STATUS OF THE PAL-XFEL PROJECT*

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Abstract

PAL-XFEL is designed to generate X-ray free-electron laser radiation in a range of 0.1 and 10 nm for users. The machine consists of a 10 GeV linear accelerator and five undulator beamlines. Electron beams are generated at a low emittance S-band photocathode RF gun and accelerated through an S-band normal conducting linac. Three hard X-ray beamlines will be located at the end of the linac. Electron beams for two soft X-ray beamlines will be switched at a medium energy from the main linac. The project started in 2011 and building construction starts in summer 2012. The status of the project is presented.

SCOPE OF THE PROJECT

The Pohang Accelerator Laboratory X-ray Free-Electron Laser (PAL-XFEL) project started in 2011. This project aims at the generation of X-ray FEL radiation in a range of 0.1 to 10 nm for users. The machine consists of a 10 GeV linac and five undulator beamlines. The linac is based on normal-conducting S-band technology, which has been used for the 3 GeV full energy injector linac for PLS-II, the 3rd generation light source at PAL. As Phase-I, one hard X-ray undulator beamline with two experiment stations and one soft X-ray undulator beamline with one experiment station will be built. Both undulator systems are variable-gap, out-vacuum type.

The new machine is to be built on the north mountain of the PAL campus (see Fig. 1). Building construction starts in summer 2012. Our current plan is to finish the project (Phase-I) by 2014; however the construction schedule may change depending on budget situation.

The system will operate at a repetition rate of 60 Hz initially. Two micro bunches per RF pulse will be made for increasing user's accessibility for FEL photons. A fast kicker to divide electron pulses into the two undulator beamlines is considered as future upgrade.

SYSTEM LAYOUT

An electron beam is generated at a photocathode RF gun. The electron beam is accelerated through an S-band linac to 3 GeV for soft X-ray FEL and to 10 GeV for hard X-ray FEL. Three experiment stations will be constructed as Phase-I. The machine layout is shown in Fig. 2. The main parameters of the PAL-XFEL machine is summarized in Table 1. Some information of the machine is described in this section.

Table 1: PAL-XFEL Baseline Parameters

FEL wavelength, soft X-ray	10 - 1 nm
hard X-ray	0.7 - 0.1 nm
Electron beam energy	10 GeV
Bunch charge	0.2
Repetition rate	60 Hz
Number of bunches per RF pulse	1 or 2
Gun type	S-band PC gun
Linac type	S-band (NC)
Linac hall length	780 m
# of hard X-ray beamline	1
# of soft X-ray beamline	1
Undulator type	out-vacuum
Hard X-ray undulator hall length	225 m
Soft X-ray undulator hall length	110 m
# of hard X-ray experiment station	2
# of soft X-ray experiment station	1
XFEL beamline hall length	105 m
Beam energy at soft X-ray branch	3 GeV
Branch position from cathode	260 m
Total building length	1110 m

Injector

The injector consists of an S-band (2.856 GHz) photocathode gun, two 3 m long S-band (2.856 GHz) traveling wave structures, and focusing solenoids [1]. The baseline gun has been developed at PAL, which consists of 1.6 cells and a high power RF coupler on the side of the second cell. Two RF input holes are made with mirror symmetry and two additional holes reduce high-order modes of the RF field [3, 2]. The peak accelerating field at the cathode is 120 MV/m and the beam energy at the gun exit is 5.7 MeV. After further acceleration through two S-band structures, the beam becomes 139 MeV.

An injector test facility (ITF) is under construction for starting beam commissioning in autumn 2012. The PAL-XFEL injector system will be fully commissioned there and new accelerator components including drive laser, gun, cathode, RF, diagnostics, laser heater and timing system will be tested and commissioned before installation to the PAL-XFEL main linac. The ITF tunnel is ready and RF/laser components are being delivered.

A next stage gun development, targeting the achievement of a lower transverse emittance as well as a higher peak current, is also started. This gun will provide an electron beam with a lower transverse emittance by optimizing the gun cell length and focusing solenoid position. With an exchangeable cathode plug, damaged cathodes can be

