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SLAC LINAC MODE MANAGER INTERFACE*

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Abstract

With the successful commissioning of the new superconducting (SC) Linac, the Linac Coherent Light Source (LCLS) now has the capability of interleaving beams from either the normal conducting (NC) Linac or the SC Linac to two different destinations, the soft (SXR) and hard (HXR) X-ray undulator beamlines. A mode manager user interface has been created to manage the beamline configuration to transport beam pulses to multiple destinations, which include the numerous intermediate tune-up dumps and safety dumps between the injectors and the final beam dumps. The mode manager interfaces with the timing system which controls the bunch patterns to the various locations, and the machine protection system which prevents excess beam power from being sent to the wrong destination. This paper describes the implementation method for handling the mode switching, as well as the operator user interface which allows users to graphically select the desired beam paths.

INTRODUCTION

The Linear Accelerator Facility (LAF) at SLAC National Accelerator Laboratory has recently met the LCLS-II project [1] key performance parameter milestones, replacing the furthest upstream 1 km section of the original SLAC linac with a superconducting electron linac capable of beam rates up to 1 MHz. This new SC Linac will complement the 120 Hz normal conducting electron linac accelerator and undulator beamlines which have been serving the LCLS user community since 2009.

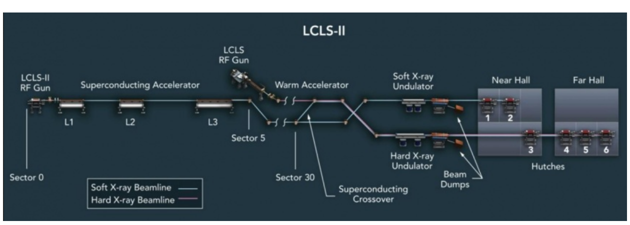

Figure 1: Schematic view of the SLAC LCLS SC and NC linacs, transport lines and switchyard, undulator lines and experiment halls.

In addition to the superconducting linac itself, the LCLS-II project included a bypass line to transport the accelerator beam past the FACET-II and LCLS-I NC Linac, as well as a reconfiguration of the beam switchyard (BSY) area where beam from either SC or NC linac can be directed to either SXR or HXR undulator lines. A schematic of the facility can be seen in Fig. 1.

The LCLS facility is designed for beam from each linac to be sent to either or both undulator lines, but not beam from both linacs to the same undulator line. We define the operating 'mode' as the combination of beamline components that define the path of possible beam from electron gun to final destination (E.g., dump). The modes are named starting with the source (E.g., NC or SC) and a unique number. Table 1 lists a sample of the most commonly used modes.

Table 1: Sample SC and NC Beam Path Definitions

Mode	Name	Description
SC10	SC Laser	Full power, 1 MHz
SC13	SC DIAG0 Line	120 Hz max
SC14	SC BSY Dump	120 kW, 100 kHz
SC17	SC HXR Dump	120 kW, 100 kHz
SC18	SC SXR Dump	120 kW, 100 kHz
NC0	NC Laser	Full charge, 120 Hz
NC7	NC HXR Tuning	Full charge, 10 Hz
NC8	NC HXR Dump	Full charge, 120 Hz
NC11	NC SXR Tuning	Full charge, 10 Hz
NC12	NC SXR Dump	Full charge, 120 Hz

The various beam paths from the NC and SC electron guns to the final HXR and SXR beam dumps, and all the various intermediate dumps can be seen in Fig. 2. This image also identifies the kickers, magnets, and stoppers that are needed to define each path. For scale, a geographical layout of the facility can be seen in Fig. 3.

Several of these stoppers are Personnel Protection System (PPS) devices and can only be inserted or retracted with a physical button in the accelerator control room (ACR). Most of the devices on this map are also inputs into the LCLS SC and NC Machine Protection Systems (MPS).

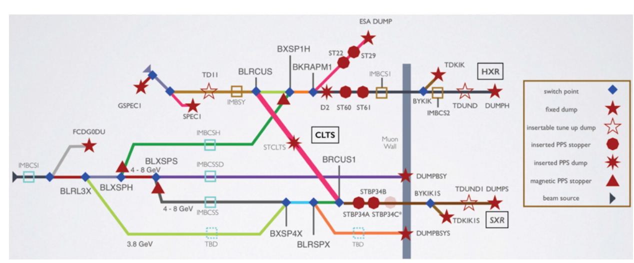

Figure 2: Overview of beam paths from SC and NC electron guns to their intermediate or final destination.

