Warsaw University of Technology
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Report on the Development of a Real-time Redundancy Subsystem for the Master Oscillator of the European XFEL

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We present recent advancements in the development of the real-time redundancy subsystem for the Master Oscillator of the European XFEL. This system improves upon the usual method of manually switching to a hot-spare in the event of a failure in the main source. Its primary objective is to maintain uninterrupted operation of the facility by minimizing the impact of potential Master Oscillator failures. By combining continuous monitoring, low-latency switching, and synchronization, the system ensures that failures result in only a brief and minor disturbance instead of a complete loss of a usable signal. As a result, little influence on the downstream systems is expected. We provide examples of the system's operation under laboratory conditions, summarize the achieved performance, discuss encountered issues, and outline further plans

System overview

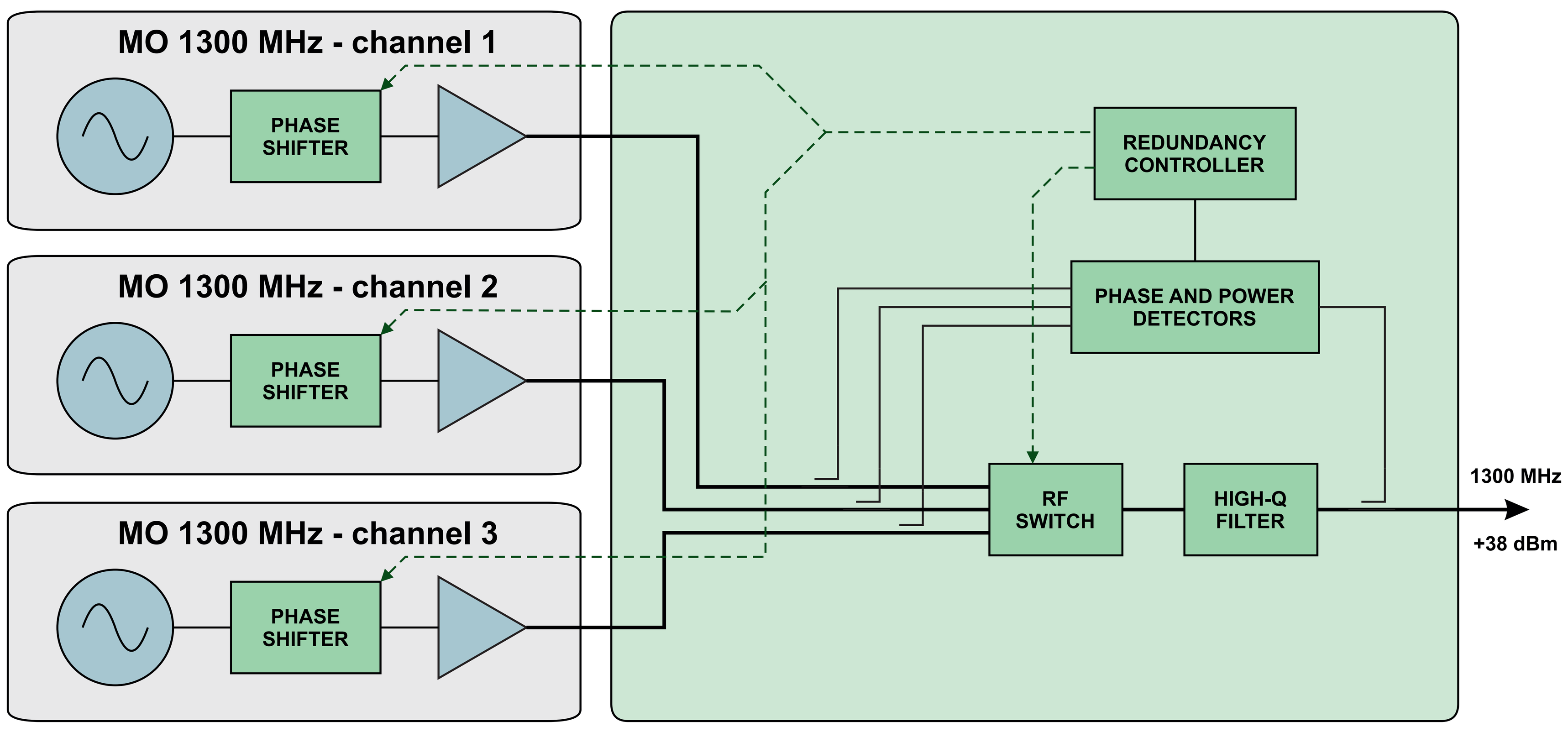

Fig 1: Simplified block diagram of the redundant master oscillator system. Connections in bold carry high-power signals. Green color indicates parts of the redundancy subsystem. Detailed description is available in [1].

