PAL-XFEL'S TURBO-ICT FOR BEAM CHARGE MONITORING*

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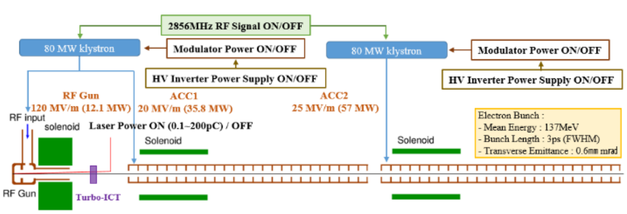
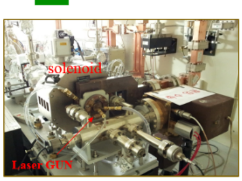
Abstract

The construction of the PAL-XFEL building, which is a fourth-generation synchrotron radiation-light source, was completed in February 2015. Accelerating devices (Cavities, Klystrons, Modulators) and undulators will be installed by December 2015. The installation of the remaining devices will be completed by the start of 2016. A Beamline user service will be started from the middle of 2016 [1]. The installation of PAL-ITF (Injector Test Facility) was completed at the end of 2012 for the production of high-quality electron bunches. Efforts were made to improve the performance of pre-injector system and diagnostic equipments. In this study, details of the performance improvements of PAL-ITF measurements using a Bergoz Turbo-ICT, which is able to measure the amount of bunch charge from 0.1 to 200pC, and the operating plan of Turbo-ICT which will be installed and operated in PAL-XFEL are introduced.

COMPOSITION OF PAL-ITF

PAL-ITF was constructed to produce the same amount of charge in the range of 0.1~200pC as PAL-XFEL and to test the laser cathode RF gun generating the electronic beams (jitter and drift are less 0.5% of set charge) and the pre-injector accelerating the beam preserving shape, emittance length and energy spread. Figure 1 shows the composition diagram of PAL-ITF [2].





Load Type	GUN	1st Accelerator	2nd Accelerator
Peak RF power [MW]	12.1	35.8	57
RF Pulse Length [us]	1.5	1.5	1
Average Power [kW]	1.1	3.2	3.4
Efficiency	35%		40%
HV Pulse Length	> 4us [FWHM]		
Repetition Rate : 1~60Hz			

Figure 1: PAL-ITF composition diagram.

After completing construction of PAL-ITF at the end of 2012, beam charge was first measured using ICT and faraday cup to monitor beam charge. There were various difficulties measuring the exact charge of 0.1~200pC due to the noise of the pulse power klystron modulator. Turbo-ICT was built in 2013 to accurately measure the charge of beams [3]. A charge of 1pC or more could be measured accurately as shown in Figure 2, after measuring the generated charge of the laser gun while changing the half-wave plate angle inside the laser system. However, it was impossible to measure a charge of 1pC or less due to the noise from the pulse power klystron modulator as shown in Figure 3 [4]. The problem of noise from the pulse power klystron modulator is serious enough to create negative effects on not only the measurement of Turbo-ICT charge but also affects the electronic circuits of all diagnostic units and control devices. Measures had to be prepared to prevent the noise from affecting the exact measurement and operation of electronic devices.

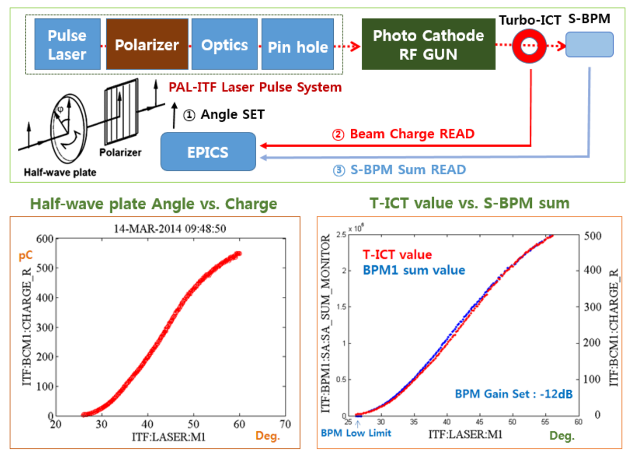


Figure 2: Generation of charge of the laser cathode gun and results of measurement of charge.

