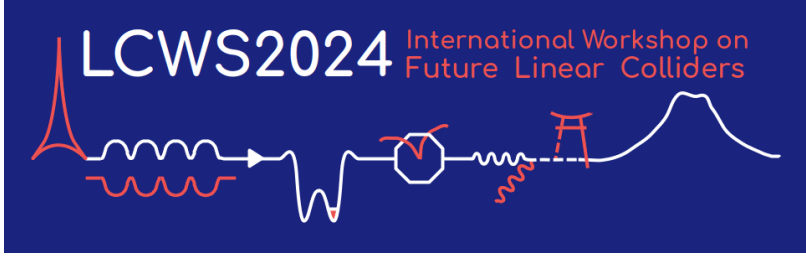

“KEK ATF Linac and Damping Ring klystrons High-Power RF field phase and amplitude stability study”

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ARYSHEV Alexander
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9th July 2024

1. Introduction into KEK ATF facility and research motivation;
2. Introduction into KEK ATF Linac and Damping Ring Low-Level RF system;
3. Developed signal processing and phase&amplitude detection algorithm;
4. Experimental results;
5. Summary and conclusion

KEK Accelerator Test Facility (ATF)

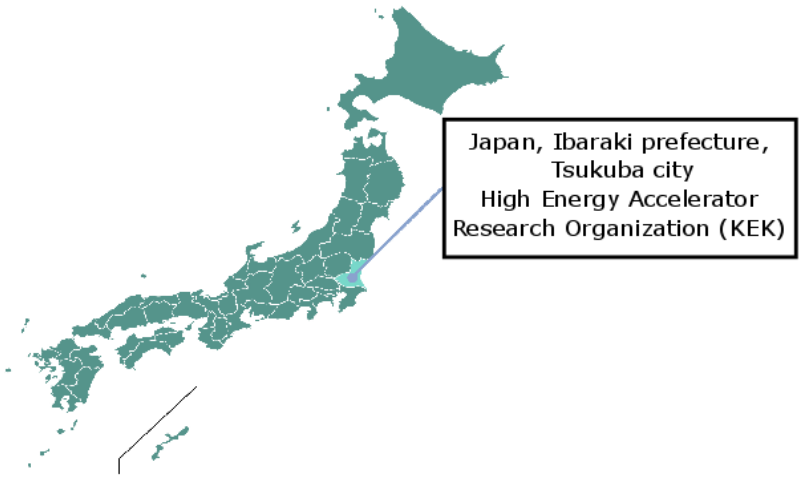


Figure 1: High Energy Accelerator Research Organization (KEK) location on the map of Japan

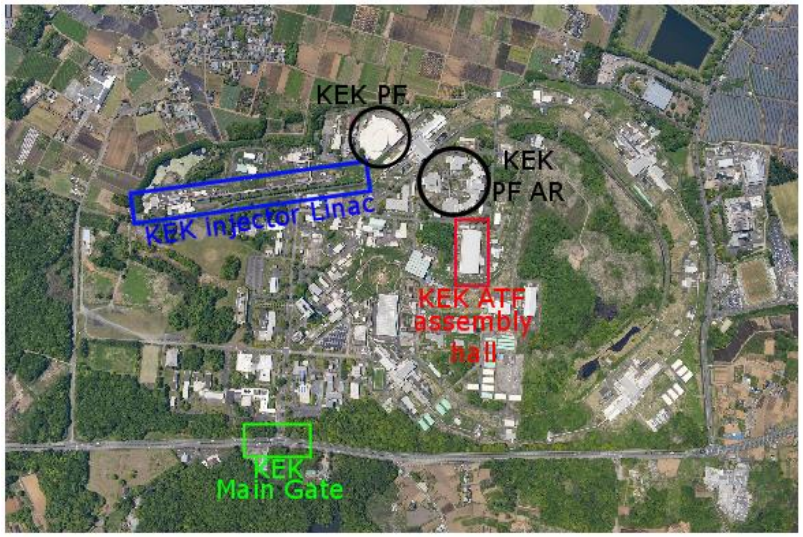


Figure 2: KEK ATF assembly hall location at the KEK Tsukuba campus

Figure 3: KEK ATF assembly hall building photo

KEK Accelerator Test Facility (ATF)

