Recent Progress of LLRF System for SACLA

XFEL R&D Division RIKEN Spring-8 Center

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Outline of This Presentation

The X-ray intensity stability of SACLA accelerator are important items.

To realize the above, stability improvements are demanded to the LLRF system of SACLA.

Modifications of the SACLA to increase user experiment ability is also demanded. The modification items of SACLA are below.

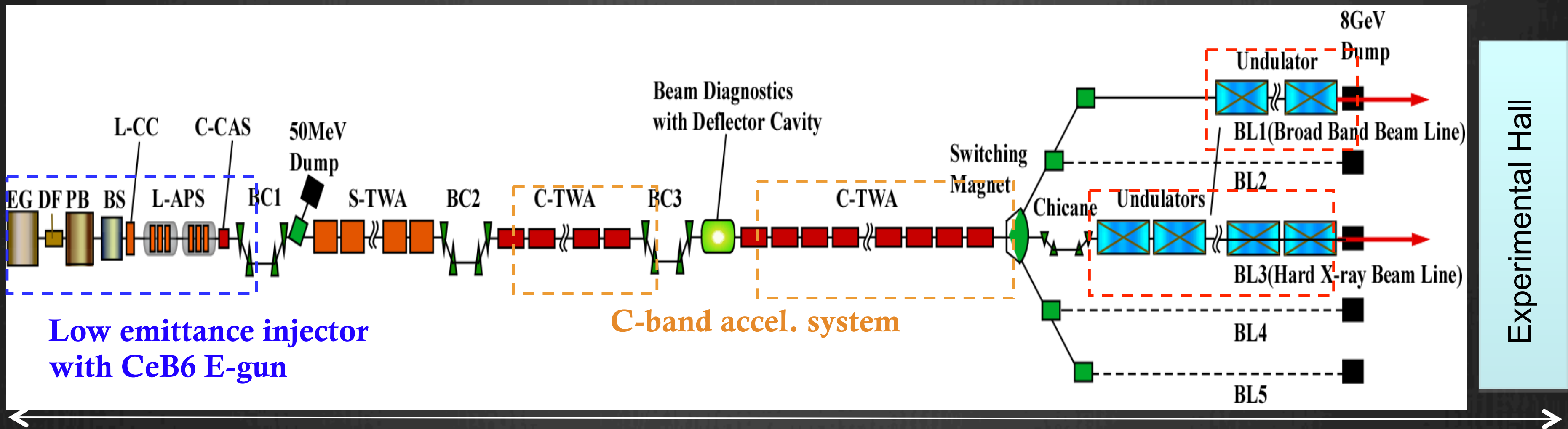
- New beamline , BL2.
- SCSS+ accelerator, as an electron driver for EUV, which is constructed by relocation of the present SCSS test accelerator into the SACLA building.

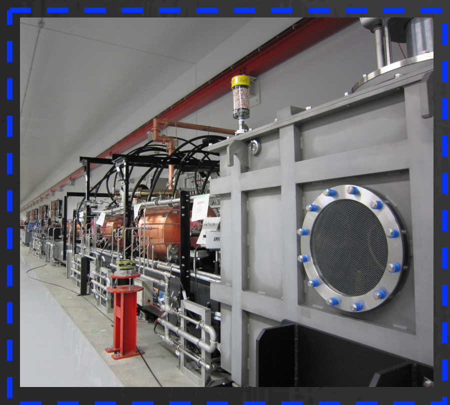
To adapt the new beamline and accelerator, the present LLRF system of the SCSS test accelerator should be modified and its stability should also be increased.

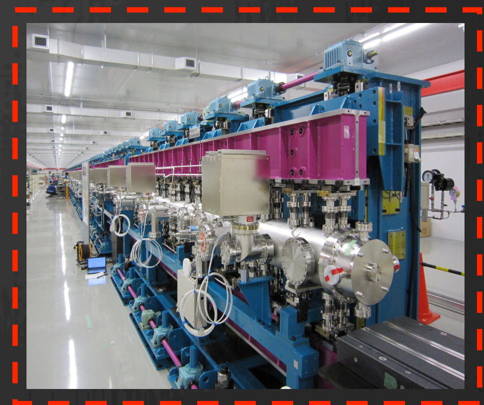
Present Machine Configuration

SCLA is basically comprises an low-emittance thermionic electron gun, C-band high-gradient accelerators and in-vacuum undulators .

In-vacuum undulators

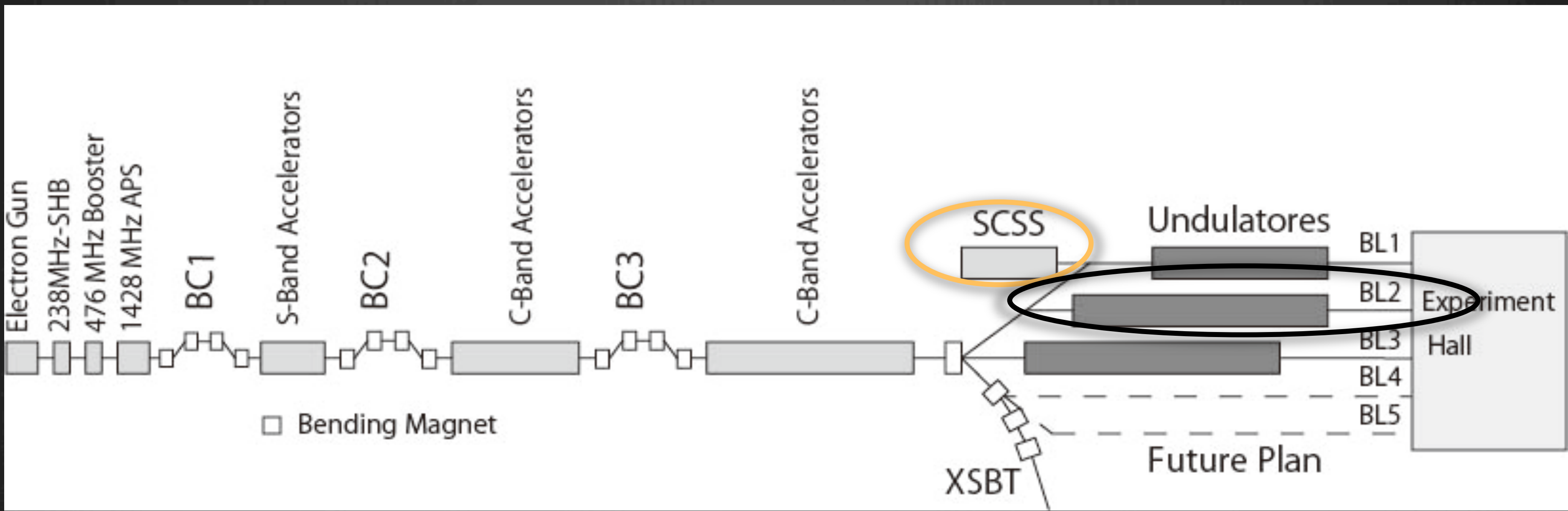






Modification Plan in SACLA

Add the modified SCSS test accelerator and the new beamline of BL2



These machines are now under construction. The commissioning of these machine will be started after next summer.