The NC Linac MPS system is designed to disable the beam permit if magnets and beamline components are not in the correct state, or reduce the allowed beam rate if specific equipment is inserted, for example maximum 10 Hz if the NC beam destination is one of the tune up dumps. The

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Figure 3: Aerial view of SLAC National Accelerator Laboratory showing the geographic scale of the LCLS-II upgrade, with the new LCLS-II superconducting accelerator section highlighted in red.

SC Linac MPS system [2] is more complicated and uses a concept of *beam power class*, which is a combination of charge, rate, and energy in a predefined window. The definition of these parameters in the firmware represent the agreement between the MPS and Timing systems. The MPS system will automatically allow or limit the beam power class depending on the configuration of equipment such as stoppers and kickers.

Together, the beam path definitions and the facility layout combine to create a compatibility table. For example:

- If SC beam path is set to send beam to the BSY dump (SC14) and the SXR undulator (SC18), it is not compatible with SC laser tuning (SC10).
- If SC beam is set to the SXR undulator (SC18), the NC beam can run to the HXR undulator (NC8) but not the SXR undulator (NC12).
- If NC beam is set to both the SXR and HXR undulators (NC8 and NC12), the SC beam can be on DIAG0 (SC13) and the BSY Dump (SC14) but not to the undulators (SC17 and SC18).

MODE SWITCH OPERATOR INTERFACE

A Mode Switch interface was designed to assist the operator to understand the current configuration of the accelerators and assist them in transitioning from one facility mode to another. According to the design, the interface should:

- Compute and visually indicate active machine mode.
- Identify what other modes are compatible with current or selected paths.
- Allow the user to transition through a ‘parked’ state to any other mode.
- Provide status of faults from other systems such as PPS or MPS.
- Aid the operator in configuring equipment in the state appropriate for selected modes.
- Automate switching procedures as available.

The interface should not:

- Manipulate any accelerator safety system such as PPS or MPS.
- Become a dependency for accelerator safety systems.
- Assert its own latches as a necessary part of operation.
- Be the sole application for modifying the current beampath.

Implementation

An EPICS IOC [3] was created to hold the calculation Process Variables (PVs) for all calculations of state, selection of desired destinations, and reporting of compatibilities. The EPICS PVs were chosen so there would be a single source of truth for the application, as opposed to using local calculations that could be different across multiple instances of the application. As an added benefit, the PVs can be archived, included in configuration save sets, and be write-restricted to the control room using standard EPICS tools.

The user interface is created using PyDM [4], the new display manager in use at SLAC. PyDM applications can be created using the Qt graphical editor ‘Designer’, by scripting with Python and importing the PyDM widgets, or a combination of Designer and Python code.

Facility Status

The main component of the interface is a graphical representation of the facility at the top of the interface. This graphic display shows the currently configured destinations, and allows the operator to select additional destinations that are compatible with the current configuration. Figure 4 shows the layout in the simplest state where the beam in both SC and NC Linacs is parked in Laser Tuning modes.

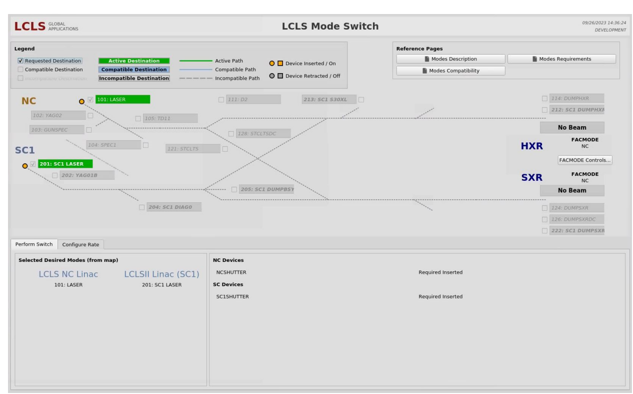

Figure 4: Mode Switch UI showing the simple case of both SC and NC beams parked in Laser Tuning mode.

