MTCA for the Optical Synchronization Systems at XFEL and FLASH

for Beam Diagnostics, Laser Synchronization, Reference Distribution

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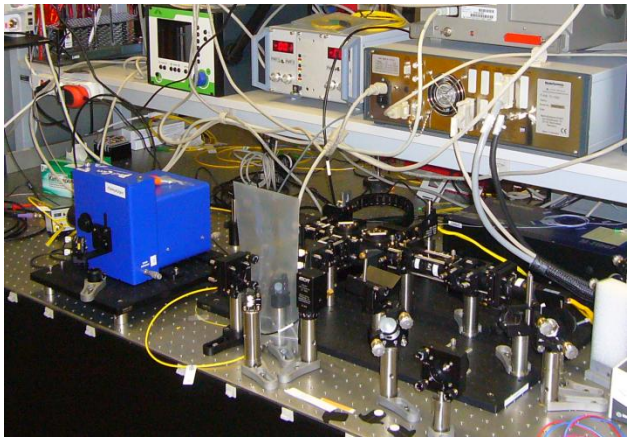
SEI Tagung Geesthacht
HZG, 10th March, 2014

HELMHOLTZ ASSOCIATION

DESY

Overview

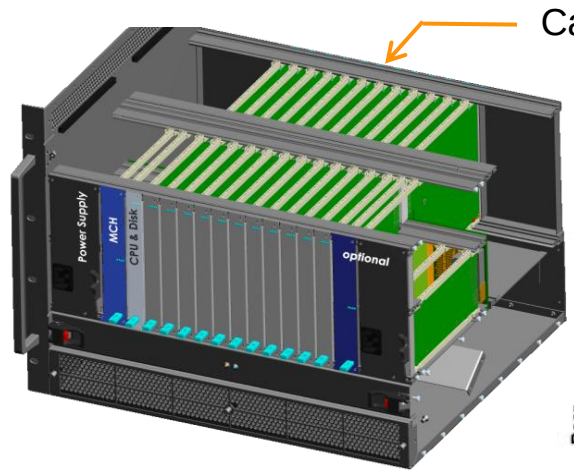
- MTCA.4
  - Crate Standard
  - Helmholtz Validation-Fond (HVF)
- Introduction
  - Optical Synchronization System
  - Fiber Link Stabilization
  - Principle System Layout
- MTCA Setups
  - Link Control: Building Blocks
  - Crate Topology
  - Laser Synchronization
- Conclusion

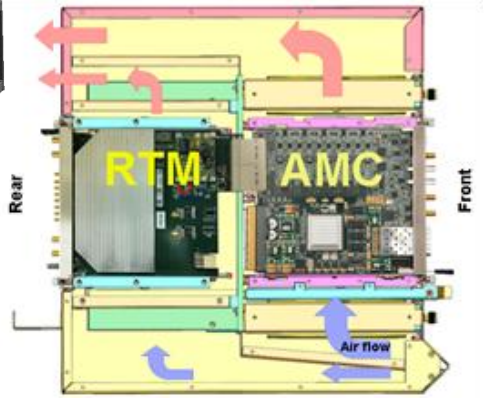


MTCA.4 Crate Standard

- Development partnership „xTCA for Physics“ (38 partner): 03/2009
  - **Research insitute:** SLAC, FNAL, IHEP, IPFN, ITER, DESY
  - **Industry:** connector-, board-, crate-, system manufacturer
- Ratification PICMG 2011 (http://www.picmg.org)
  - **M**icro **T**elecommunications **C**omputing **A**rchitecture .4 (MTCA.4)

- Modular + modern architecture
  - Reusability + PCIe + Ethernet
- High availability
  - Redundant power and fan optional
  - Well defined remote management
- High digital performance
  - Very low analog distortions
  - 4 lanes PCIe: 400 MB/s ... 3.2 GB/s

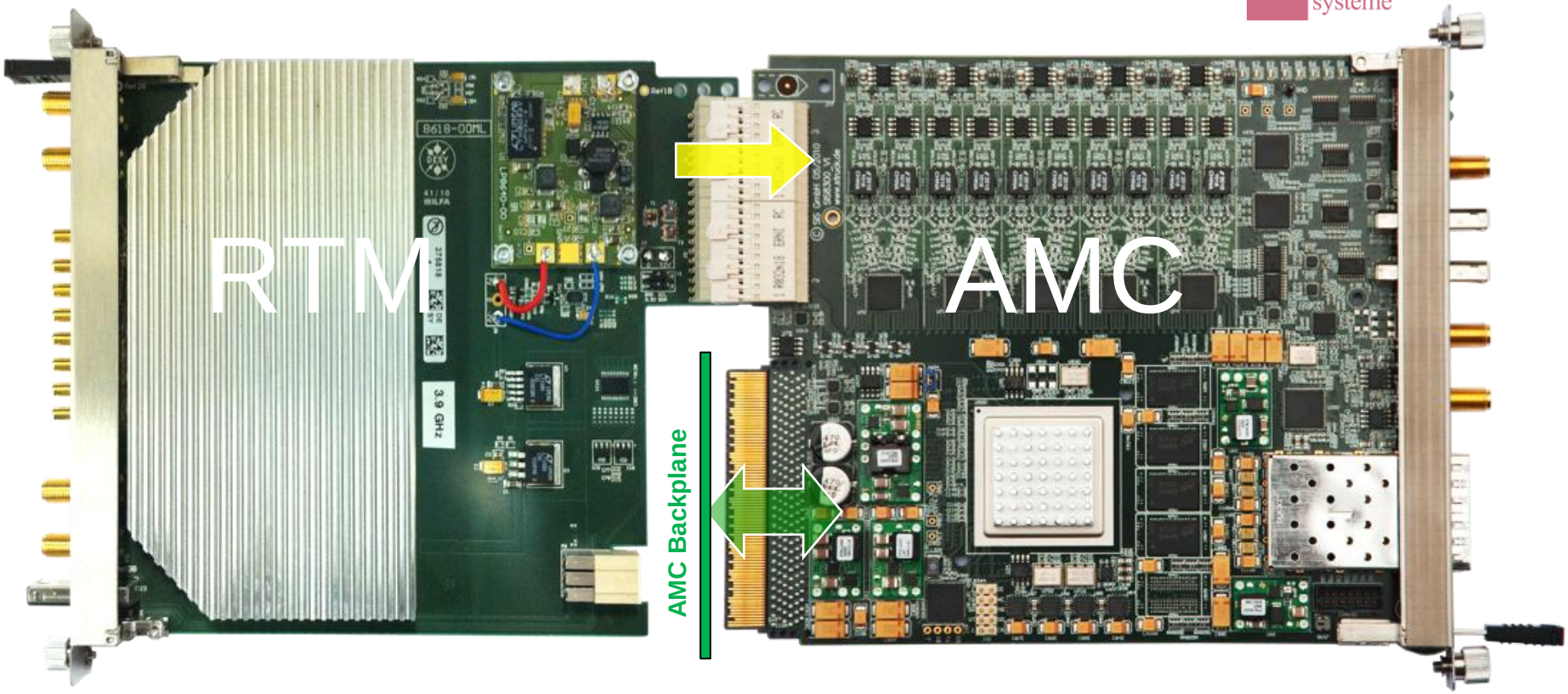




Example: Signal Conditioning and Digital Processing

- High frequency Down-Converter
  (Application specific, DRTM-DWC10)
- Multi-Channel fast ADC Digitizer
  (Universal board, SIS8300)

struck innovative systeme



- 10 channel field detection
  (1.3GHz, …, 3.9GHz)
- Resolution, 0.003%, 0.003deg, < 10fs

- 10 channel ADCs (125Msps, 16-Bits)
- FPGA pre-processing partial cavity vector sum
- Low latency links via MTCA-backplane

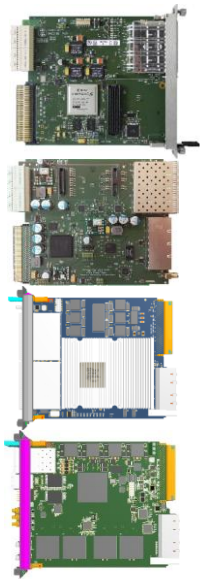
DESY

MTCA.4 Developments at DESY and Industry . . .

Rear Transition Modules

- Machine Protection System
- DRTM-AD84
  - 8 ch ADC 95 MSPS, 16bit
  - 4 ch DAC 16 MSPS, 16bit
- Test RTM
- Coupler Interlocks
- BPM Readout
- 2 ch APD Pulse Stretcher
- Beam Loss Monitors
- Toroid protection / readout
- Wire Scanner
- Clock & Trigger Contr. for Exp.

Advanced Mezzanine Cards



- DAMC2 - Xilinx Virtex 5, FMC carrier, 4 SFPs (100 pcs in production)
- X2Timer - ps Clock and Timing Distrubution
- DAMC-TC7 (in production) - Kintex 7 FPGA, 16Gb DDR3 DRAM, 8xSPF+(12.5GBPS), PCIe x4 gen. 3 (8GBPS), 2x GbE (1 GBPS).
- DRTM-VM2 (in production) - 2 channel Vector-Modulator, 1.3GHz
- DAMC-DS800 - 8/4 channel ADC (12-bits, 800/1600Msps, 2.7GHz)
  - 2 channel DAC (16-bits, 160Msps, 400Msps)
  - Xilinx Virtex 6, DDR Memory, 2 SFPs

. . . and more and more from Industry . . . http://mtca.desy.de

Crates
PS-1138/…
PM Wiener
SIS8300/8900
AM900
uLOG (RTM)
ADQxxx
MCH
TAMC900
ADIO24 . . .

struck innovative systeme
powerBridge Computer
TEWS TECHNOLOGIES
Schroff®
ELMA Your Solution Partner
CONCURRENT TECHNOLOGIES
kontron
Telkoor Power Supplies Ltd.
vadatech inc. THE POWER OF VISION
SP Devices Signal Processing Devices
W-IE-NE-R Plein & Baus GmbH
N.A.T.
Instrumentation Technologies

DESY

MTCA.4 hardware platform – availability: Crates –

12 Slot

6 or 7 Slot

Elma

Schroff

MTCA.4 for Industry (HVF-0016)

To foster industrialization of MTCA.4 :

- DESY designs -> industry (licensing)
  - Cost and quality improvements
  - New modules to complete portfolio
- Supporting industry to
  - Add missing modules
  - Improve EMI with test environments and shielding
  - Gain new MTCA.4 applications in more markets
- Support for institutes and industry
  - Consulting: Help to start with MTCA
  - User guide and Web Site
  - Organization of workshops and exhibitions

→ Technology Transfer Division / DESY

Project duration: mid 2012 … mid 2014

Work Packages of HVF

AP 3.1 Support and consulting

FAQ, Helpdesk
Request Tracker system
Hotline
Available product lists / evaluations
Templates for AMC/RTM management & MMC firmware

AP 3.2 MTCA.4 user guide

Book published DESY/N.A.T.