Specifications of SCSS & Modified SCSS

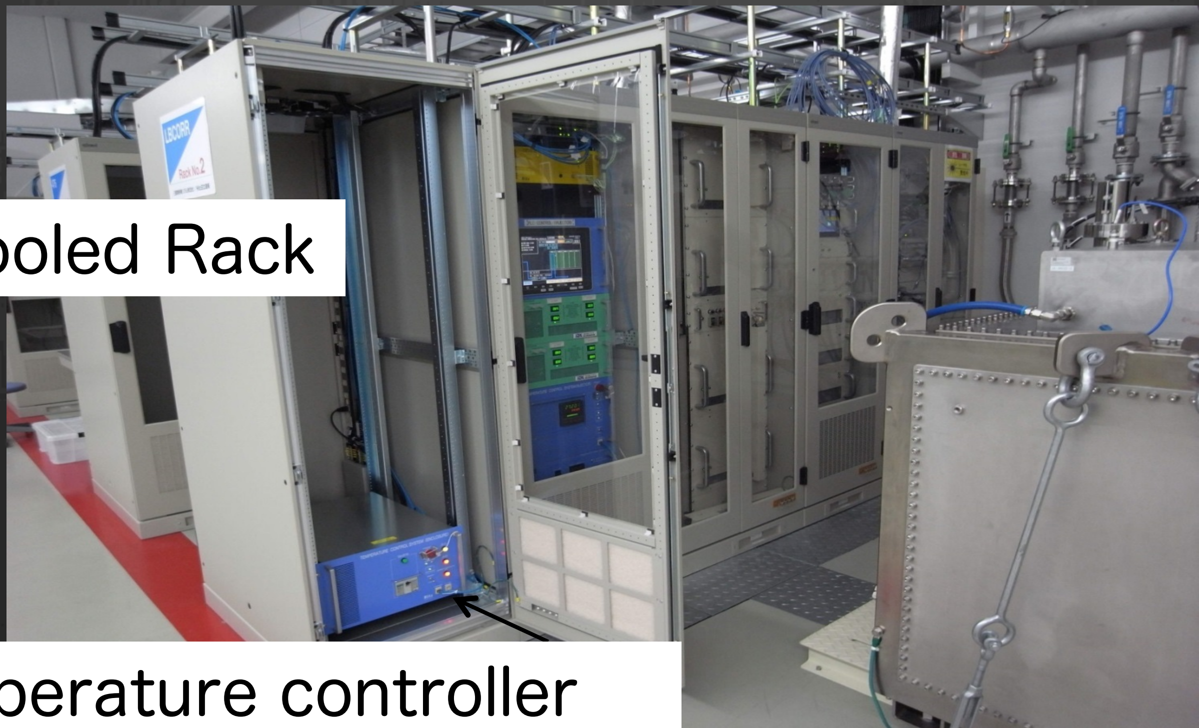
	SCSS	SCSS+
Operation period	2005 ~ 2013	2015 ~
Accelerator		
Beam energy	250 MeV	420 MeV
Bunch charge	~0.3 nC	~0.3 nC
Peak current	~300 A	~500 A
Repetition	60 pps (max.)	60 pps (max.)
Undulator		
Periodic length	15 mm	18 mm
K parameter	1.5 (max.)	2.1 (max.)
Photon Beamline		
Wavelength	50-60 nm	30-40 nm
Pulse energy	10-30 μJ/pulse	100 μJ/pulse

Specification of BL2

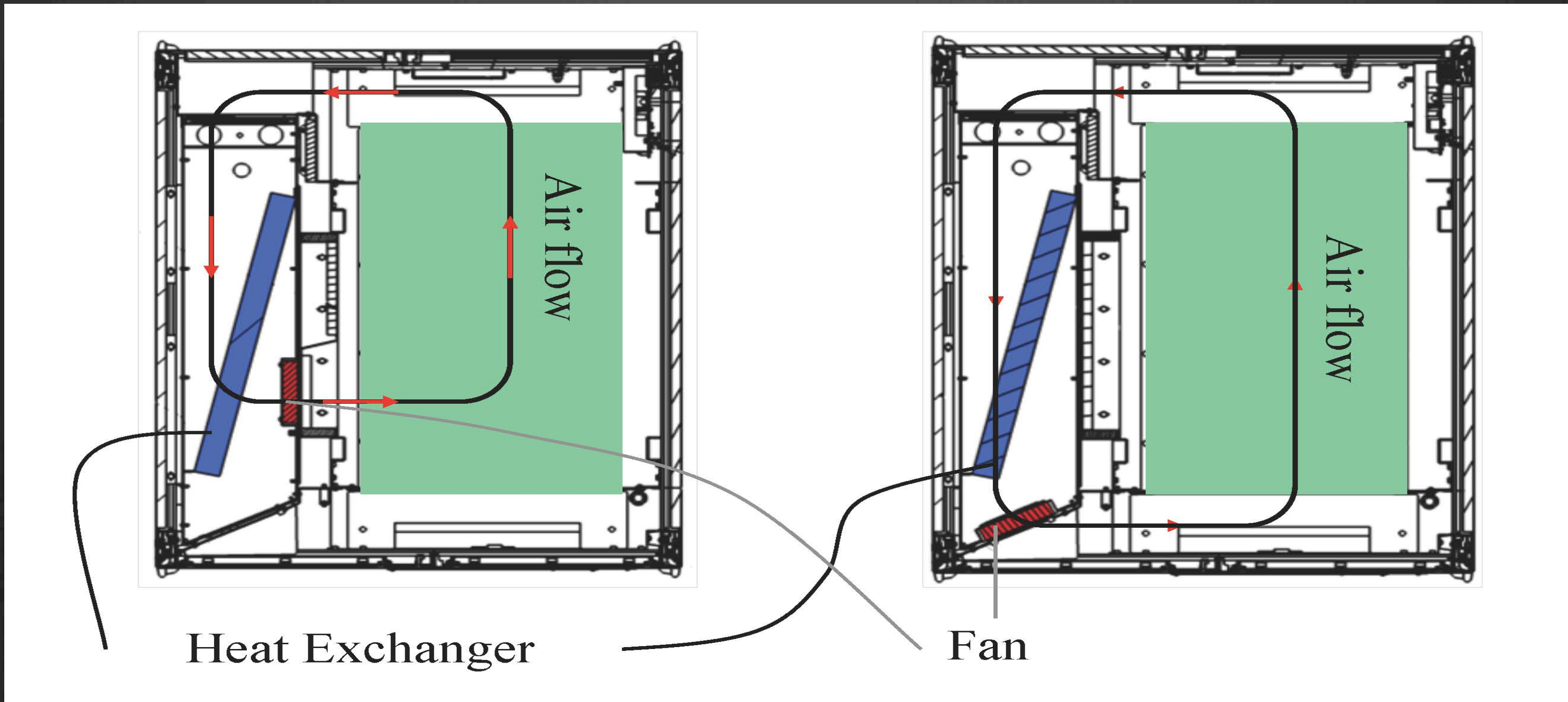
Number of undulators	15 ~18
Undulator length	5 m
Number of periode (undulator)	277
Minimum magnetic gap (undulator)	< 3.5 mm
Maximum K vale (undulator)	< 2.2
Effective length of the beam line	~ 70 m
Output wave length	~ 0.1 nm
Electron beam energy	~ 8.5 GeV
Electron focusing	FODO
Use self seeding scheme	

