MAX IV Timing/Trigger Systems

Workshop "Full Energy Injection"

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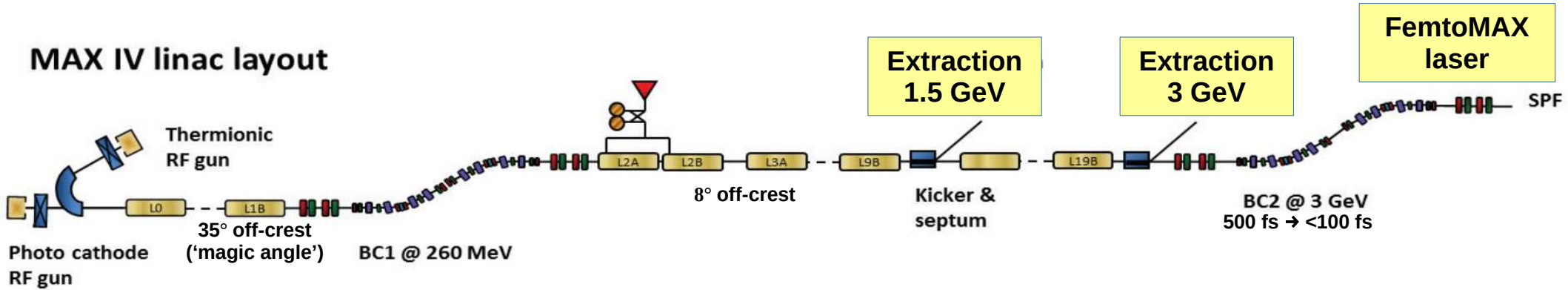
11 March 2026

LUND UNIVERSITY

Linac synchronisation overview



Need to synchronize

injector laser, RF modulators, diagnostics,

ring injections – nominally with thermionic gun,
– photo-gun as backup and for *clean* single-bunch injections,
– top-up every 10 minutes, duration ~15 s,

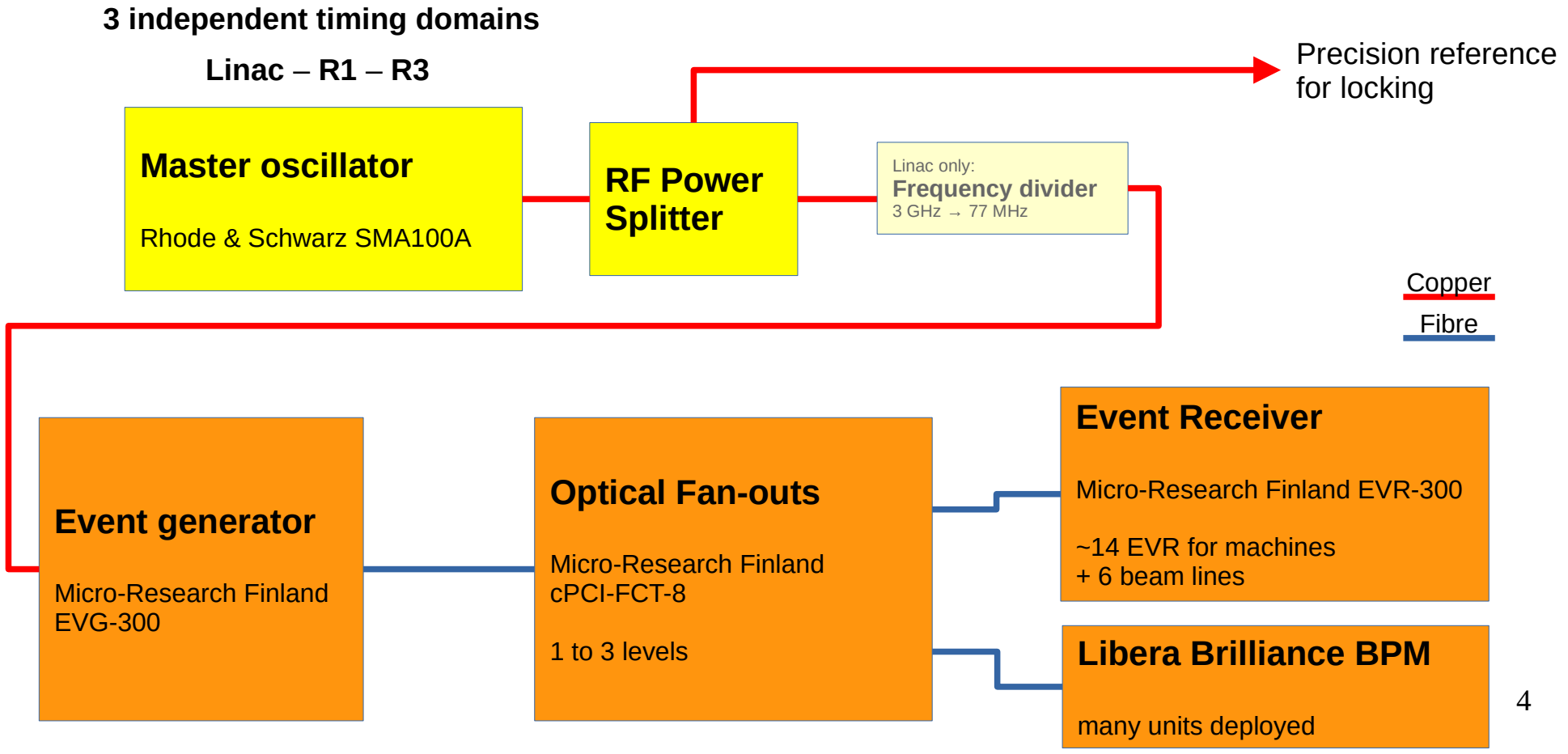
FemtoMAX laser – bunch lengths 100's to few femtoseconds (photo-gun only)
– pump/probe experiments

