The Bunch Arrival Time Monitor at FLASH and European XFEL.

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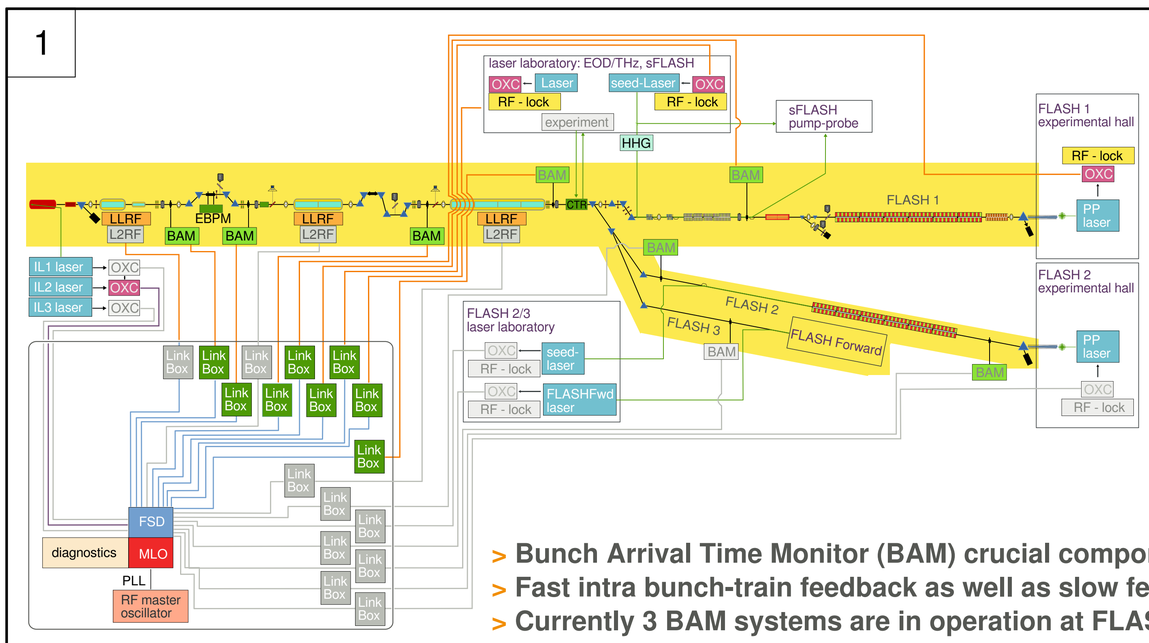

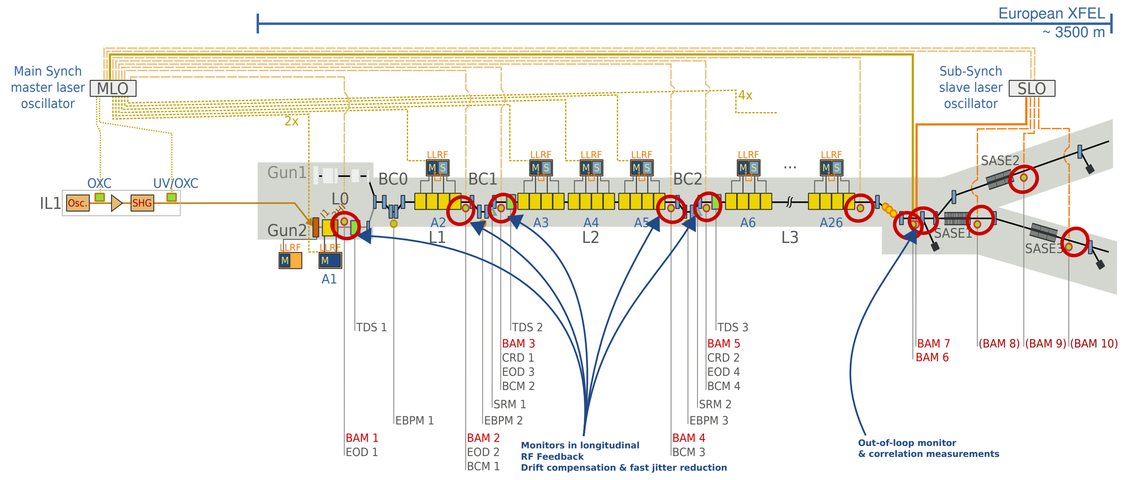

> Bunch Arrival Time Monitor (BAM) crucial component of the Beam Based Feedback.
> Fast intra bunch-train feedback as well as slow feedback is provided.
> Currently 3 BAM systems are in operation at FLASH and 5 at the European XFEL [1][2].