Improvement of Temperature Stability of Water cooled 19" Enclosure for LLRF

- To mitigate the RF characteristic drifts of LLRF circuits by temperature drift, we applied a highly precise temperature controller as same as that of an acceleration cavity to the LLRF.
- Temperature stability: form the present ±0.2 K → to ± 0.01 K

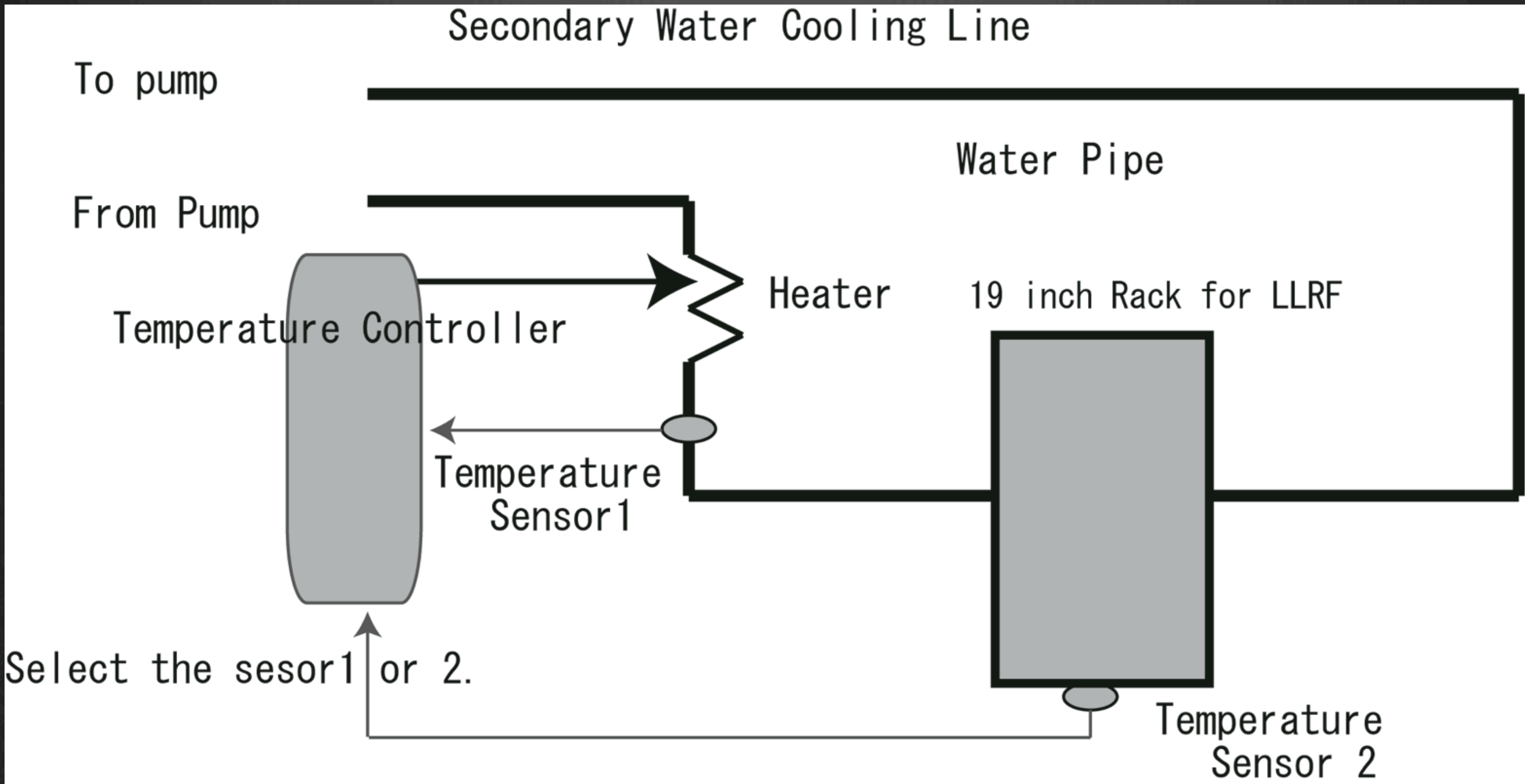


Air circulated & Water cooled 19” Rack for LLRF



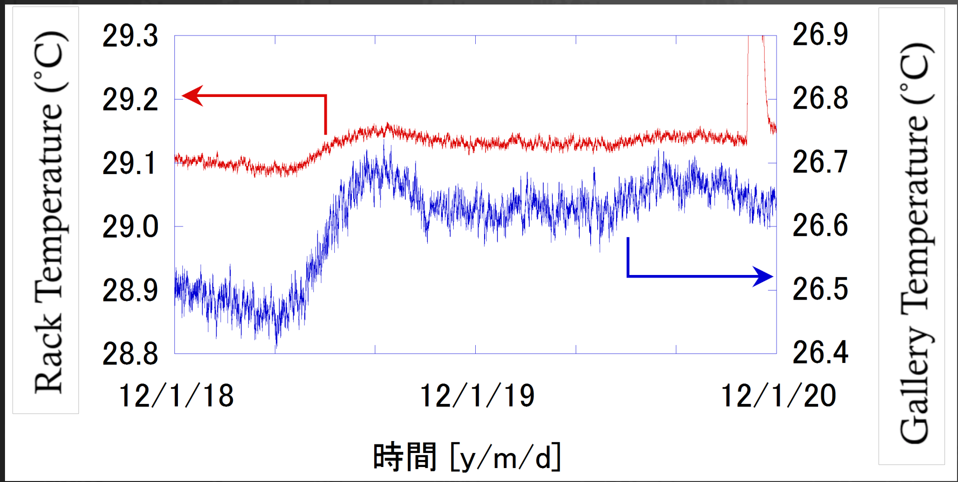
This enclosure uses the heat exchanger between air and cooling water, which is settled in the left side of the instrumentation rack (green part). The air cooled by the exchanger circulates around the instruments and the exchanger.

