Operational Experience of the Drift Compensation Module at the European XFEL and FLASH.

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Abstract

The European XFEL and FLASH are high performance free electron lasers operated at DESY, demanding very precise RF field regulation as well as long term stability and reproducibility of given machine setups. Operational experience shows that environmental influences, especially humidity changes, have strong impact on the RF field measurement. In order to minimize these effects a drift compensation module has been developed, installed and commissioned for each RF station within these machines. The module itself induces a reference pulse with a 10 Hz repetition rate to detect and correct for changes in the measurement chain. Here we are going to present results from the commissioning phase as well as regular machine operation within the last year. Possible limitations and further improvements are discussed.

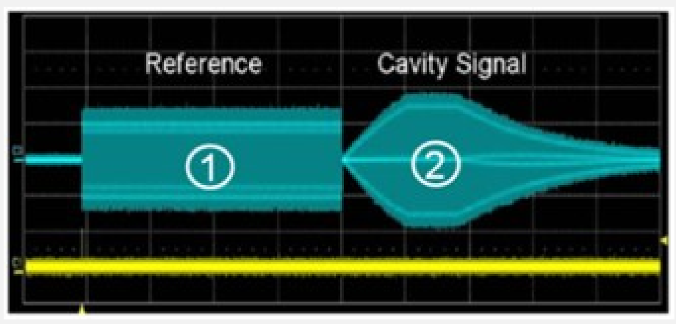
Motivation and status

- *Goal:* calibration of the RF detection chain
- Installed and commissioned modules in FLASH and XFEL
  - 5 modules in FLASH (4 x 1.3 GHz ; 1 x 3.9 GHz)
  - 50 modules installed at XFEL (1 x 3.9 GHz)
- Permanent operational in all SC modules
- Used also for other facilities within DESY (ARES, REGAE)
- Mainly stabilization for long term machine drifts due to environmental condition changes
  - Improvement of the long term stability of the RF field regulation
  - Improvement of the machine reproducibility
- Sealed and temperature stabilized system for amplitude detection
- Development for CW Version, currently first tests

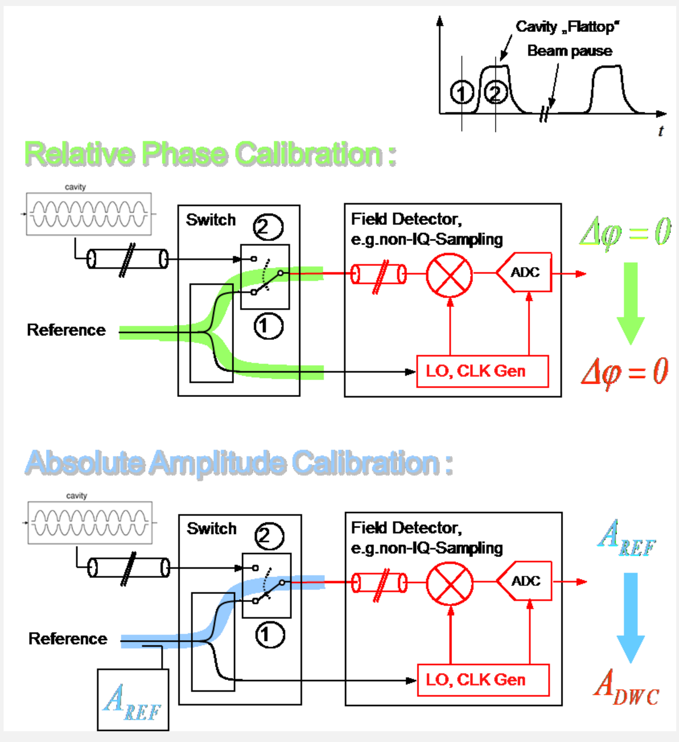
Drift compensation module, front and rear view of the 2U, 19" Hardware