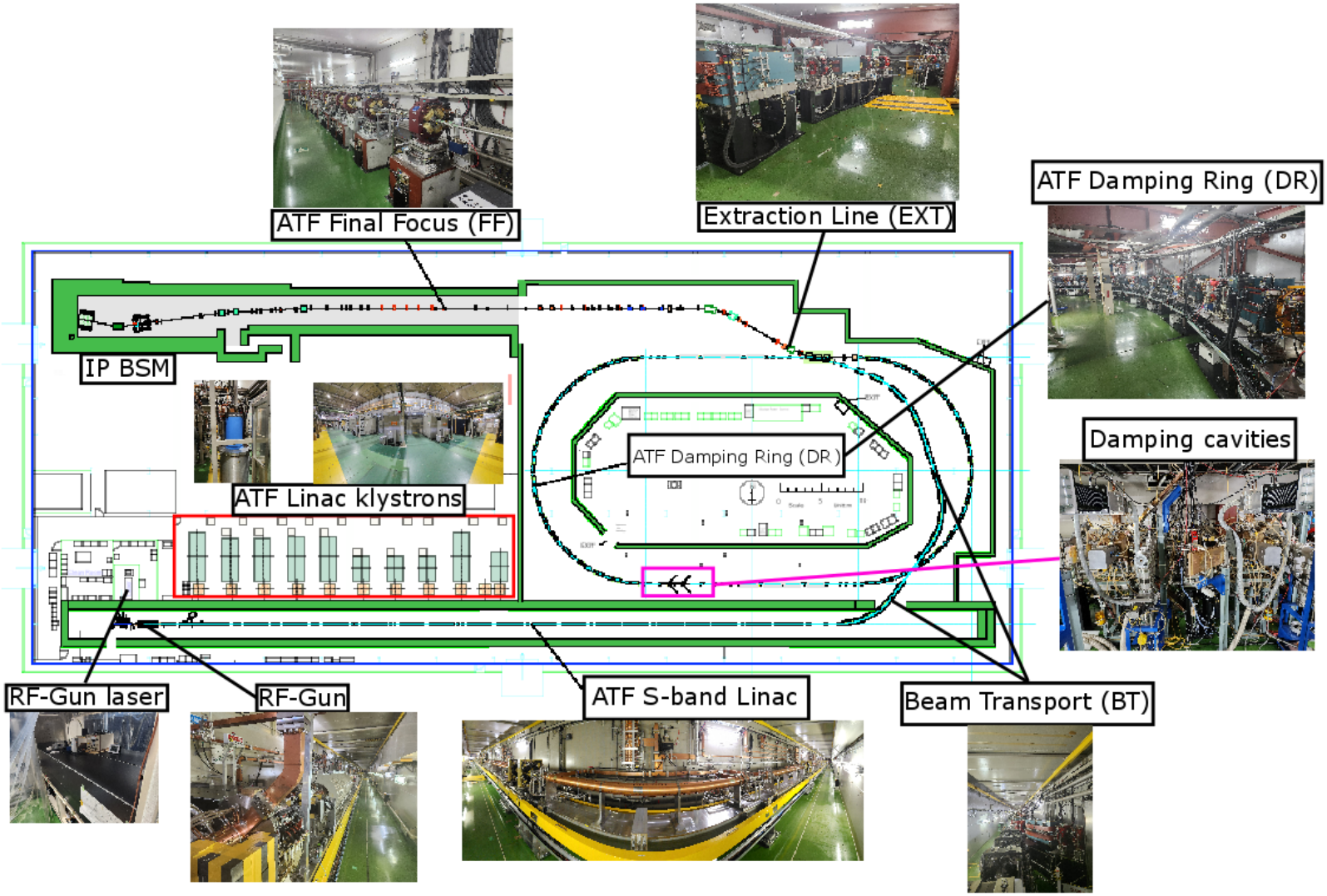


Figure 4: KEK ATF facility layout

<u>Motivation:</u> ATF Linac and DR klystron phase&amplitude drift can affect the beam injection, extraction and transmission stability. → <u>Goal:</u> investigate the ATF Linac and DR klystrons High-Power RF phase&amplitude stability.

KEK ATF Linac Low-Level RF system

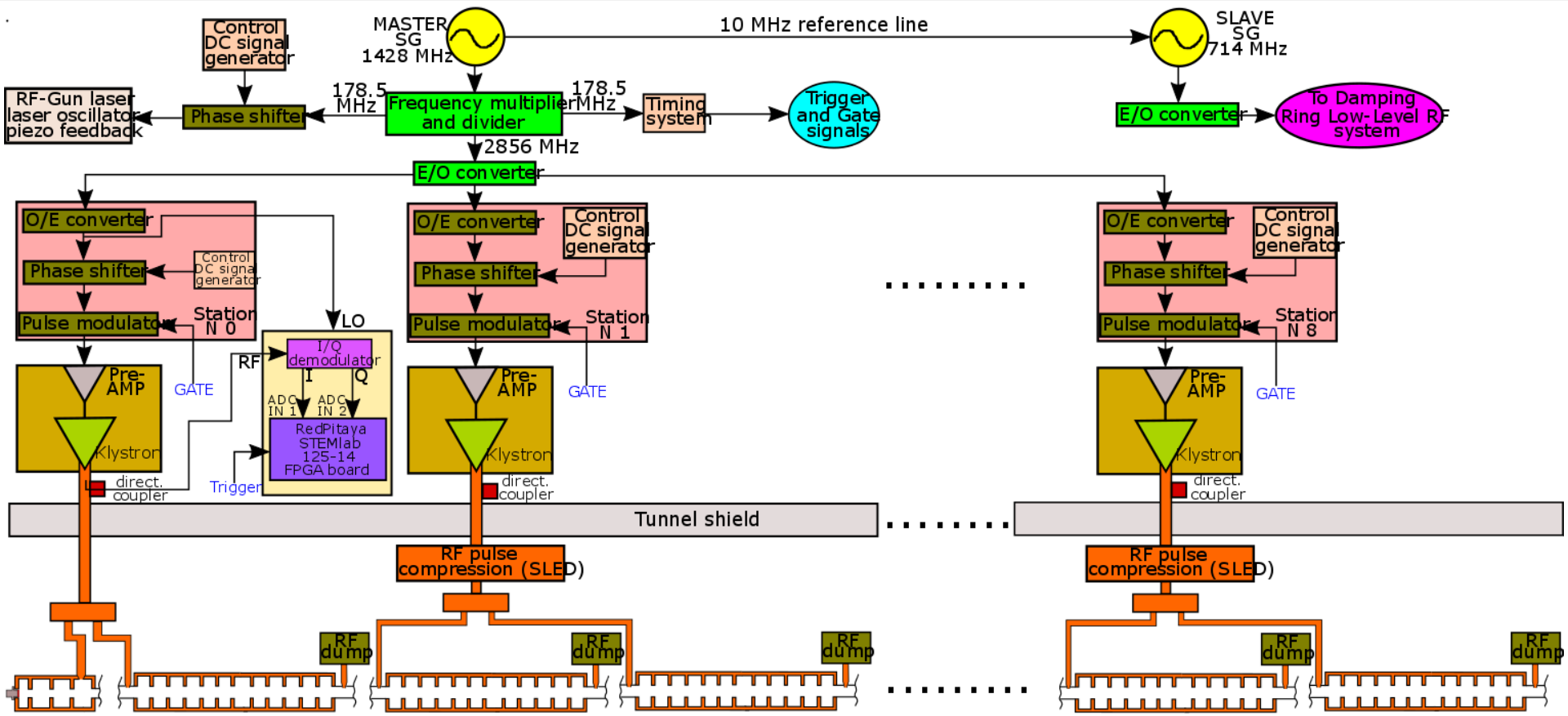


Figure 5: KEK ATF Linac Low-Level RF system simplified block-diagram with High-Power RF part

