Developments of XFEL Master Laser Oscillator Controls based on MicroTCA.4

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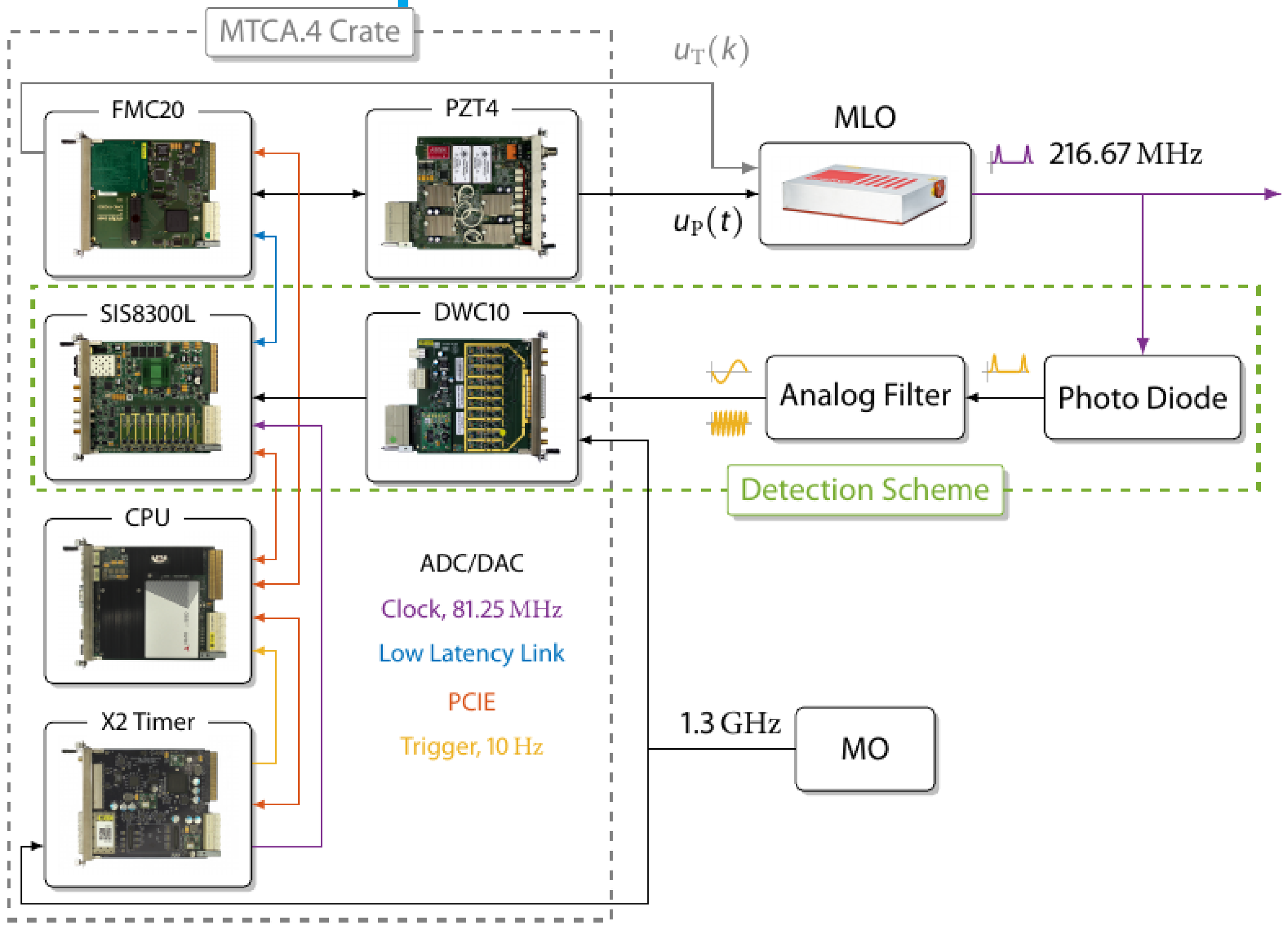
Abstract

