Measurement of XFEL pulse intensity under CBXFEL-like conditions at LCLS

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M. D. Balcazar, R. Margraf, J.Tang, T. Sato, D. Zhu, A. Halavanau

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1 Purpose and Scope

This document describes recent measurements of the LCLS pulse intensity, in preparation for the cavity-based XFEL (CBXFEL) experiment at SLAC.

2 SASE photon number measurement

Cavity-based XFEL (CBXFEL) is a future photon source concept under development at SLAC. It is considered a path towards full 3D coherence at angstrom wavelength, delivering another 2-3 orders of magnitude leap in source brightness compared to current XFELs configurations. In the first phase of the project, one of the goals is to demonstrate the regenerative amplification by returning and amplifying the seed pulse from 7 LCLS Hard X-ray Undulators (HXUs) with a rectangular Bragg crystal cavity. We report on the recent measurement of early stage XFEL lasing characteristics at 9.831 keV photon energy by using 7 LCLS HXUs under e-beam conditions close to those chosen for the first phase of CBXFEL gain demonstration. The experimental schematics is shown in Fig. 1.

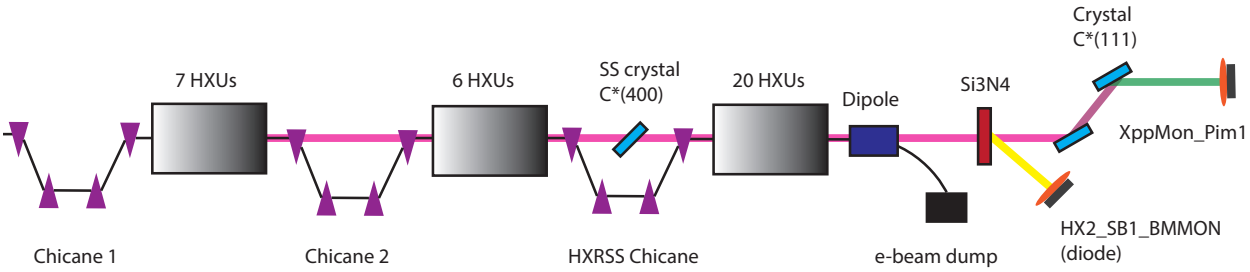

Figure 1: LCLS HXU beamline layout (not to scale) as of 2024: 7 tunable undulator sections are flanked by two electron beam chicanes for CBXFEL experiment, followed by 6 undulator sections, hard x-ray self-seeding (HXRSS) chicane and 18 more undulator sections. The resulting x-rays are intercepted with a Si_3N_4 membrane for pulse intensity measurements, follow by a double crystal monochromator (DCM) and a photodiode detector.

In the experiment, we have registered hard x-ray pulse intensity with two diagnostics - pulse intensity monitor measuring total SASE photon flux, and a tunable double crystal

monochromator (DCM) measuring photon flux in the 0.7 eV bandwidth. We first retracted all but the first three LCLS HXUs, and repeated the pulse intensity measurements inserting additional HXUs one at a time. The x-ray photon energy was chosen to be close to CBXFEL value of 9.831 keV. The resulting gain length measurement is presented in Fig. 2. We

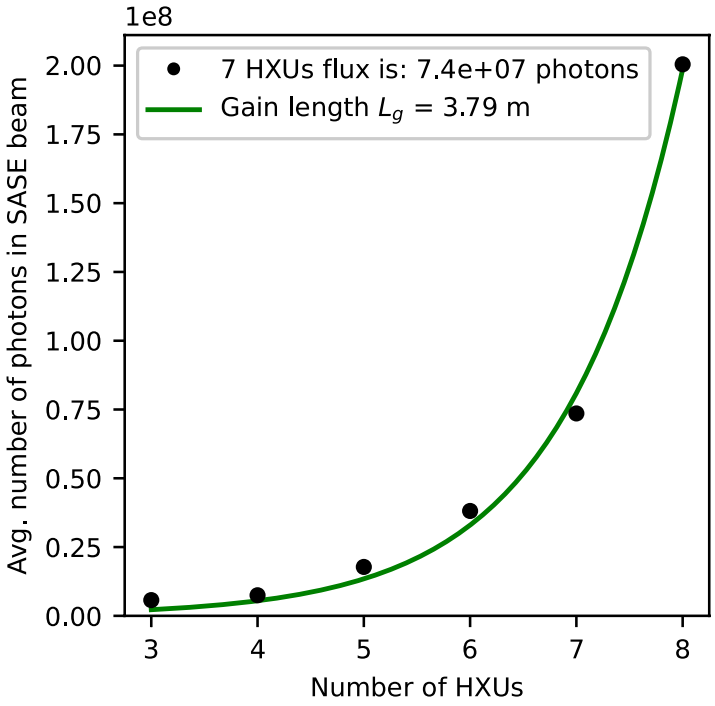

Figure 2: Hard x-ray pulse intensity as a function of number of LCLS HXUs. The fitted value of FEL gain length is about 3.8 m.

confirmed that LCLS HXR FEL is in the exponential gain regime in the first 8 undulator sections. The average number of SASE photons after 7 undulator sections was measured to be about $7.4 \cdot 10^7$ photons. The average number of photons in a 0.1 eV bandwidth at the center of the spectrum measured after the monochromator was obtained to be 3.4×10^5 photons/pulse. This number will be subject to strong shot-by-shot fluctuations.

References

[1] Xie, Ming. "Exact and variational solutions of 3D eigenmodes in high gain FELs." *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 445.1-3 (2000): 59-66.