New development of X-band LLRF for PAL- XFEL Linearizer

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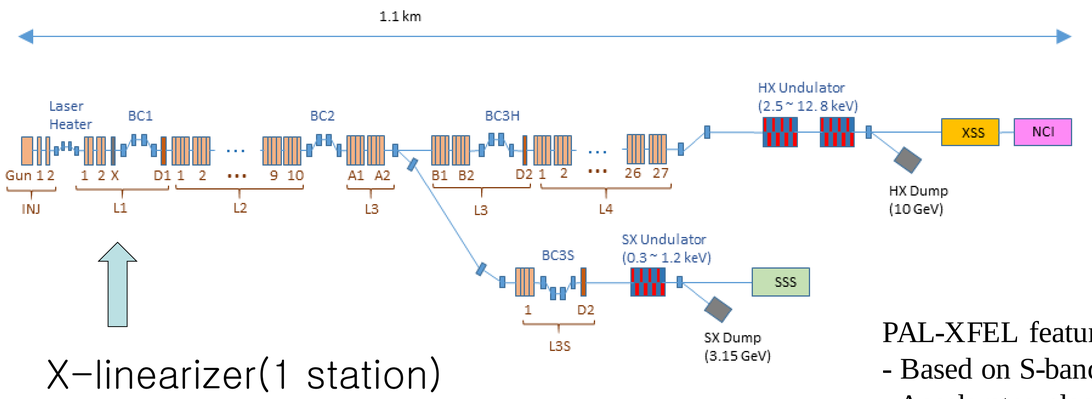
Abstract :

Current X-band LLRF for PAL-XFEL has been operated reliably for about 8 years. However, the RF jitter and drift values of the LLRF were relatively big. Therefore, new development of X-band LLRF was initiated a few years ago. Current X-band LLRF in operation had been designed in direct- or single-conversion method between X and IF bands. The new X-band LLRF was designed to run in dual or two step conversion among X, S and IF bands to minimize development efforts by redeveloping only converter between X and S bands and by reusing S-band LLRF. The new LLRF showed about 2 times better values in jitter and drift at lab test. The new LLRF is expected to be installed and verified in July 2023.

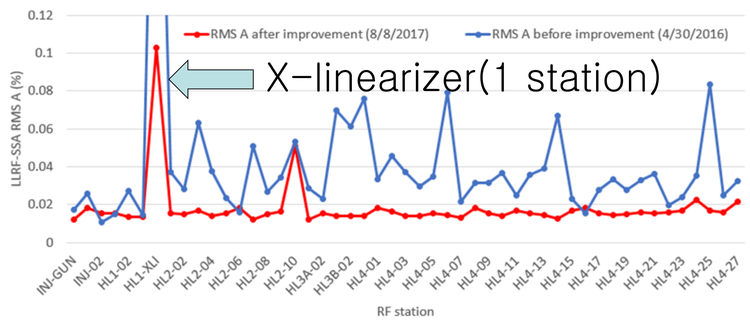
Motivation

PAL-XFEL layout



X-linearizer(1 station)

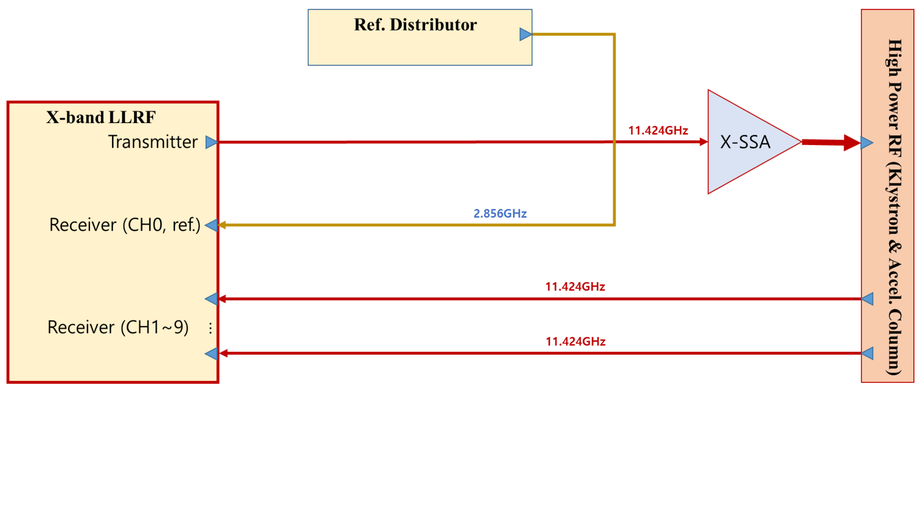
PAL-XFEL RF stabilities of amplitude(RMS)