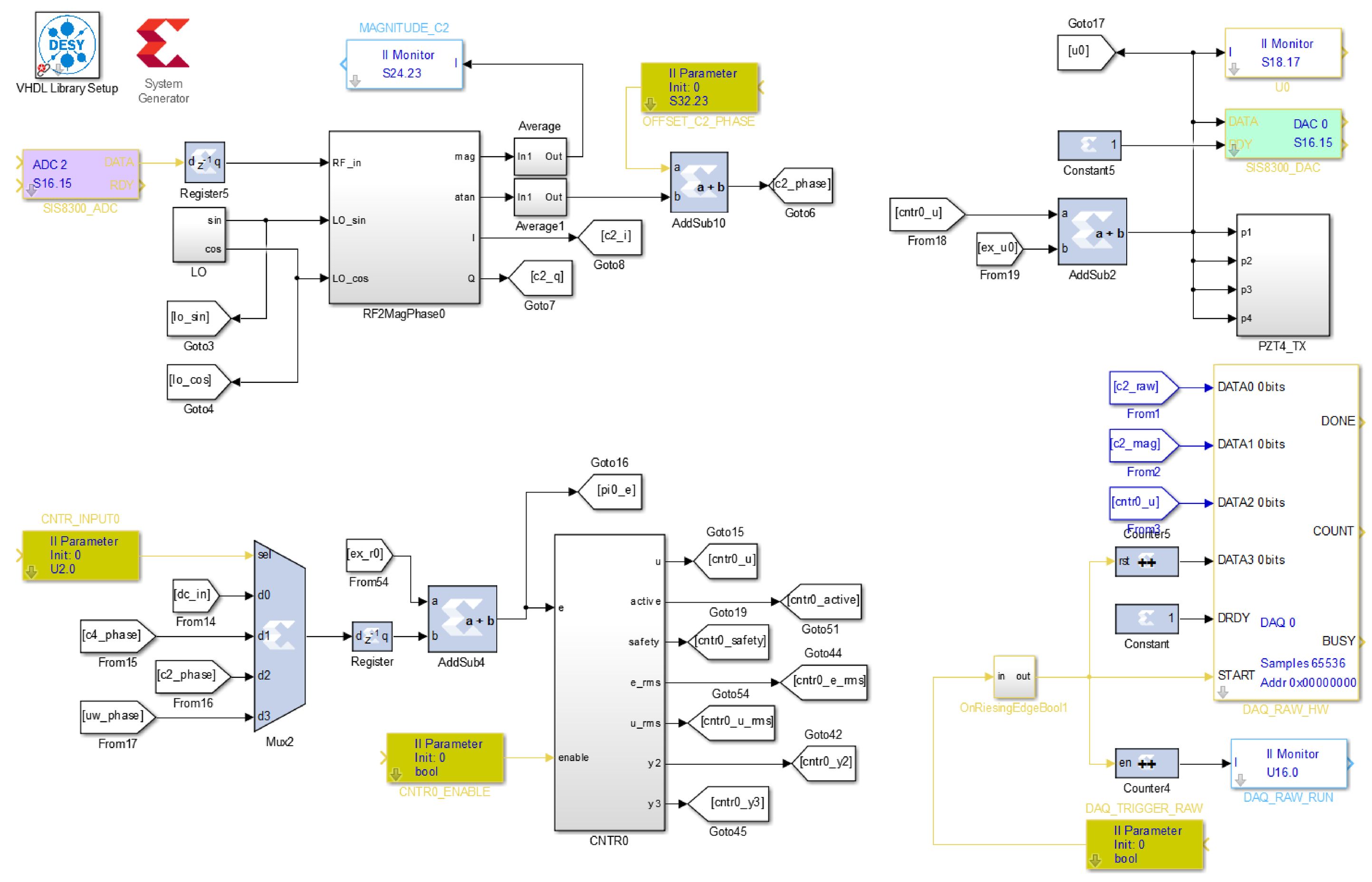
The European X-ray Free-Electron Laser will generate high energy laser light pulses in the femtosecond range to perform experiments with atomic scale resolution. In order to control the electron beam to its requirements the diagnostic devices used for the beam based feedback require a precise timing signal to synchronize the measurements to the beam and to the radio-frequency (RF) modules. A laser based synchronization scheme is used for this purpose in which a master laser oscillator (MLO) generates a laser pulse train which is the synchronization signal for the attached end stations. This laser is synchronized to the Maser Oscillator (MO), the main clock source of the facility. This contribution will show the current status of the MLO developments for the European XFEL.