LLRF 19” Rack Temperature Control System



Temperature Stability of the LLRF Enclosure

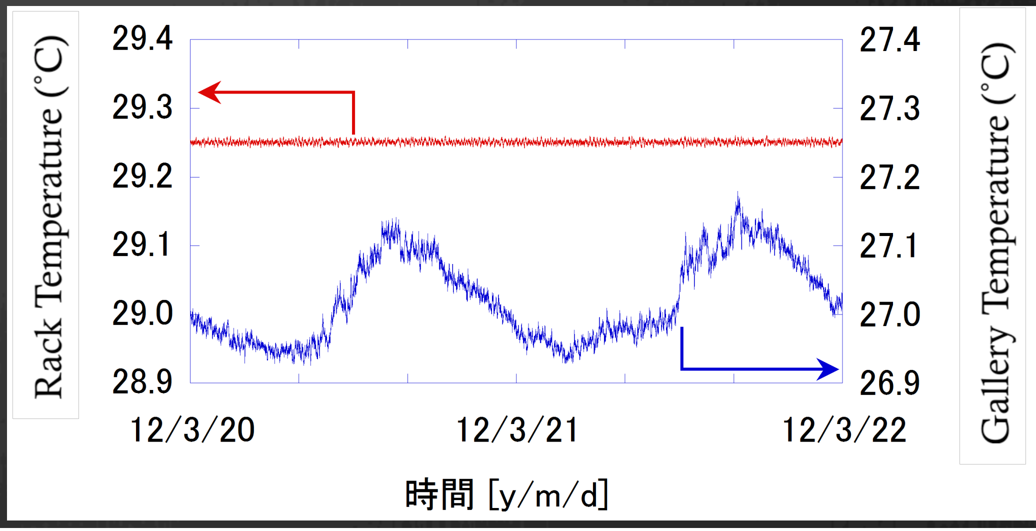
Before installing the precise temperature controller.



0.1 K pk-pk

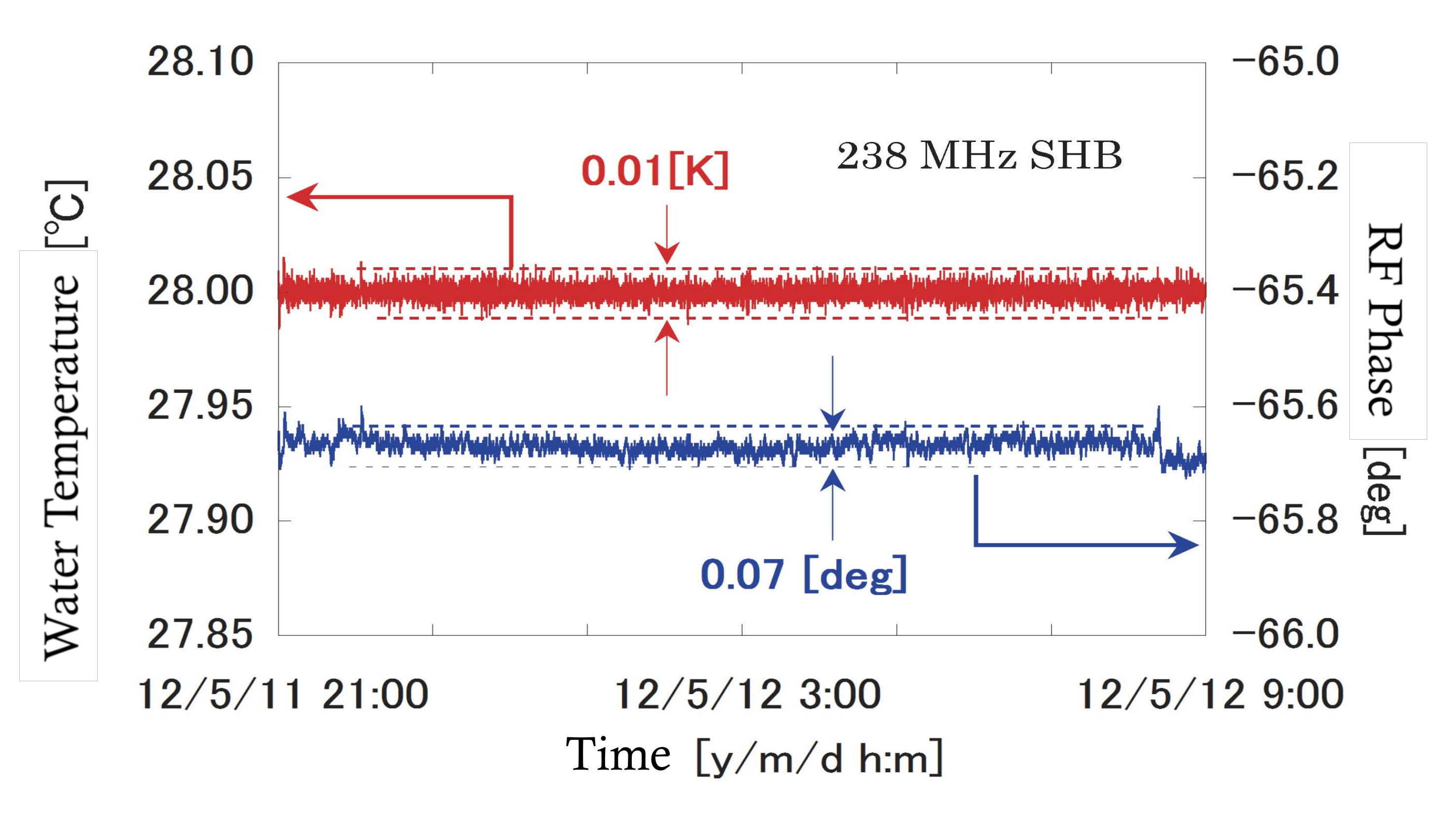
0.01 K pk-pk

After installing the precise temperature controller.