AP 3.3 Product marketing & information

2x MTCA workshops
Support for interests groups / task force / discussion forum
Marketing of industrial exhibitions
Road show through HGF
Webpage

MTCA Training:
http://mtca.desy.de/support/training

Training Schedule

Date
29 April - 30 April 2014 09:00 to 17:00
24 June - 25 June 2014 09:00 to 17:00
29 July - 30 July 2014 09:00 to 17:00

The **3rd MTCA workshop for industry and research** will be held from 9th December to 11th December 2014 in Hamburg

Webpage URL http://mtca.desy.de/

Workshop URL http://mtcaws.desy.de/

- Goal of the workshop is to foster the MTCA.4 standard in further industrial applications and in research projects. The first half-day will be dedicated to people new in MicroTCA. A tutorial given by experts will give an overview of the MTCA.4 standard. Talks and discussion of the remaining one and a half days will cover lab reports and presentation from industry
- Program:
  - Status of projects and applications their experience and requirements
  - Availability of existing and planned MTCA modules
  - Discussion of possible improvements
  - Finding common interfaces and sharing of hardware, firmware and drivers
  - Further topics: management, clocks and triggers, data links, backplane, EMI, Hot-plug, drivers, …
- Exhibition: Presentation of modules and systems from industry and research

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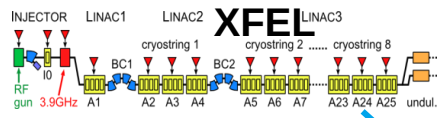
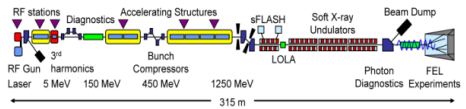
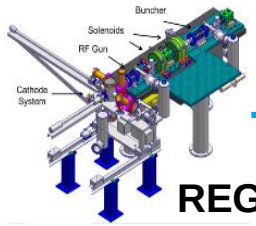
Single Cavity LLRF Systems in MTCA.4 Europe / Worldwide

> Involvement in Facilities:

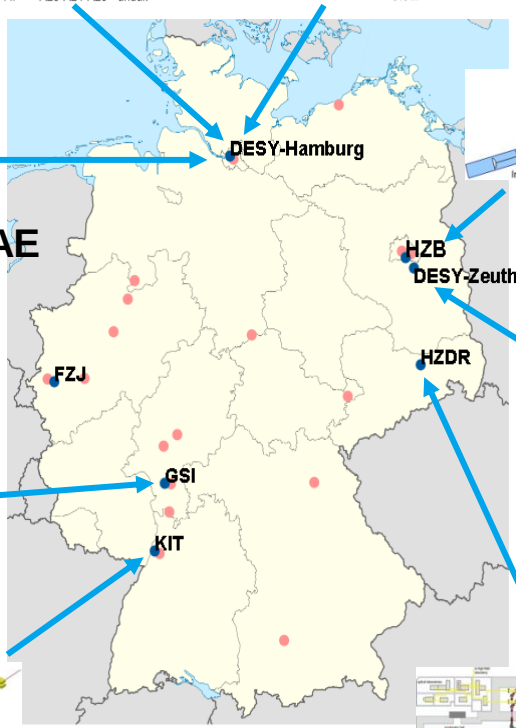


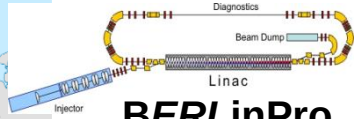


FLASH



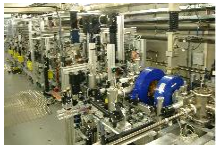
REGAE





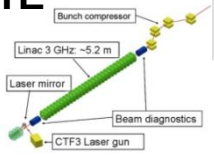
BERLinPro

PITZ



FAIR

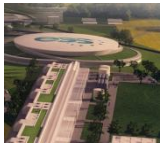
FLUTE



ELBE

> … and in Europe:

✓ ESS EUROPEAN SPALLATION SOURCE — Total budget ~ 1,47B€ Construction: **2013-2019**



✓ iter — the way to new energy — Total budget ~ 1,47B€ Construction: **2013-2019**

polfel

✓ AMPEGON

STFC ASTeC

TARLA, . . .

> Worldwide:

✓ SLAC NATIONAL ACCELERATOR LABORATORY

✓ KEK HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

PAL POHANG ACCELERATOR LABORATORY

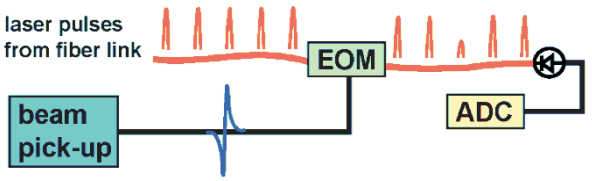
. . .

DESY

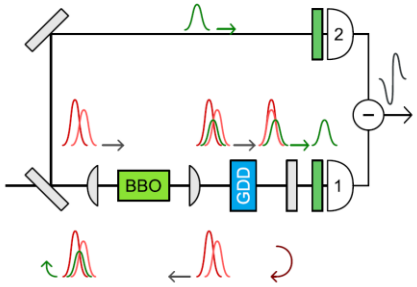
Introduction – Optical Synchronization System

Provide a global reference for the synchronization of timing-critical (fs-level) subsystems of the accelerator

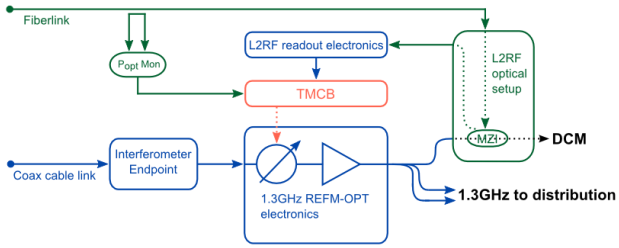
- Bunch arrival time measurements (BAM)
  - These monitors are used by the beam-based feedback to synchronize (= stabilize) the arrival time of individual bunches to the optical reference



- Laser synchronization (L2RF & L2L)
  - Injector-, Seed-, and Pump-Probe lasers (their repetition rate and phase of the pulse train) are synchronized to the optical reference.

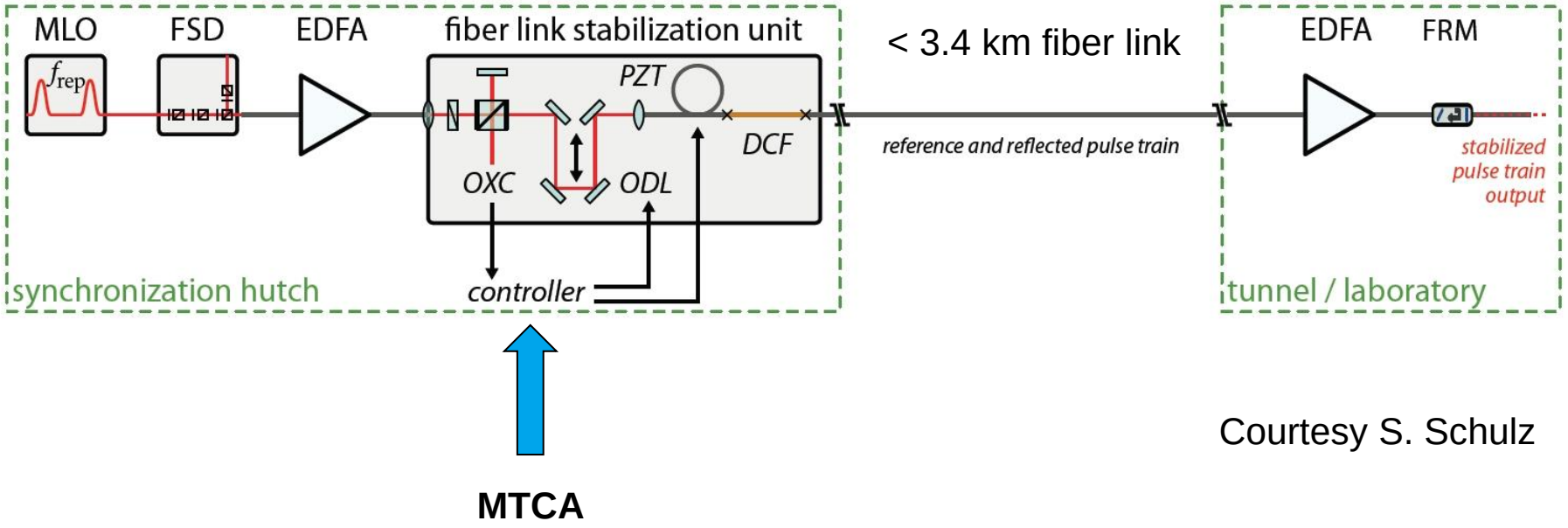


- RF synchronization for LLRF-reference (L2RF)
  - The 1.3 GHz reference input for from the main drive line is synchronized to the optical reference in the REFMs



Introduction – Fiber Link Stabilization

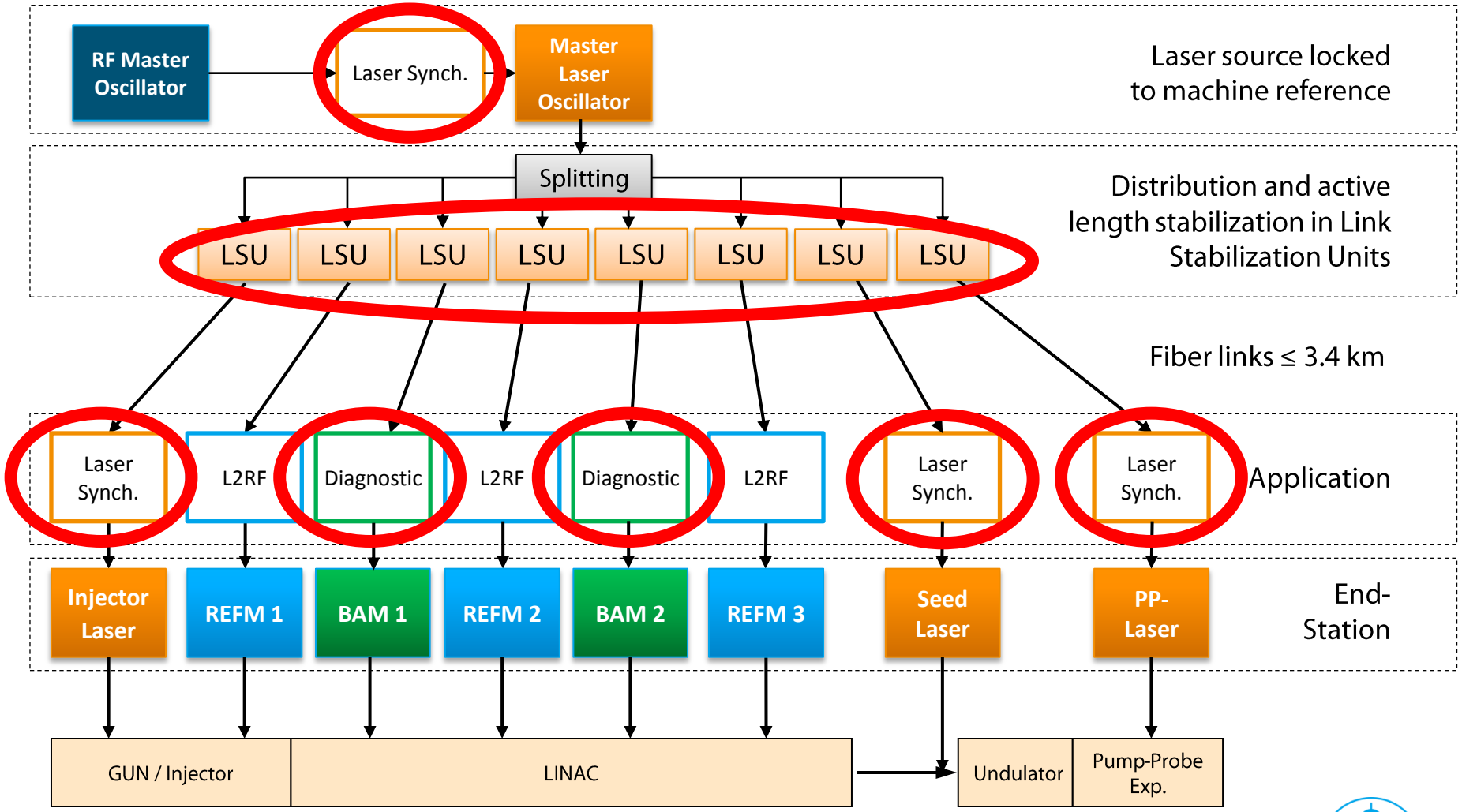
- **Long- and short-term phase-stable optical pulse train has to be distributed along ≤ 3.4 km**
- **Active fiber link length stabilization**