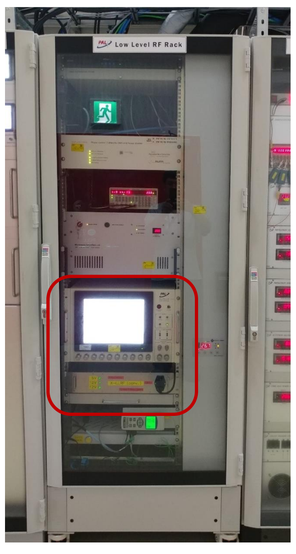
PAL-XFEL features :
- Based on S-band Normal-Conducting linac
- Accelerates electron bunches up to 10 GeV at up to 60Hz
- 2 Beamlines : One for hard X-ray, the other for soft X-ray

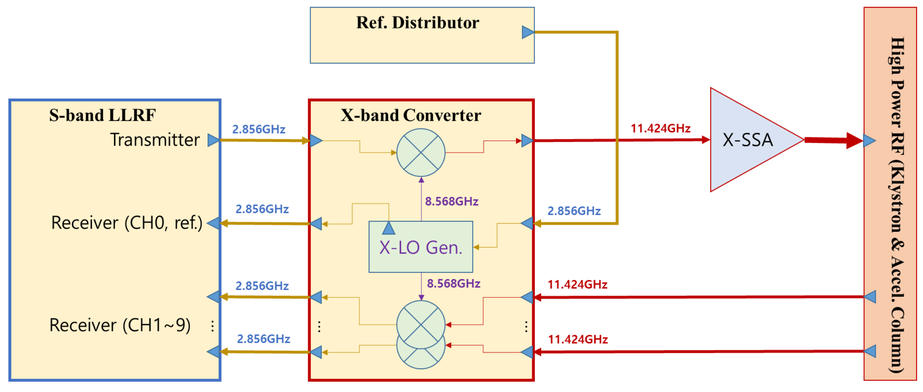
Original X-linearizer status :
- Relatively large RMS stabilities of RF amplitude and phase
- Relatively large drift of RF amplitude and phase
- Need to improve

Original X-band LLRF

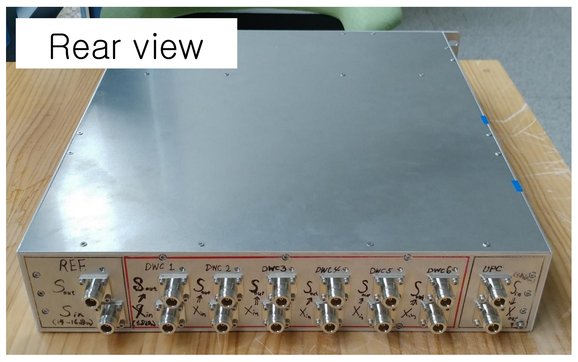


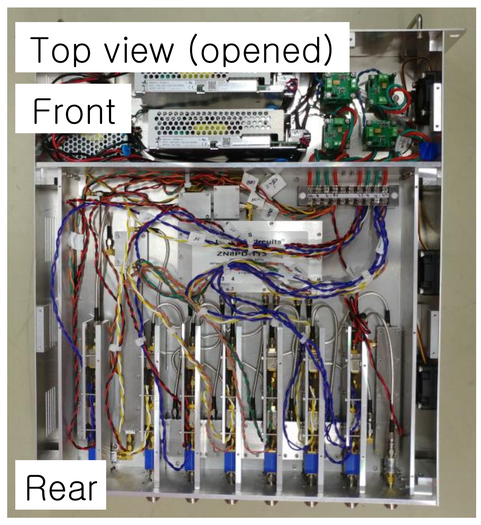
Newly developed X-band LLRF





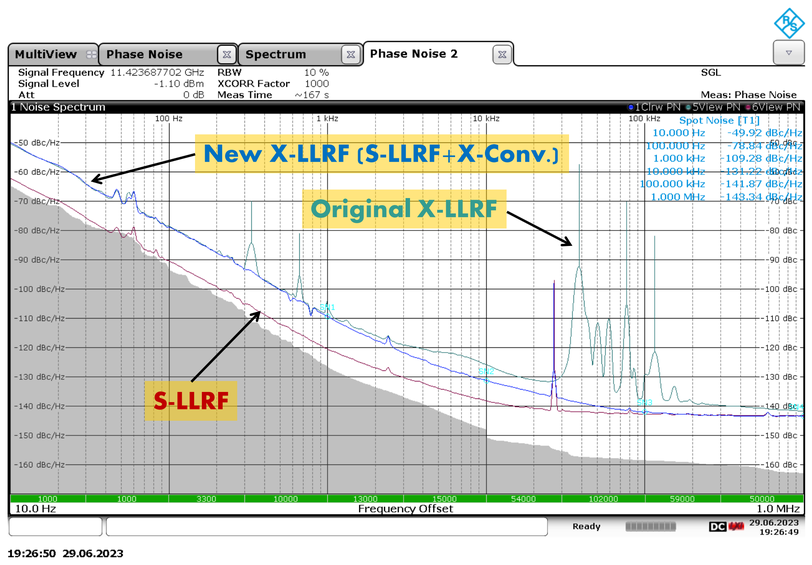
X-band converter





- X-band converter : X ↔ S
- 2U height & 19” rack installable
- In-house development