To change to another set of destinations, the operator would first de-select the Laser modes. The compatibility calculations would then enable the selection checkboxes for

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all destinations. The operator would first select the furthest downstream destination for each linac. The calculations would then restrict the selection of additional destinations to those that are compatible. Figure 5 shows a configuration where the NC beam is destined for the SXR line, and the SC beam is destined for the HXR line where the BSY-Dump and DIAG0 lines are able to be selected as compatible.

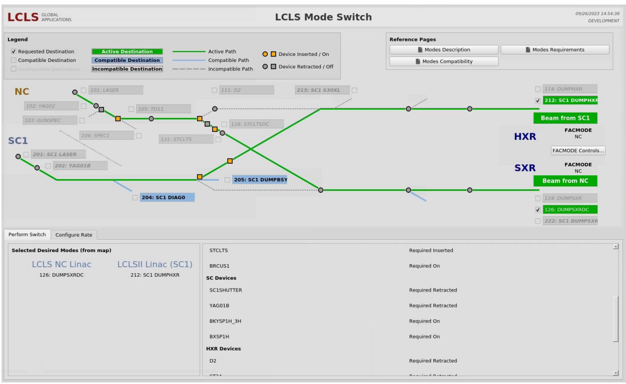

Figure 5: Mode Switch UI showing the case where the SXR line is the destination for the NC beam and the HXR line is the destination for the SC beam.

Figure 6 shows a state where both SC and NC beams are sent to beam dumps, and the configuration will allow the operator to select both HXR and SXR lines as destination for the SC beam.

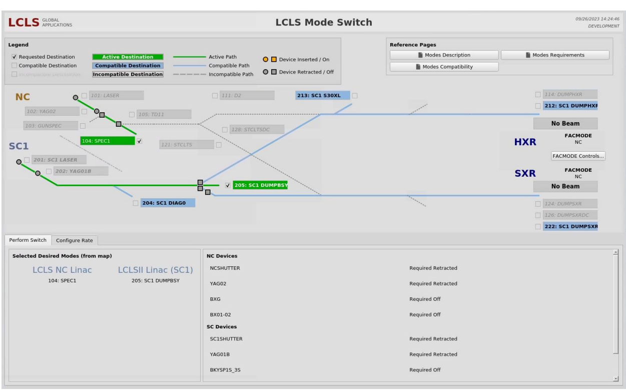

Figure 6: Mode Switch UI showing both beams on beam dumps, where both the SXR and HXR lines can be set as destinations for the SC beam.

In all cases, the state of the beam stoppers, magnets, and kickers is indicated on the display.

Accelerator Device Setup

For the initial version of the Mode Switch UI, the required state of shutters, magnets, and kickers is listed underneath the map. This list is dynamic, only showing equipment that is relevant to the selected destinations. The information displayed is intended as an aid to the operators who manually configure the machine to prepare for sending the beam. If the equipment is not in the correct state, the MPS system will either revoke the beam permit (NC Linac) or lower the beam class (SC Linac).

Originally, the intent for the beamline equipment configuration section of the interface was to offer convenience controls for the operator to set those states instead of simply listing what is required. In practice, this was not so simple to implement as there is often more context needed for each device so the operators prefer to use their normal interfaces to do this set up. The longer-term goal is to embed these manual processes into a set of EPICS sequence records that will automatically change the states of devices in a prescribed order. The outcome of that future improvement will reduce the potential for inadvertently mis-configuring the equipment and invoking MPS trips.

Timing Selection

Once the desired beam paths and destinations are selected, the operator switches to a separate UI for selecting the timing rate and pattern. The NC Linac uses an MRF Event Generator/Receiver timing system [5] to distribute the available 120 Hz beam pulses. To the operator, there are 14 predefined options such as ‘HXR 0 / SXR 120’, ‘HXR 60 / SXR 60’, or ‘HXR 110 / SXR 10’. For the SC beam the selection is not as simple. The SC Timing System [6], developed at SLAC, is able to provide timing patterns with variable rates from 1 Hz to 1 MHz with interleaved bunches to multiple destinations. The NC and SC timing systems are physically separate fiber networks, each with a pattern (SC) or event (NC) Generator that distributes information to pattern or event Receivers. In shared downstream areas the receivers are able to switch which source to trigger on so the same equipment can be used for either beam.