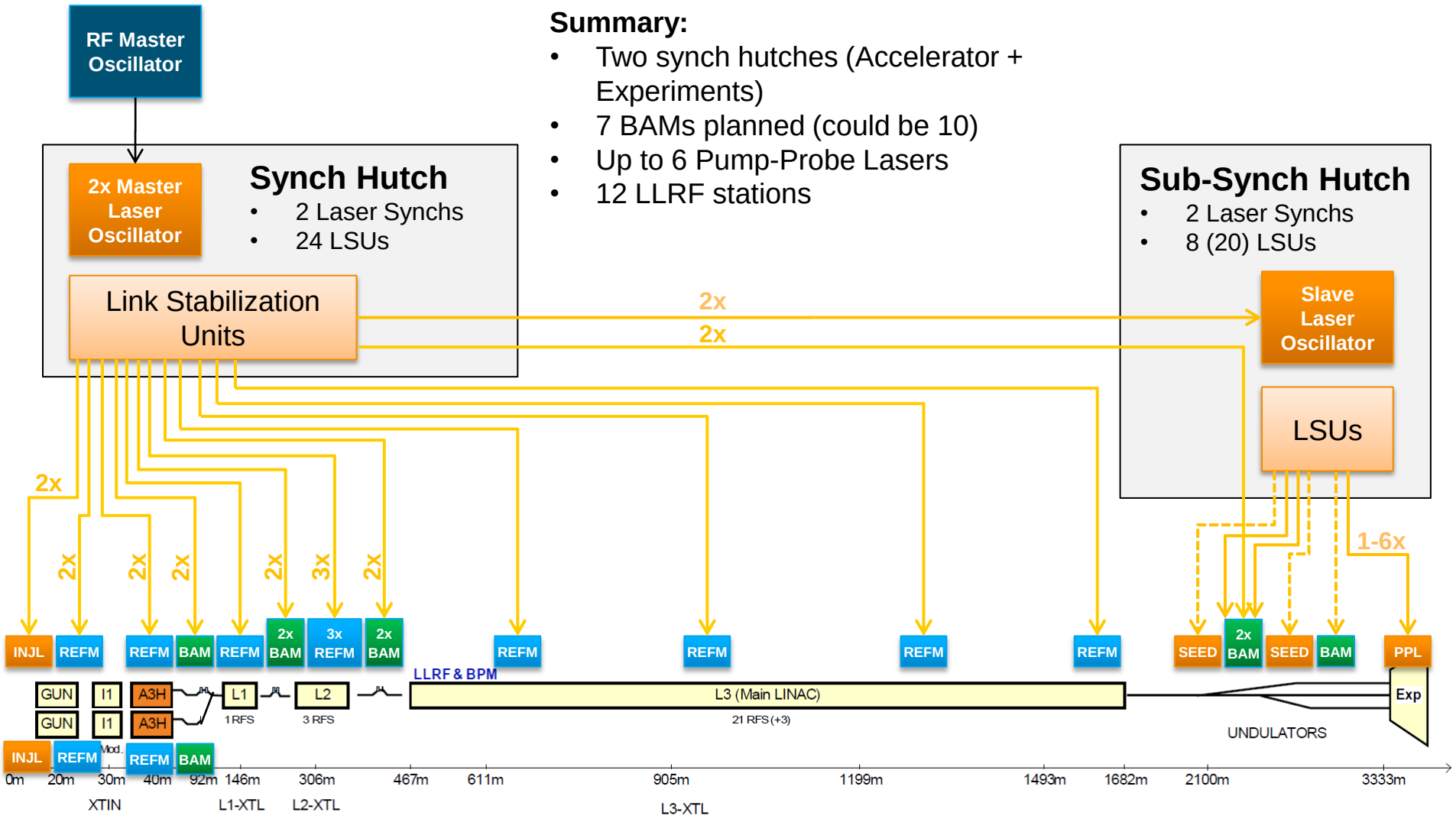
Courtesy S. Schulz

Introduction – Principle System Layout

The reference timing information is encoded in the precise repetition rate of an optical pulse train



Introduction - Optical Links at the European XFEL



MTCA integrates many components in a compact form factor

Now: Electronic Infrastructure for Opt. Synch @ FLASH (2 MLOs, 16 LSUs)

- 4 x 42 HE Racks
- 5 x VME Crates (ADCs, DSPs, DACs, BAM-Readout, LDDs)
- 6 x PLC (Beckhoff Step-Motors, GPIO, Temperature, Monitoring)
- 18 x Piezo-Driver
- 6 x Vector Modulators

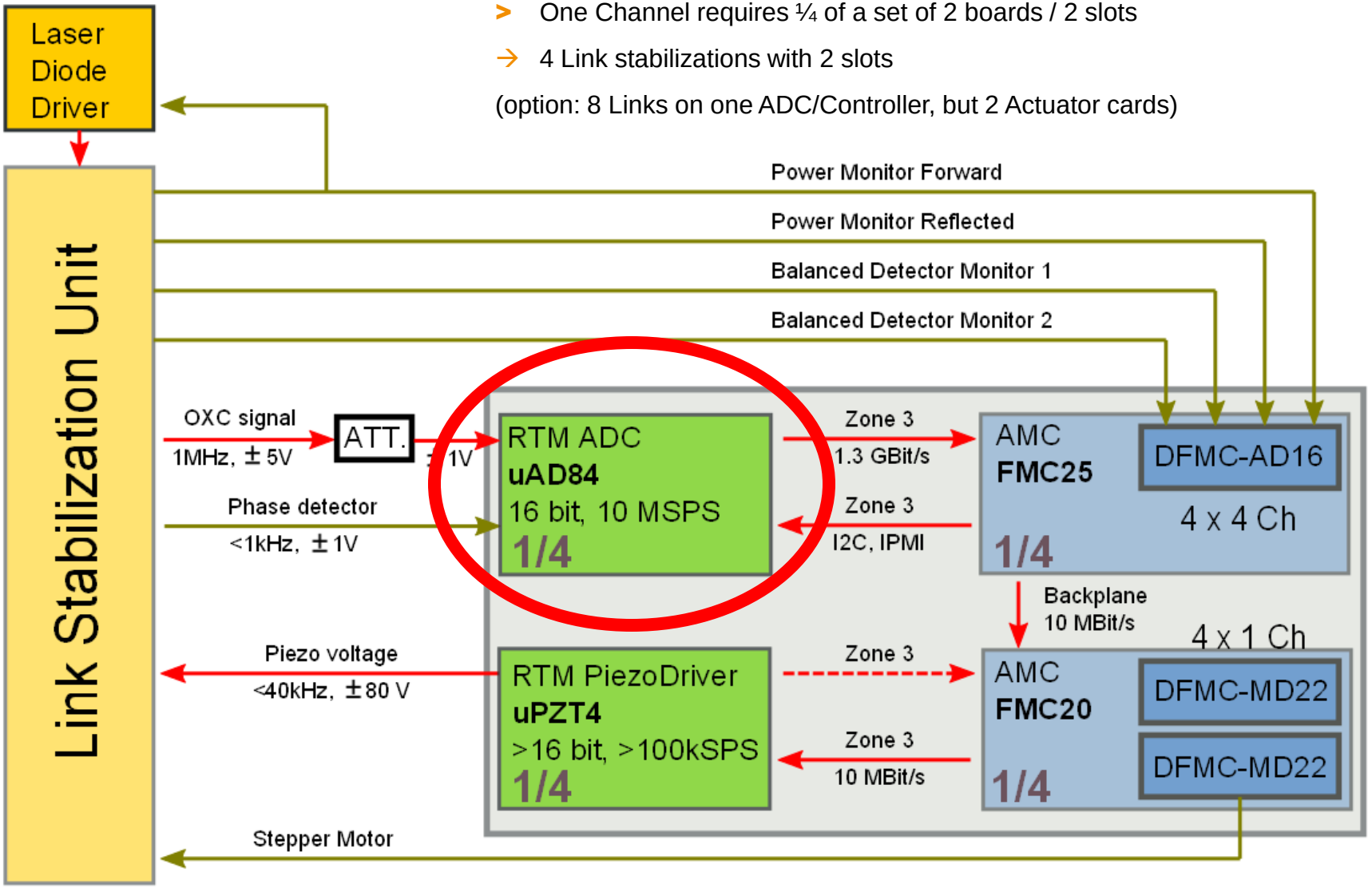
Future

- 1 x 42 HE Racks
- 3 x MTCA Crates

MTCA Setups – LSU Control: Building Blocks

- One Channel requires ¼ of a set of 2 boards / 2 slots
- → 4 Link stabilizations with 2 slots

(option: 8 Links on one ADC/Controller, but 2 Actuator cards)



MTCA Setups – LSU Control: Building Blocks

Digitizer-RTM

DRTM-AD84

- 8 x ADC:
  - 16 bit
  - 10 MSPS
  - 50 Ω or 1 kΩ
  - 90 MHz (2 MHz)
  - ±1 V
- 4 x DAC
  - 16 bit
  - 1 (16) MSPS
  - ±1 V / ±3 V @ 50 Ω
- Zone 3: D1.0 / D1.1

Developed by Robert Wedel, Desy

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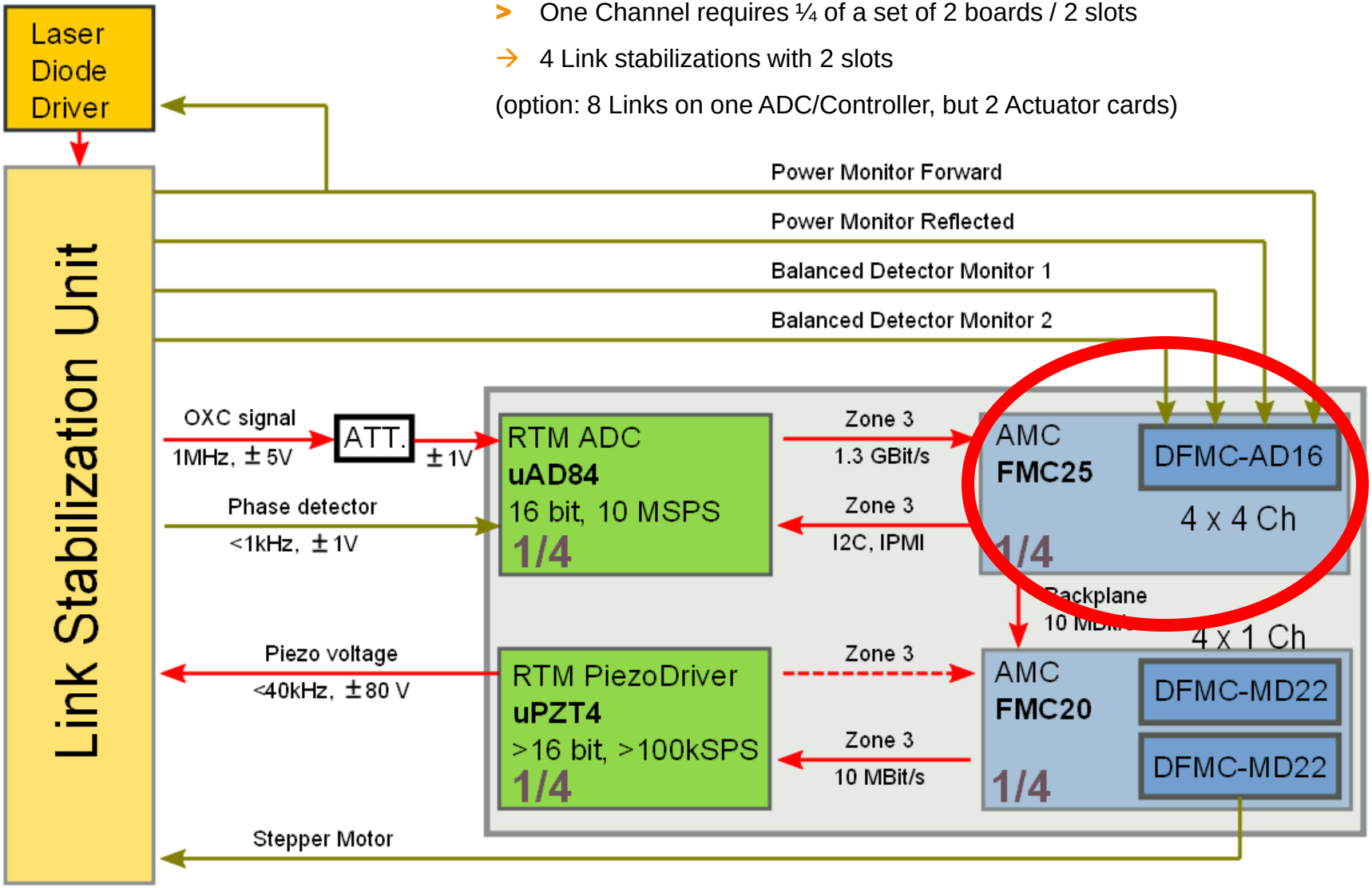
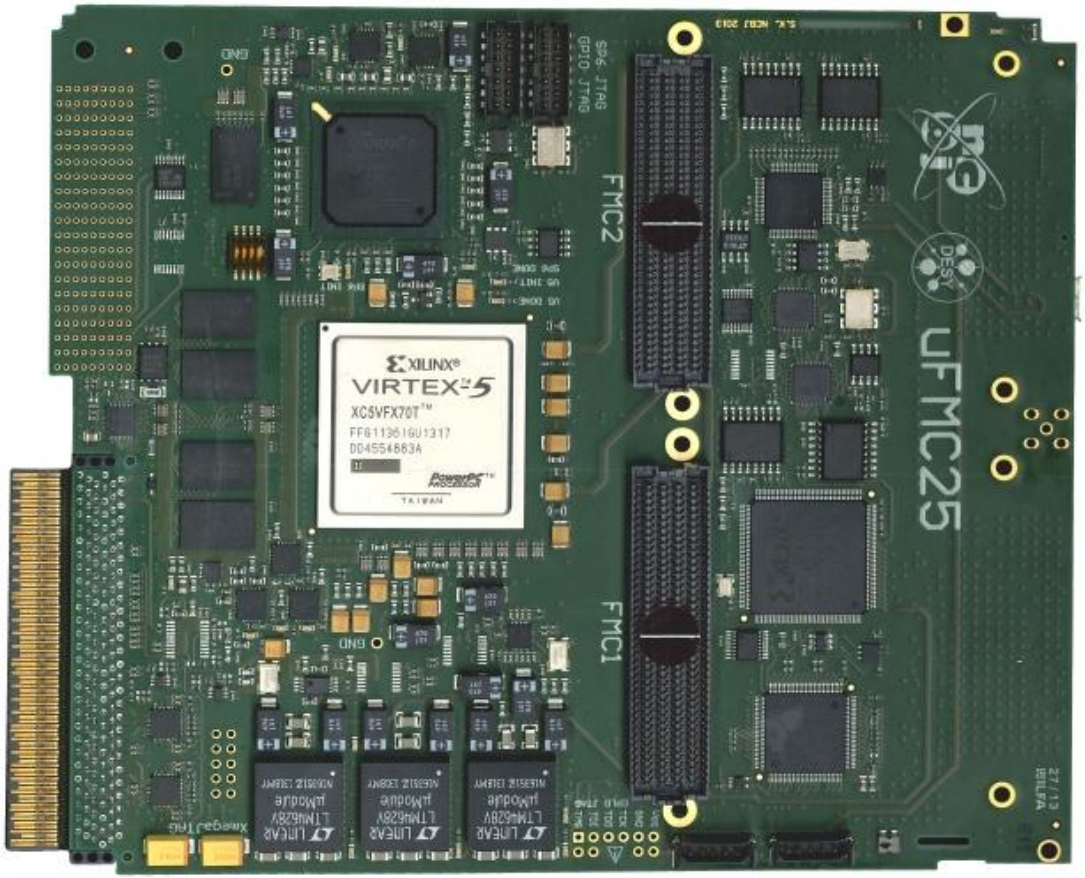