3 unrelated master oscillator frequencies

Linac	RF **2.9985 GHz**	700 ns pulse duration, repetition rate 10-100 Hz
1.5 GeV ring	RF **~100 MHz**	32 bunches, ~900 ps long, 3.125 MHz revolution frequency
3 GeV ring	RF **~100 MHz**	176 bunches, ~190 ps long, 568 kHz rev. freq.

100 MHz varying: presently Δf is -68.614 kHz and -68.788 kHz.

Basic timing system



EVG/EVR optical data transmission

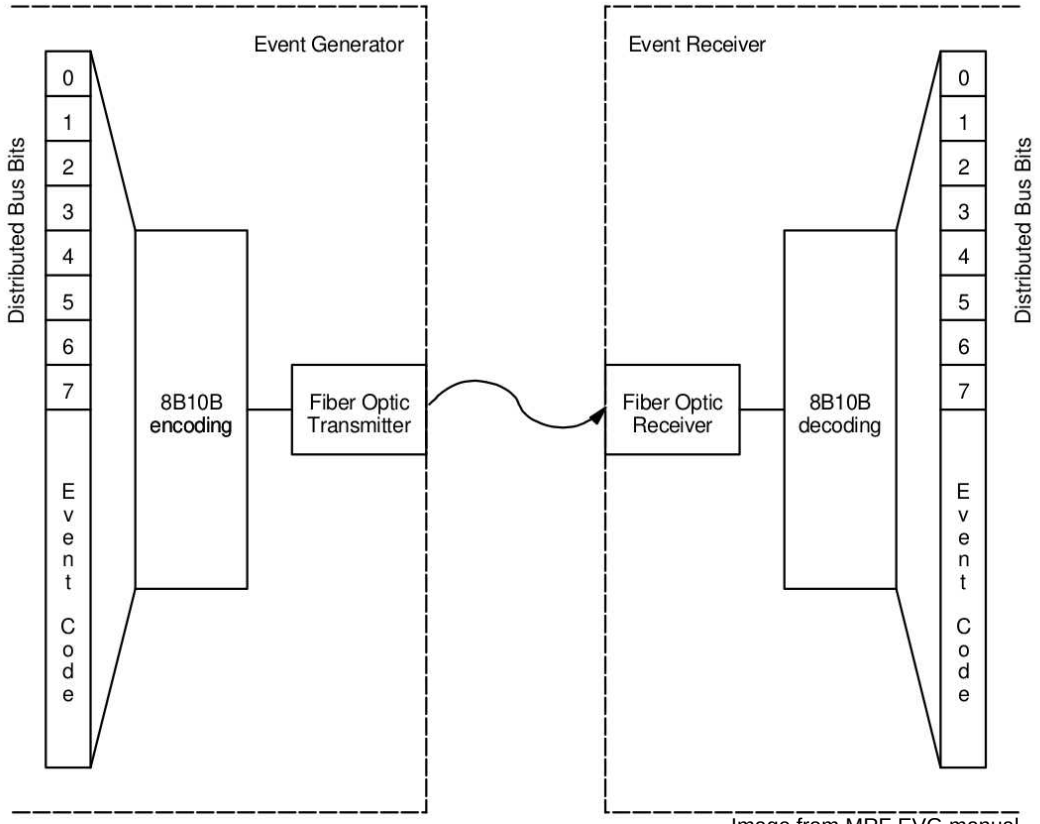


Image from MRF EVG manual

Event rates 50-125 MHz

- event clock derived from RF signal up to 1.6 GHz
- fractional synthesizer for stand-alone operation
- fastest EVR clock output at half event rate

Continuos bit stream

- bit rate 20x event rate
- clock recovery on receiver side
- special 8b10b character for word boundary detection

Other

- EVR back-events re-emitted by EVG
- time stamp transmission via DBUS (not used)

Event codes

Event codes have arbitrary meaning