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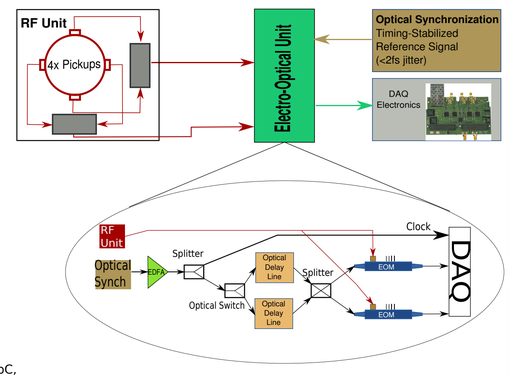
BAM is composed of 3 main parts

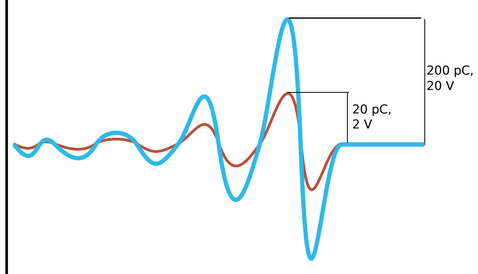
> RF Unit: RF signal generated by the electron bunch collected by pickups along the beam line [3].
> Electro-Optical Unit: it combines the RF signals with timing-stabilized laser pulses to provide the bunch arrival time [4].
> Data Acquisition System [5].

The laser-based synchronization system provides 216 MHz laser pulses used in the measurement.

Rf Unit

> Signals of 2 opposite pick-ups combined to reduce dependency on the transversal beam position (RF signal).
> The RF signal strength is a function of the bunch charge.
> One RF signal is fed to a low pass filter and a power limiter in order to be able to measure the arrival time for bunch charge up to nC.





Electro-Optical Unit

> Optical amplifier.
> Two or more Optical Delay Lines to adjust the delay for each SASE submacropulse independently.
> Two Electro-Optical Modulators (EOMs) to cross-correlate the RF signals with laser pulses, each EOM with different RF bandwidth to provide optimal sensitivity for different bunch charges [6].

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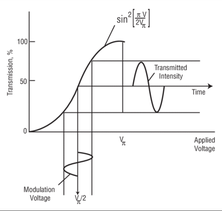
Electro-Optical-Modulator

> Based on a Mach-Zehnder type interferometer
> Light transmission depends on the applied voltage
> Bias voltage chosen in such a way that with no RF signal transmission is 50 %



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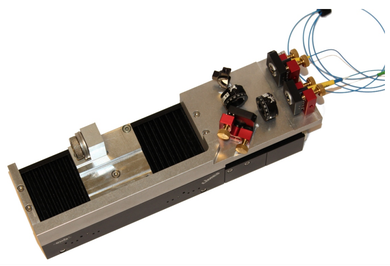

Optical Delay Line

> Add delay to laser pulses up to ca. 260 ps.
> A different delay can be set independently for each SASE submacropulse.
> 2 phase bipolar stepper motor with linear stage.
> Absolute position encoder for calibration purpose.

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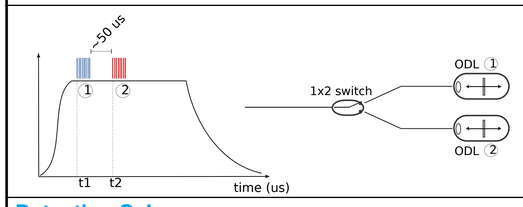

Optical Switch

> Select the proper delay line [7].
> Switching time in the order of 100 ns.

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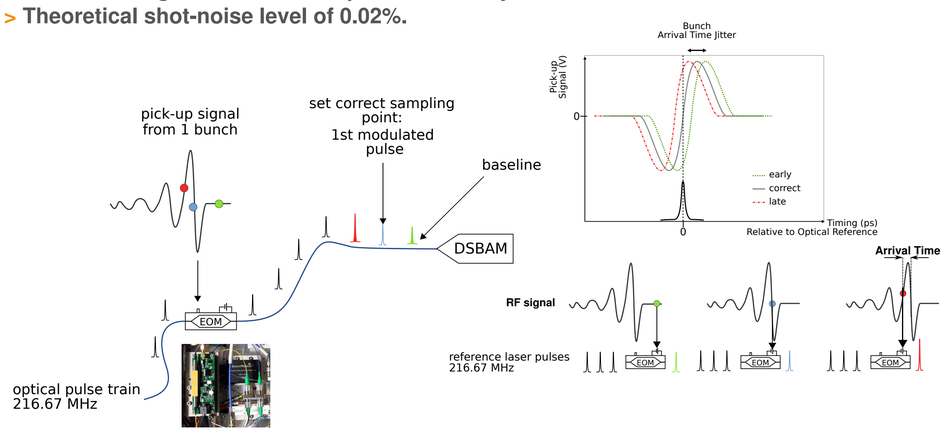
Detection Scheme

> Distance between 2 peaks of the RF signal ca 10-20 ps.
> The ringing can take up to tens of nanoseconds.
> Laser pulses have a FWHM of ca. 1 ps and repetition rate of 4.5 ns (216.67 MHz).
> Depending on the synchronization between laser pulses and RF signals, pulse height can be modulated.
  > If no RF signal is encountered or the laser pulse is perfectly synchronized no modulation occurs.
  > If the RF signal and the laser pulse are not synchronized a modulation occurs.
> Theoretical shot-noise level of 0.02%.