MTCA Setups – LSU Control: Building Blocks

Controller-AMC

DAMC-FMC25

- Processing:
  - Virtex 5
- Communication:
  - Spartan 6
- 2 x FMC (HPC)
- Zone 3: D1.1 / D1.2 / D1.3



Developed by Jaroslaw Szewinski, NCBJ

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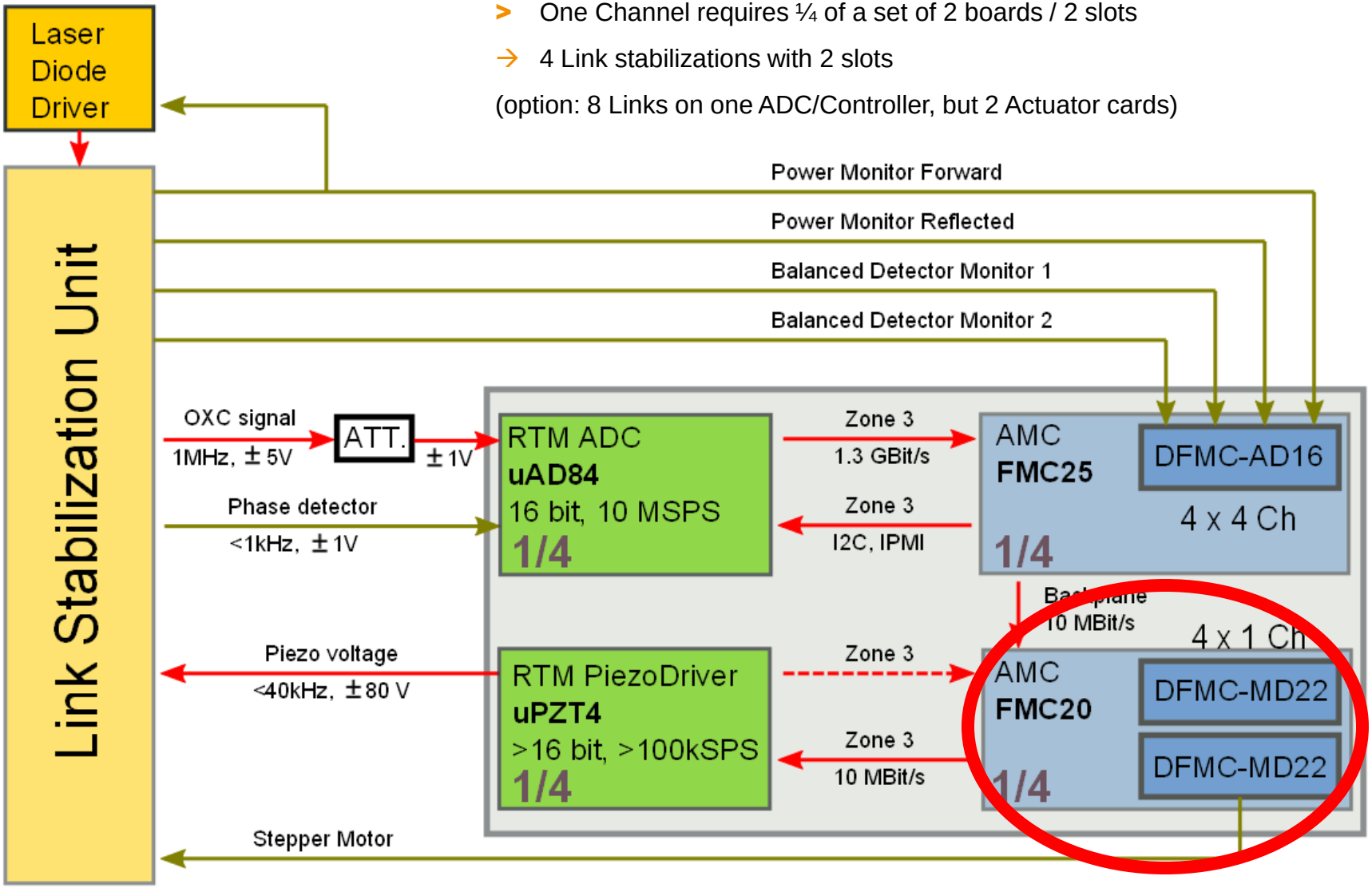
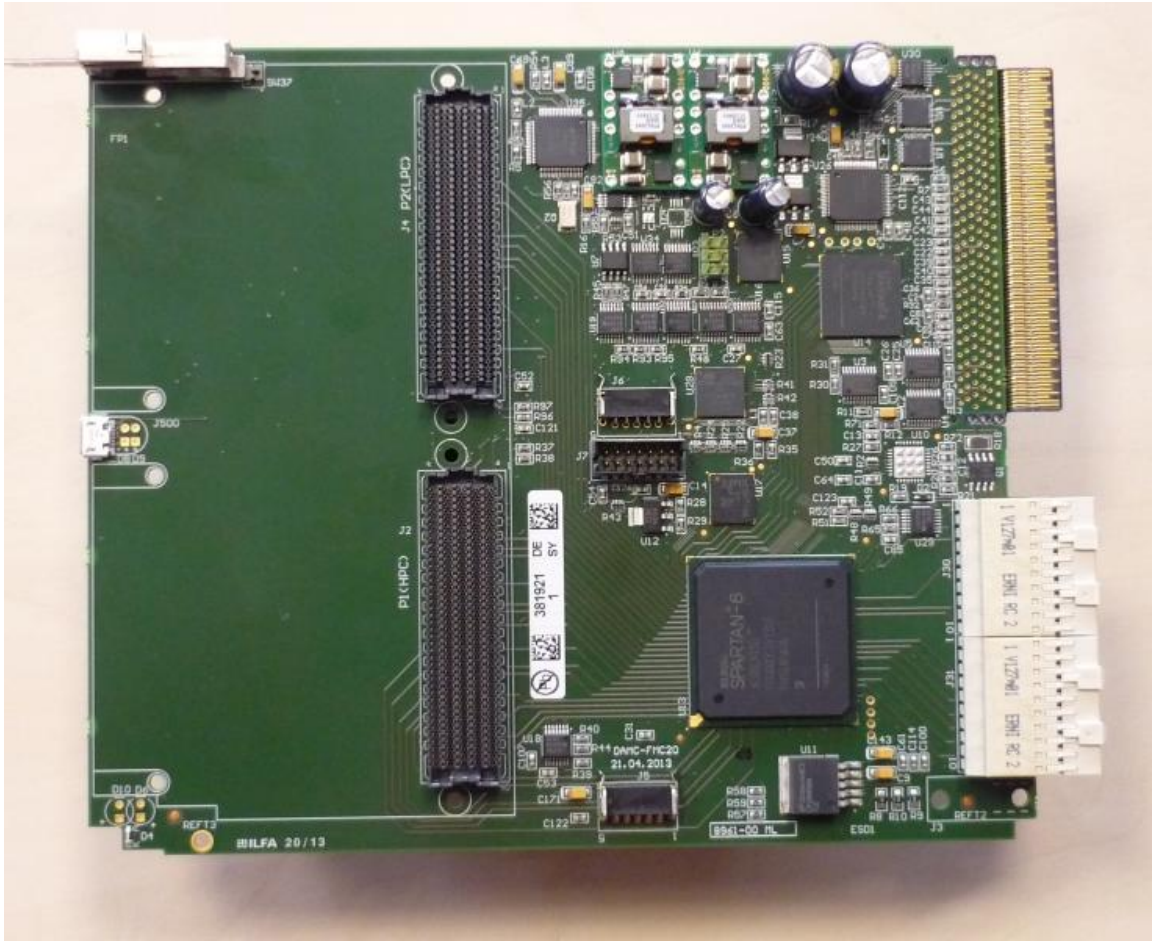


FMC Carrier-AMC

DAMC-FMC20

- Processing:
  - Spartan 6 (LX150)
- Communication:
  - Spartan 6 (LX45)
- 2 x FMC (HPC/LPC)
- Zone 3: D1.0
- Licensed to EicSys