except few with special function

Event sources

- Rising edge on external input
- Internal counter
- AC mains voltage
- Upstream (back) events
- **Internal sequencer table**
  2 tables with up to 2048 entries available

Example event table

3 GeV ring injection table

Time (unit 10 ns)	Code
116	0xA0
117	0xA4
10000001	0xA0
20000001	0xA0
30000000 (300 ms)	0x7F

0xA0: Trigger modulators of linac
0xA4: Trigger thermionic gun and diagnostics
0x7F: Re-start table

Linac pulsed at constant 10 Hz
Ring top-up injection at 3.3 Hz

Event Receiver

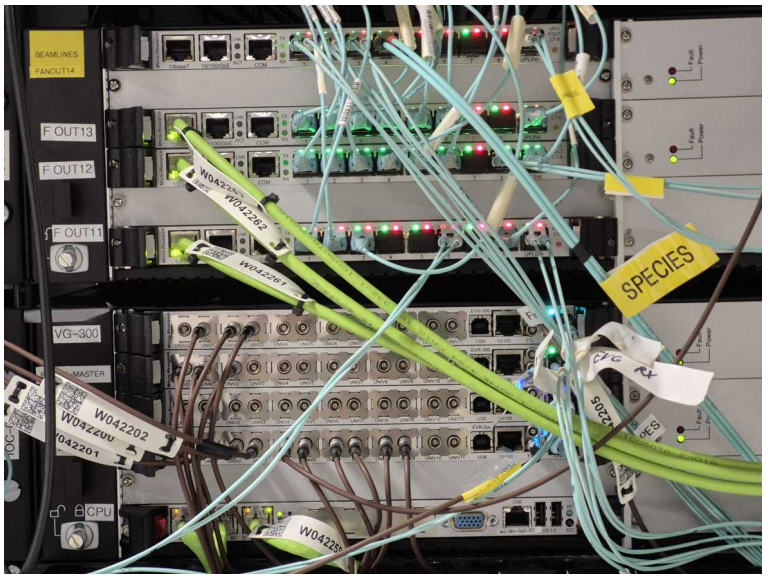
12 Outputs configurable to react to

- Event reception
  Pulse length and delay adjustable with 10 ns resolution (some output 10 ps)
- DBUS bit
  Rings: **RF/2** + **bunch clock**
  Linac: **RF/2**, **20/100/500 Hz** for laser
- 3 internal pre-scalers
  Counting with event rate, minimum division 2