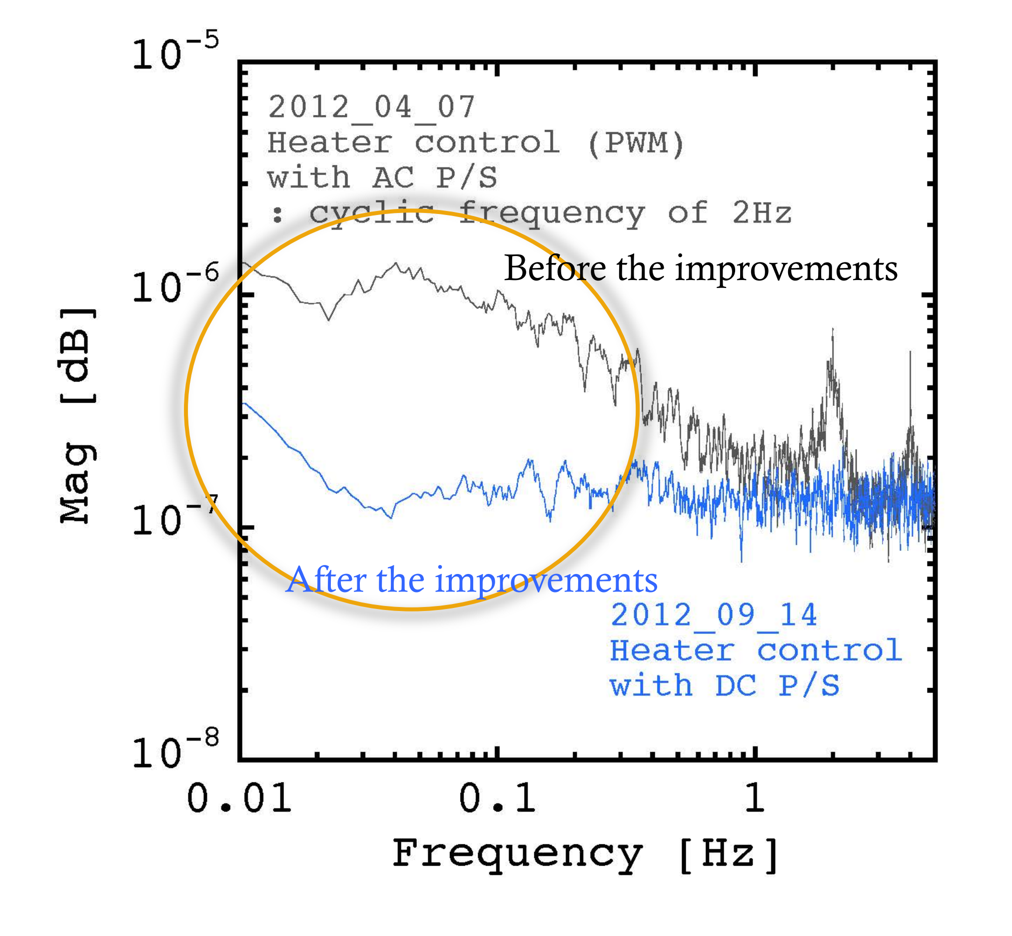
Improve the enclosure temperature stability to reduce up to one order.

Temperature & RF Phase Stabilities of the 238 MHz SHB cavity



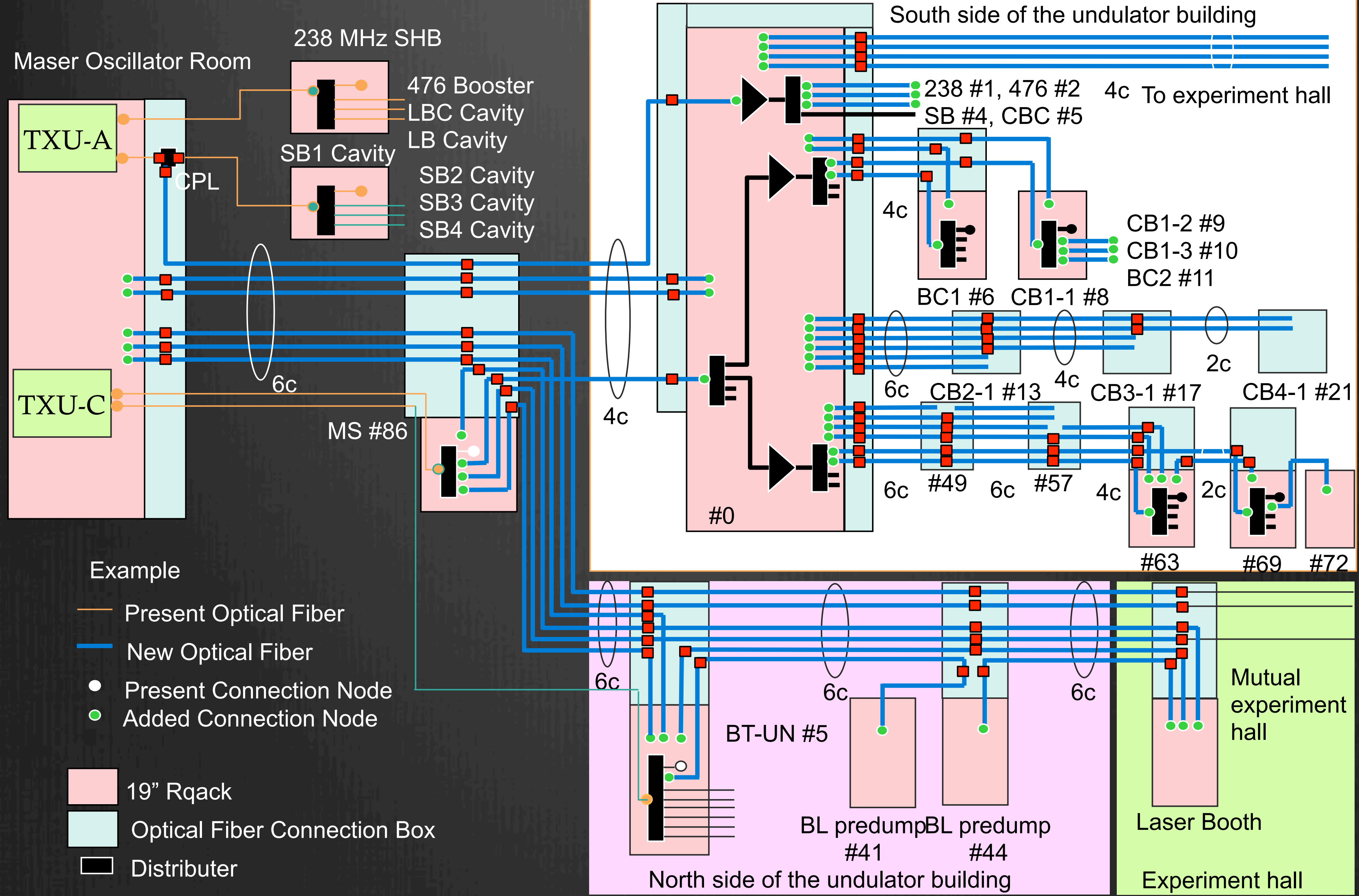
The temperature of the SHB is controlled within 10 mK, and its RF phase is also controlled within 0.07 deg. Some part of this phase performance is supported by the improvement of the temperature controller of the LLRF rack.