PAL-ITF -40-UHV-Turbo1-304-H 180MHz Cable 30M

BCM	Purpose	ICT Size	Turbo-ICT	BCM-RF	Charge [pC]
1	Laser Gun Charge	CF4.5"-ID34.9mm	#3088	#009	0.015766 x 10 $^{\text{BCM-RF[V]} / 0.817896}$

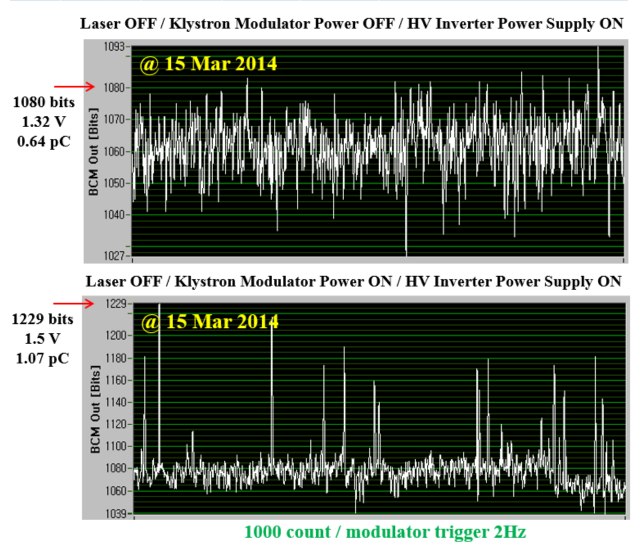


Figure 3: Effects of the klystron modulator noise observed from Turbo-ICT.

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IMPROVEMENT OF PAL-ITF

Existing components of the pulse-forming network (PFN) of the modulator and HV inverter power supply were improved in order to reduce noise from the klystron modulator. The modulator cabinet (panel) shielding was strengthened to prevent noise from inside of the modulator from being discharged to outside as much as possible [5]. As shown in Figure 4, the noise was reduced after improving the klystron modulator. In addition, it was possible to measure 0.1pC as shown in Figure 5.

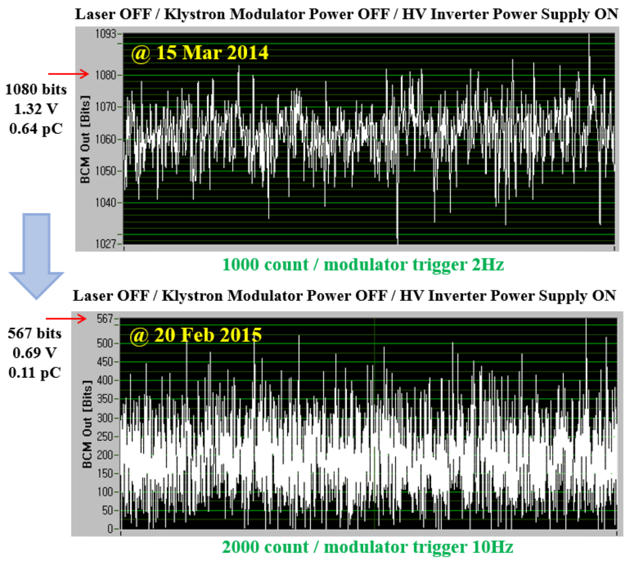

Figure 4: Data of Turbo-ICT measurement after improving the modulator.

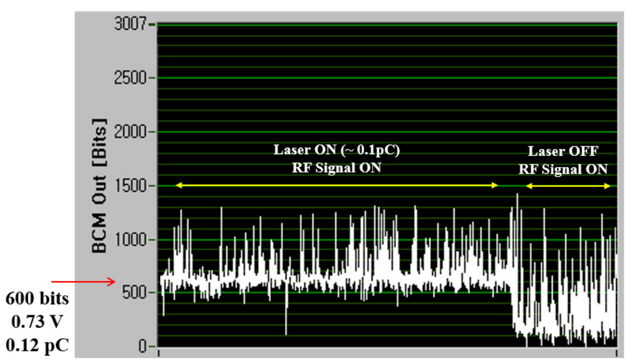

Figure 5: Measurement of 0.1pC of Turbo-ICT.

DARK CURRENT MONITOR

As shown in Figure 6, the noise signal greatly increases if RF power fed into the gun when the laser power is off. Presumably, it is not the noise generated from the modulator but dark currents generated from the laser cathode RF gun. As shown in Figure 8, a plan was prepared to install six 2856MHz Cavity-formed dark current monitors in PAL-XFEL in order to measure dark currents creation from accelerating tubes [6].

