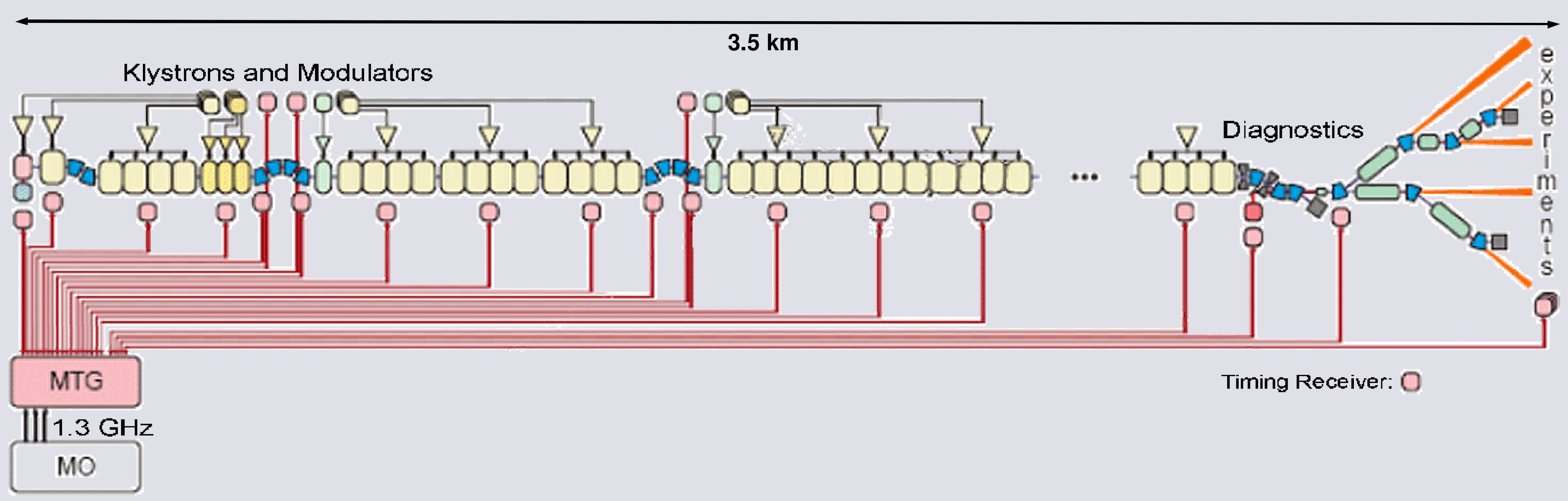
A Pico-Second Stable Clock and Trigger Distribution System for the European XFEL

Patrick Gessler[1], Kay Rehlich, DESY, Hamburg, Germany
Christian Bohm, Attila Hidvégi, Stockholm University, Stockholm, Sweden

