DASEL Facility for Accelerator-Based Dark Sector Experiments

Dark Sector Experiments at LCLS-II (DASEL) will deliver an almost CW beam of 10nA electrons at 4 GeV for HEP experiments using the LCLS-II superconducting RF (SCRF) linac in a parasitic mode. The LCLS-II is being constructed at SLAC as part of the photon science FEL program. The FEL requires electron pulses at roughly one MHz while the linac has an RF frequency of 1.3 GHz. The approach for DASEL is to fill the unused RF buckets with a low current that will not impact the LCLS-II FEL program. This low current beam will be picked off downstream of the extraction points to the FEL undulators and diverted to the existing SLAC End Station A experimental hall as illustrated in Figure 1.

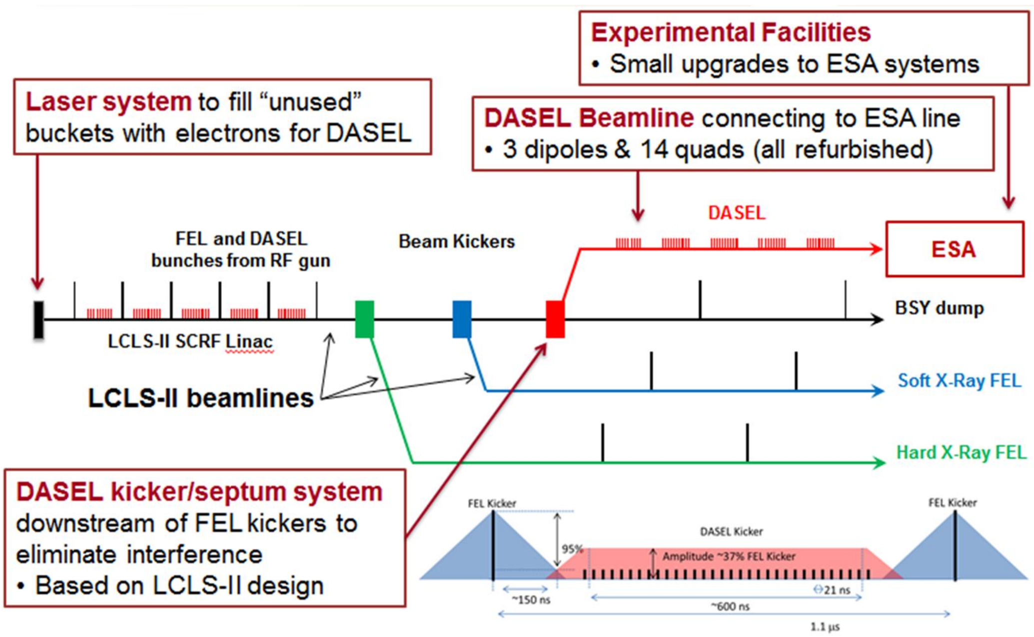

Figure 1. Schematic of the DASEL facility at SLAC based on the LCLS-II SCRF linac.

More specifically, the initial implementation of LCLS-II SCRF linac will accelerate up to 250 kW (nominally 62 μA at 4.0 GeV) of electrons to the SLAC beam switch-yard (BSY). The baseline LCLS-II design has a maximum bunch rate of 929 kHz but the linac RF operates at 1.3 GHz, the RF gun operates at 186 MHz, and the RF gun laser operates at 46.4 MHz. Two high-speed kickers can deflect FEL bunches towards either the soft x-ray (SXR) or hard x-ray (HXR) undulators; unused beam travels to a high-power dump in the BSY.

DASEL takes unused pulses from the gun laser operating at 46.4 MHz to produce a low-current beam in buckets between the primary LCLS-II bunches. These "dark" bunches, with 21.5 ns bunch spacing, are diverted to the DASEL beamline headed to End Station A with a third (new) kicker. A 220 meter long beamline takes the dark current from the DASEL kicker/septum system to connect with the existing ESA beamline where the beam can be further collimated. The charge delivered to DASEL is controlled by the spoiler/collimation system. DASEL operation is parasitic to LCLS-II, since the DASEL beam is low-current (<1μA compared to 62 μA nominal LCLS-II current) and is deflected downstream of the kickers to the undulators. Parameters for DASEL are listed in Table 1.

Table 1. DASEL Parameters for initial implementation and a possible future upgrade.

Experiment Parameters	LDMX-style (2020)	DASEL Upgrade (2025)
Energy	4.0 GeV (possible to upgrade to 8.0 GeV)	4.0 GeV (possible to upgrade to 8.0 GeV)
Bunch spacing	21.5 ns	5.4 ns
Bunch charge	0 – 20 e-	70,000 e- (10 fC)
Macro pulse beam current	0 – 150 pA	2 uA
Duty cycle	55% (600 ns out of 1.1 us)	55% (600 ns out of 1.1 us)
Beam emittance	~100 um; < 1000 um	~1 um
Bunch energy spread	<1%	<1%
IP spot size	4 cm x 4 cm – rastering at f > 2 MHz could be used	<250 um including jitter
Max beam power	0.5 W	5 kW
Spoiler		
Charge reduction	0 – 99.99%	N/A
Emittance increase	>10x; <1000x	N/A
Max beam power	55 W	N/A
Accelerator Parameters		
Macro pulse beam current	0 – 25 nA	2 uA
Beam emittance	~1um; < 25 um	~1um; < 25 um
Bunch energy spread	<2%	<2%
Bunch length	<1 cm	<1 cm
Max beam power	55 W	5 kW

An upgrade to the LCLS-II to increase the beam energy to 8 GeV has received CD-0 from the DOE. DASEL is being constructed to be fully compatible with the 8 GeV upgrade.

LCLS-II is expected to operate >5000 hours per year. DASEL has been designed to ensure zero impact to LCLS-II operations so that DASEL can operate in a fully parasitic mode whenever LCLS-II is operating. As illustrated in the schematic in Figure 1, the new facility would include four modifications to the LCLS-II:

- Addition of a low-power photo-cathode laser operating at 46 MHz
- Addition of a long-pulse kicker and septum onto the beamline headed to the BSY dump
- A 220-meter long beamline extending from Sector 30 through the BSY to connect with the existing End Station A beamline
- Small modifications to the End Station A (ESA) beamline and safety systems

A detailed schedule and a fully loaded cost estimate with escalation and contingency has been made. The cost of the DASEL facility will be significantly less than 10M$, the threshold for the HEP Small Projects Portfolio. The operation costs have not been fully developed but are expected to be less than 1M$ per year.