these shutoff paths comes in the form of the Acousto-Optic Modulator (AOM) that acts as a fast switch and rate selector for the lasers. The second is a slower mechanical shutter that will block the lasers just before they enter the electron beamline. When a fault occurs, the AOM will divert the lasers into a beam dump until the mechanical shutter has had time to close. Once the shutter is fully inserted, the AOM will be allowed to send beam down so that the beam can be diagnosed and aligned if need be.

In order to stably deliver the laser pulses to their respective destinations, there will be several automated steering feedbacks that will maintain the beam centroid calculated from camera data by tilting upstream mirrors in the horizontal and vertical planes. Most of these feedbacks will be capable of maintaining both position and angle of the beam trajectory, but due to space constraints there will be some that are only able maintain position.

Finally, there will be a variety of other beam diagnostics for remotely tracking the properties of the lasers along their transport. Cameras, powermeters,

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oscilloscopes, irises (collimators), cross-correlators, humidity/temperature sensors, and timing will all be accessible remotely and have data archived for analysis and troubleshooting.

ARCHITECTURE

Hardware

A large variety of equipment is necessary to be used for control and readback of the laser systems (Figure 3). Wherever possible, controllers and sensors were chosen to be compatible with commonly used equipment elsewhere in LCLS-II and LCLS-I. Due to the specific wavelengths of the laser light (particularly with regards to the Shortwave IR light used for the Heater) some exceptions to this were necessary for the cameras.

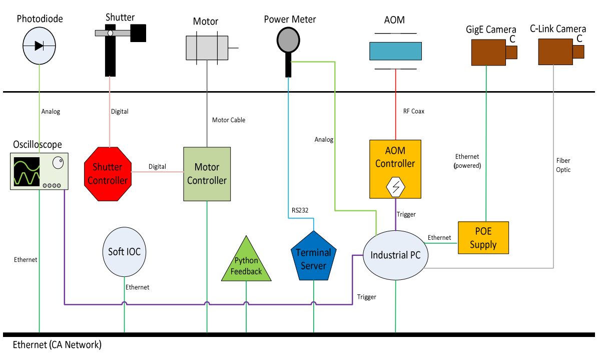

Figure 3: Generalized Controls Architecture.

The center of the controls architecture is the Software Input/Output Controller (SIOC) where the EPICS software is run. In applications where direct interface to hardware is required for timing, cameras, or analog/digital data an Industrial PC will be used. LCLS-II has chosen the 1U and 2U units from Advantec as the Common Platform for LCLS-II and the Laser System will follow that standard.

The PC will run LinuxRT and inside will be several PCIe cards. A timing card developed at SLAC will be used to bring in the LCLS-II scheduled timing patterns which can be used for BSA time-stamping of data as well as for outputting TTL hardware triggers for use in triggering devices such as the powermeters and the AOM. General I/O data will come into the PC through a PCIe carrier card for Acromag Industry Pack modules.

Camera data will be acquired via one of two methods. A SLAC designed framegrabber card will be used for talking data from Camera-Link style cameras. Camera-Link has proved through testing to be more resilient in radiation environments and so will be used in all high availability installations (feedback cameras, iris profile, etc.). The framegrabber is capable of communicating with eight cameras simultaneously and has an integrated timing module for triggering as well as Beam Synchronous Acquisition (BSA) of data. For the Drive Laser, the JAI CM130-CL will be used as we have had good results with their cameras in the past in UV. Meanwhile, the Basler acA2040-180kmNIR will be used for the Heater Laser. This camera's sensor is not optimized for 1 um light, but in testing it appears that it should be good enough for the purpose of alignment and it is far less expensive than true SWIR cameras. In the case that the sensor does not prove good enough for the laser physicists to maintain the quality of the beam, the AVT Goldeye has been chosen as a backup as it is intended for operation at this wavelength and should have greater fidelity. In the laser transport lines that will only be used during initial alignment, the plan is to use Gigabit-Ethernet cameras, in this case the AVT Manta G033B that has broad use in LCLS-I currently. These cameras will be connected directly to the Ethernet port of the PC and use Power-Over-Ethernet which requires minimal cabling and is somewhat easier to setup and troubleshoot.