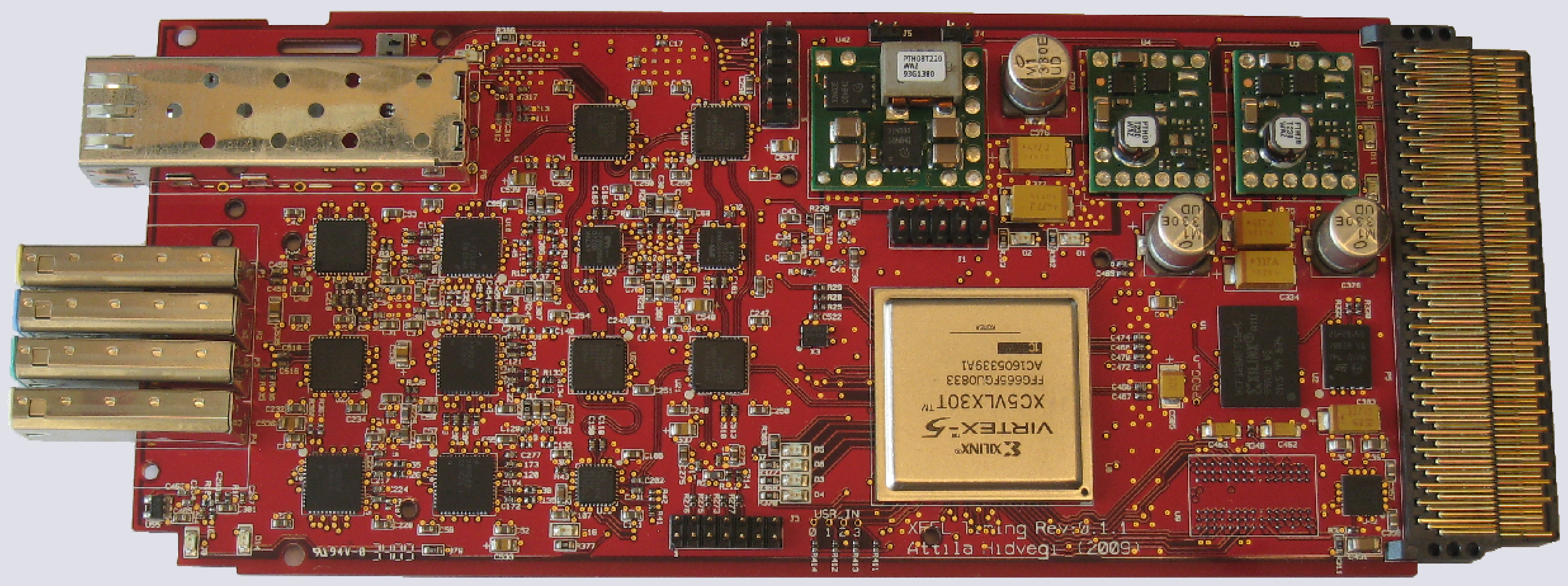
Abstract

For the operation of the European X-Ray Free Electron Laser (XFEL), a system wide synchronous low-jitter clock and precise, adjustable triggers must be generated and distributed throughout the 3.5 km long facility. Consumers are numerous diagnostics, controls, and experiments. Fast ADCs require the jitter of a distributed 1.3GHz clock to be in the order of a few pico seconds (RMS) and synchronized to the accelerating RF. Due to cable lengths, and the temperature dependence of the propagation speed, temperature drifts are a serious issue. Therefore a complex monitoring and compensation mechanism has been developed to minimize these effects. The hardware platform of the XFEL will be based on the new standard µTCA and ATCA. Therefore the timing is implemented as an AMC (Advanced Mezzanine Card) module that fits into both crate systems. A prototype of this new clock and trigger system has been developed and first measurements have shown, that the strong requirements can be fulfilled.