Figure 7: SC timing pattern selection UI.

Figure 7 shows the SC Timing Pattern Selection UI. This interface provides the operator with menus listing available rates to all selected destination, hiding destinations that are incompatible with the current mode. The SC timing system requires knowledge of the MPS beam classes and bunch charge, only allowing selection of rates that will keep the maximum power below the MPS limit. Once the selections are made, the pattern is loaded into the Timing Pattern Generator and applied.

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FACILITY TIMING MODE

Devices in the common beamline sections downstream of the linacs must be able to switch their timing mode from NC to SC. An EPICS PV for each undulator line has been created called 'SXR:FACMODE' and 'HXR:FACMODE'. Control room operators switch this PV between 'SC' and 'NC' to indicate which timing system the line should listen to. EPICS IOCs for relevant systems, such as MPS, Beam Position Monitors, and other diagnostics such as wire scanners, use these FACMODE PVs to trigger the behavior appropriate for the specific system. Several high-level software applications also read these PVs to configure themselves at startup. A common PV template for these client IOCs has been developed and includes a manual override feature so that the client can be switched to SC or NC independent of the global FACMODE specified. Figure 8 shows a simple interface the engineer can use to override the global mode, demonstrating how an alarm is generated if there is a discrepancy.

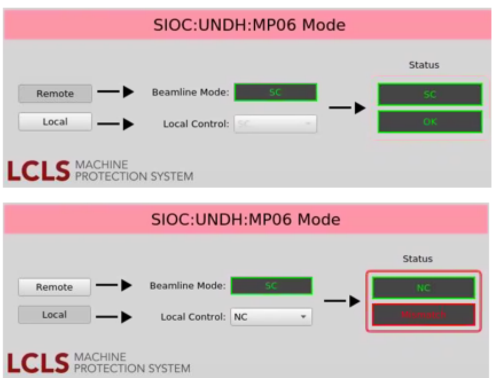

Figure 8: An interface for overriding the global facility mode, showing (top) the matching state, and (bottom) the mismatched state.

CONCLUSION

A Mode Manager Interface has been created for the LCLS facility now that it has the capability of running electron beams from either the SC or NC linac through the two undulator lines. The interface aids operators in understanding the current state of the accelerators, and with switching from one configuration to another, and selecting multiple compatible beam destinations. Currently, the interface provides a list of magnets, kickers, and stoppers and the state they need to be in for the selected mode to be implemented and allowed by the MPS system. Once the mode is chosen, operators can use the SC timing pattern selection interface to choose what rate to send to each destination.

Commissioning is ongoing, and the operations group is gaining experience setting up typical operating modes for both linacs. Currently, they switch modes and configure the beamlines manually following their standard methods and procedures. As these procedures become routine, commonly executed sequences are expected to be migrated into sequence records in EPICS IOCs for automation.

REFERENCES

[1] The LCLS-II Project Team, "LCLS-II Final Design Report", SLAC, Menlo Park, CA, USA, LCLSII-1.1-DR-0251-R0, Nov. 2015.

[2] J. A. Mock *et al.*, "Commissioning of the LCLS-II Machine Protection System for MHz CW Beams", in *Proc. IBIC'23*, Saskatoon, Canada, Sep. 2023, paper TU3I01, pp. 155–160.

[3] EPICS, `https://epics-controls.org`

[4] PyDM, `https://slaclab.github.io/pydm`

[5] J. E. Dusatko, S. Allison, J. Browne, and P. Krejcik, "The LCLS Timing Event System", in *Proc. BIW'10*, Santa Fe, NM, USA, May 2010, paper TUPSM083, pp. 379–383.

[6] P. Krejcik, C. Bianchini Mattison, and M. Weaver, "LCLS-II Timing System and Synchronous Bunch Data Acquisition", presented at IBIC'23, Saskatoon, Canada, Sep. 2023, paper TH1I01, unpublished.