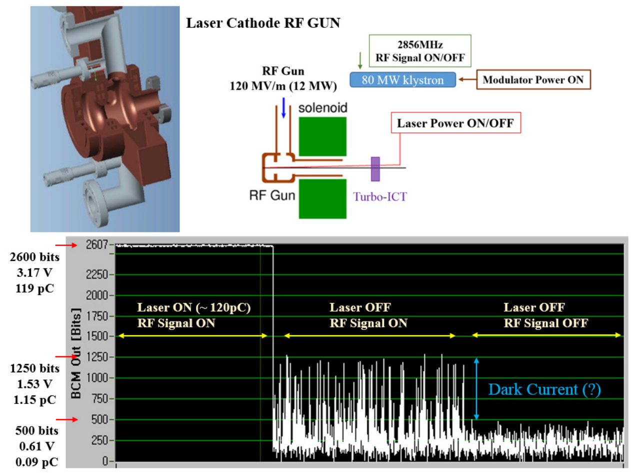

Figure 6: Presumably dark currents.

EMI/EMC

Klystron modulators, power supplies, motor actuator and vacuum pumps handling high voltage and high power are devices producing noise, but some products are designed and operated in violation of regulations regarding EMI (Electro-magnetic Interference) and EMC (Electro-magnetic Compatibility). In consequence, people taking charge of electronic devices related to low voltage should concern themselves with problem of noise. To reduce the effects of noise from the klystron modulator, grounding work of PAL-XFEL was conducted as shown in Figure 7, after dividing the ground into various types, including klystron modulator ground, mesh (220V) ground and data (signal) ground, in the stages of building, designing and ground work.

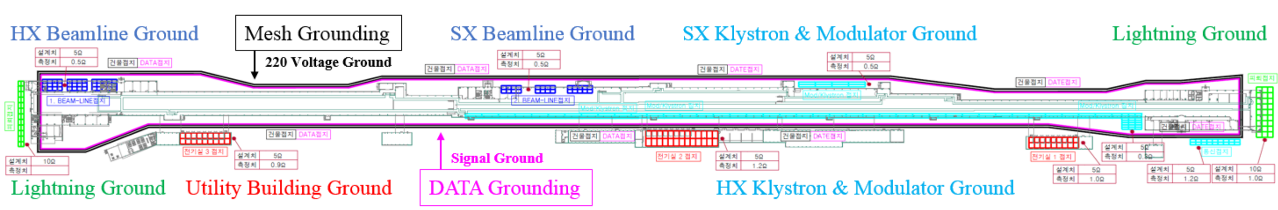

Figure 7: Drawing of locations where the grounding equipments of building grounds are laid and grounding resistance is performed.

Wiring of electric wires was done after installing cable trenches. Cable trenches were divided into those for high voltage, low voltage (220V) and signalling. There also were efforts to reduce EMI while designing the modulator system [7]. Regarding coaxial cables of Turbo-ICT, double-shielded GX03272-D06 cables (BCM-DSC) were chosen to reduce the effects of noise from the outside. Several ferrite cores were attached to both ends of Turbo-ICT cables to filter the noise. To solve the noise problem scientifically, there is a plan to continuously measure the

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strength, cycle and wave form of noise using a spectrum analyzer and FFT and record the results.

PLAN TO OPERATE TURBO-ICT OF PAL-XFEL

Figure 8 shows the installation location of Turbo-ICT of PAL-XFEL. After manufacturing Turbo-ICT, BCM-RF and signal cables a calibration is performed by Bergoz Instrumentation so that the absolute charge of Turbo-ICT can be measured [8]. Figure 9 shows the transfer functions determined by Bergoz Instrumentation after conducting calibration on Turbo-ICT and BCM-RF. Losses of electronic beam charge can be detected using the beam charge monitor (BCM) that can measure absolute charge and can be utilized for machine protection interlock (MPI) systems and personal safety interlock (PSI) systems using BCM measurements [3].

