MTCA.4 Usage in Longitudinal Electron Beam Diagnostics at the European XFEL

Operation Principles & Data Processing

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Overview.
Longitudinal Diagnostics
Measurement Principles
Measuring Longitudinal Electron Bunch Properties

Detection Methods.

- **Electro-Optical Method, Spectral Decoding**
  - Encoding of the electric field density onto an optical Spectrum.

- **Measurement of the Longitudinal Profile.**

- **Ultra-relativistic Electron Bunch**

- **Electrical THz Field Detection and Direct Sampling**
  - Forcing the Electron Bunch to emit coherent THz radiation. Its frequency and intensity varies with the bunch length.

- **Measurement of the Compression Rate.**

- **Optical Spectrum**
  - Optical Sampling of a picked-up RF Voltage signal with 40GHz bandwidth.
  - Measurement of the Arrival Time. (relative to an optical time reference)

Measuring Longitudinal Electron Bunch Properties

Locations at XFEL.

MTCA.4 Special Diagnostics crate

Girder with different diagnostics downstream of bunch compressor B2

<table>
<thead>
<tr>
<th>Energy</th>
<th>125MeV</th>
<th>700MeV</th>
<th>2.5GeV</th>
<th>17.5GeV</th>
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MTCA.4 Usage for

BCM: Bunch Compression Monitor
BAM: Bunch Arrival Time Monitor
EOD: Electro-Optical Detection System

Individual Setups
Bunch Compression Monitor

Readout Electronics.

Formfactors @ 100pC

Shaper Board (2 channels direct)

ADC (16 Bit, 108MHz)

BCM.BC0
Det1: 90 GHz Antenna (Millitech)
Det1: 120 GHz Antenna (Millitech)

BCM.BC1 & BCM.BC2
Det1: DESY Pyro
Det1: DESY Pyro

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Bunch Arrival Time Monitor

Measurement Principle.

Converting the high precision timing measurement problem into a problem of low noise detection of a laser pulse amplitude.

Synchronised laser pulse train
216MHz repetition rate (time reference ≈3fs jitter)

Integrated Electro-Optic Device

Mach-Zehnder Modulator

Optical Fiber

Photodiode

Applied Voltage (DC Bias + RF Modulation)

RF voltage (40GHz Bw)
From the electron bunch field, used for laser pulse modulation

Modulation Voltage

1 Sample carries the Arrival time information.

216MHz clocked ADC each sample is one laser pulse.

achievable: 10fs resolution.

Direct optical Sampling of the 40GHz RF signal
Bunch Arrival Time Monitor

MTCA.4 Components

DFMC-DSBAM
Specialized Board for Interleaved Sampling Of Pulsed Optical Input Signals.
Dual FMC Adapter (HPC/LPC compliant)
Dual Channel SFP/SFP+
Clock Generation from Optical Signal + Delay Chip
Clock Output (SMA on Frontpanel)
Dual Input Channels, each:
800MHz Bandwidth Photodiodes (InGaAs)
2x ADC 250MSps, buffered differential input, 16bit
Customized board by DESY

2x DAMC-FMC25
FPGA for processing Virtex5 (XC5VFX70T /100T) for communication Spartan6
2x FMC slots (HPC); Zone3: D1.1/D1.2/D1.3
Available at CAENels.

DFMC-SFP4
Dual- & Quad Channel SFP/SFP+ Adapter
LPC FMC Module (HPC compliant)
Vddj 1.5V-3.3V
Available at CAENels.
Info: FMC-4SFP+

DFMC-MD22
Dual-Channel Stepper Motor Driver
each ch. 1.8A 12V or 24V (with ext. Power supply)
Support for switchable EnDat2.2 or ABN encoder
Available at CAENels.
Info: FMC-MOTDRV22

DAMC-FMC20
FPGA for processing Spartan6 (LX150) for communication Spartan6 (LX45)
2x FMC slots (LCP + HPC); Zone3: D1.0
Datasheet: DAMC-FMC20
Electro-Optical Detection

Measurement Principle.

Chirped laser pulse:

\[ \rightarrow \text{Defined relation between time and frequency} \]

Raw signal from 5 bunches each line averaged and corrected with laser chirp

Stacked data
Electro-Optical Detection

Electronics – Laser Synchronization.

System now fully integrated in 19”:

- MTCA.4 system for:
  - Detection and controls: Struck ADC + downconverter RTM
  - Piezo driver: MTCA-RTM PZT4 for fiber stretcher and linear piezo stage
  - RF-front-end: temperature stabilized in Special Diagnostics Module chassis (SDM, together with LDDs and laser temperature control)
- Yb fiber laser and amplifier

SmarAct SLC-1730 piezo stepper for coarse tuning
Evanescent Optics fiber stretcher 915B for fast synchronization
Electro-Optical Detection

Electronics – Spectrometer & Signal Processing.

HOLD

High-speed Optical Line Detector

(Kalypso + Gotthard Carrier + optical fiber + MFMC readout card)

Currently 256 pixel array from Si or InGaAs with 1MHz line rate

Ready for higher readout speed with additional optical links to the MFMC readout card
Experience from Operation.

First Results.
Machine Stability & Feedback Systems

BCM.

Bunch Compression Monitor

Information is used in standard operation of the European XFEL.

All 3 BCMs are incorporated in slow feedback loops to stabilize the bunch compression state at different locations of the accelerator.
1) Injector Laser phase jumps:
Phase jumps of photo injector laser synchronization lead to \( \approx 300 \) fs arrival time jumps at the injector BAM.

2) Local LLRF oscillator L1:
(A): Arrival time jitter of 100 fs in the injector is 'compressed' to 50 fs after BC0. However, it increases after BC1 and BC2.
19/09/17: Local LLRF system (A2) of L1 has been fixed.
(B) Arrival time jitter after BC1/BC2 now 30-40 fs without intra bunch-train feedback.
EOD signal from 1500 consecutive bunches (1st of each train) ...and their arrival time measured with EOD and BAM

Arrival time jitter usually 30fs (after last compression stage)

Single shot EOD traces and fitted Gaussians from the same bunch train

Arrival time and bunch length from fitted Gaussians for 10 bunches.
Summary

- All systems installed and hardware operational
- Not all systems commissioned yet
- Slow feedback on BCM in operation
- Slow feedback on BAM needs commissioning time
- Server and high level software development needed for EOD and intra train feedback
Thank you for your attention!