2 inputs to generate back events

- Post-mortem signal
  Liberas will freeze buffers

R1: EVG, EVRs, FOUTs



MRF system for ring injections

Injection events by rings EVG's trigger:

0xA4	- thermionic gun/chopper	fills ≈ 7 linac buckets (2.3 ns)
	- injection kickers	optical EVR output
	- diagnostics	cameras, BPMs, etc

0xA0 - linac klystron modulators (kept always at 10 Hz)

Trigger selector box connects 3 timing domains to linac

For photo-gun injection need coincidence detection between master oscillators.

EVR Timing Jitter

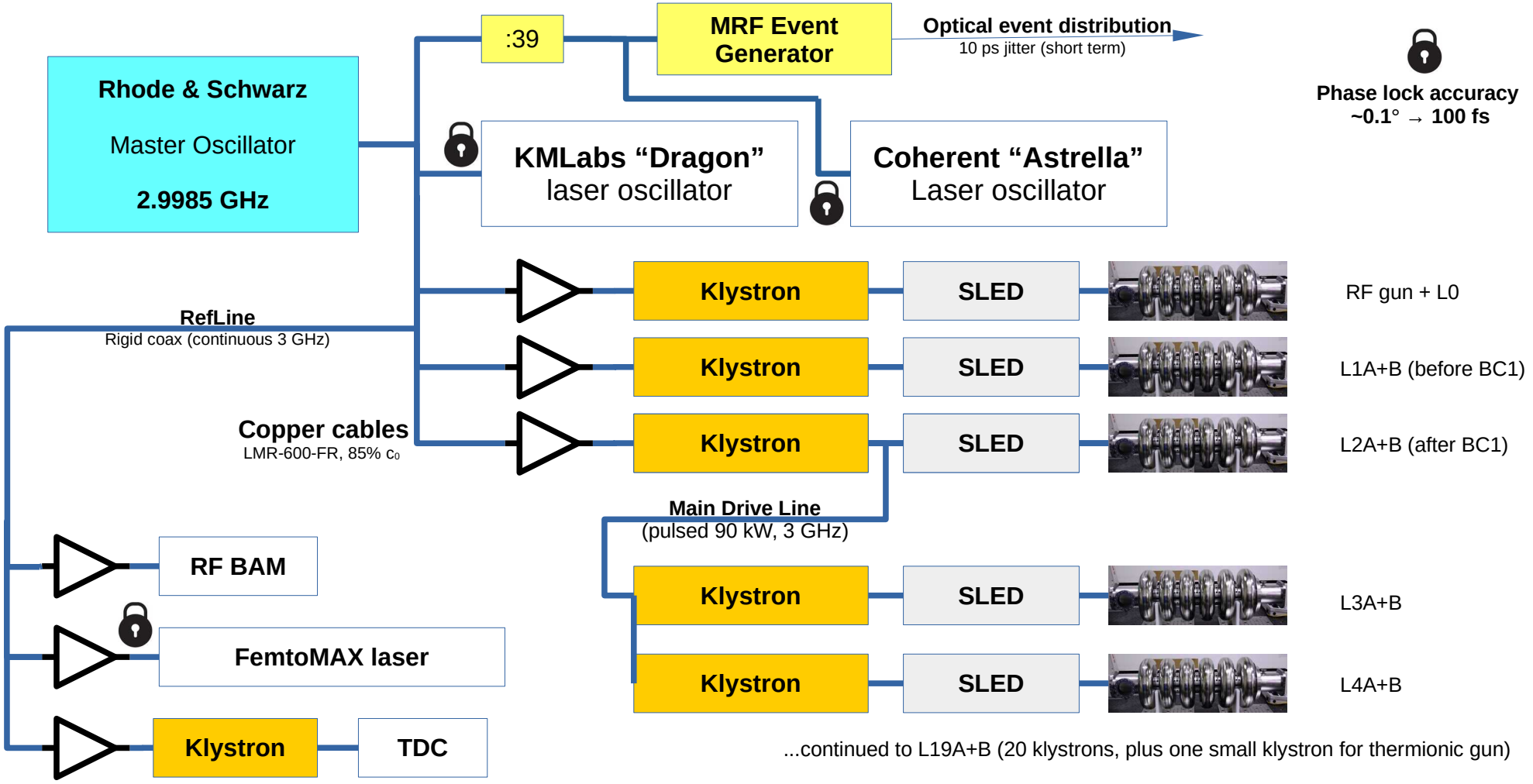
Rohde & Schwarz FSWP Signal Analyzer

Linac timing domain (77 MHz)