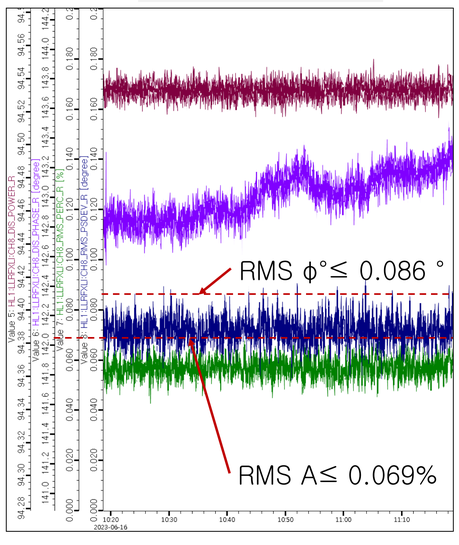
Phase Noise Characteristics of LLRF Transmitters:



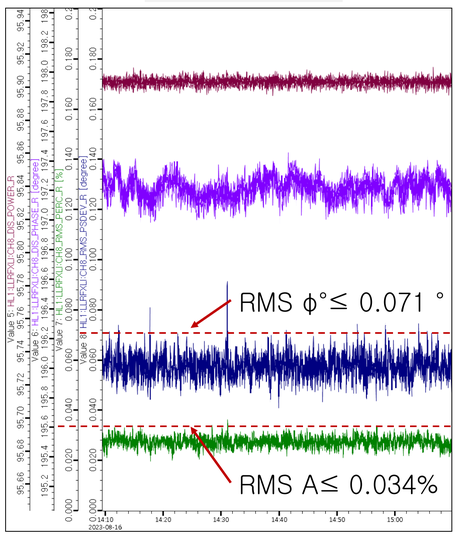
Performance (Jitter)

- After installation at PAL-XFEL X-linearizer
- Amplitude jitter(RMS) : 0.069% (original) → 0.034% (new) (2x improved)
- Phase jitter(RMS) : 0.086° (original) → 0.071° (new) (slightly improved)

Original X-LLRF

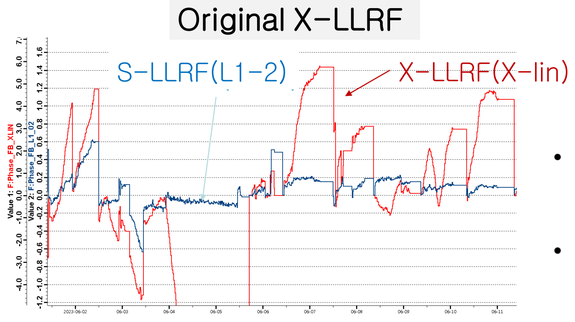


New X-LLRF



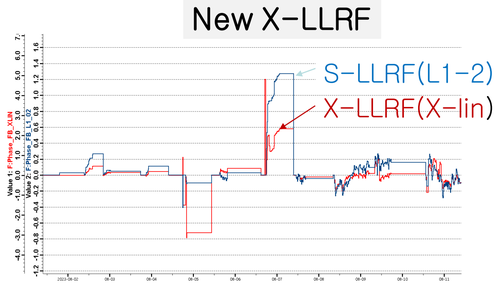
Performance (Drift)

Original X-LLRF



[Period: 2023/6/1~11]

New X-LLRF



[Period: 2023/8/1~11]

- After installation at PAL-XFEL X-linearizer
- LLRF drift estimation ≈ beam based(BB) feedback(FB) correction(phase)
- Rel. drift definition :

$$\frac{BB-FB\ correction\ of\ X-LLRF}{BB-FB\ correction\ of\ S-LLRF}$$

- Rel. drift :
  ~30 (original) →
  ~4 (new)
  (~7 times improved)

Conclusion

- Original X-band LLRF enhancements required to improve RMS stability and drift performance
- New X-band LLRF(i.e. S-band LLRF + X-band converter) has been developed efficiently
- The New X-band LLRF showed improvements in RMS stability (amplitude≈2x) and drift (~7x)
- The new X-band LLRF has been operating successfully for PAL-XFEL since Aug. 2023
- Further improvements in X-band LLRF are planned in the long term in two ways :
  - upgrade of original X-LLRF
  - more improvement of X-Converter