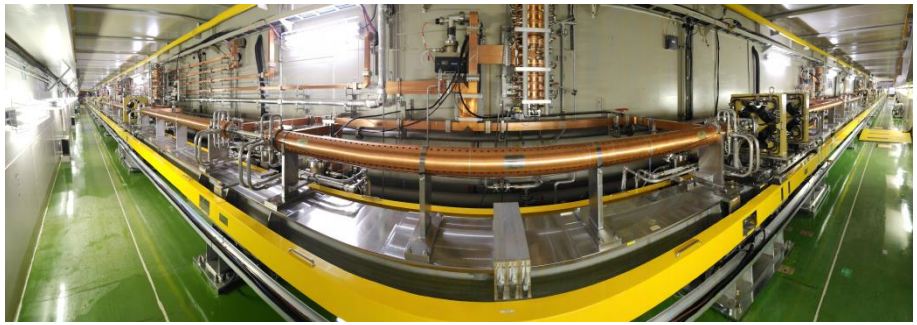


Figure 6: KEK ATF Linac photo

KEK ATF Damping Ring Low-Level RF system

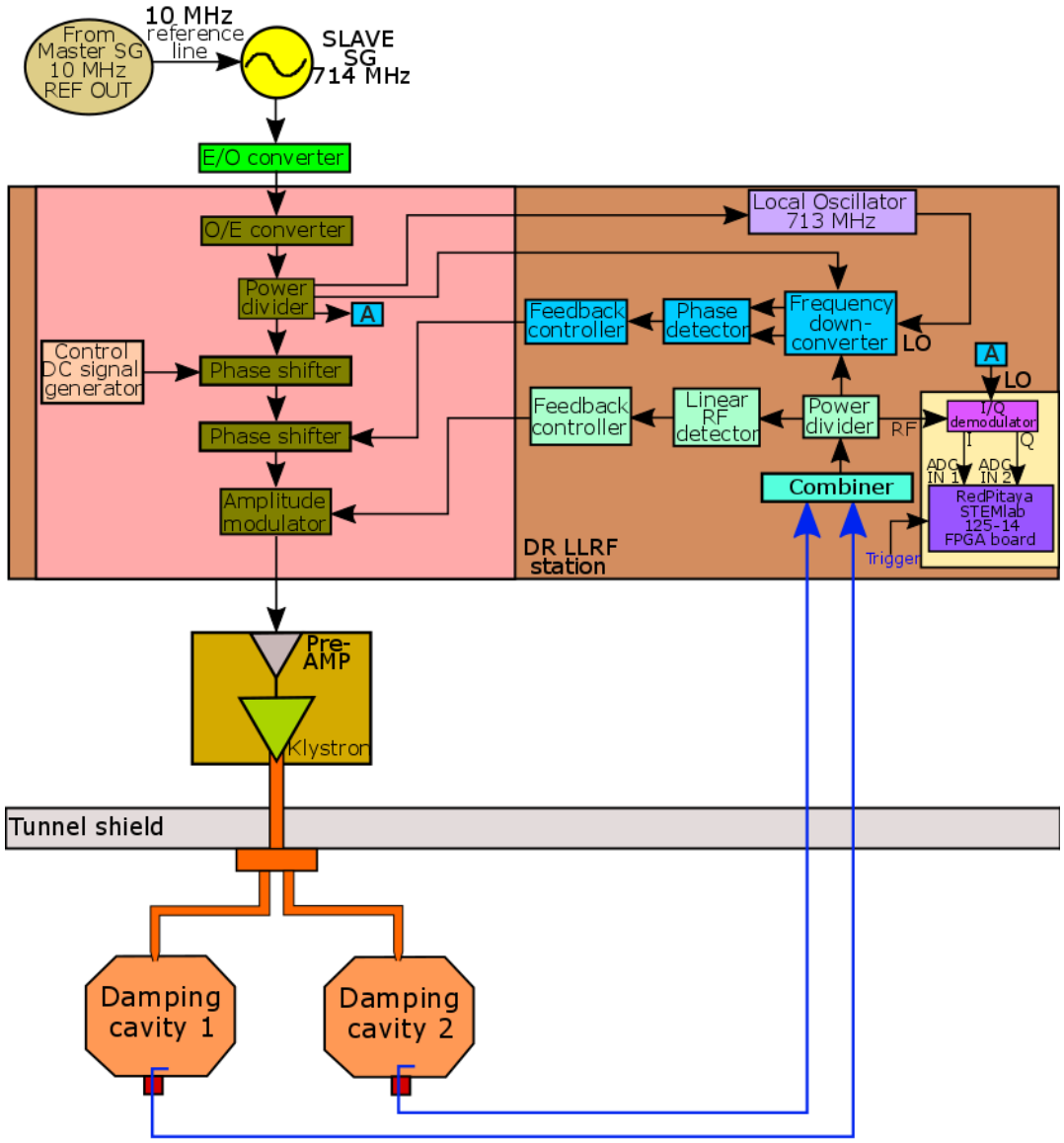


Figure 7: KEK ATF DR Low-Level RF system simplified block-diagram with High-Power RF part

ATF Linac klystrons High-Power RF phase shift effect on the beam position at the Beam Transport