Developed by Hans-Thomas Duhme, Desy

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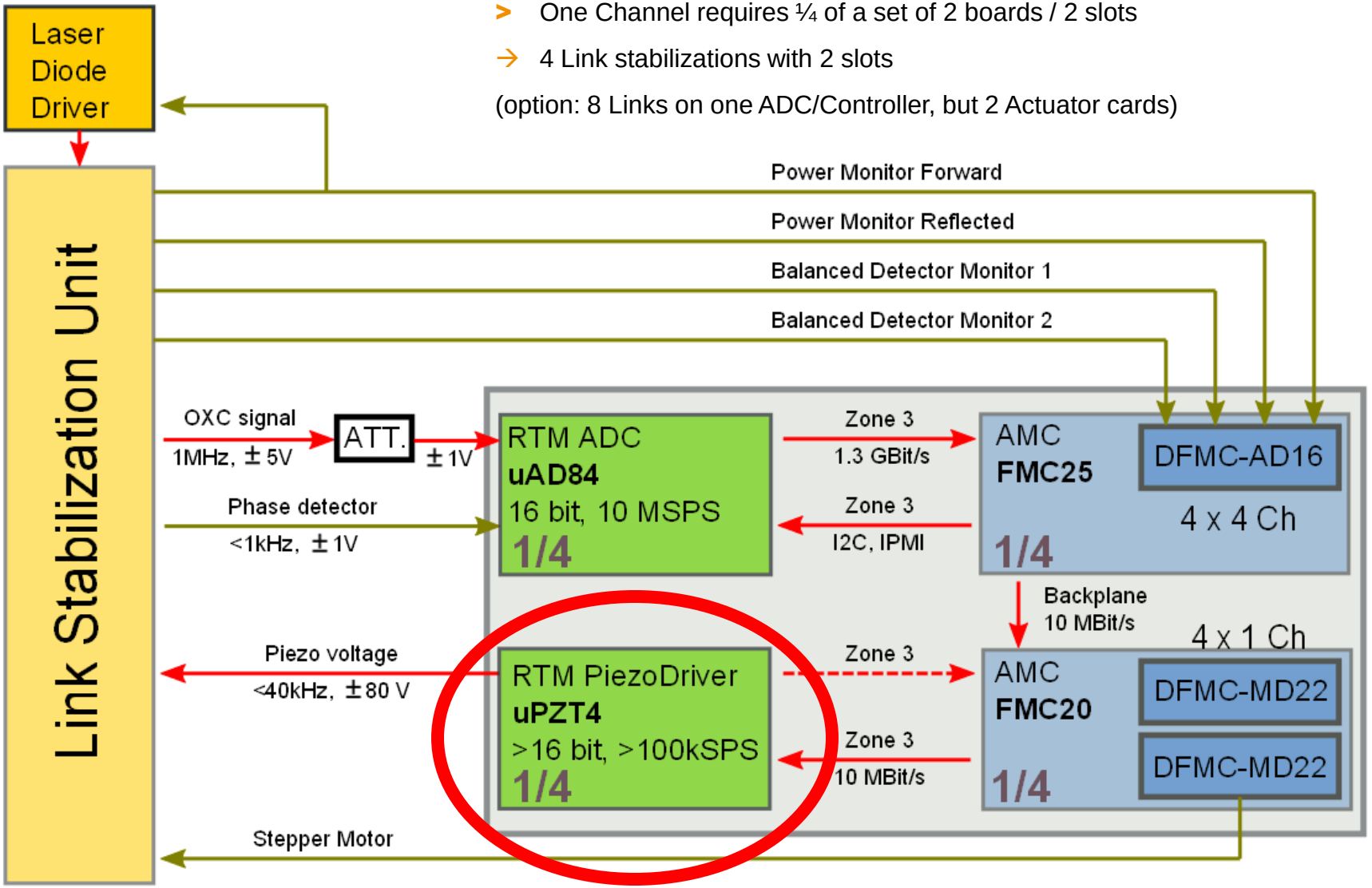
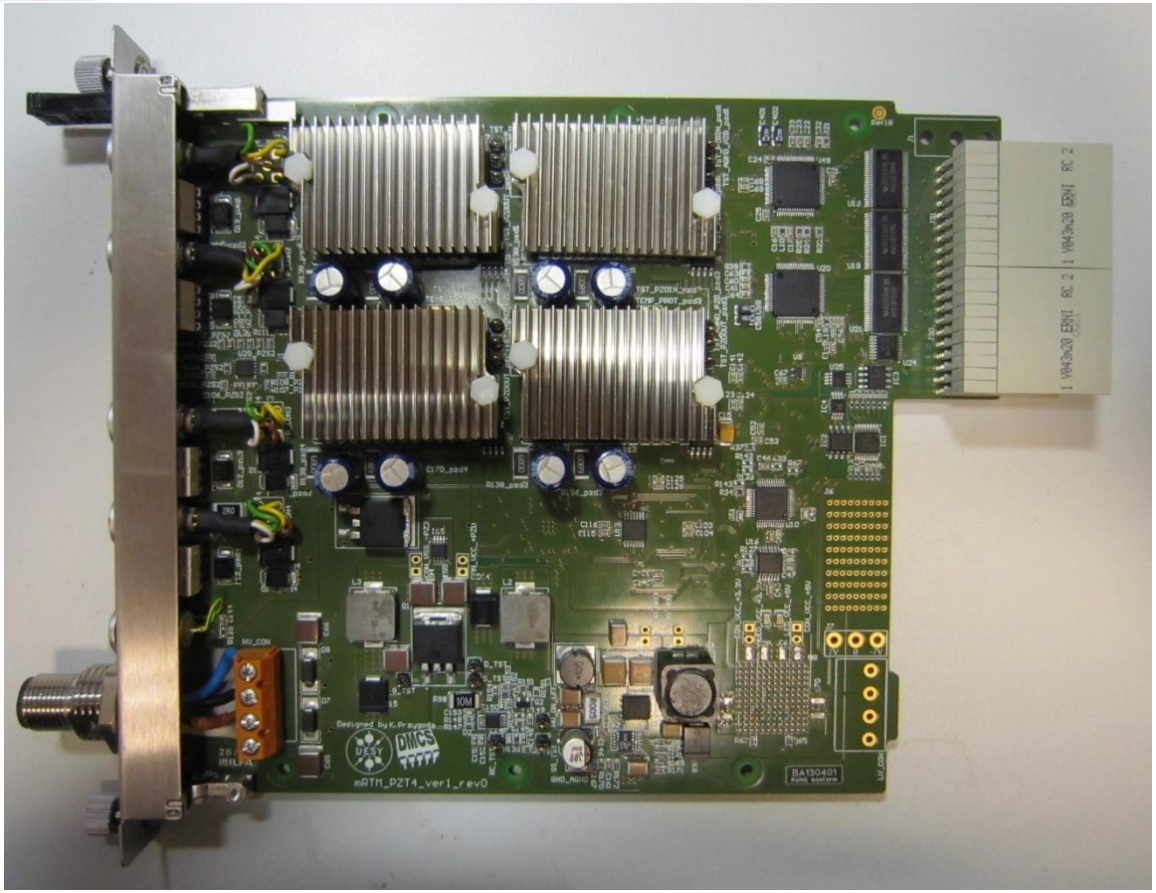


Piezo Driver-RTM

DRTM-PZT4

- 4 x Channel
- On-board ±85 V PS
- On-board DACs
- Metal-cover
- Zone 3: D1.0 / D1.1
  D1.2



Developed by Konrad Przygoda, DMCS

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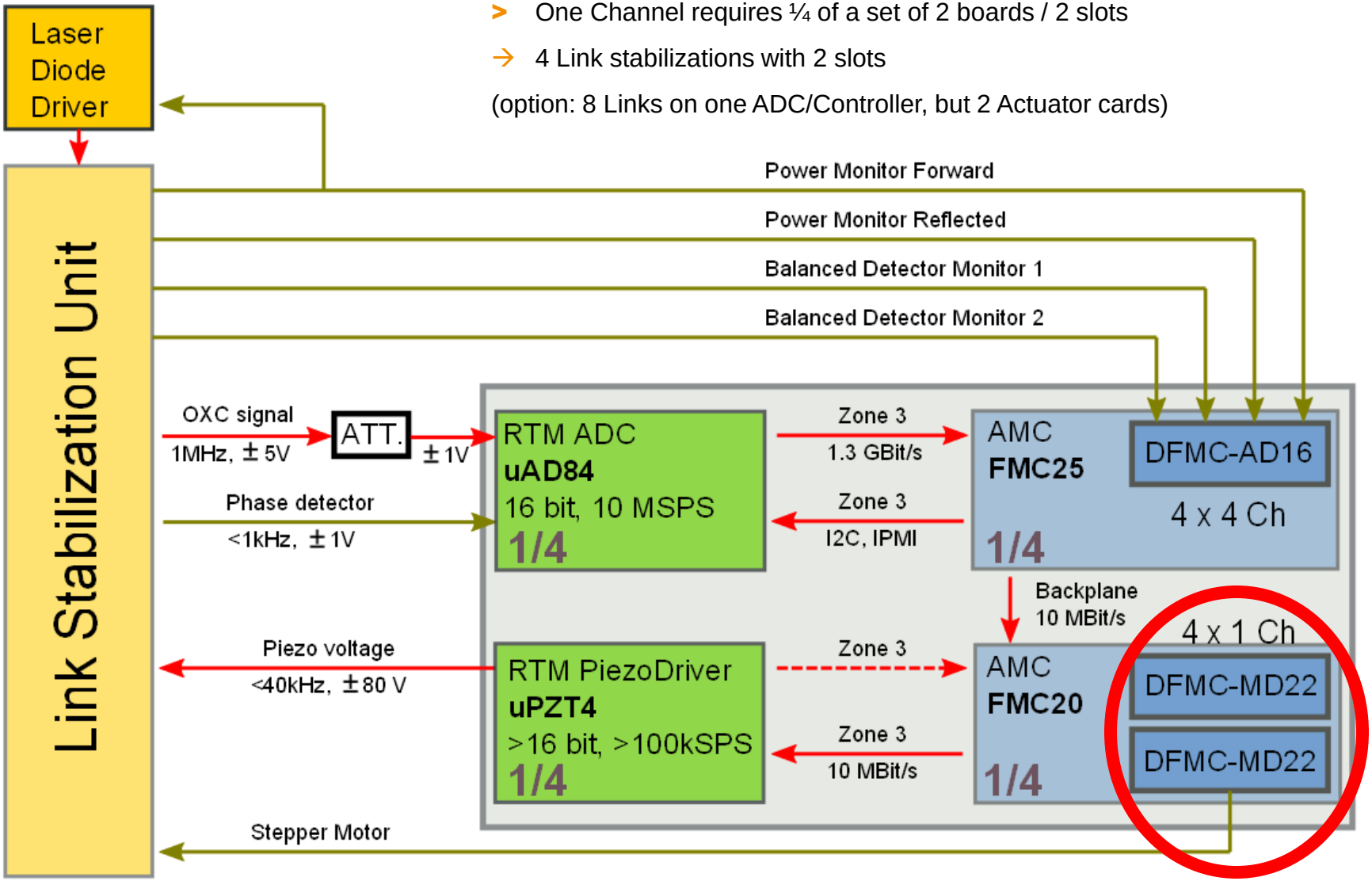
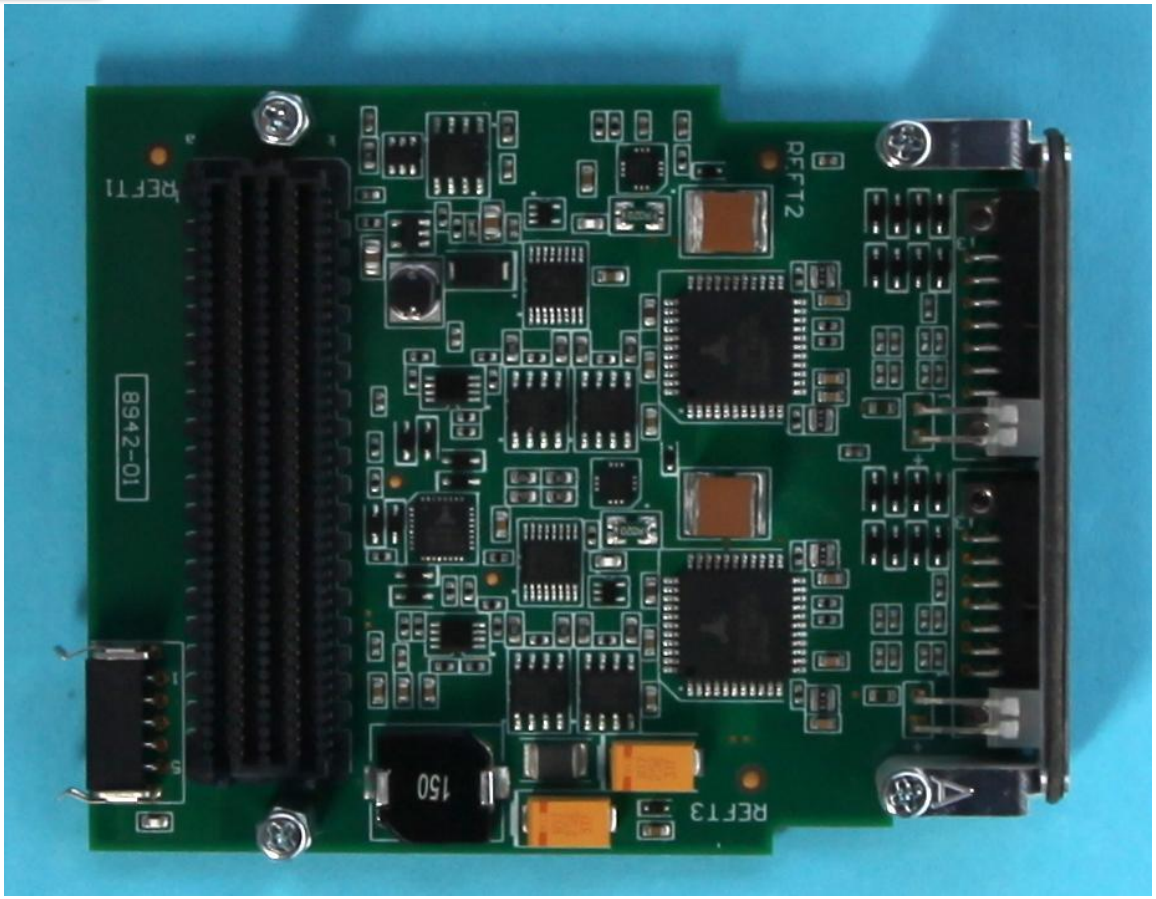


