Optical Synchronization at the European X-FEL

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on behalf of the LbSyn Team

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DESY, Hamburg, Germany
European XFEL optical synchronization scheme

Master Oscillator

Interferometer

XTIN

Master Laser Oscillator

3.4km fiber

Link Stabilization Unit

Laser2RF

REFMopt

12x

7x

4x

RF

Arrival time

BAM

Laser2laser

XHEXP1

Slave Laser Oscillator

Arrival time

BAM

Laser2laser

Future experiments

4x

5x

12x
European XFEL Synchronization Overview

- XTIN: 25 link stabilization units at injector site
- XHEXP1: 2nd synchronization room in the experimental hall
  - Slave laser oscillator
  - 9 link stabilization units (space for up to 21)
Characteristics of the Optical Synchronization at XFEL

> 46 Link Stabilization Units to be deployed (largest stage of expansion)

> About 20km of PM fibers needed only for optical synchronization
  - Quite expensive, but ...
  - No timing error due to Polarization Mode Dispersion!
  - No polarization correction necessary

> 2 links from the Master Laser Oscillator to the Slave Laser Oscillator
  - Redundancy => avoiding a single point of failure
  - Continuous out-of-loop measurement for the longest length (3.4km)

> Two Bunch Arrival Time Monitors side by side, after LINAC section, before SASE
  - Important FEL diagnostic tool and used in control-loops
  - One is served from the MLO and the other from the SLO
  - Continuous out-of-loop measurement
Link Stabilization Unit: New Version V4

XFEL Synchronization:

> More links to stabilize
> But space is constrained
> New design required
> Also longer delay stage required
> First prototype running in 26a

> Advantages
  - Huge space savings
  - Highly modular
  - Spatial separation of functions
Status: Equipment & Infrastructure

> Room infrastructure in progress

> Optical tables are at their place

> Optics (PBC, lenses, mirrors, etc.)
  - 70% already delivered/available and ready for assembly
  - Remaining optics should arrive within few weeks

> Optomechanics (Mirror mounts, custom mechanics, etc.)
  - Ordered or in-production or at least close. Should arrive within few weeks

> Optoelectronics (balanced detector, link electronics)
  - Should arrive within few weeks
MTCA for optical synchronization

> One Card-Set (8 cards) handles 4 Link Stabilization Units

> 24 LSUs => 6 sets

> 16bit 10MSps

> Virtex 5 FPGA

> Stepper drives

> ±80V Piezo driver

> Monitoring ADCs
Two Crate Configuration serves up to 32 Links

> “Sensitive” Crate
  - Balanced detectors
  - Monitoring ADCs
  - Number crunching

> Optical data connection
  - No EMI

> “Dirty” Crate
  - Stepper motors
  - Piezo signals

Courtesy: M. Felber
Timeline bottleneck

- SynchRoom ready for installation
- MTCA, PSM, LDD installed?
- MO via interferometer installed?
- Master laser oscillator locked
- Link Stabilization to injector laser locked

Fiber installations

A lot of optics adjustment

Gun tests
- at least RF needs to be there
Still some way to go ...

Thank you for your attention

XTIN Synchronization room, UG5/R25
“Laserraum1”, 5 May 2014
Long-Term Femtosecond Timing Link Stabilization Using a Single-Crystal Balanced Cross-Correlator

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Figure 1: (a) Operation of a single-crystal balanced cross-correlator. (b) Autocorrelation trace using 0.34 nJ, 170-fs pulses at 1550 nm.
Optical Stabilization Scheme

- **Master-Laser-Oscillator** (217MHz) locked to RF Master-Oscillator (1.3GHz)
- Optical delay compensates for fiber drifts (temperature, humidity, movement)
- **Balanced Optical Cross-Correlator** detects timing changes (~ 5mV/fs)
- Endstation uses directly optical pulses or converts to RF
Link Stabilization Unit V3.2 used at FLASH
Optical synchronization system at FLASH
Room plan for the optical synchronization at XFEL

- Climatisation air outlet from roof down to 50cm above ground
- Dry wall (5cm thick?) to suppress thermal flow and acoustics
- Optical tables standing on concrete ground
- Rack standing on concrete ground
- Mobile rack
- Operating environment

- Workplace 160x80cm
- Workplace 160x80cm
- Tools 72x71
- Tools 72x71
- Tools 72x71
- Chair
- Chair
- 1m sliding door
- 1m sliding door
- 7.0 m
- 4.4 m
- 5.0 m
- 7.3 m
- 0.05 m
- 2.25 m
- 0.85 m
- Double size Rack 120x140cm²

### Sources of drifts

#### Optical fibers
- Nufern PMF: 120 fs/K/m + ? fs/%RH/m
- Standart SMF: 40 fs/K/m + 2.5 fs/%RH/m
- Furukawa PSOF: 18 fs/K/m + 1.2 fs/%RH/m (coated)
- Linden STFOC: 5 fs/K/m + 0.8 fs/%RH/m
- Furukawa PSOF: 3.2 fs/K/m + 0.4 fs/%RH/m

#### Free space
- Aluminum: 77 fs/K/m
- Steel: 33 fs/K/m
- Invar: 2-6 fs/K/m
- Air @ 1550nm: 3 fs/K/m + 0.03 fs/%RH/m
- Superinvar: <1 fs/K/m