Figure 8: KEK ATF Beam Transport (BT) beginning photo

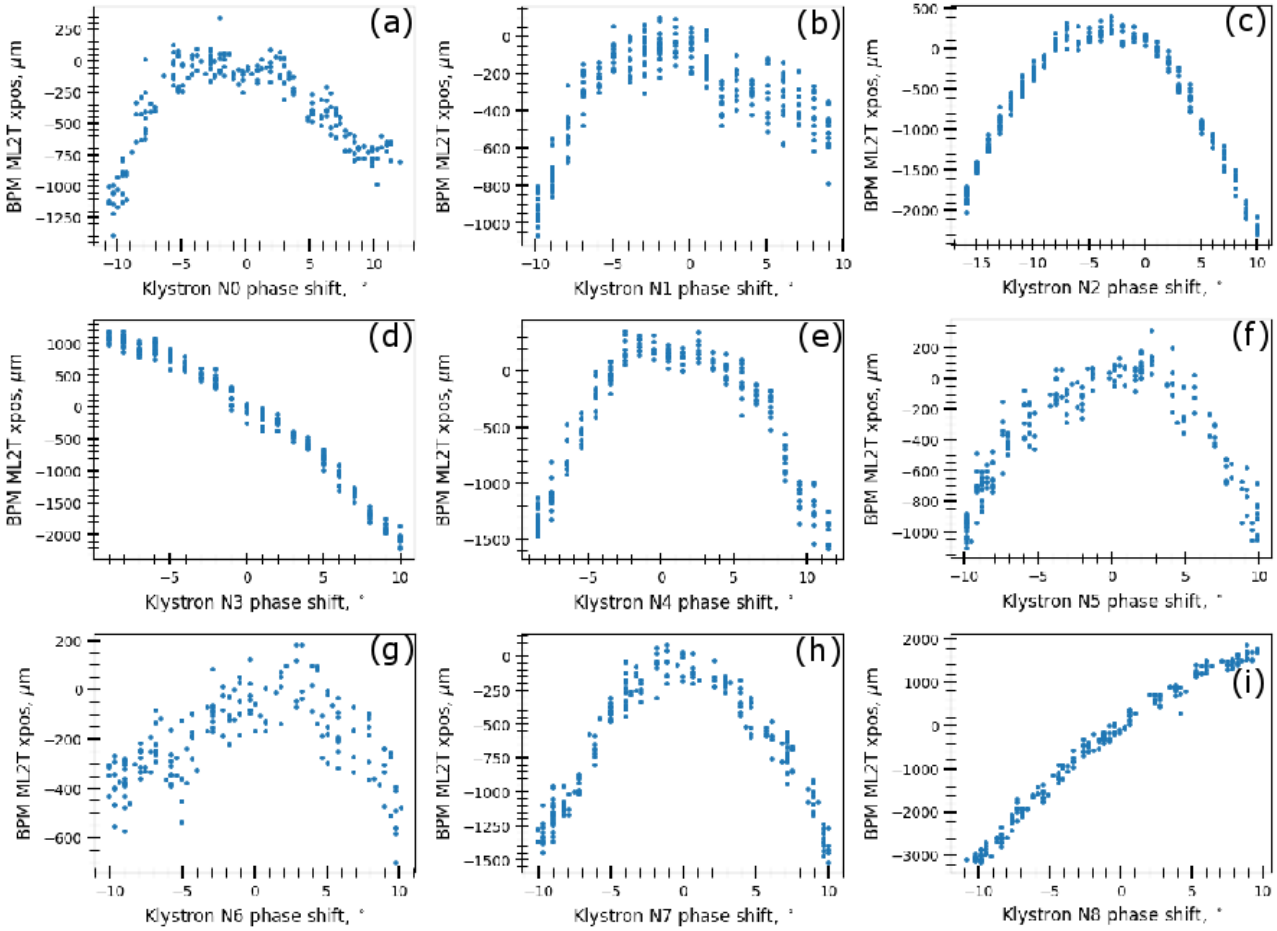


Figure 9: ATF Linac klystron High-Power RF phase shift vs beam position at the Beam Transport beginning: (a) is the kly N0 phase shift vs beam position, (b) is the kly N1 phase shift vs beam position, (c) is the kly N2 phase shift vs beam position, (d) is the kly N3 phase shift vs beam position, (e) is the kly N4 phase shift vs beam position, (f) is the kly N5 phase shift vs beam position, (g) is the kly N6 phase shift vs beam position, (h) is the kly N7 phase shift vs beam position, (i) is the kly N8 vs beam position

KEK ATF Linac Low-Level RF system

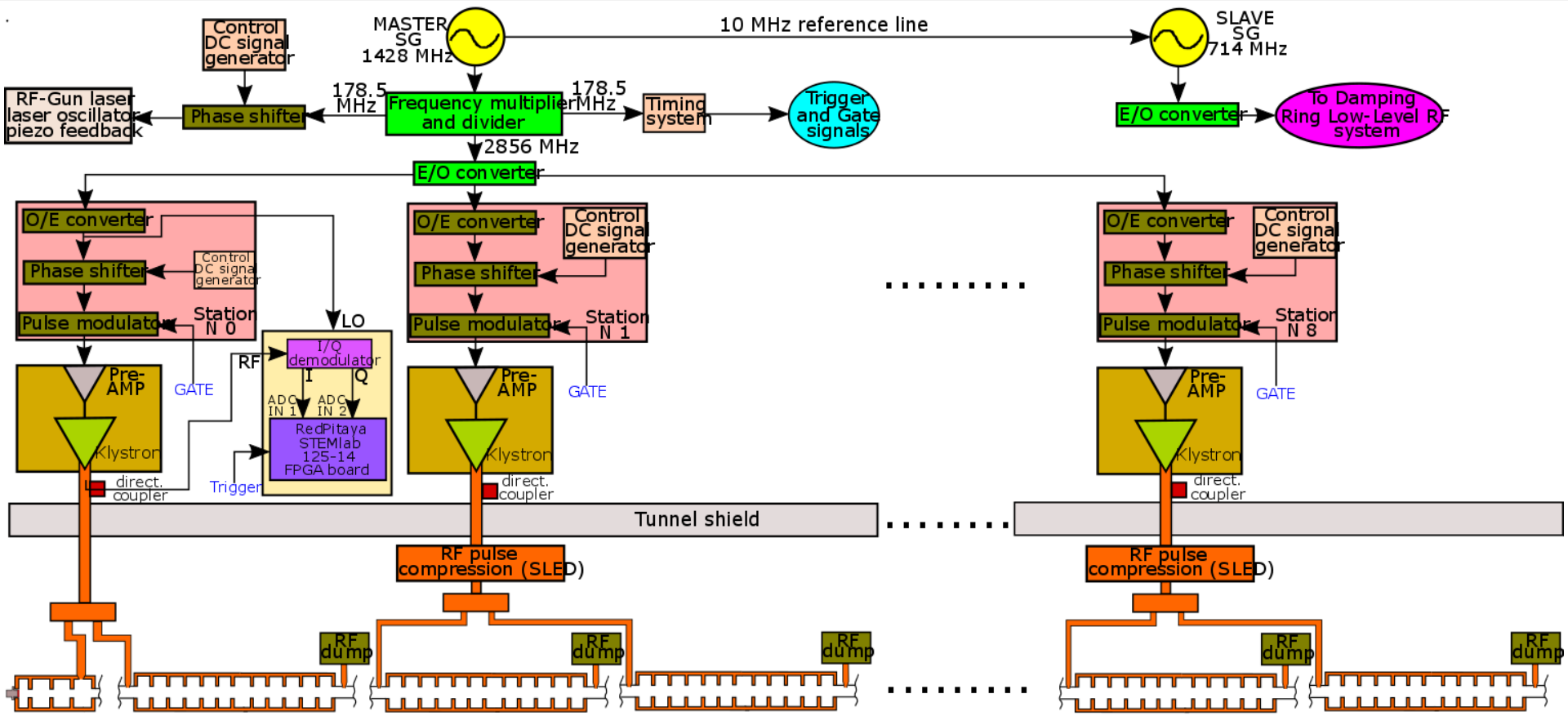


Figure 10: KEK ATF Linac Low-Level RF system simplified block-diagram with High-Power RF part