Motors will generally all be compatible with the Newport XPS-Q8 controller. This motor controller platform is heavily used throughout LCLS-I for laser applications which provides for a large support structure and ready spares. The exception to this is that the laser oscillators as delivered from the manufacturer utilize stick-slip piezo motors from SmarAct. This therefore necessitates the use of the SmarAct MCS controller for this application. This controller is also used in some other installations in LCLS-I, but in much more limited scope than the Newport XPS-Q8.

For motors that require long cable runs, particularly into the tunnel, SLAC-designed extension chassis will be used to amplify and condition the control and readback signals. These chassis support a variety of motor types (steppers, servos) and position readbacks (LVDTs, potentiometers, encoders) as well as some general purpose I/O. As a downside, these amplifiers are not compatible with the Newport Enhanced System Performance (ESP) technology for Plug-and-Play configuration of the motor stages. This technology relies on an EEPROM chip embedded in the cable of the motor though which will likely be adversely affected by the radiation environment and possibly rendered unusable anyway, therefore motors will be configured manually at the controller and the configuration files saved in version control.

Software

As mentioned above, the Injector Laser controls will be EPICS based SIOC applications. Most of these applications will be running on centralized LCLS-II productions servers except in the instance discussed earlier where direct interaction with hardware is required in which case a local Industrial PC will be used.

For EPICS, the plan for LCLS-II will be to standardize on version 3.15. For Early Injector Commissioning this year however 3.14 may be used for some of the Laser system applications that are directly based on reuse of LCLS-I code. These will all be upgraded however for the final turn-on.

Many standard EPICS collaboration modules will be utilized for the laser controls. For all motion control the

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standard motor record will be used, though the exact version/branch is still under discussion. Similarly all camera data will be handled through Area Detector. All of these as well as the serial communication to the powermeters will rely on Asyn and StreamDevice. The steering feedback code will be largely repurposed from the working code used in LCLS-II. This code is written in State Notation Language and relies on a sequencer.

The basic user interface will initially be done in EDM and largely based off of the existing panels for LCLS-I (Figure 4). The eventual plan however is to convert all screens and interfaces over to use the new PyDM display manager based on Python and Qt5 currently under development as part of an international collaboration led by SLAC.

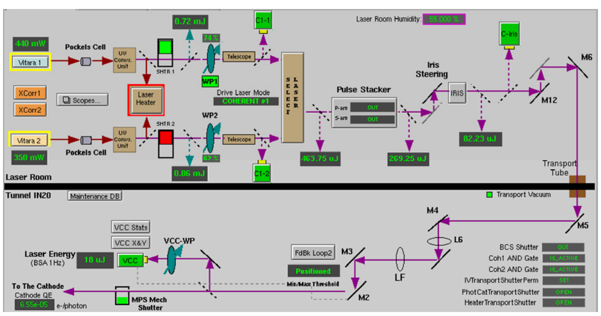

Figure 4: LCLS-I EDM Laser Main Panel (LCLS-II will be of similar design).

Finally, there are a few high level applications that will be repurposed from LCLS-I. Automated maintenance scripts written Python (Figure 5) take daily data on the laser and upload it to an online database. There are also several Matlab scripts for performing a variety of actions on the laser from profile image analysis to operating the cross-correlators.

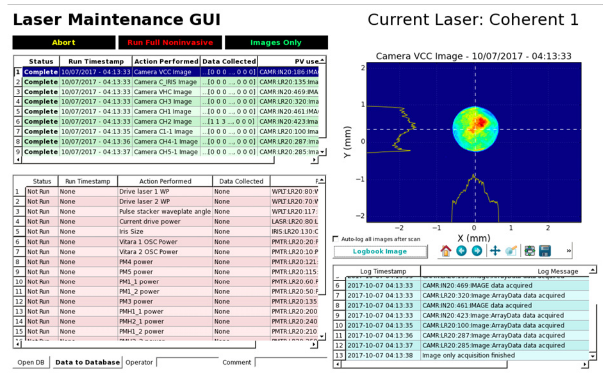

Figure 5: LCLS-I Laser Maintenance Python GUI.

ACKNOWLEDGMENT

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