Failure reaction performance at +38 dBm input power

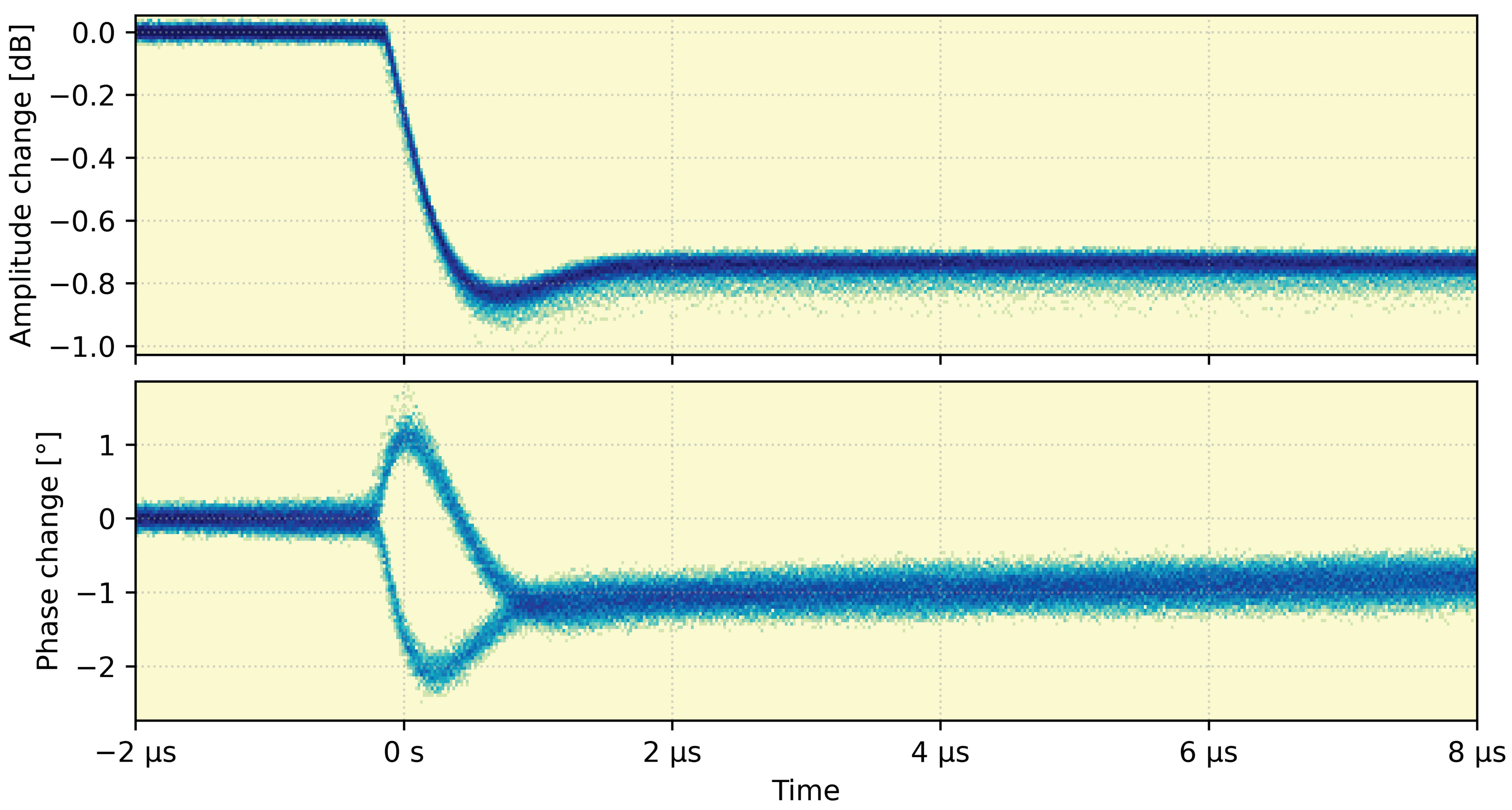

Fig. 2: Accumulated amplitude-and-phase plots show disturbances in the output signal for over 100 system reaction events to a random phase jump.