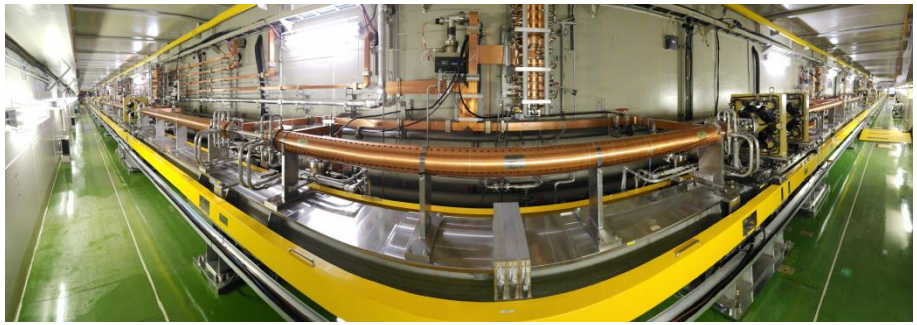


Figure 11: KEK ATF Linac photo

Klystron N0 High Power RF field waveform

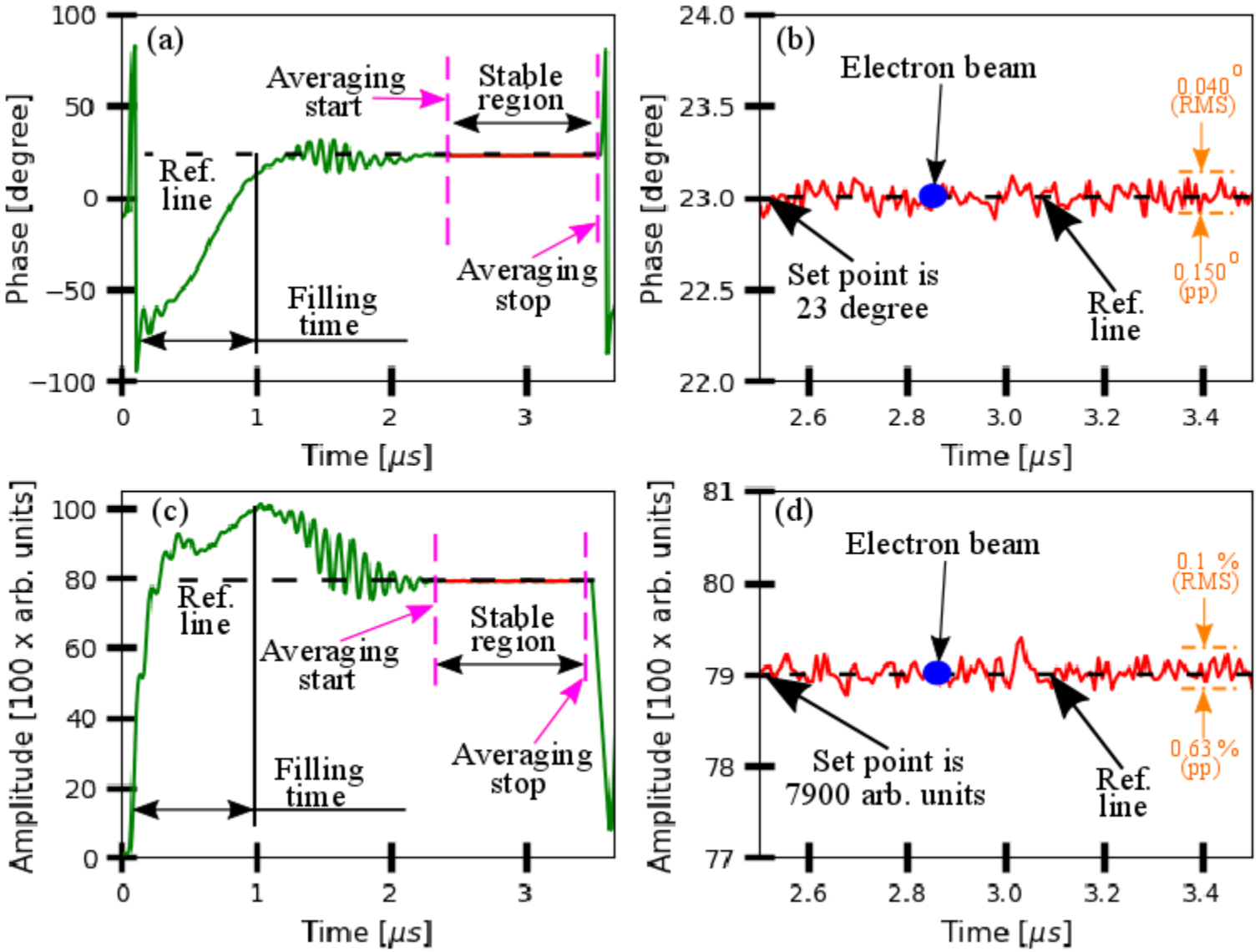


Figure 12: Klystron N0 High-Power RF waveform: **(a)** and **(b)** are High-Power RF field phase and zoomed in stable region of the phase, **(c)** and **(d)** are High-Power RF field amplitude and zoomed in stable region of the amplitude