Motor Driver-FMC

DFMC-MD22

- Stepper Motors
- 2 x Channel
- End switch readout
- Encoder readout



Developed by Robert Wedel, Desy

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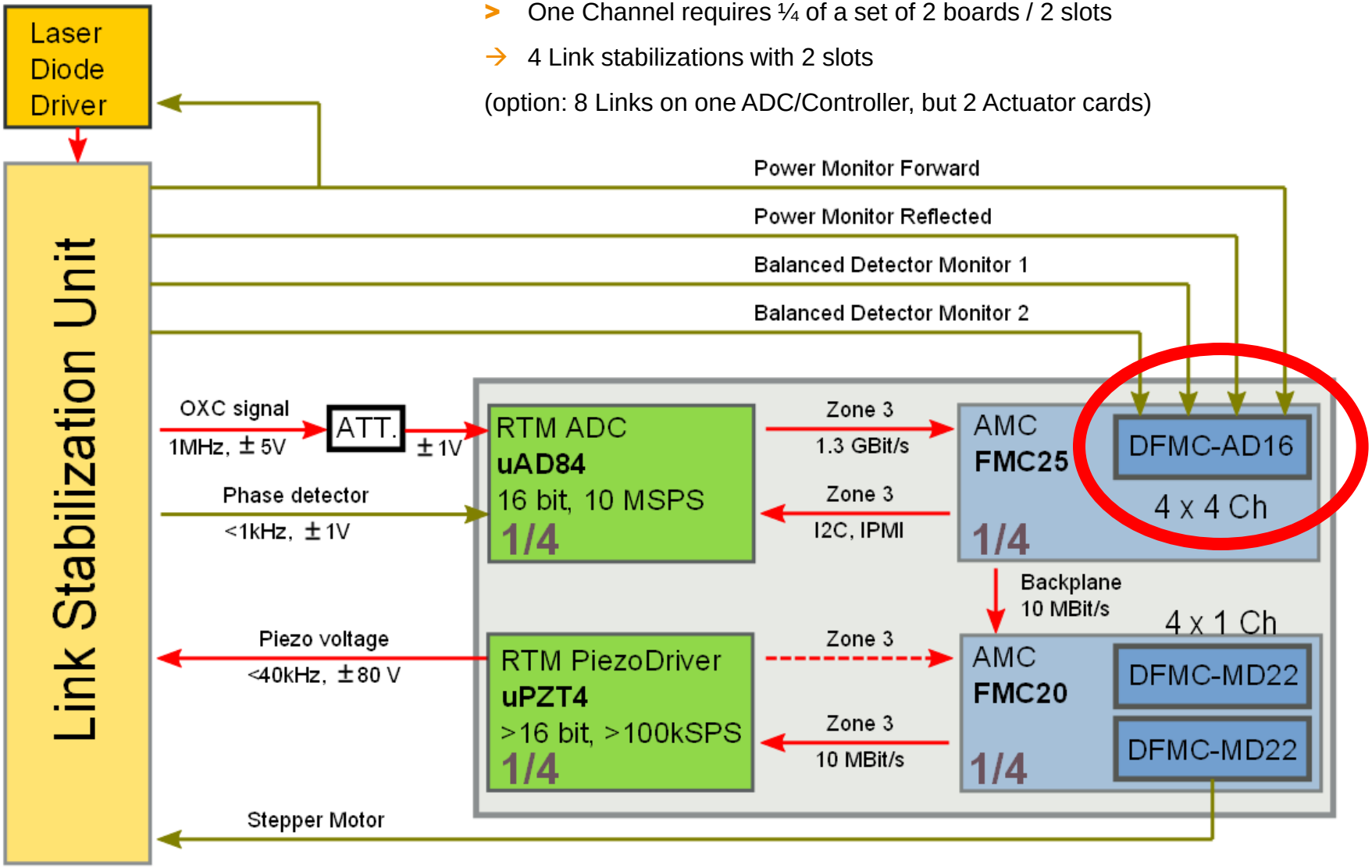
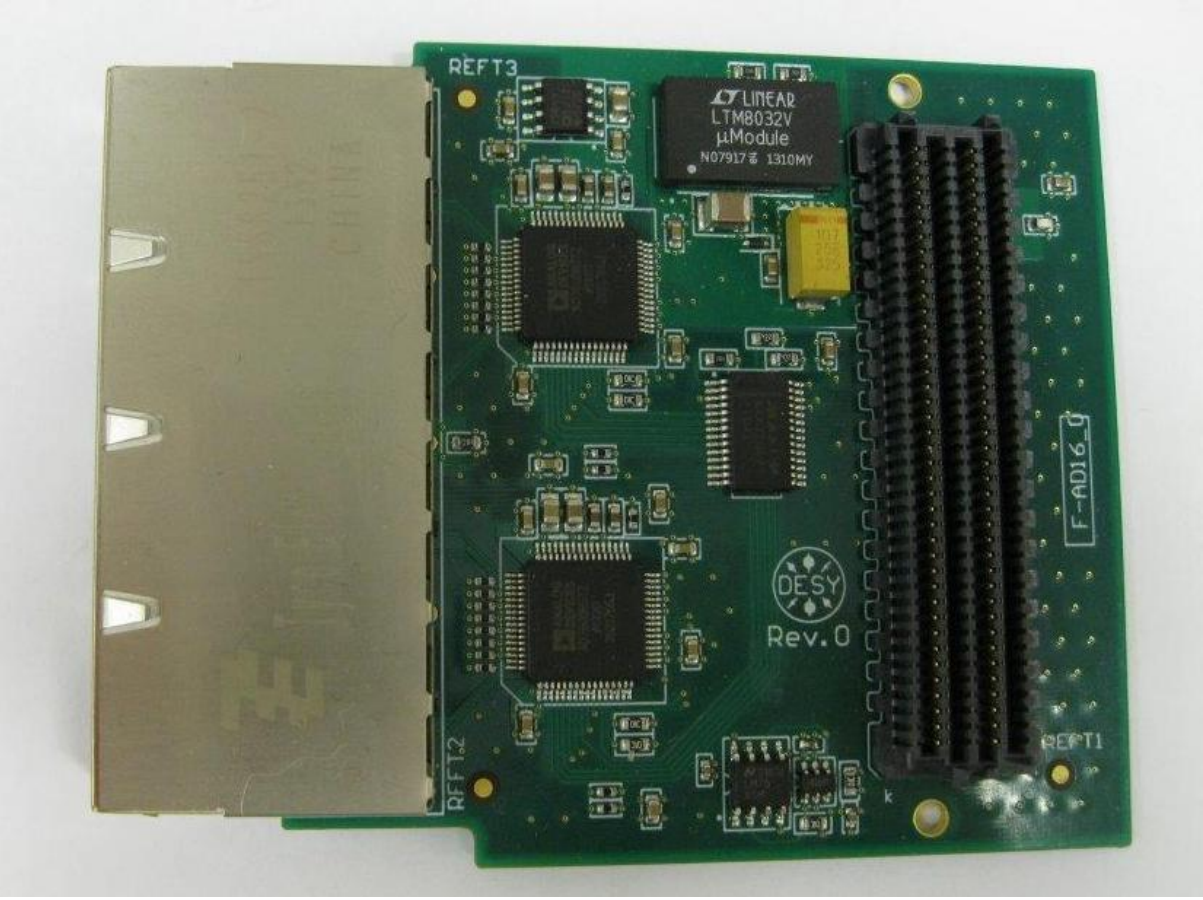


Monitor ADC-FMC

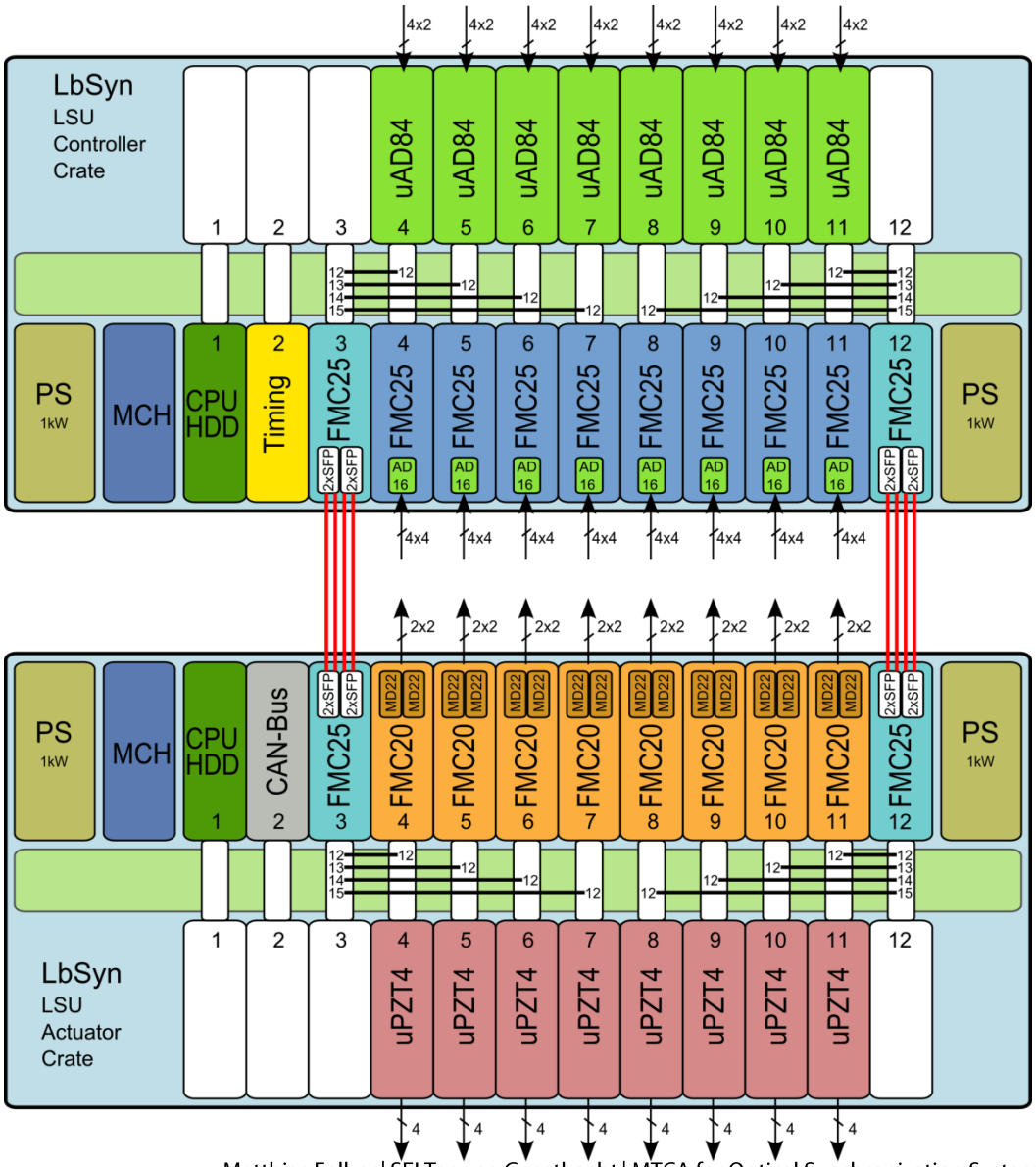
DFMC-AD16

- 16 (2x8) x ADC
  - 18 bit
  - 200 kSPS
  - 1 MΩ
  - 23 kHz / 15 kHz
  - ±10 V / ±5 V