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BAM Box Generation 3

> 19" box rack-mount chassis.
> Compartment with fibre-optics actively temperature stabilized (2 temperature controllers) and passively humidity stabilized.
> Laser Diode Driver for laser pulse amplification (LDD board).
> Power management (FRED Board).
> Box management (TMCB Board).
  > Setting temperature controllers.
  > Bias Voltage for EOM.
  > Temperature and humidity sensors.
  > Control Optical Switch.
> Three linear stage for optical delay lines (OWIS).

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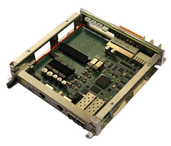
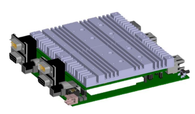
Electronics & Software, Standalone Boards



> Temperature Monitoring and Control Board (TMCB).
> General Purpose I/O Board used for Box Management
> 14 ADC and 10 General Purpose Inputs and Outputs (GPIOs).
> Interface for 2 temperature controllers.
> The same hardware is shared with the EOD project, but different interface to access register.
  > EOD direct connection via Ethernet.
  > For BAM connection via optical link and register mapped on a MTCA board.
> ChimeraTK package allows one software interface for both hardware configurations.

> Fuse Relay Board (FRED).
> Control and monitor up to 8 DC voltage channel.
> Individual fuse and current limitations.
> Connection based on telnet session and string commands to set the channels.
> Qt Interface also available.



> Laser Diode Driver (LDD)
> Carrier board and up to 8 mezzanines.
> Each mezzanine provides the current source for a Laser Diode
> Ethernet and CAN bus interface is available on each mezzanine
> Temperature controller for the laser diode
> Two operation modes: constant current or constant diode output power.
> Interface based on TCP/IP protocols with the usage of binary packages
> command lines and QT interface also available

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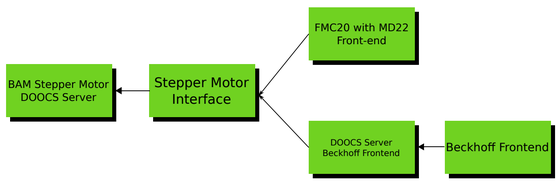
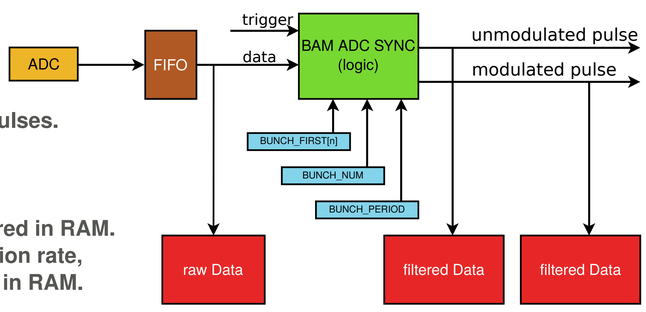
Electronics & Software, MTCA Boards

> FMC20 with DFMC-MD22.
> Carrier board with 2 mezzanines, each mezzanine can control up to two bipolar two-phases motors.
> Each mezzanine employs a driver and a controller chip from the company Trinamic.
> Old BAM systems use front-end control from the company Beckhoff.
> The software libraries had to be written to be transparent to these 2 hardware setups.



> FMC25 with DFMC-DSBAM [8].
> Carrier board with a dual mezzanine.
> 3 photo-diodes to couple with the laser pulses. and 4 16-bit ADCs.
> Attenuators and clock distribution chip.
> Firmware
  > 1024 ADCs samples at 216 MHz are stored in RAM.
  > Data filtered according to bunch repetition rate, bunch number and trigger delay stored in RAM.
  > Data transferred via DMA.
  > Uncalibrated arrival time for the beam based feedback [8].
> High Level Software
  > Control and Data Acquisition.
  > Elaborate and save the data in a persistent way.
  > Calibration of the system.
  > Slow feedback.



> All boards are custom-made and developed at DESY [9].
> The Software was written using C++11.
> For each Board (standalone or MTCA) a corresponding DOOCS [10] servers were developed.
> For the MTCA and the TMCB board the package ChimeraTK [11] was employed.

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