Component description / functionality and method

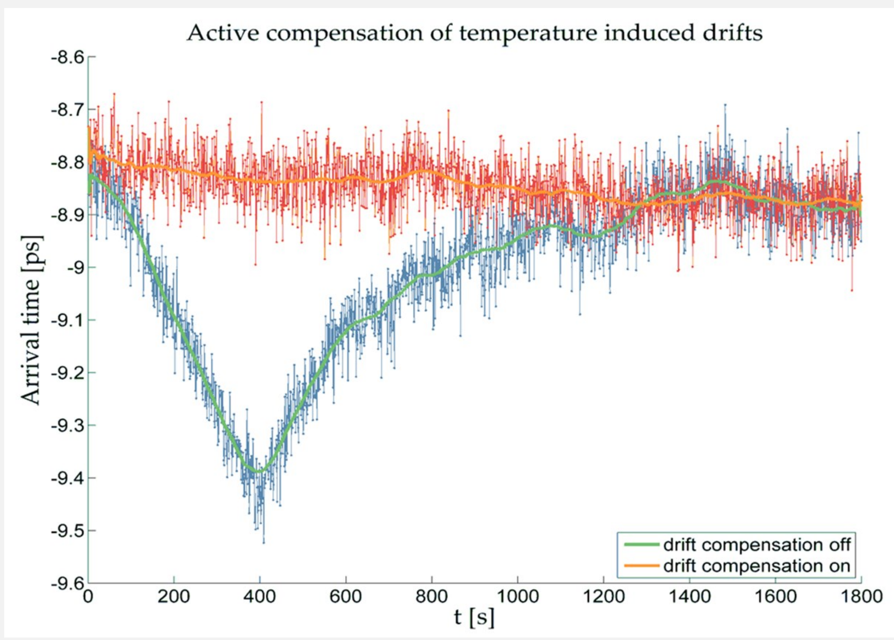
- Switching in between the RF pulses to a reference source and apply changes of this measurement to the used field detector
  - Absolute amplitude measurement due to independent amplitude detector inside the DCM box
  - Pre-pulse measurement and application for the upcoming pulse, correction steps down to 10 Hz
- Temperature controlled and sealed electronics
- Exception handling (switch check, compensation limit)



Scope measurement of the switching process between two RF sources



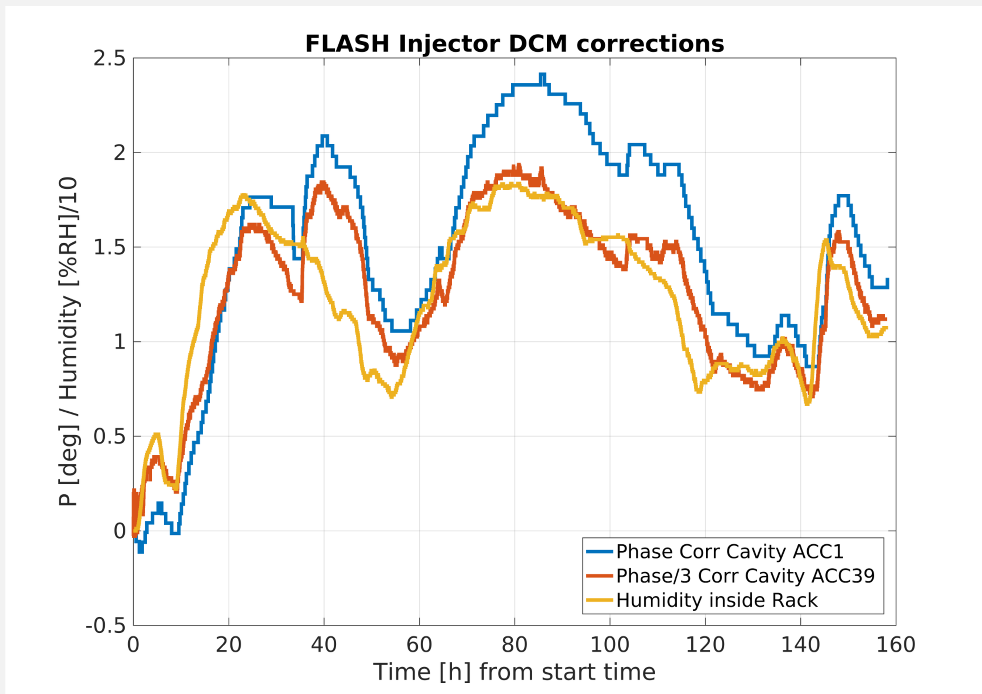
DCM basic functionality sketch for pulsed machines