Developed by Robert Wedel, Desy

LSU Control: Crate Configuration (max. 32 Links)

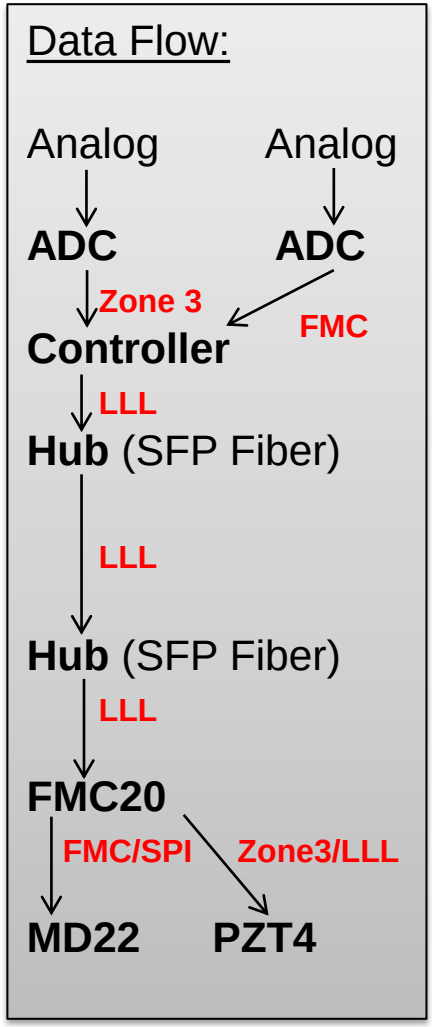


ADCs

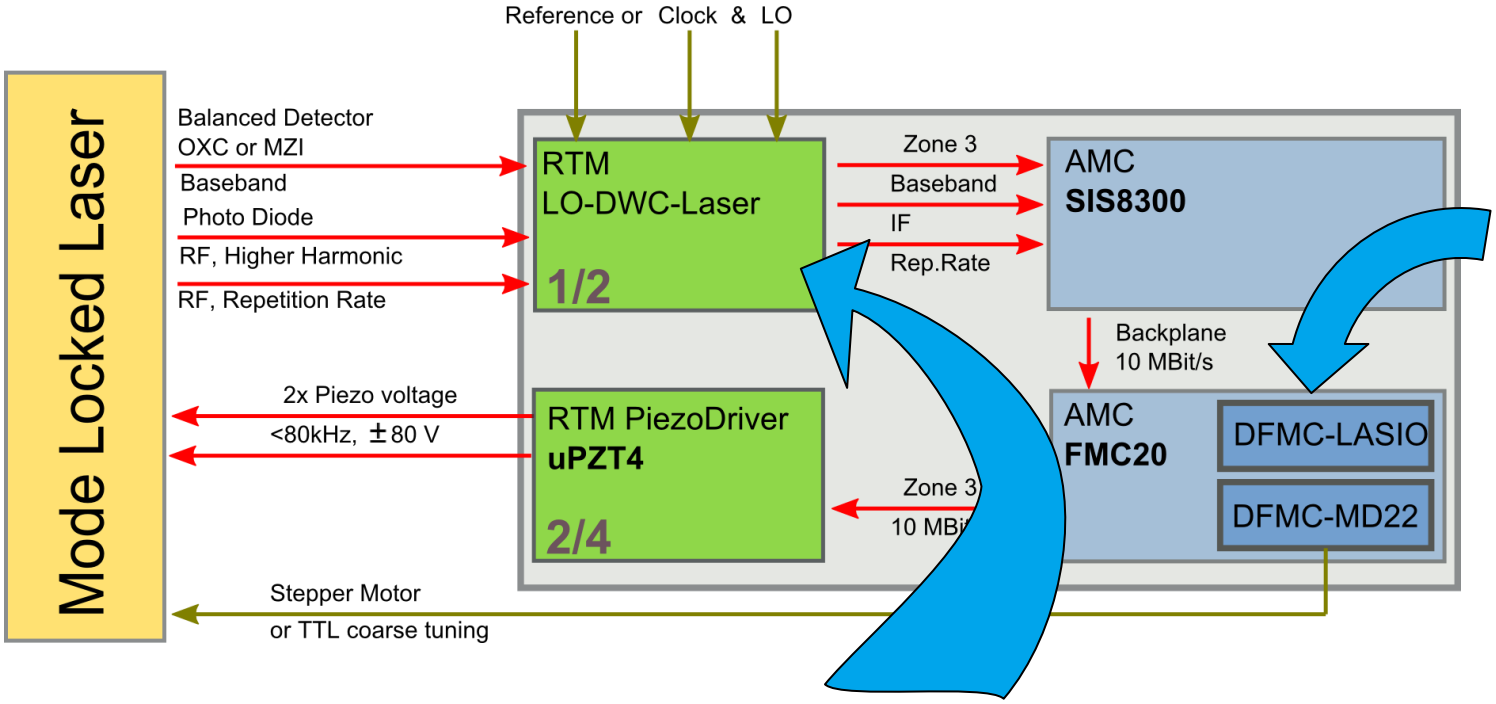
Controllers

Motor Actuators

Piezo Actuators



MTAC Setups - Laser Synchronization



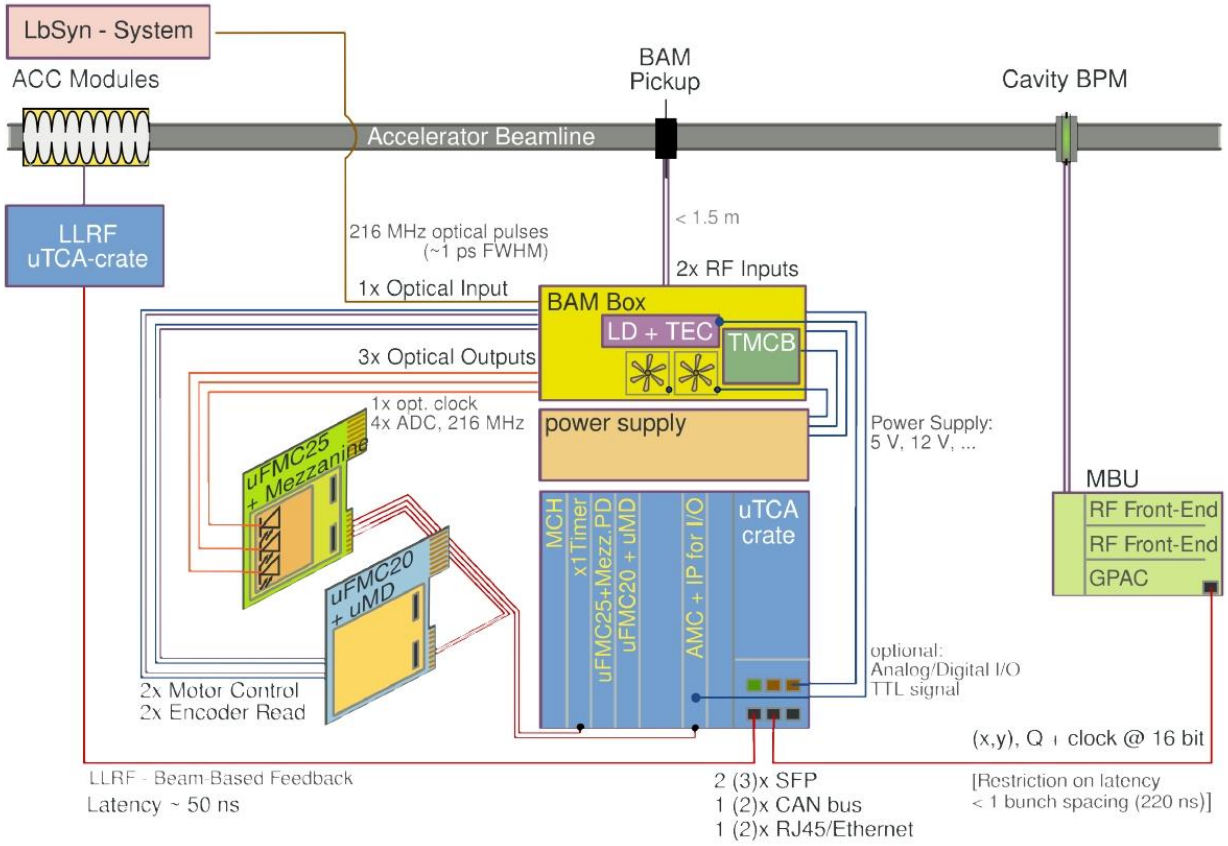
New FMC, specially for laser control

- 25 TTL GPIO pins, jumper activation/ deactivation
- RS232 interface
- Shutter driver

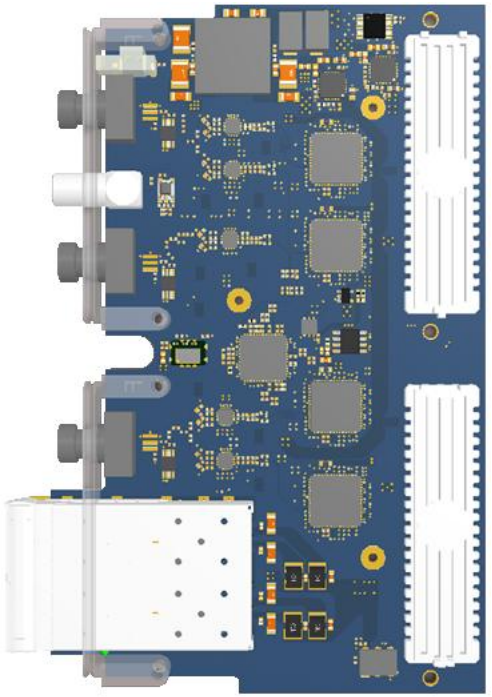
New RTM, specially for laser synchronization

- 4 DWC cells - only two with mixer, others for bucket detection (direct sampling)
- External LO/Clk input or internal generation from Reference
- Baseband inputs for balanced detector
- DAC for external feed of PZT4 or other analog driver
- Laser signal:
  - RF input (ext. diode)
  - Optical input (int. diode)
    - PS for ext. Diode

MTCA Setups - BAM Electronics



Courtesy M. K. Czwalinna



DFMC-DSBAM

- 3 x On-Board PDs
- 4 x ADC (216 MSPS)
- Clk generation/management

Conclusion

- MTCA.4 is the new crate standard for high performance computing (FPGA, PCIe) combined with low noise analog signal conditioning (LLRF, BPMs, …)
- The HVF opened the possibility for a wide applicatiopn portfolio and acceptance in research and industry
- For the optical synchronization, MTCA will replace most of the existing hardware solutions (VME, Beckhoff, Piezo Driver, …)
- AMCs: FMC20, FMC25, SIS8300L, CAN, x2Timer
- RTMs: AD84, PZT4, DWC10 (-> “LO-DWC-LAS”)
- FMCs: MD22, AD16, LASIO, DSBAM
- Laboratory Test-Setups available
- First implementation (‘System Ready’) in 3 month!

Backup Slides

Helmholtz association (HGF) validation-fond (HVF)

What is the HGF validation fond?

