Estimated Number of High Power Cycles of the DUMPBSY Beam Dump *

J. Welch

April 25, 2017

This note documents an estimate of the number of high power cycles the beam dump in the Beam Switchyard of LCLS-II (DUMPBSY) will experience in the facilities lifetime. The number of high power cycles can be used as an input when evaluating the effects of cyclic thermal stress on the aluminum of the dump core. This note supersedes a previously written memo covering this topic and provides more explanation [1]. As in the previous memo, the estimated number of high power cycles of the DUMPBSY in the lifetime of the facility is 4000.

To arrive at the estimate a basic pattern of operation is assumed, where the electron beam is first tuned up at low power, and then the electron beam power is increased to generate the FEL x-ray beam in the configuration desired by the users. This pattern repeats, more or less, in cycles as illustrated in Figure 1.

In consultation with x-ray physicists, 20 different user x-ray beam configurations were identified and the probability for each x-ray configuration was assigned. For example, one configuration has a 20 W x-ray beam in the SXR line generated by the electron beam from superconducting linac, and at the same time the electron beam from the copper linac generates a low power hard x-ray beam in the HXR line. This configuration is assumed to be used about 25% of the time beams are delivered. The first block of Table 1 displays all 20 x-ray configurations and the assigned probability. The sum of the probabilities of all 20 configurations equals one.

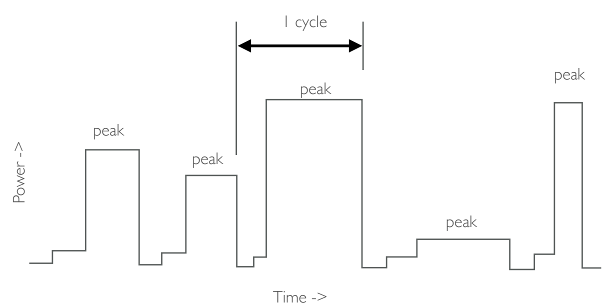

Figure 1: Schematic illustrating typical electron beam power cycles expected on the DUMPBSY.

These configurations and probabilities are almost the same as those used for the beam loss estimates in the Beam Loss PRD [2]. One additional assumption was made that 5% of the time we would be running 1 W of FEL x-ray beam in the SXR line in a tune up mode in preparation for running with a maximum power 120 kW electron beam.

For each user x-ray beam configuration the electron beam power diverted to the DUMPBSY was estimated. Determination of the DUMPBSY electron beam power is somewhat complicated by the fact that we will generally keep constant the electron beam power in the superconducting linac and use the spreader kicker to allocate the appropriate electron beam to the two undulator lines. The DUMPBSY

*Work supported in part by the DOE Contract DE-AC02-76SF00515. This work was performed in support of the LCLS-II project at SLAC.

is used to absorb beam power in excess of what is needed to make the user beams. Various assumptions about what electron beam power is required to generate a particular FEL x-ray beam configuration, such as the number of millijoules of x-ray pulse energy produced per electron bunch, were conservatively made by accelerator physicists. The resulting DUMPBSY electron beam power estimates for each configuration are displayed in the second block of Table 1.

Using the first two blocks of Table 1 one can form a histogram representing the probability distribution as a function electron beam power on the DUMPBSY. As shown, this third block of Table 1 displays the probably of each x-ray configuration when the electron beam power on the DUMPBSY is between 200 kW and 250 kW. Below the third block are the data obtained for other power intervals that are used in the histogram plotted in Figure 2. The beam will be between 200 and 250 kW only 5.5% of the time.