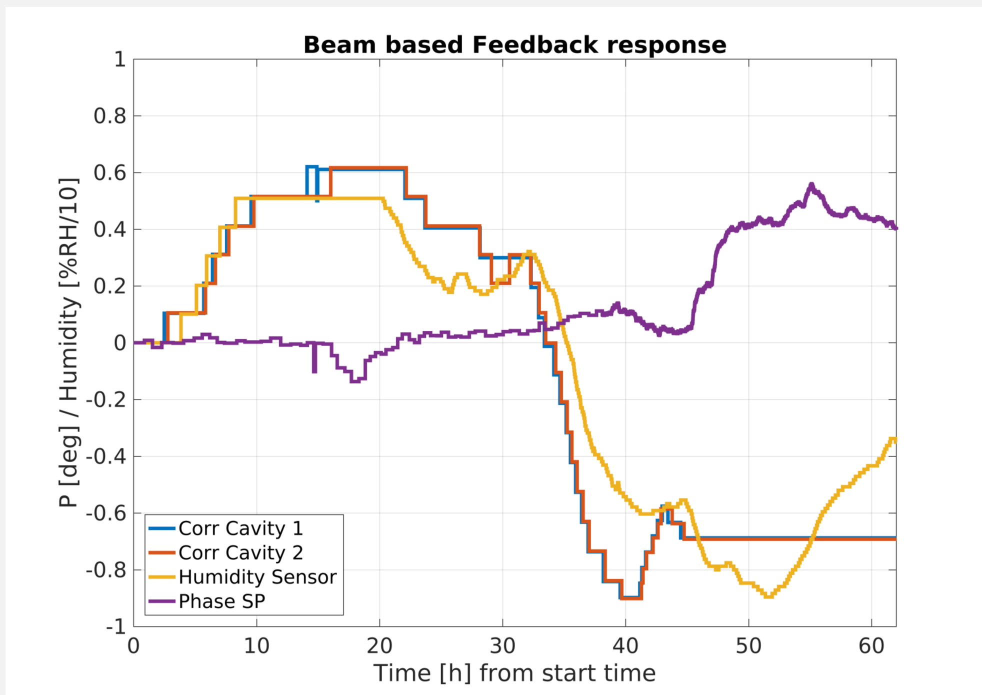
Measurement of beam arrival time as function of an environmental condition change with and without DCM

Measurement results

- *Goal*: Proof the functionality of the DCM in terms of stabilization of the measured RF signals. Crosscheck with the electron beam as ultimate out of loop measurement.
- Measurement of a strong correlation between RF phase changes and humidity changes
  - 0.1 deg / %RH @ 1.3 GHz ; 0.3 deg / %RH @ 3.9 GHz
- DCM on ➔ beam based compression feedback shows almost no corrections on the RF phases



Long term drift measurement in the FLASH injector. There is a strong correlation between the humidity changes in the rack and the corresponding phase corrections being applied by the drift compensation module



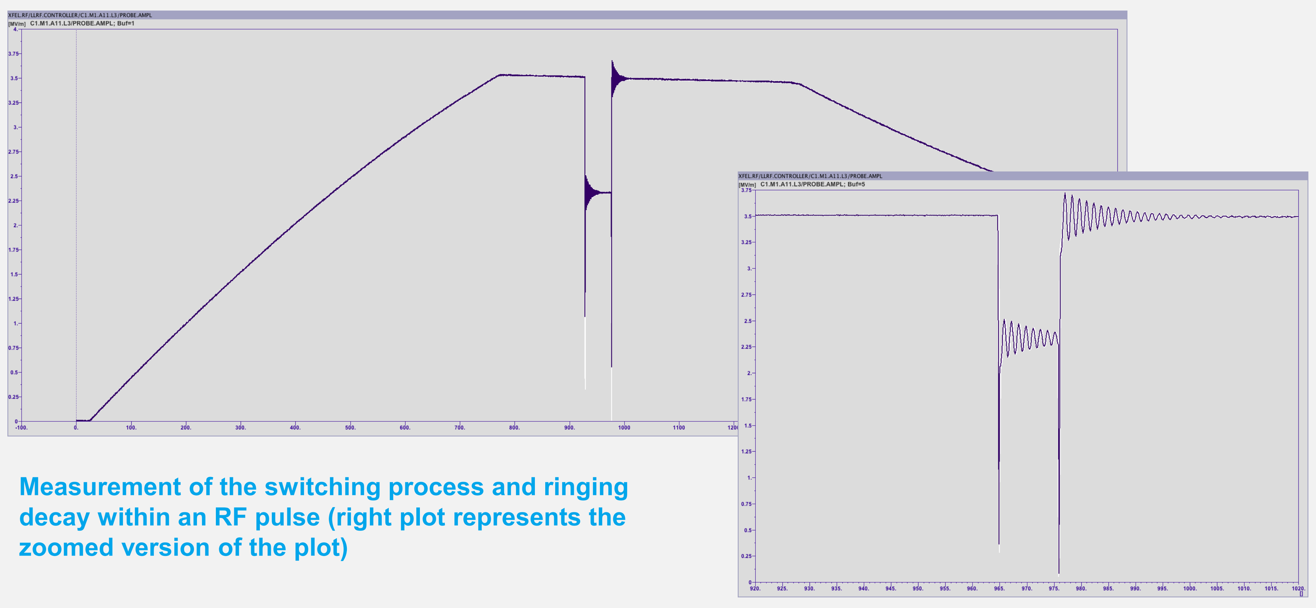
Crosscheck of the influence to the beam based feedback system response when the DCM is on and off. As long as the DCM modules apply corrections, the phase setpoint manipulated by the compression feedback is almost inactive, whereas it follows the humidity curve after the DCM corrections are switched off at about 43 hours after start