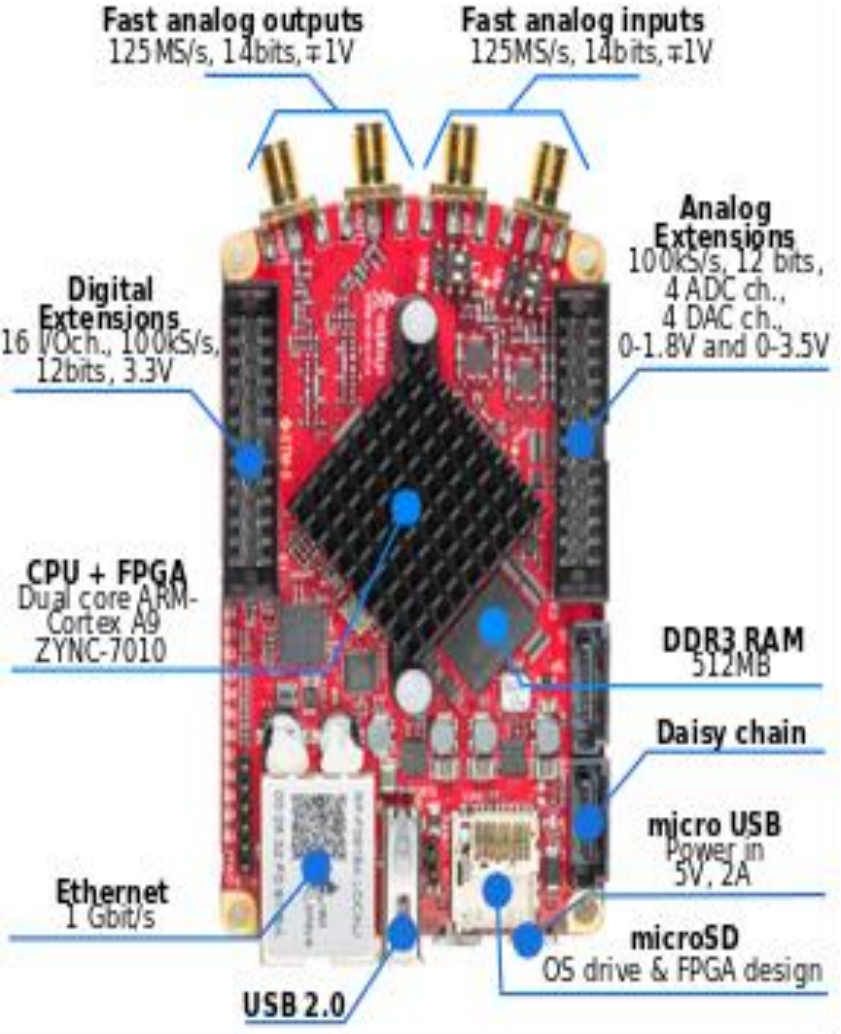


Figure 13: RedPitaya STEMlab 125-14 FPGA board

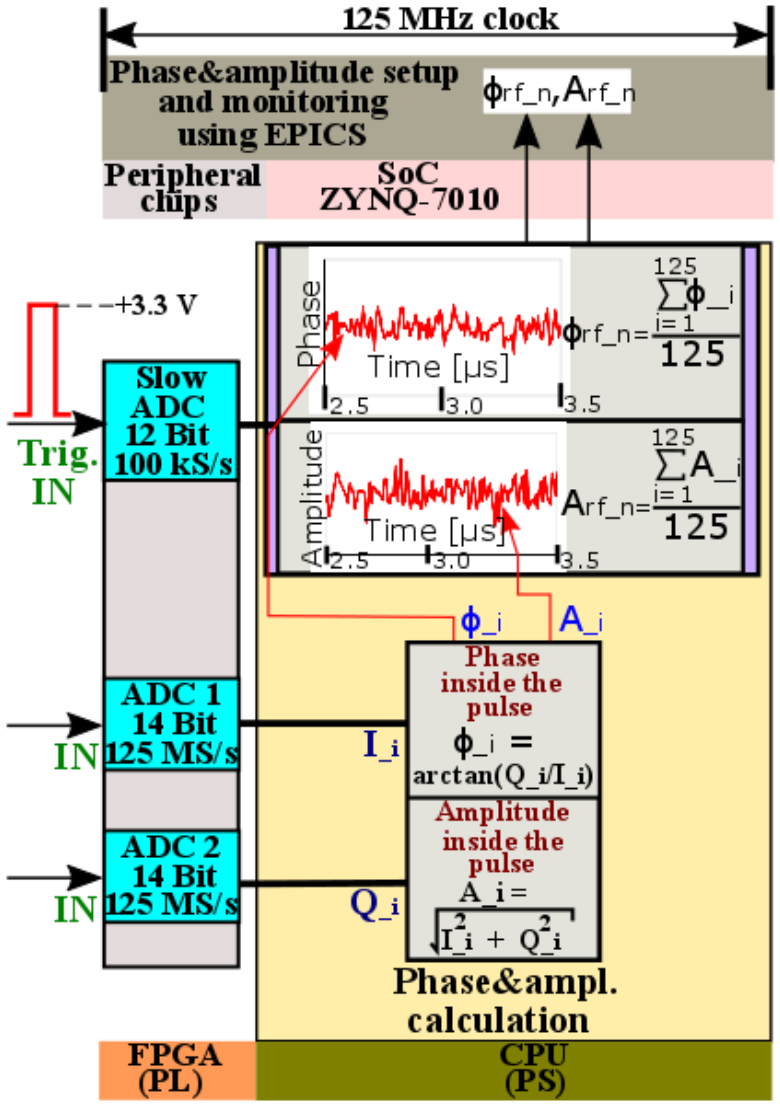


Figure 14: Block diagramm of the signal processing and phase&amplitude detection algorithm implemented into the RedPitaya STEMlab 125-15 FPGA board

The High-Power RF phase drifts 14 degrees peak-to-peak within 72 hours, while the amplitude drifts 1.5 % peak-to-peak. The phase and amplitude drift in-phase.