After the Temperature Stability Improvements of the LLRF System & Injector Cavities



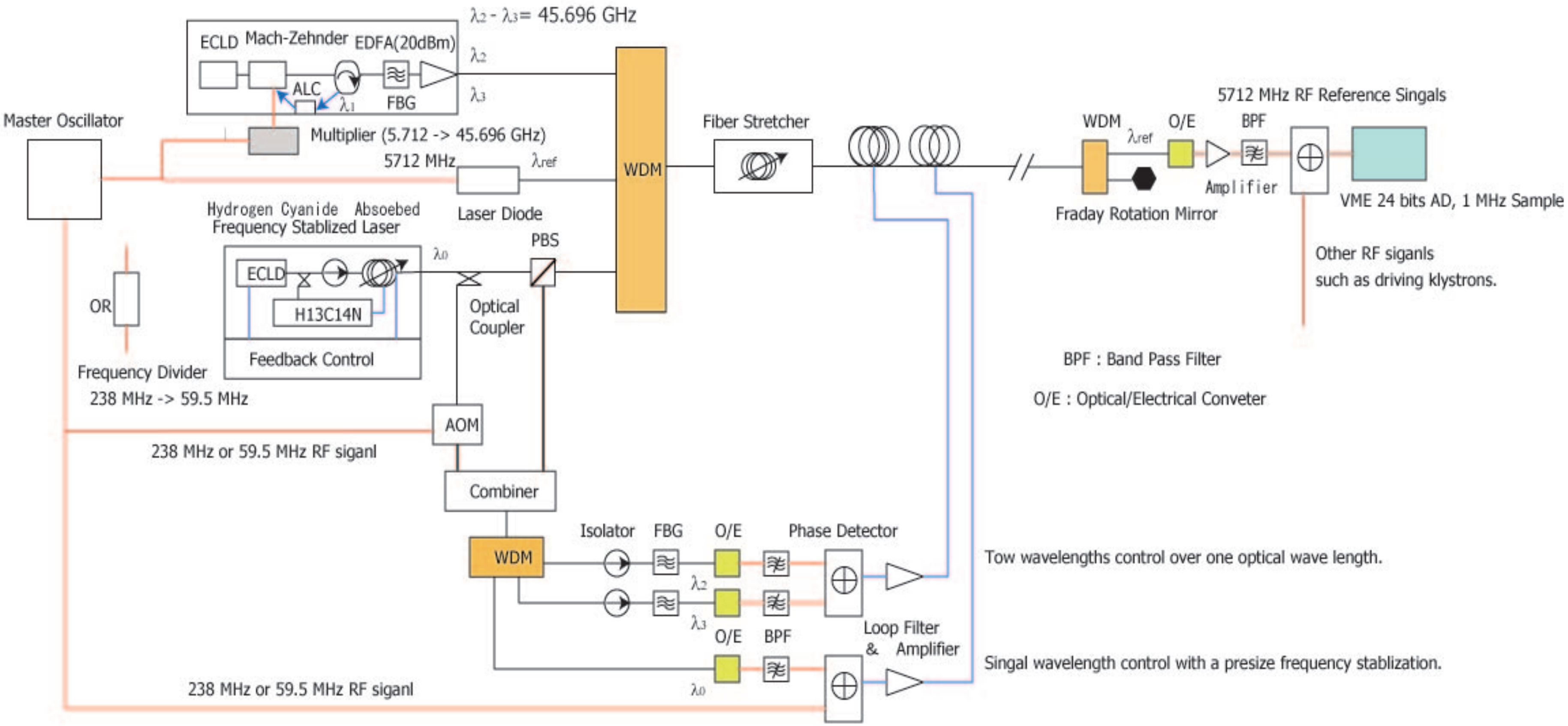
The position stability of X-ray lasers in the low-frequency components on the graph was improved, after the temperature stabilities of the injector acceleration cavities and the LLRF system rack were improved. Some part of this low-frequency component (drift) improvement is support by the temperature stability improvement of the LLRF rack

Installation of Further Optical Fiber Timing Reference System for SACLA



Block Diagram of Fiber Length Controller

Two fiber length feedback control loops using the Michelson interferometry are installed. One for fine control, and the other is for coarse control over one optical wave length.



The fine control loop refers to a λ_0 (1548.96 nms) optical wave length, and the coarse control uses the 90 GHz frequency difference component between two wave lengths of λ_2 (1552.15 nm) and λ_3 (1552.89 nm).