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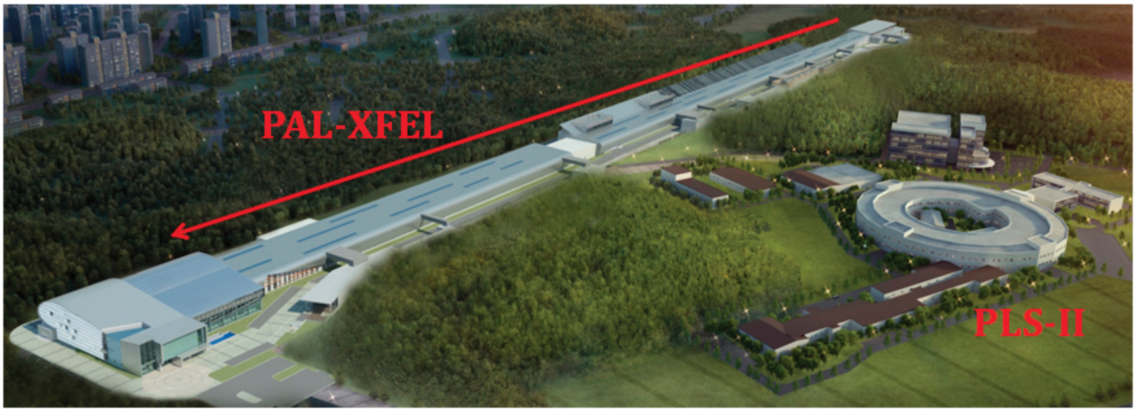

Figure 1: Site view with existing PLS-II and PAL-XFEL to be constructed at the north part of the PAL site.

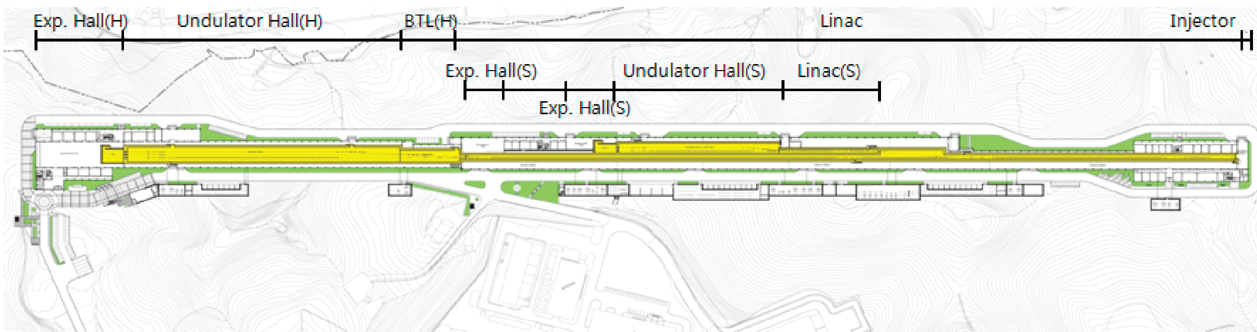

Figure 2: Layout of PAL-XFEL.

replaced with a fresh one easily. Cathodes with high quantum efficiency and/or low thermal emittance will be tested at the gun.

RF Linac

Normal conducting constant gradient S-band traveling wave structure is adopted as accelerating structures for the injector and main linac. The S-band accelerator technology has been used for the PLS-II injector linac at PAL for 20 years. The PLS-II injector provides 3 GeV electron beam for top-up operation of the PLS-II ring [4].

One RF station will feed four accelerating columns at the high energy part of the linac, e.g., after the 1st magnetic bunch compressor (BC1). SLED cavities will be used for doubling the peak power from klystrons. Since RF jitter is more sensitive at the low energy part, every two columns before BC1 will be fed by one RF station and each column at the injector will have an RF station. J-type quasi-symmetric high power RF input/output couplers will be used for the columns at the low energy part of the linac. Simpler RF couplers will be used for the columns at the high energy part for reducing fabrication cost. R&Ds for RF high power modulators as well as low level RF control are ongoing [5, 6, 7]. A dedicated accelerator test facility (ATF) is under preparation.

The current design of the PAL-XFEL linac layout is shown in Fig. 3. An electron bunch compression scheme with three magnetic chicanes is considered to maximize flexibility of the beam operation for both the hard and soft X-ray beamlines. One X-band (11.424 GHz) cavity linearizes the longitudinal phase space of an electron beam before BC1. A de-chirper using longitudinal wake field is considered for reducing the energy chirp at the soft X-ray line. More details on the linac design and jitter study are described in [8, 9].

Undulator

The layout of the undulator beamlines is shown in Fig. 4. The hard X-ray undulator beamline is located at the linac end, where the beam energy is 10 GeV. A SASE FEL radiation of 0.1 nm will be produced by twenty two planar undulators. The undulators are 5 m long, variable gap and out-vacuum type. The hard X-ray undulator hall is 225 m long; therefore some space is reserved for possible further installation for seeding schemes.