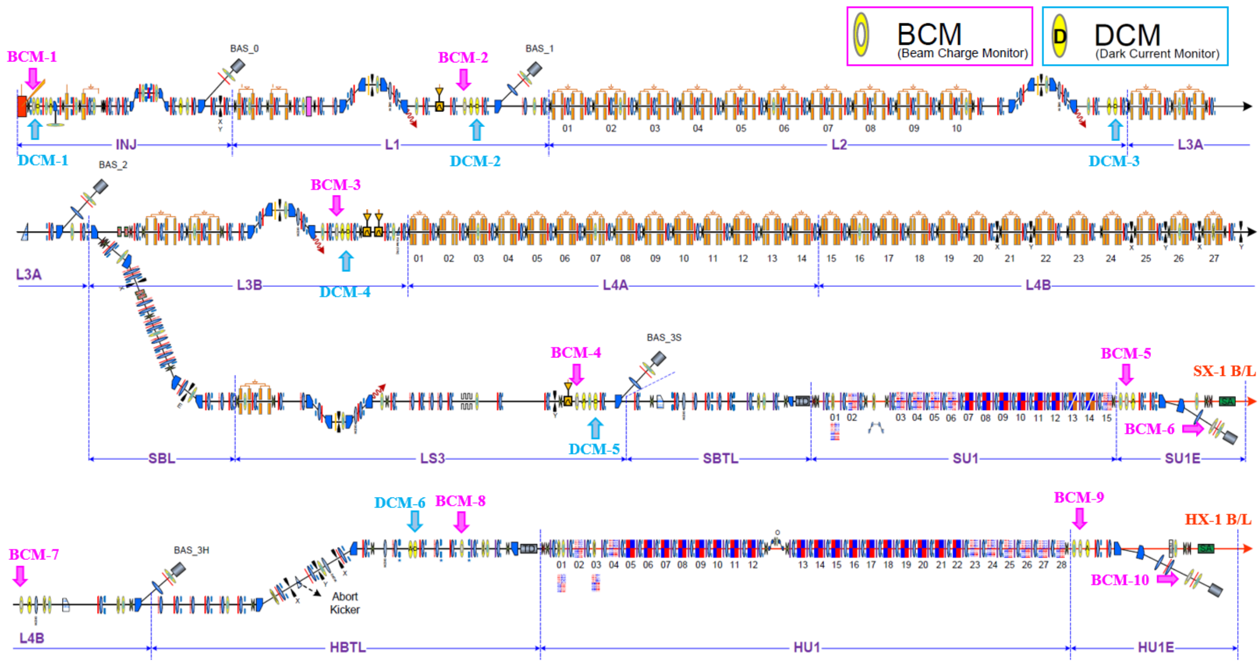

Figure 8: Installation position of Turbo-ICT & DCM.

PAL-XFEL -40-UHV-Turbo1-316LN-H 180MHz / Cable 30M

BCM	Purpose	ICT Size	Turbo-ICT	BCM-RF	Charge [pC]
1	Laser Gun	CF4.5”-ID38.0mm	#3256	#024	$0.01209 \times 10^{\text{BCM-RF[V]} / 0.85666}$
2	Pre-Injector	CF3”3/8-ID22.2mm	#3188	#014	$0.01970 \times 10^{\text{BCM-RF[V]} / 0.85405}$
3	L4 Input	CF3”3/8-ID22.2mm	#3189	#015	$0.01997 \times 10^{\text{BCM-RF[V]} / 0.85946}$
4	SX Input	CF3”3/8-ID22.2mm	#3190	#016	$0.01930 \times 10^{\text{BCM-RF[V]} / 0.85041}$
5	SX-1 Output	CF4.5”-ID34.9mm	#3257	#025	$0.01413 \times 10^{\text{BCM-RF[V]} / 0.86111}$
6	SX-1 Dump	CF8”-ID96.0mm	#3193	#019	$0.01786 \times 10^{\text{BCM-RF[V]} / 0.83559}$
7	L4 Output	CF3”3/8-ID22.2mm	#3191	#017	$0.02129 \times 10^{\text{BCM-RF[V]} / 0.83897}$
8	HX-1 Input	CF3”3/8-ID22.2mm	#3192	#018	$0.02115 \times 10^{\text{BCM-RF[V]} / 0.84280}$
9	HX-1 Output	CF4.5”-ID34.9mm	#3258	#026	$0.01871 \times 10^{\text{BCM-RF[V]} / 0.86590}$
10	HX-1 Dump	CF8”-ID96.0mm	#3194	#020	$0.01855 \times 10^{\text{BCM-RF[V]} / 0.85722}$

Figure 9: Transfer function of Turbo-ICT.

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