Phase jumps were induced by changing phase setting in synthesizers used as signal sources, had random direction and random amplitude in 5° to 20° range.

Shape of phase trace clearly reflects jump direction, but otherwise the shape shows good repeatability. Visible change in power and phase drift are mostly due to transient behaviour of the RF switch (→see section on the right).

To make fig. 2, system output was recorded with a fast (4 GHz, 20 GS/s) oscilloscope, IQ-demodulated on a PC, and finally converted to amplitude and phase signals. Trigger (time scale zero) is approx. 100 ns after control signals for RF switch start changing due to detected failures.

Synchronization accuracy limitations

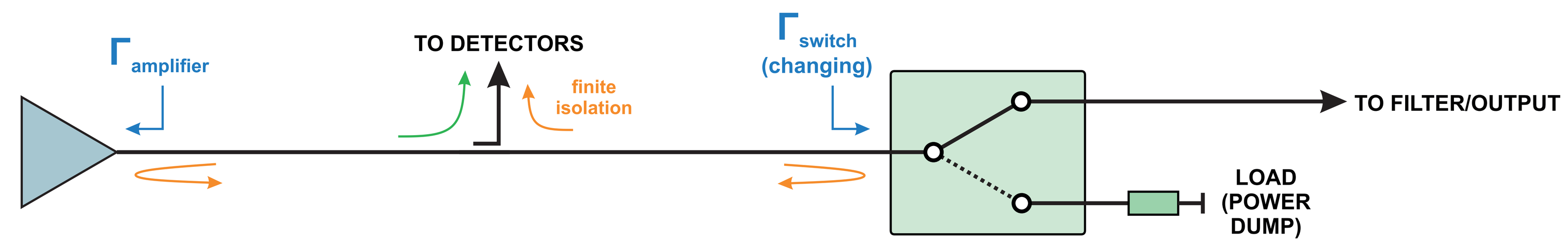

Fig. 5: Phase measurement issues in a single channel. Finite reflection loss of the amplifiers and directivity of the couplers affect the measured phase. As downstream reflection coefficient changes with switching, measured phase will be affected and so will synchronization error. Thus, this issue cannot be solved with a static setpoint. Two different values are necessary: one per switch state.