Operational experience and adjustments

Timing adjustment

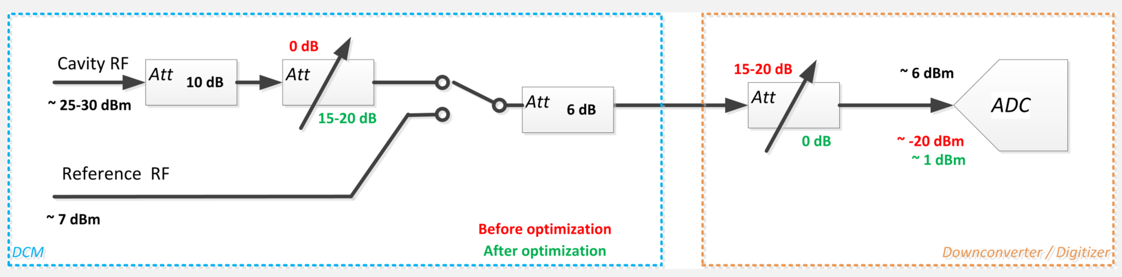
Goal: Optimal setup of the switching period between Reference and cavity signal

- Period in operation is 15 ms long switch to reference about 2 ms before the RF pulse starts
- Reference measurement takes place about 2 ms after switching

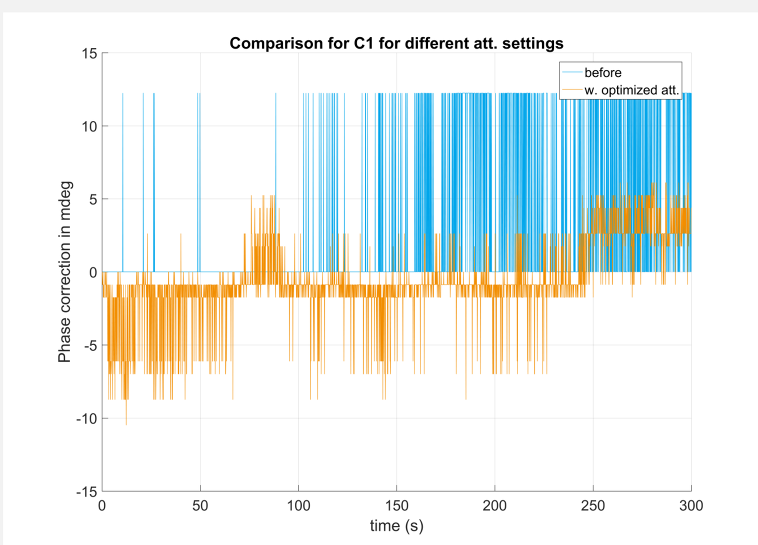


Measurement of the switching process and ringing decay within an RF pulse (right plot represents the zoomed version of the plot)

Attenuator adjustment



- *Goal*: Optimization of the signal levels on the detection ADC
- So far the adjustable attenuators have been used on the DWC
  - Optimized for the nominal cavity signal levels on the given ADC range
  - Now reference signal requires no attenuation, therefore the attenuation must take place in cavity channel only
  - Optimal balancing of both signals, i.e. more precise results



Comparison of the DCM corrections applied on the phase level, Improvement of phase correction minimum step x10

Conclusion and Outlook

- DCM is installed and commissioned for FLASH and XFEL
  - Running continuously in operation, so far 1 malfunction in operation
- Long term drift compensation is proven, using beam based methods
  - DCM stabilizes to 0.02 deg_pp and 0.02 %_pp at 1.3 GHz
- Currently in a stage of gaining further experience and optimization of:
  - Hardware settings and firmware
  - Software, including exception handling and interface
- CW under development, 2nd tone integration, method change

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