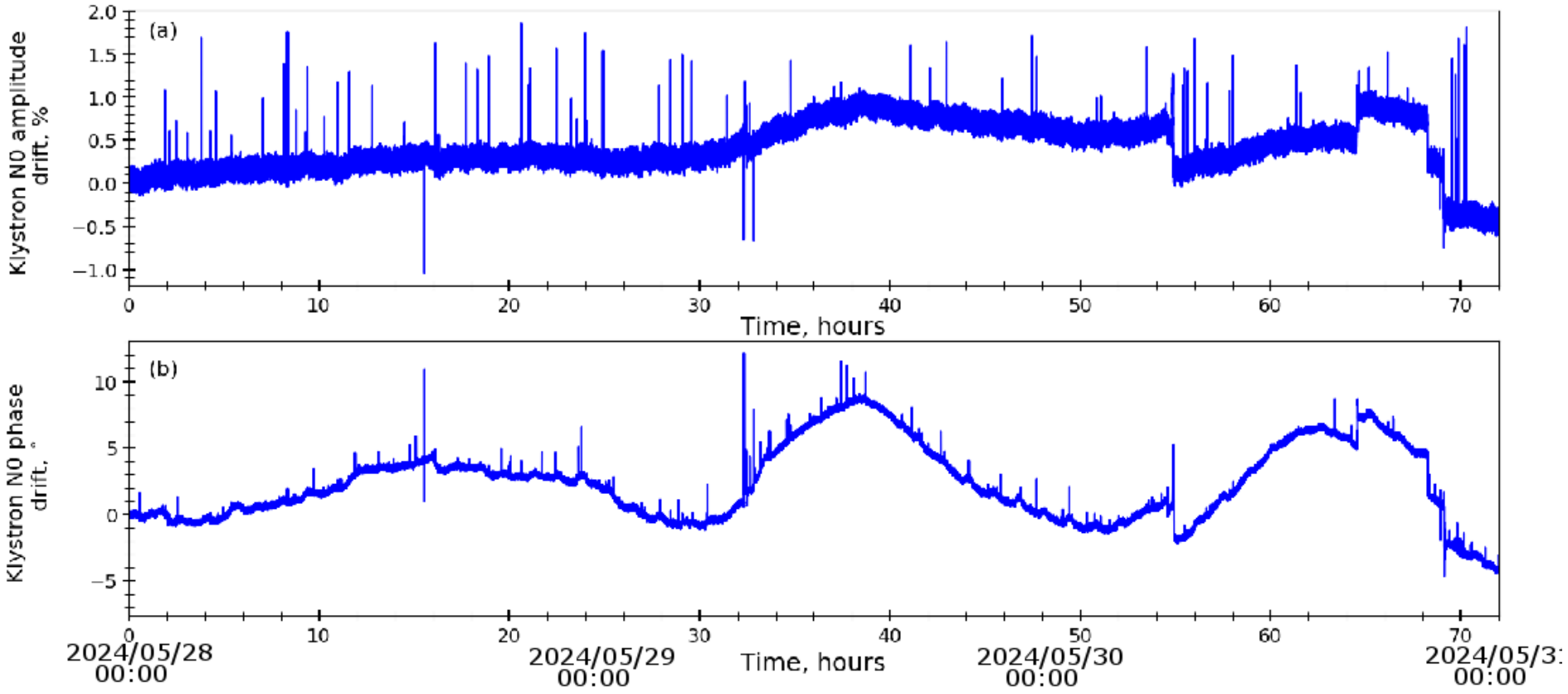


Figure 15: Klystron N0 High-Power RF phase and amplitude stability study results: (a) amplitude drift vs time, (b) phase drift vs time

KEK ATF Damping Ring Low-Level RF system

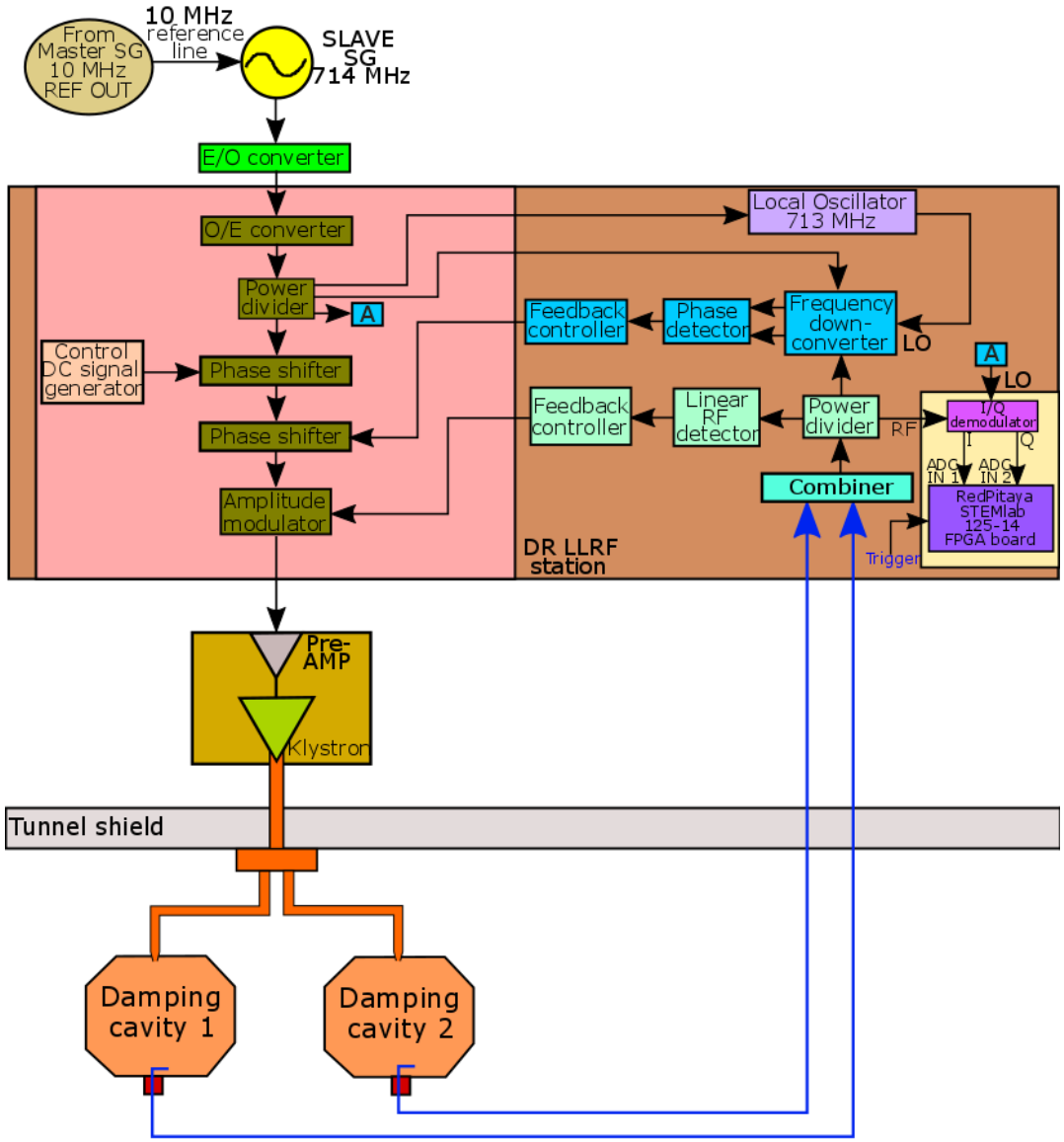


Figure 16: KEK ATF DR Low-Level RF system simplified block-diagram with High-Power RF part