Hardware Setup



The **MLO**, a **OneFive Origami** laser, generates the 216.67 MHz laser pulse train. This optical signal is delivered to several end stations. Using a fast photo diode the optical pulses are converted and fed into the Phase Detection Scheme shown below.. The **SIS8300L AMC** Board is used to sample the analog signals and run the control algorithm. A **FMC20 AMC** receives the controller output over a **Low Latency Link** and uses a **PZT4 RTM** to excite the piezo crystal inside the laser, tuning its repetition rate.

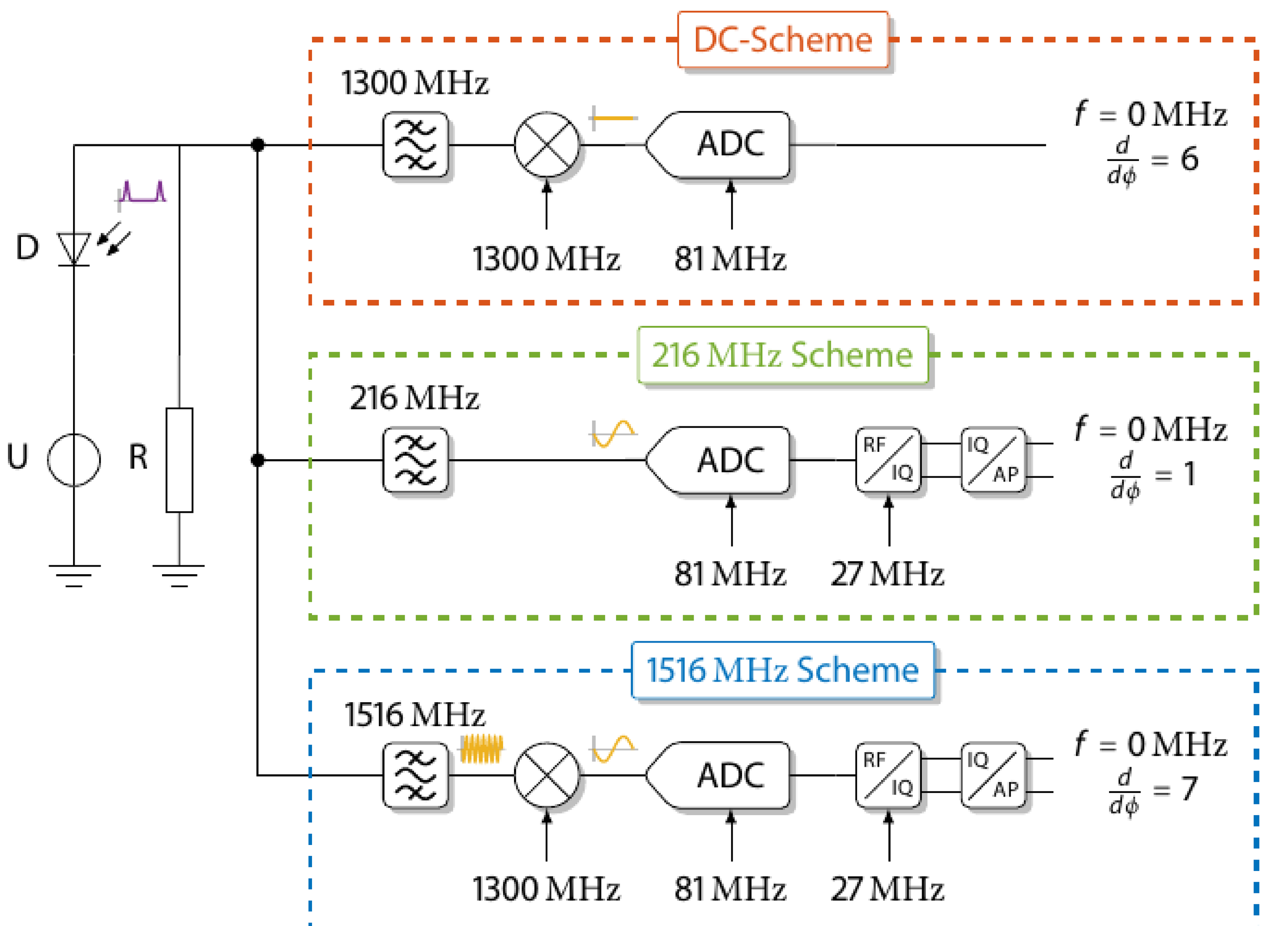
Rapid-X Firmware Rapid Prototyping



The application part of the firmware which includes e.g. the control algorithm is developed in **MATLAB Simulink** with **Xilinx System Generator** and the in house developed **Rapid-X** toolbox. Advantages of this scheme are:

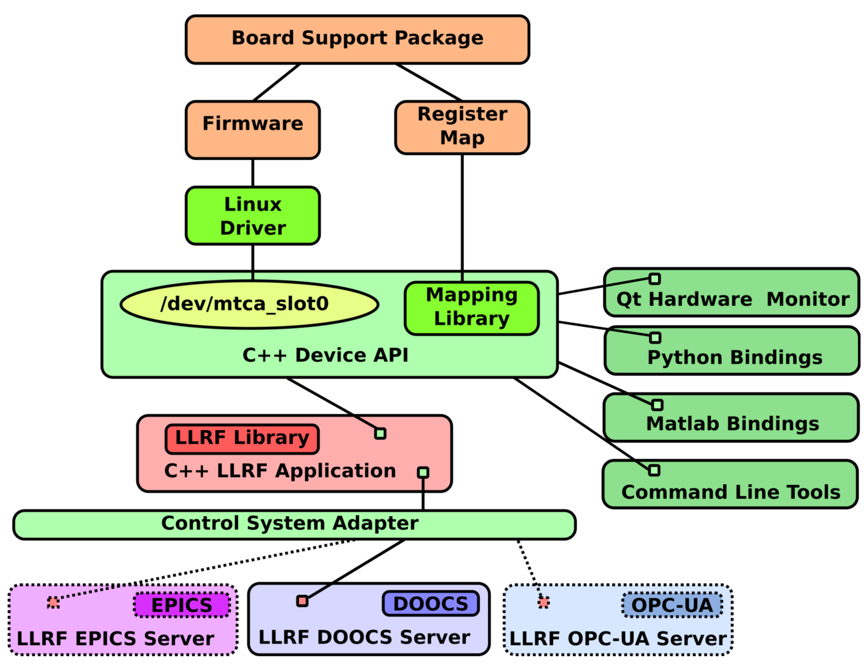
- **No VHDL Knowledge required** for the application part
- Application part can be simulated prior deployment
- Simplified workflow and faster implementation of new features

Phase Detection Scheme



The controller minimizes the phase difference between **MLO** and **MO**. The DC-Scheme mixes the 6th harmonic of the pulse train with the MO frequency to generate a DC signal which gives the phase error. The 216MHz-Scheme directly samples the 216MHz fundamental of the pulse train and the 1516MHz-Scheme the 7th harmonic mixed with the MO signal. The phase is extracted by an IQ-Detection and Magnitude/Phase calculation.

MicroTCA4U and the MATLAB Tools



The **MicroTCA4U** library is used to access the registers and memories in the firmware. It provides a C++ interface for device access. On top of this **MATLAB**, **Python** and a **Command Line** Interface are available to acquire data directly to the engineering tools.