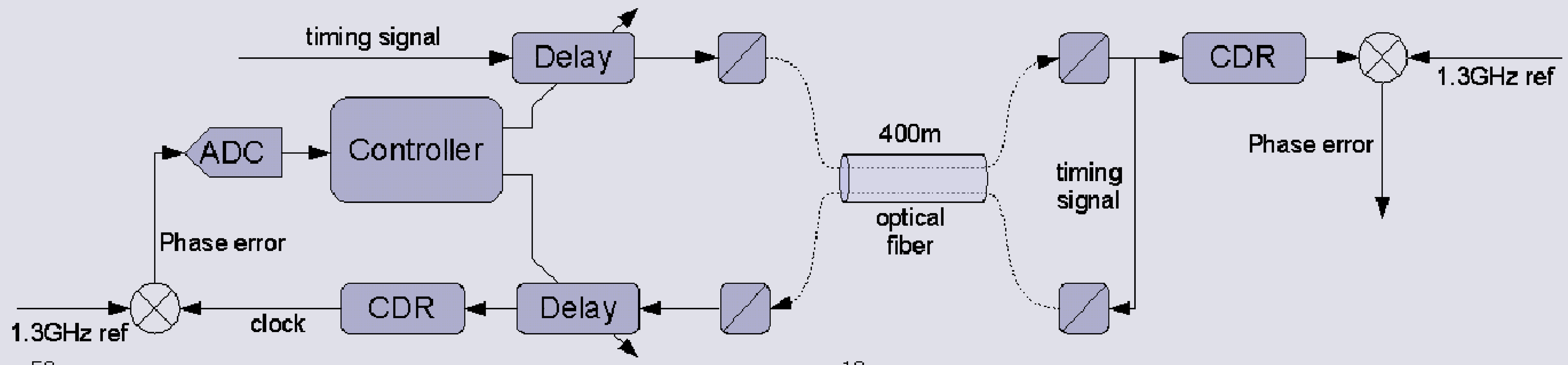
Layout of the Timing System

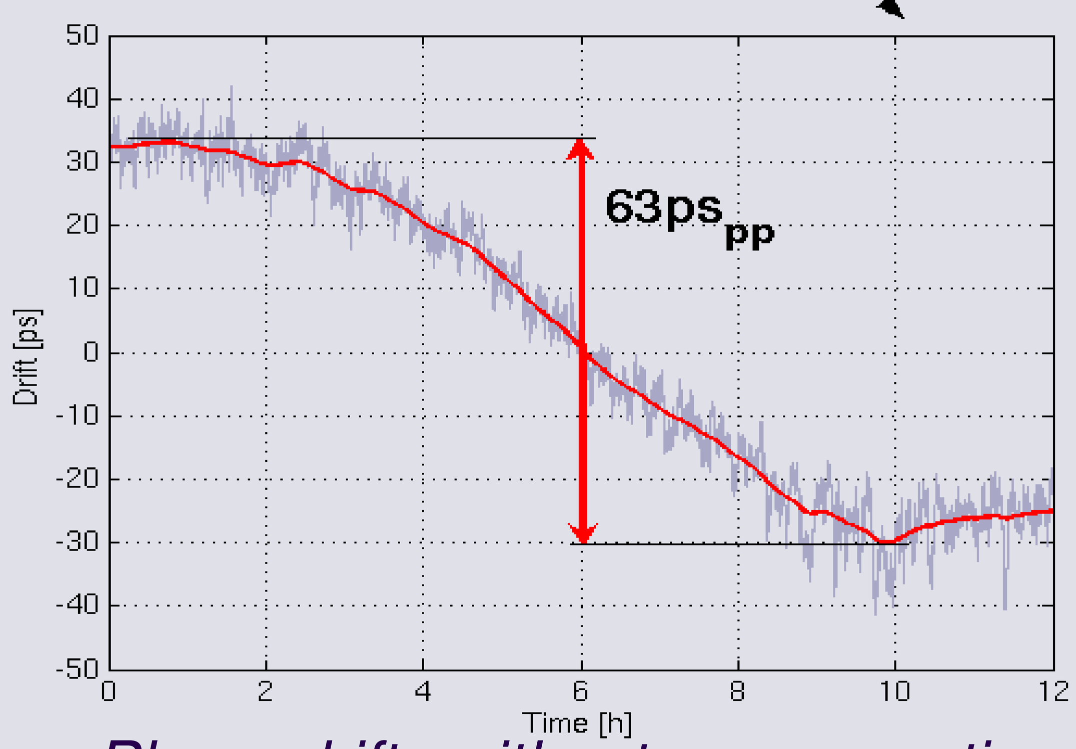
Starting from the centralized master timing generator the timing signals are distributed directly to the approximately 100 endpoints along the 3.5km long facility.
Timing receivers extract the stabilized 1.3GHz clock as well as trigger information from the received timing signal.