ATF Damping Ring cavities RF field phase stability

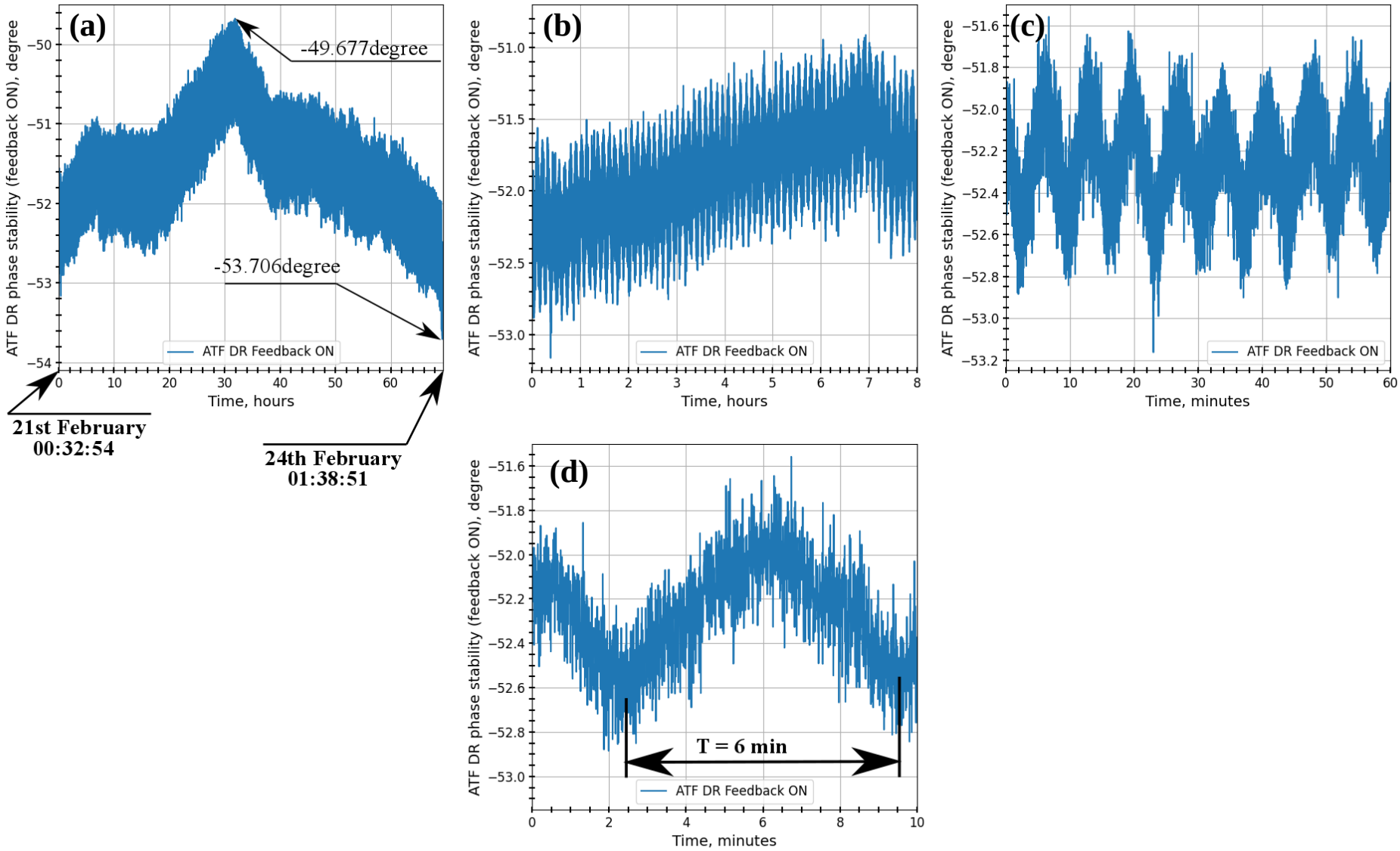
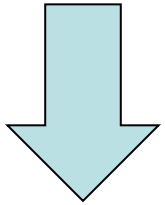


Figure 16: ATF Damping Ring cavities RF field phase stability study results: (a) is the phase vs time (72 hours span), (b) is the phase vs time (8 hours span), (c) is the phase vs time (60 minutes span), (d) is the phase vs time (10 minutes span)

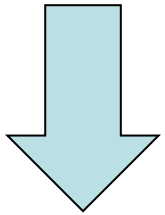
Summary and conclusion

1. The effect of the Klystron High-Power RF phase shifts on the beam position at the Beam Transport line beginning was investigated.
2. The phase monitoring setup based on I/Q demodulator and RedPitaya STEMlab 125-14 FPGA boad was developed, programmed and implemented at the ATF Linac Klystron N0 LLRF station and ATF Damping Ring LLRF station.



The phase shift of the Klystron High-Power RF greater than 5 degrees affects the beam position more than 1 mm, which influence on the beam injection and transmission. Phase shift naturally happens during the ATF operation due to the drift of the phase. **The klystron N0 High-Power RF phase stability monitoring results demonstrate 14 degrees (14 ps for 2856 MHz) drift during 72 hours of the facility operation.**

The Damping Ring cavities RF field phase stability monitoring results shows 4 degrees (16 ps for 714 MHz) drift during 72 hours operation.



These drifts can be eliminated by the FPGA board based digital LLRF feedback implementation into the ATF Linac and DR LLRF systems.