EVR output: DBUS RF/2

Jitter ~10 ps 1 kHz-10 MHz

Current linac RF distribution/synchronisation



New: Optical master oscillator

Wenzel RF oscillator

76.88 MHz

MRF Event Generator

MenloSystems C-Fiber 780
Erbium fibre laser

76.88 MHz rep rate
Pulse duration ~100 fs

780 nm

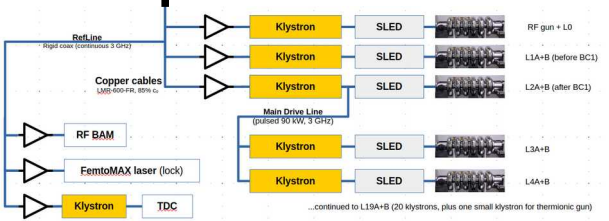
Direct seeding

KMLabs “Dragon”
Amplifier

Coherent “Astrella”
Amplifier

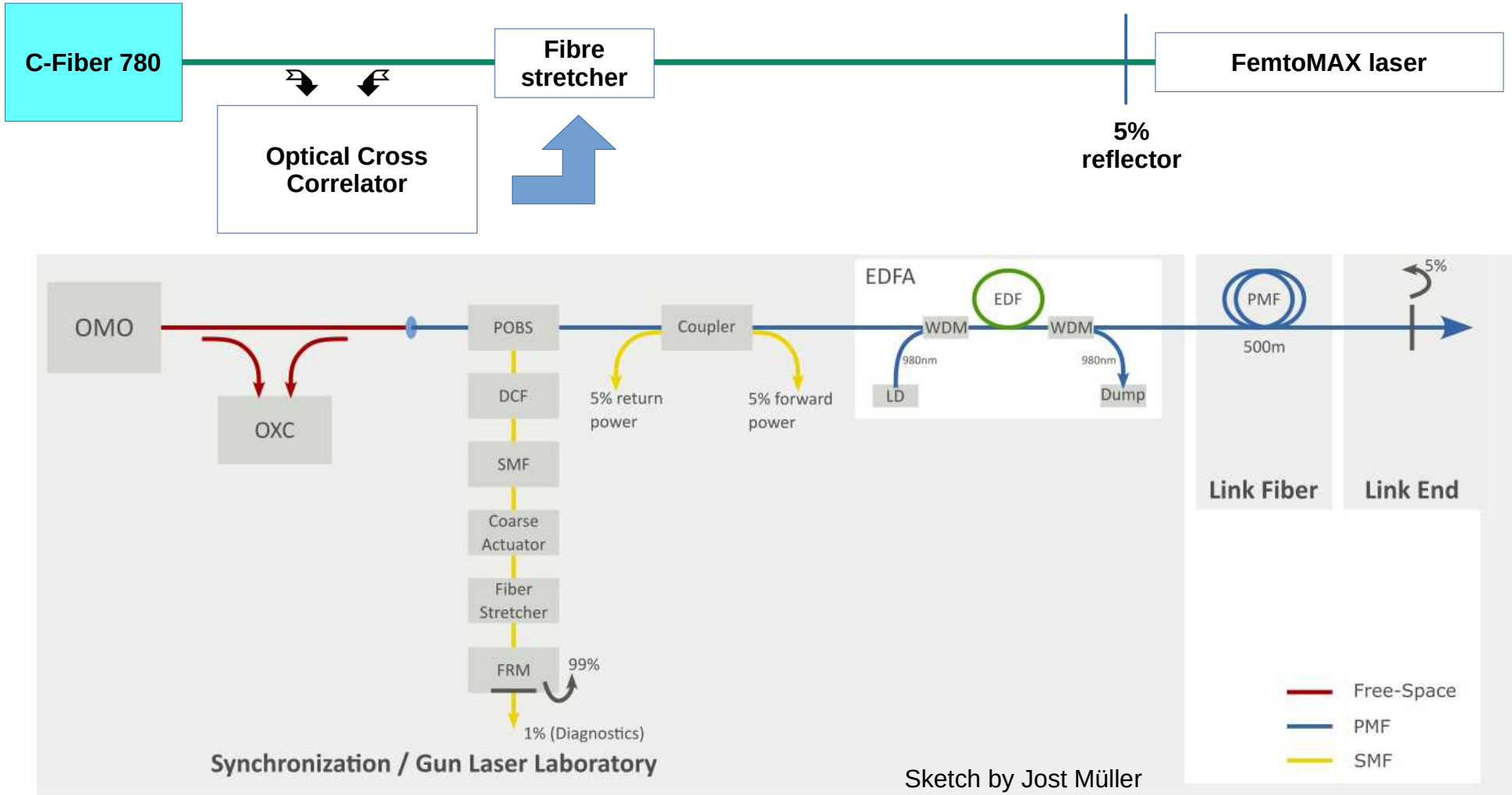
1550 nm

Direct photodiode conversion
39th harmonic = 2.9985 GHz



Stabilized optical fibre links
to EO-BAM, FemtoMAX, ...

Stabilized fibre link



Sketch by Jost Müller

Outlook: White Rabbit