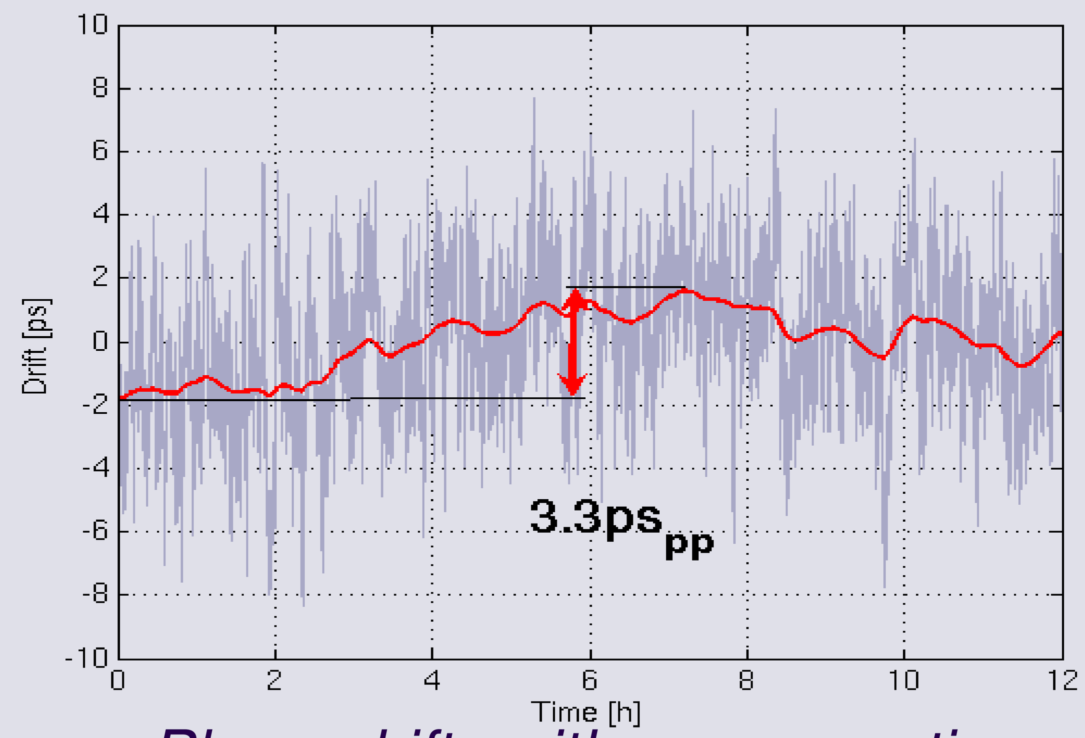
Prototype AMC Timing Modul

- Interfacing
  - Implements Transmitter and Receiver functionality
  - Optical SFP Transceiver for Timing signal
  - 2 additional Clock inputs
  - Timing Signal output/input (for sub-distribution)
  - 6 Dedicated Clock outputs
  - 5 Clock-or-Trigger outputs
  - 2 Clock outputs to Backplane
- Main Functions
  - Drift compensation (between Transmitter and Receiver)
  - Event decoding
  - Clock generation/distribution
  - Trigger generation/disribution





Phase drifts without compensation



Phase drifts with compensation

Measurement Setup

The timing signal is transmitted at 1.3Gb/s to the receiver over 400m optical fiber and sent back to the sender. The sender will stabilize the phase with two delays based on the phase change of the received clock compared to the reference.
The long term phase stability at the receiver will be measured and the performance of the drift compensation scheme investigated.

Measurement Results

Without compensating for drifts a phase change of 63ps could be observed within 12h (left figure). The temperature at the fibers changed in the range of 3 °C to 7 °C.

With active compensation the three complementing feedback loops could reduce the drift by more than a factor of 10 to 3.3ps at same temperature variations (right figure). The RMS value for the measured signal reaches only 2.28ps.

Conclusion and Outlook

In the next step the designed prototype AMC module for µTCA will be programmed to deliver configurable clocks and triggers.
Further measurements need to verify, whether the current stability could be maintained at these outputs, what changes have to be considered.

References

- A Pico-Second Stable and Drift Compensated High-Precision and Low-Jitter Clock and Trigger Distribution System for the European XFEL Project, P.Gessler et.al, PAC09, TH6REP089
- A System for Distributing High-Speed Synchronous High-Precision Clock and Trigger Data over Large Distances, A. Hidvégi et.al, NSS2008, PID773180
- http://www.xfel.de

[1]patrick.gessler@desy.de