The X-ray self-seeding scheme [10] will be applied to the Phase-I hard X-ray undulator beamline when the baseline goal, saturation of SASE radiation, is achieved. Shorter wavelength (0.06 nm) of X-ray FEL radiation will be also tried at the first undulator line. Two more hard X-ray undulator beamlines will be added in the future.

The electron beam branch to the soft X-ray undulator beamline is located at 260 m from the cathode, where the beam energy is 3 GeV. Twelve 5 m long planar undulators

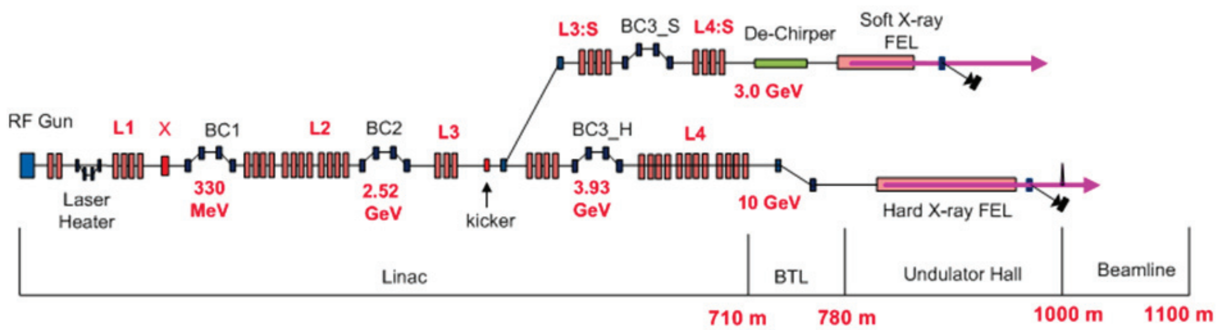

Figure 3: Layout of the current design of the PAL-XFEL linac.

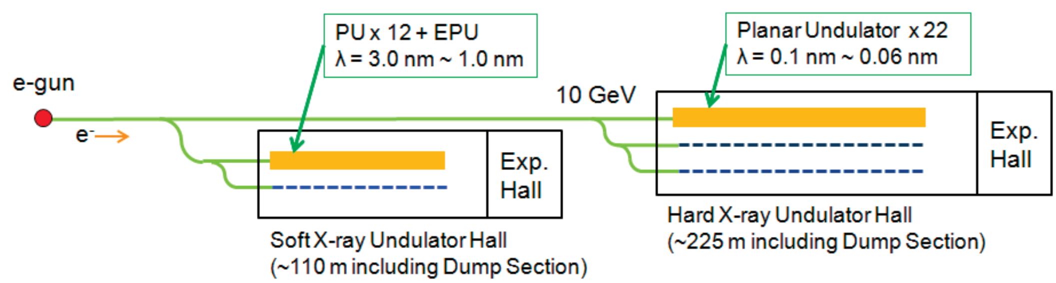

Figure 4: Layout of the current design of the PAL-XFEL undulator.

and a few elliptically polarized undulators (APPLE-II type) will be installed for full polarization control. The soft X-ray undulator hall is 105 m long. One more soft X-ray undulator beamline will be added in the future. More details on the PAL-XFEL undulator system can be found in [11].

Photon Beamline

Three experiment stations are to be constructed as part of Phase-I. Following the requests of Korean synchrotron radiation user societies, priority has been given as following: An X-ray pump-probe (H-XPP) and a coherent X-ray imaging (H-CXI) experiment stations at the hard X-ray beamline; An X-ray pump-probe experiment station (S-XPP) at the soft X-ray beamline. R&Ds on photon optics and detector are ongoing.

SUMMARY

10 GeV linac and two undulator beamlines for FEL radiation in a range of 10 to 0.1 nm are going to be built at the PAL site by 2014. An electron beam is generated at an S-band photocathode gun and accelerated through S-band traveling wave accelerating sections. Three magnetic chicanes compress the beam from a few tens ampere to a few kilo ampere. Planar, out-vacuum undulators are installed at the linac end for hard X-ray FEL radiation. A combination of planar and elliptically polarized undulators will be installed at 3 GeV point for soft X-ray FEL. Three user experiment stations will be built as Phase-I of the project.

A new gun development for lower transverse emittance and more reliable operation is ongoing. The X-ray self-seeding scheme and atto-second photon pulse generation are considered as a short-term upgrade plan after completion of Phase-I. Two more hard X-ray undulator beamlines and one more soft X-ray undulator line will be added as next phases.

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