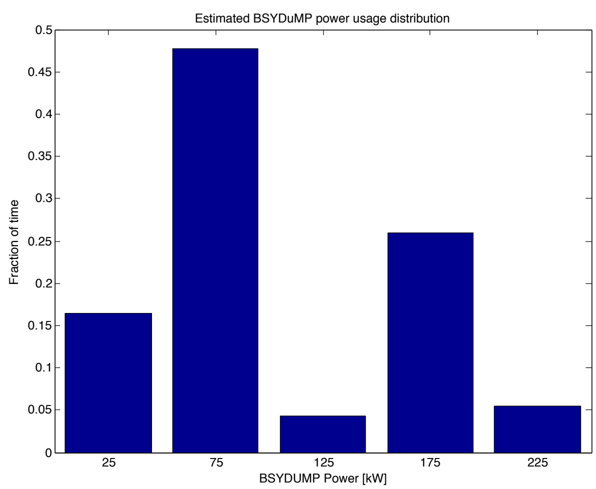

Figure 2: Histogram of expected power levels on DUMPBSY.

The number of cycles where the dump power reaches near the highest power are of primary interest for estimates of the effects of cyclic thermal stress in the dump. We estimate the number of cycles to 200 kW or more electron beam power with the following factors:

- 1 cycle every 4 hours per beamline
- 2 beam lines which cycle indpendently
- facility lifetime of 30 years at 5000 hr/y.
- 5.5% probability of power greater than 200 kW.

These factors multiply out to about 4000 high power cycles in the expected lifetime of the facility.

The assumption of 1 cycle per 4 hours per beam line is meant to be conservative. Currently, at LCLS users have 12 hour shifts and often just need one beam power and energy. In the future, energy change can be done by changing undulator gap without changing the electron beam power in undulator, as there will be no need to retune the linac energy. If the user wants to interrupt the x-ray beam they many do so by using the photon shutter, thus the electron beam would not be cycled. Furthermore, it is expected to take considerable time to tune up and stabilize the x-ray lines when running near the highest power because of heating of the mirrors. So it is not likely that an experimenter would want to rapidly change from very high power to low power repeatedly and create a large number of high power cycles.

References

[1] J. Welch, 'Estimated number of high power cycles on LCLS-II Dumps', memo, Nov. 2016

[2] "LCLS-II Electron Beam Loss and Maximum Credible Beam", Physics Requirement Document, LCLSII-2.7-PR-0079-R1

Table 1: Usage table of probabilites and power levels for different configuration.

Usage Matrix - Operational Mode

		HXR	**HXR**	**HXR**	**HXR**	**HXR**
	probability listed for each combination	From Cu linac	From SC linac 20 W	From SC linac 1 W	From SC linac harmonics	1 W tune beam for 120 kW operation
SXR	20 W FEL beam power limit	0.25	0.125	0.075	0.025	0.025
SXR	1 W tune up beam	0.2	0.1	0.06	0.02	0.02
SXR	harmonics	0.025	0.0125	0.0075	0.0025	0.0025
SXR	1 W tune beam for 120 kW operation	0.025	0.0125	0.0075	0.0025	0.0025

		HXR	**HXR**	**HXR**	**HXR**	**HXR**
	BSYDUMP Power for each combination	From Cu linac	From SC linac 20 W	From SC linac 1 W	From SC linac harmonics	1 W tune beam for 120 kW operation
SXR	20 W FEL beam power limit	90510	12000	87000	12000	127000
SXR	1 W tune up beam	165510	87000	162000	87000	202000
SXR	harmonics	90510	12000	87000	12000	127000
SXR	1 W tune beam for 120 kW operation	205510	127000	202000	127000	242000

	Probabilty for P >	**200**	**250**	**HXR**	**HXR**	**HXR**
	Probability for each combination	From Cu linac	From SC linac 20 W	From SC linac 1 W	From SC linac harmonics	1 W tune beam for 120 kW operation
SXR	20 W FEL beam power limit	0.0000	0.0000	0.0000	0.0000	0.0000
SXR	1 W tune up beam	0.0000	0.0000	0.0000	0.0000	0.0200
SXR	harmonics	0.0000	0.0000	0.0000	0.0000	0.0000
SXR	1 W tune beam for 120 kW operation	0.0250	0.0000	0.0075	0.0000	0.0025
	Total probability	0.0550				

Results table	Probability	between	lower kW	high kW
	0.055		200	250
	0.26		150	200
	0.0425		100	150
	0.4775		50	100
	0.165		0	50