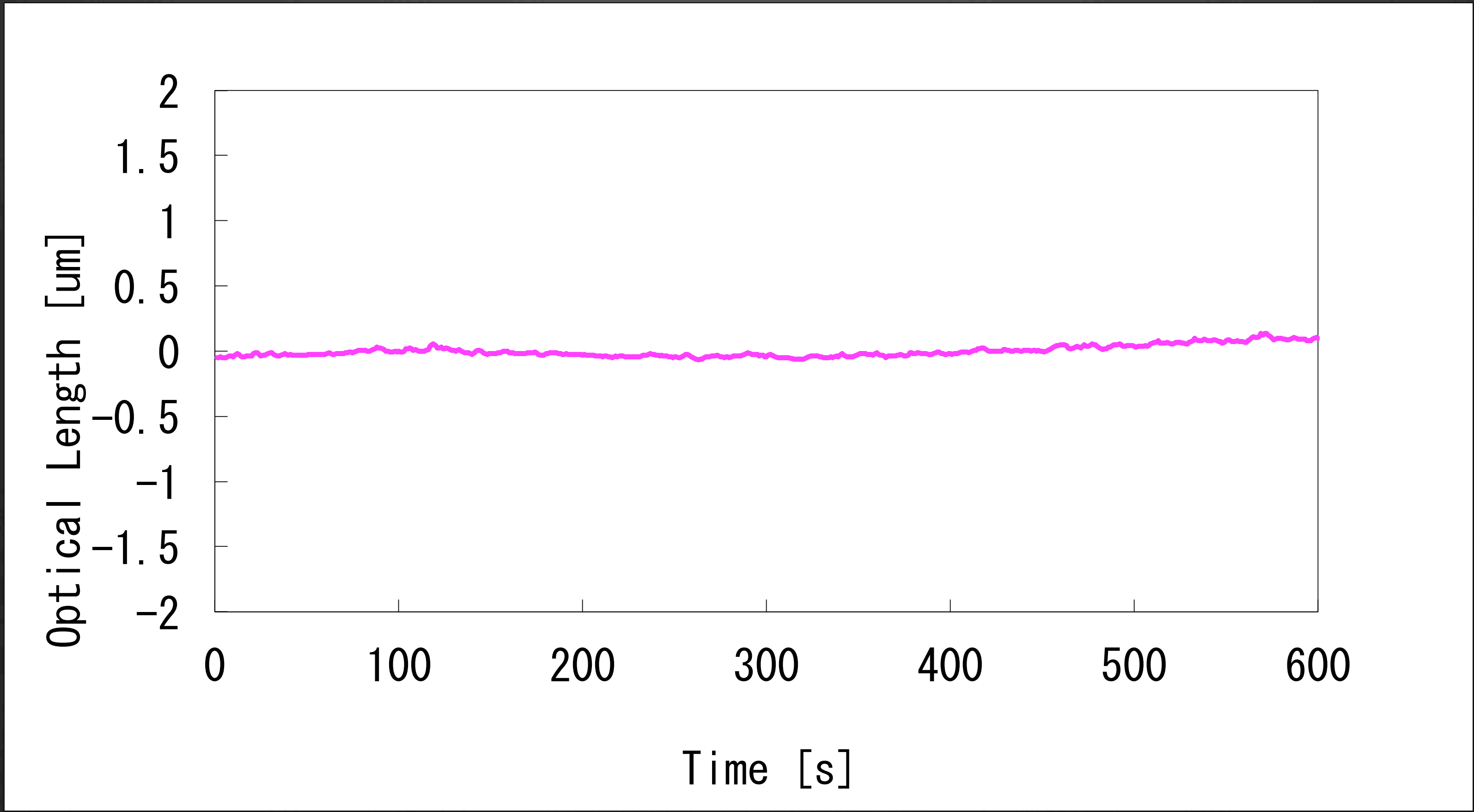
Optical Fiber Length Control Items

We will install 12 optical fiber length control lines in total.

- 4 lines : 238 MHz SHB, 476 MHz Booster, L-band (1428 MHz) correction cavity, L-band APS and C-band correction cavity in the injector.
- 1 line : S-band acceleration structures before BC 2.
- 4 lines : C-band acceleration structures before & after BC3.
- 2 line : Cavity BPMs (one for a beam arrival timing at the end of the accelerator).
- 1 line : Experimental station.

Fiber Length Control Performance using Light with λ_0

Case of the fine length control

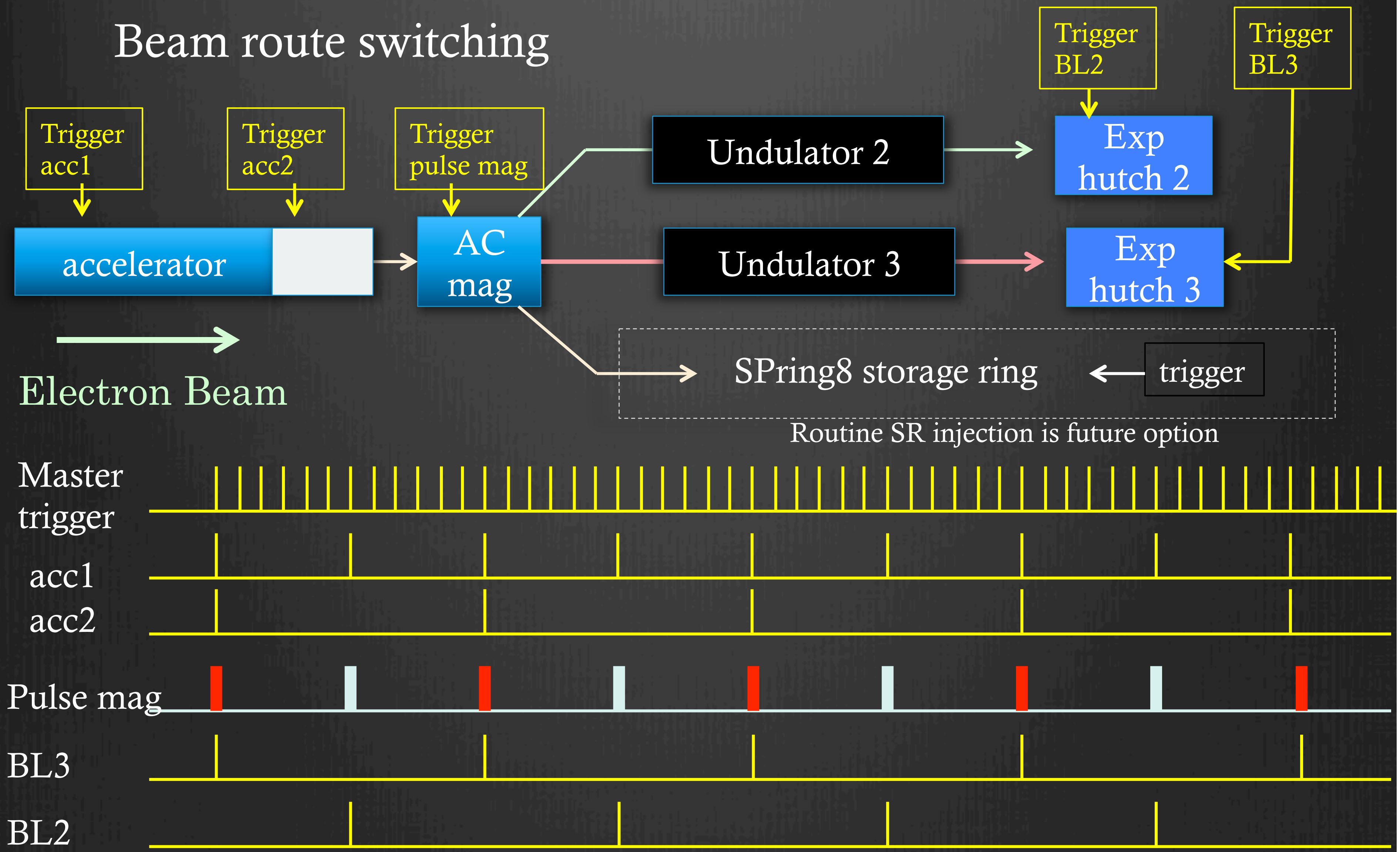


The total length of the Phase Stabilized Fiber is 1500 m.