white-rabbit.web.cern.ch

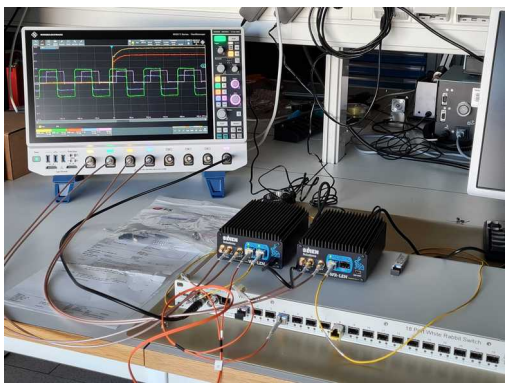
Complement/enhance/replace MRF system

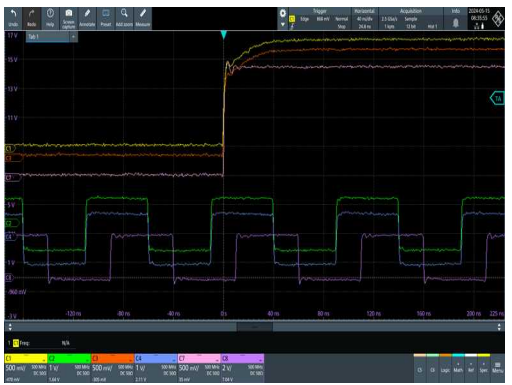
- = trigger/event distribution
  systems have similar jitter ~10 ps
- + not locked to single vendor
- + automatic link stabilization
  against e.g. temperature drift
- + easier to develop own hardware (maybe)
- + Data and timing over one network interface
  MRF also has some data transmit capabilities
- - new hardware

RF distribution over fibre

- + arbitrary frequencies
  MRF also allows to distribute sub-harmonics of the RF

Elementary test setup





Phase noise 100 Hz – 1 MHz: **4 ps**