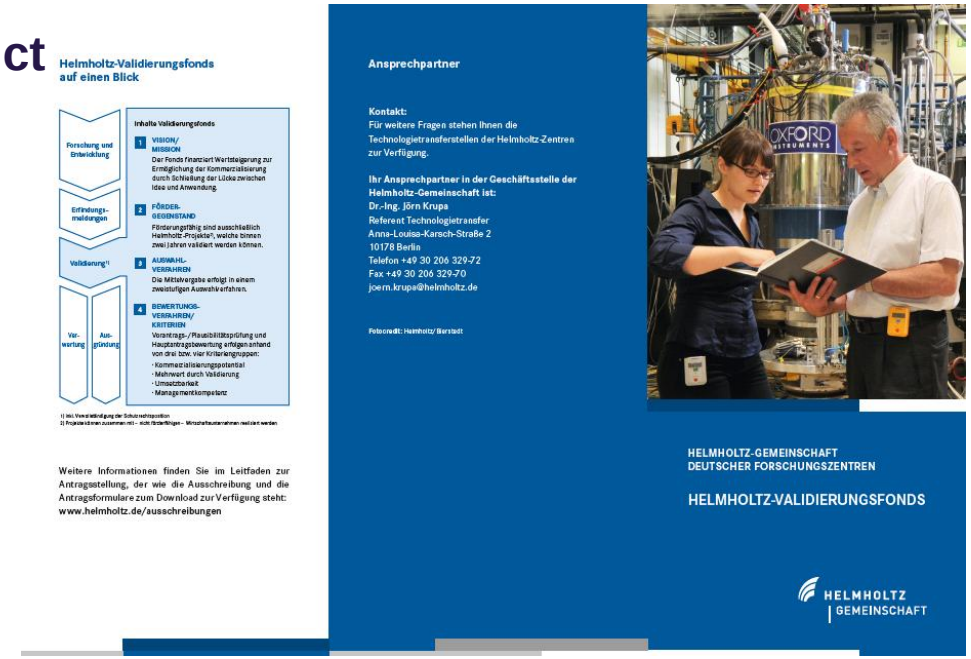
- Finance instrument to support the spin-off and technology transfer from scientific, technical inventions or developments from HGF centers to the industry and society
- Validation: increase of value (material/immaterial) with direct application to society / industry
- Ideally: generate commercial product

Boundaries:

- Duration max. 2 years
- Funding max. 2 M€/a (50% by HGF)

Screening of DESY (2011):

- “MTCA.4 ….” good candidate



Projects HGF Validation-fund

Main objectives of project:

Establish MTCA.4 electron crate system

- In accelerator community
- Industrial branches
- Scientific community

by reducing the market entry barriers and foster MTCA.4 to industry

Business model:

- Marketing for the RF controls modules via Company using DESY License

Consortium:

Consortion is steadly growing …

- Status 30. September 2013
  - **Cooperation partners**
    - ***Original HVF Consortium:***

ELMA Your Solution Partner

N.A.T.

struck innovative systeme

AMPEGON

Schroff®

TEWS TECHNOLOGIES

AD-TE-C

    - ***New Partners:***

IC INTERFACE CONCEPT ADVANCED ELECTRONIC SOLUTIONS

powerBridge Computer

eicSys GmbH Embedded Integrated Control Systems

COSYLAB

    - ***Negotiation phase:***

CAEN Tools for Discovery

kontron

vadatech inc. THE POWER OF VISION

Laurin AG

DESY

Structure of HGF Validation-fund proposal

AP1 Commercialization of LLRF module developments:

- **AP1.1 Industrialization of existing modules**
- **AP1.2 Optimization for single (small number of cavities) LLRF systems**
- **AP1.3 Extension of portfolio for frequencies 10MHz – 6 GHz**
- **AP1.4 Supplementary systems for RF controls**
- **AP1.5 Full integration of RTM-RF Backplane in MTCA.4**

AP2: Completion of MTCA.4 for industry and institutions:

- **AP2.1 Extension of product portfolio for MTCA.4**
- **AP2.2 EMI optimization and classification of MTCA.4 components**
- **AP2.3 Applications of MTCA.4 in industry** *(LLRF system…)*
- **AP2.4 Industrial market evaluation / demands in scientific community**
- **AP2.5 Large scale integral system test MTCA.4 and reliability study** *(FLASH …)*

AP3: Consulting and support for industry and institutions:

- **AP3.1 MTCA.4 support and consulting**
- **AP3.2 Users guide for MTCA.4**
- **AP3.3 Exhibition and marketing**
- **AP3.4 Workshops**

Status: Kommerzialisierung von LLRF Modulen

> a) Ergebnisse /Erfolge der wissenschaftlichen Arbeiten

- Komponenten: Module für Single/Multi Cavities (AP1.1-AP1.3)

AP1.1.1: uDWC
Entwicklung abgeschlossen
Lizenz an Struck vergeben
Produktion bei Struck erfolgreich
Vorserie (40) in Lieferung

struck innovative systeme

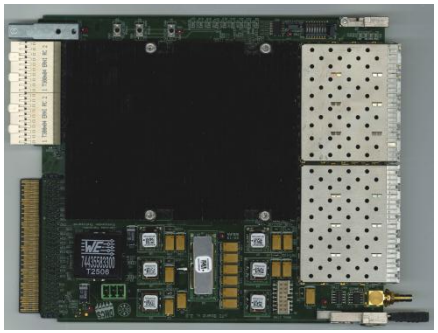
AP1.1.2: uTC
Prototyp im Test
8 x 10GbE ok (32 MGT)
Kintex7 K355/K420
Nur kleinere Fehler/MMC
Lizenz: Vadatech/I-TECH

AP1.1.3: uVM
Prototyp im Test
Analog (ok)/Digital ok
Footprint Fehler
Impedance matching
Lizenz: I-TECH

AP1.1.4: uLOG
Prototyp im Test
Lizenz an Sandona vergeben
Peltier Regelung fehlt
HF Mezzanine im Test

HF Felddetektor

DRTM-DWC10

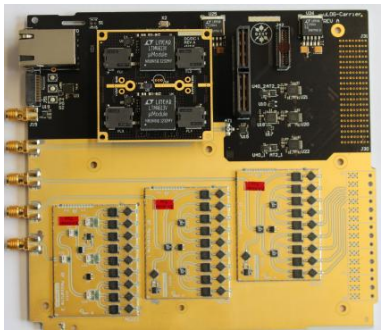


Controller

DAMC-TC7

HF-Steuereinheit

DRTM-VM2



Lokale Frequenz & Clock Generierung

eRTM-LOG1300

DESY

Status: Kommerzialisierung von LLRF Modulen

> a) Ergebnisse /Erfolge der wissenschaftlichen Arbeiten

- Komponenten: Supplementäre Module (AP1.4)

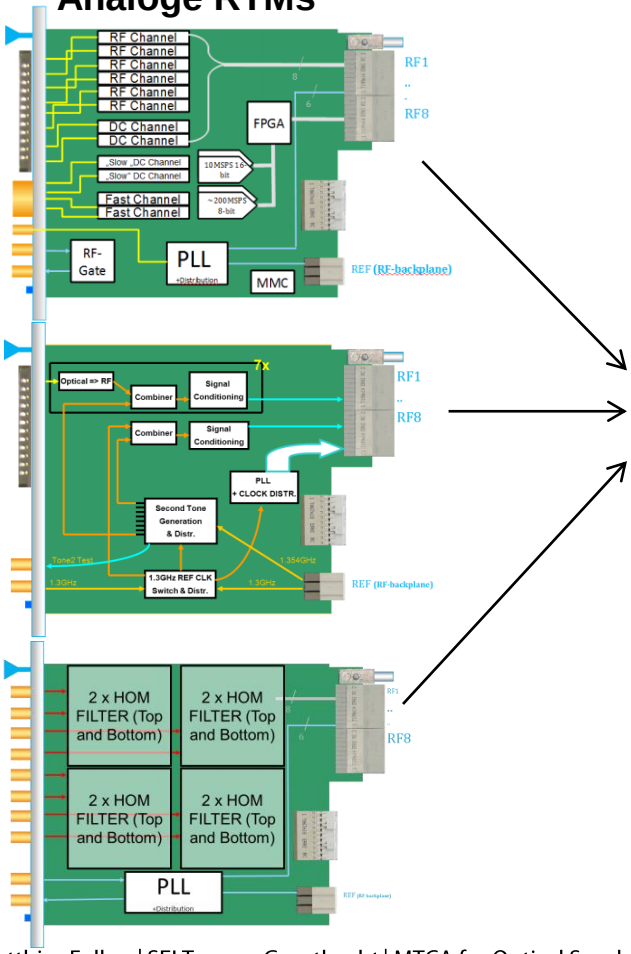
Anwendungs-Beispiele:

Klystron life-time Management

High-Order Mode Messungen (1.3/1.7/2.4GHz)

Femtosecond Fiberoptic Synchronization

Analoge RTMs



AP1.4.1: uDS800

Prototyp im Test

8 x 800MSPS, 12 bit

Bestückungsfehler Firma

Lizenz:Struck/Vadatech/CAEN

Sehr breites Anwendungsspektrum

Anfrage von
ITER/Frankreich
INFN/Italien
KIT/Deutschland
Uni. of Hawaii

Direkte HF Abtastung

DAMC-DS800

Status: Kommerzialisierung von LLRF Modulen

> a) Ergebnisse /Erfolge der wissenschaftlichen Arbeiten

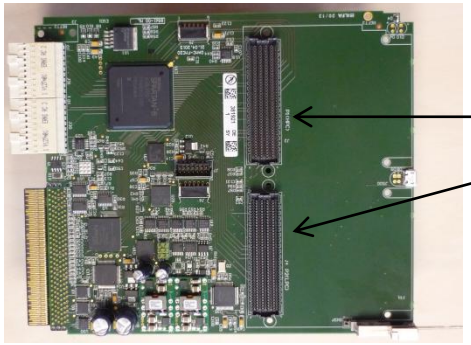
- Komponenten: Supplementäre Module (AP1.4)

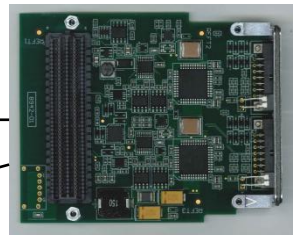
AP1.4.2.1: uFMC20
Prototyp im Test, Rev.1
Kostengünstig, FMC Carrier
Bauteilbeschaff., MMC
Breites Anwendungsfeld!
Lizenz: Eicsys

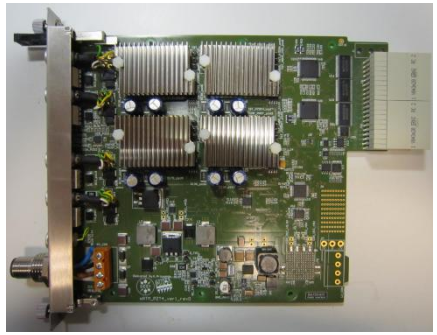
AP1.4.2.2: FMC_MD
Entwicklung abgeschl.
Kostengünstig
Real Time Motoranst.
Nicht Beschl. Spez.
Lizenz: ESD, TEWS

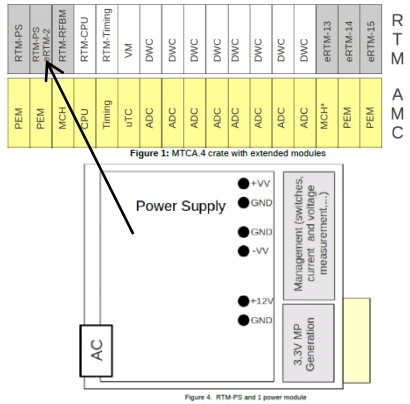
AP1.4.2.3: uPZ4
Prototyp im Test
HV-DCDC inkl.
kleine Fehler
Nicht Beschl. Spez.
Lizenz: I-TECH, …

AP1.4.2.4:uHVPS_eRTM
Projekt verschoben
HV mit hoher Leistung
Steckmodul eRTM
Industrieauftrag
Management AP1.5.1.1









FMC Trägerboard | **Motor Treiber** | **Piezotreiber** | **HV-PowerSupply**

DAMC-FMC20 | DFMC-MD22 | DRTM-PZ4

Structure of HGF Validation-fond proposal

AP2: Completion of MTCA.4 for industry and institutions

Extension of product portfolio for MTCA.4

1. Industrial production of timing module
2. 2 MSPS, 4 channel , 12bit ADCs on RTM & AMC
3. Management low noise power supplies

EMI optimization and classification of MTCA.4 components

1. EMI test board development
2. EMI current distribution in MTCA.4 crate
3. Optimization of crate-contact transitions
4. Shields for AMC/RTM boards
5. EMI Bypass-concept
6. Vibration studies and vibration reduction
7. EMI classification of AMC and RTM boards commercially available
8. AMC Backplane/connector/board development towards 10Gbit/sec

brightone

Application of MTCA.4 in industry

1. Integrated klystron life-time and LLRF system

Evaluation of MTCA.4 market

1. Market evaluation for industry
2. Market evaluation for institutes
3. Optional industry order after evaluation

Integral test of MTCA.4 in large facility, availability, failure analysis

1. Inter-compatibility of boards/sub-systems, radiation, remote controllability

DESY