Trigger Sequence for Multi-beamline of SACLA

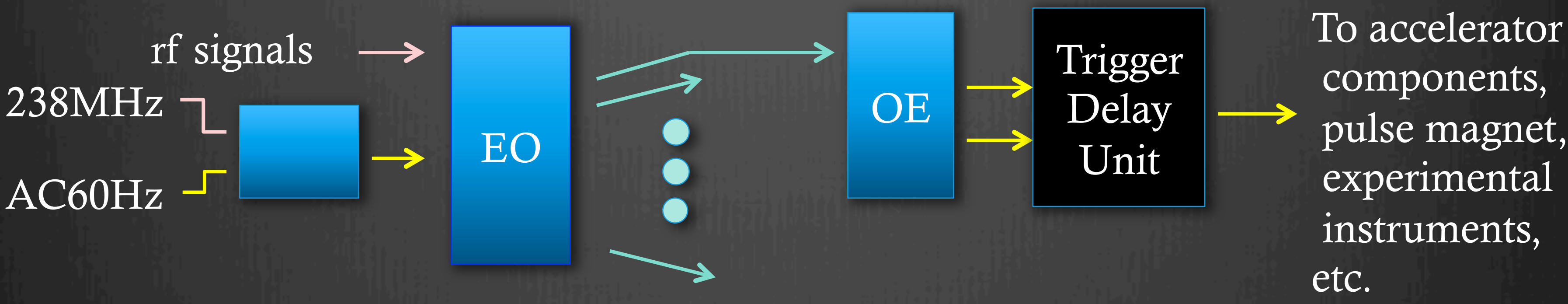
Different energy extractions in pulse by pulse.

Beam route switching

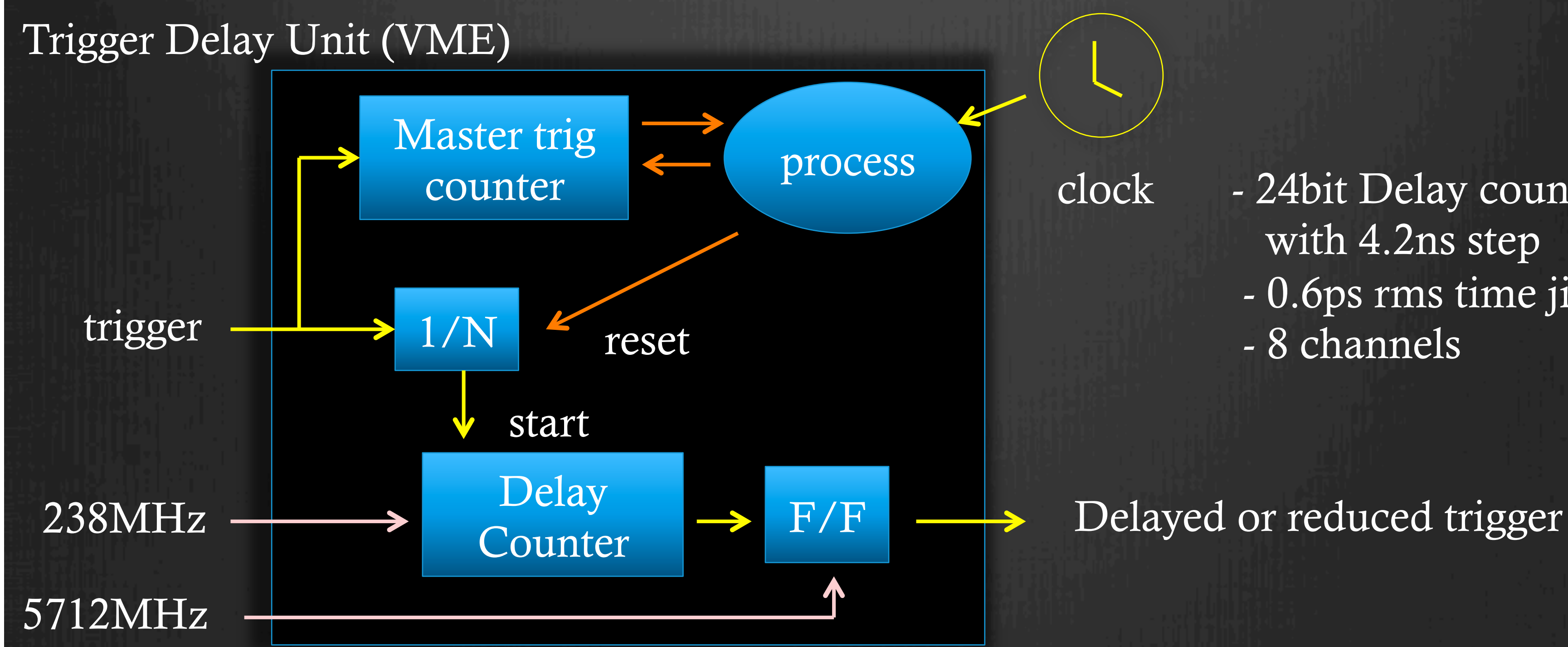


Triggering Process to Extract Electron Beam to Multi-beamlines

Trigger distribution



Trigger Delay Unit (VME)



- 24bit Delay count
  with 4.2ns step
- 0.6ps rms time jitter
- 8 channels

Summary

- The temperature stability of the LLRF 19” Rack was improved from +/- 0.1 K to +/- 0.01 K (p-p). This improvement helped to increase the intensity stability of the X-ray laser.
- To increase the X-ray intensity stability, the optical fiber length control system is constructing. This construction will be finished until the end of this fiscal year.
- The LLRF system for SACLA is modifying to adapt a new beamline, BL2, to emit a X-ray laser and SCSS+ to emit EUV laser.
- To handle electron beam extractions to multi-beamlines, the timing and RF transmission system for SACL is also modifying. This work will be finished by the year after next.