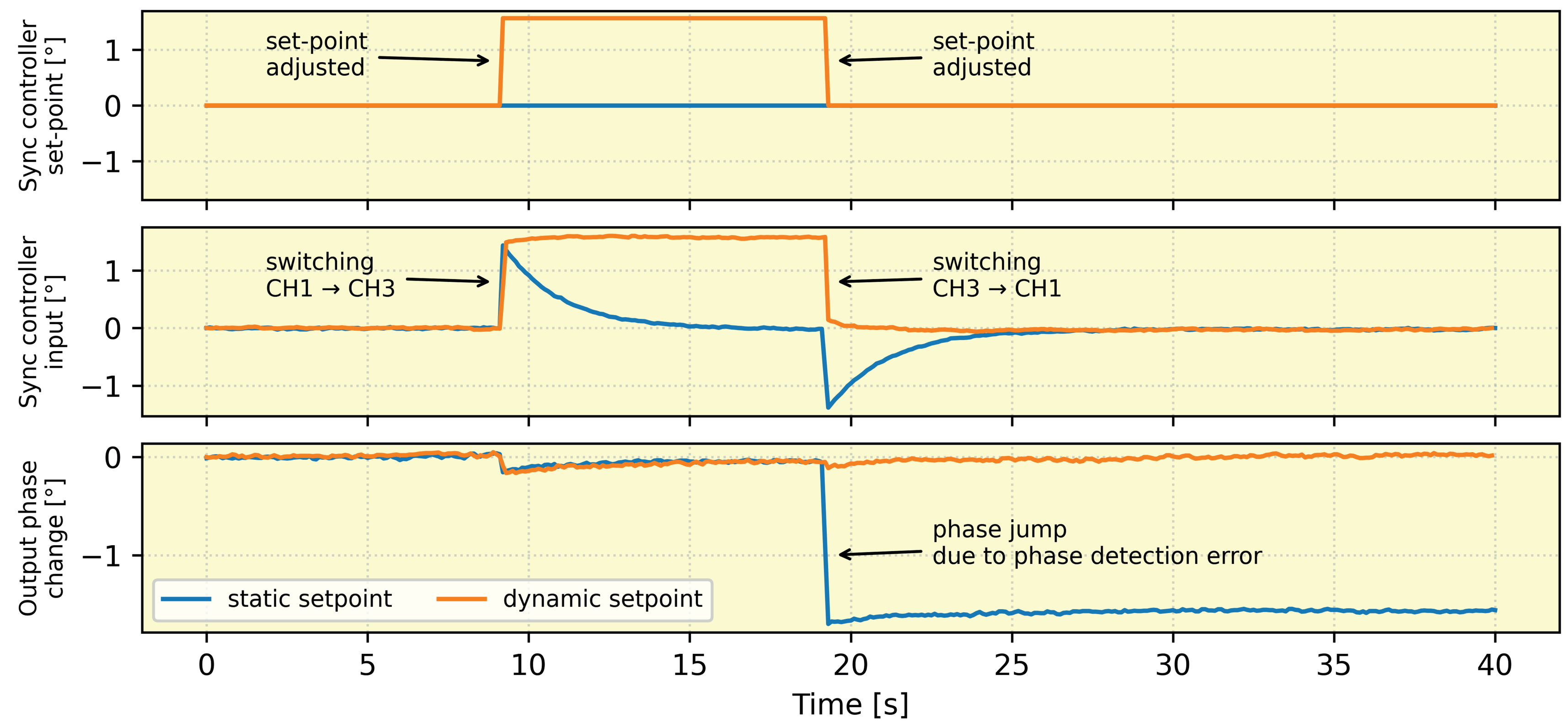

Fig. 4: Performance comparison of phase synchronization solutions. Simple approach of a static (constant) setpoint is visibly affected by system errors. Proposed solution reduces this issue significantly. In these measurements synchronization controller was slowed down for illustrative purposes.

RF switch transients

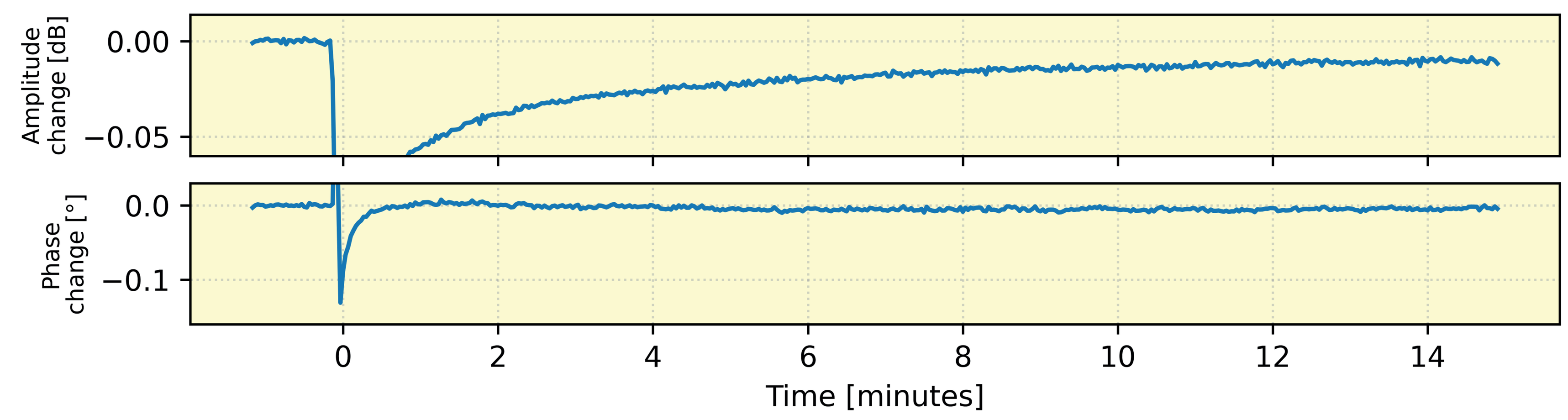

Fig. 5: Minute-scale transient in RF switch after switching from channel 1 to channel 2, and shortly back to channel 1 (@ t = 0).

Ideally phase and amplitude should quickly return to the original values. However, there is a small deviation that dissipates over several minutes, especially in case of the amplitude. We suppose this is at least partially caused by the thermal effects.

References

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