MATLAB Example

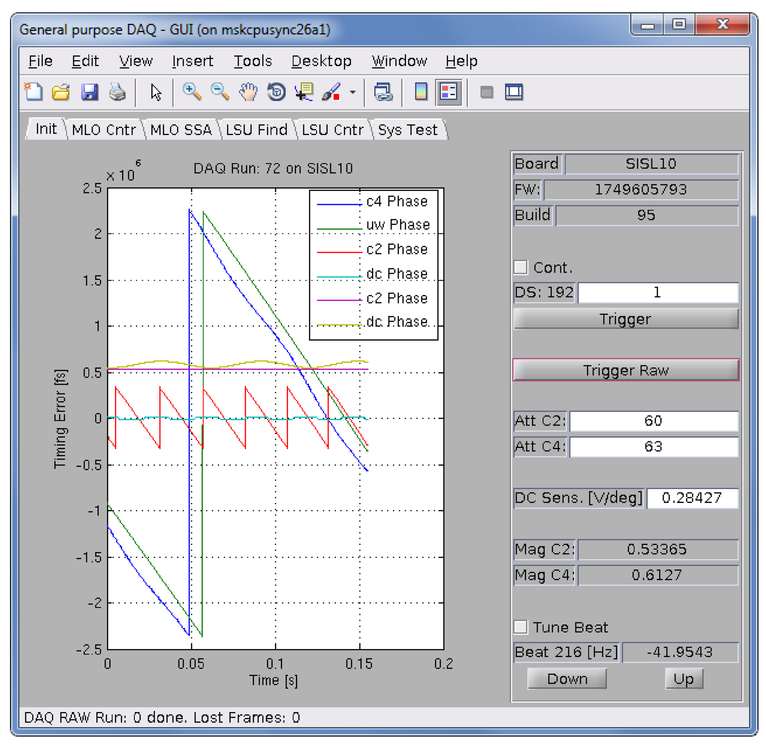
m = mtca4u('SISL'); % Create device handle

% Read register
m.read('APP0','WORD_GAIN')

% Write register
m.write('APP','WORD_GAIN', 4)

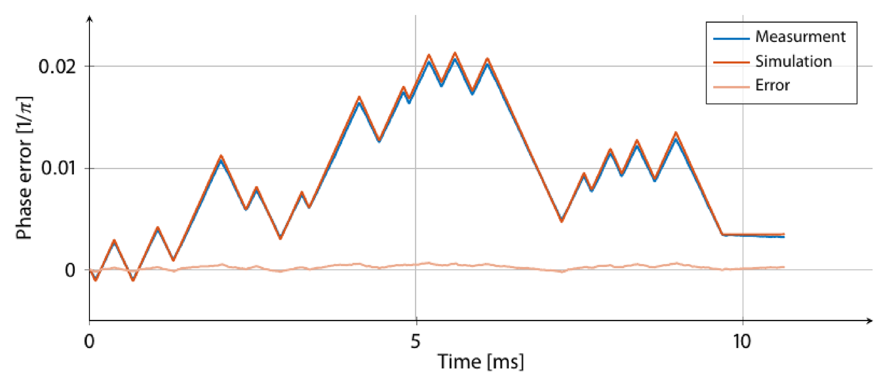
% Read DAQ sequences 1 and 5
m.read_seq('APP0','DMA',[1 5])

MATLAB LaserSync GUI:

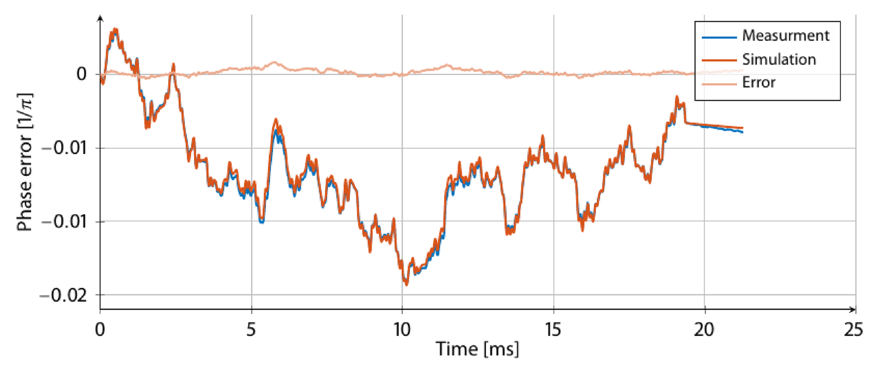


System Identification and Control

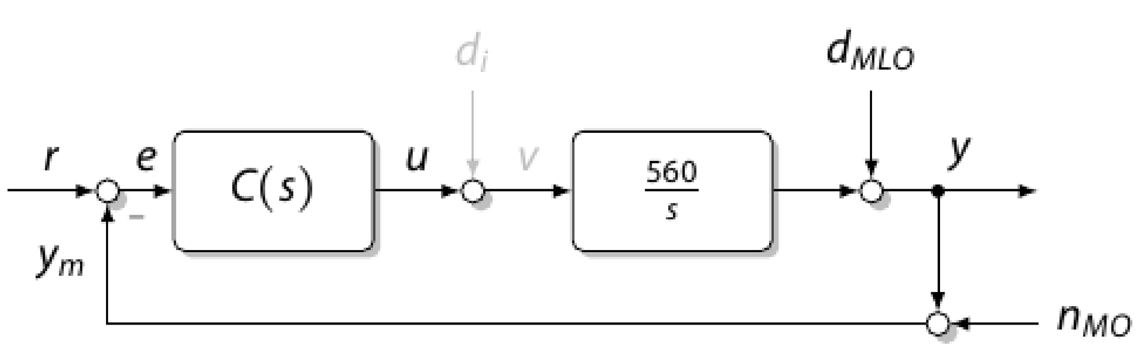
Response to PRBS Excitation:



Response to Band Limited White Noise Excitation:

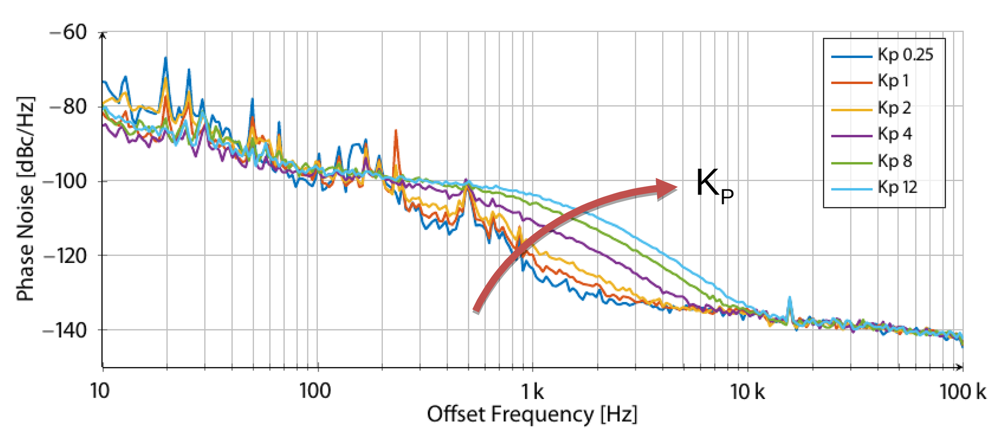


System Model:



To acquire a mathematical model of the MLO control system it is excited with a **PRBS** signal and with **band limited white noise**. From the response the system above can be identified. This description can be used to calculate a controller using model based approaches. The signals in the model above are timing differences with respect to a perfect clock.
Main control target is to minimize y while keeping u in an allowed range.

PI Controller Experiments:



Just an increase of the controller gain does not lead to a minimal phase noise. Increasing the controller bandwidth also leads to an amplification of measurement noise and increases the waterbed-effect. An optimal trade-off has to be found for each system individually.

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