MEMBER of EPIC

Fiber based Optical Frequency and Timing Solutions

Cycle
EPIC Defence

Starachowice / 2023-09-06

Daniel Petters

CEO

Cycle

Agenda

Cycle GmbH

- Company
- Technology
- Research & Development

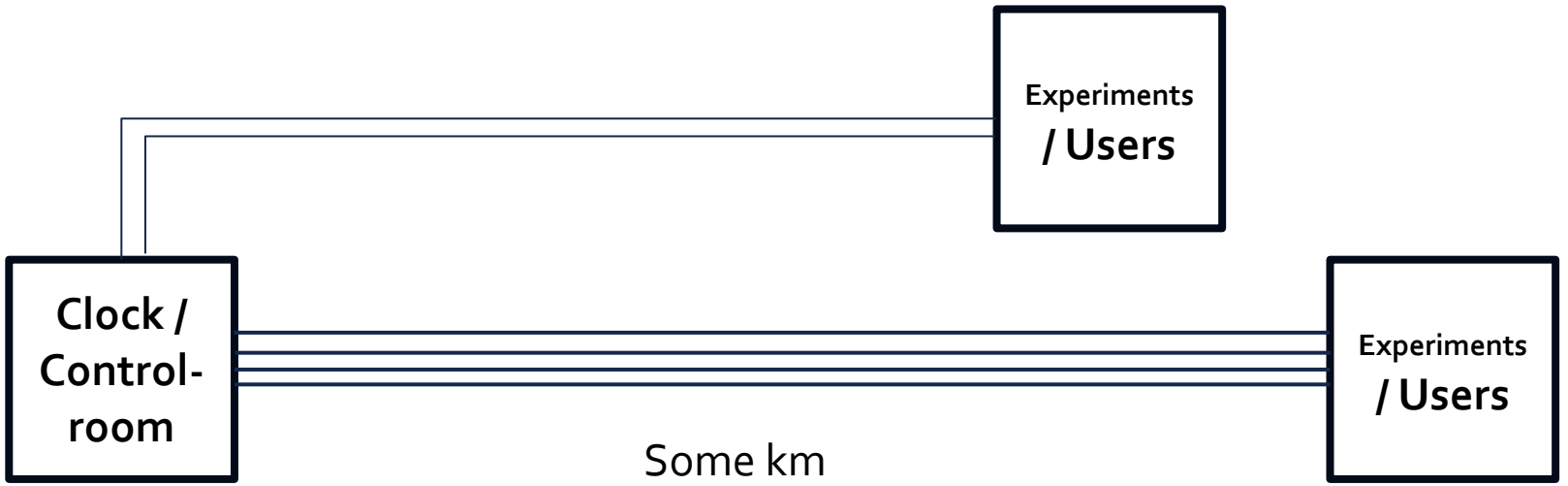
Cycle GmbH from Hamburg, Germany is a DESY spin-off founded in 2015 by Prof. Franz Kärtner (University of Hamburg)

"Based on unique knowledge and exclusive rights of use for patents in the field of ultrashort pulse laser technology, we develop, manufacture and market products for our customers in research and industry which open up new applications in the markets of **precision time measurement**, materials technology and life sciences."

Cycle

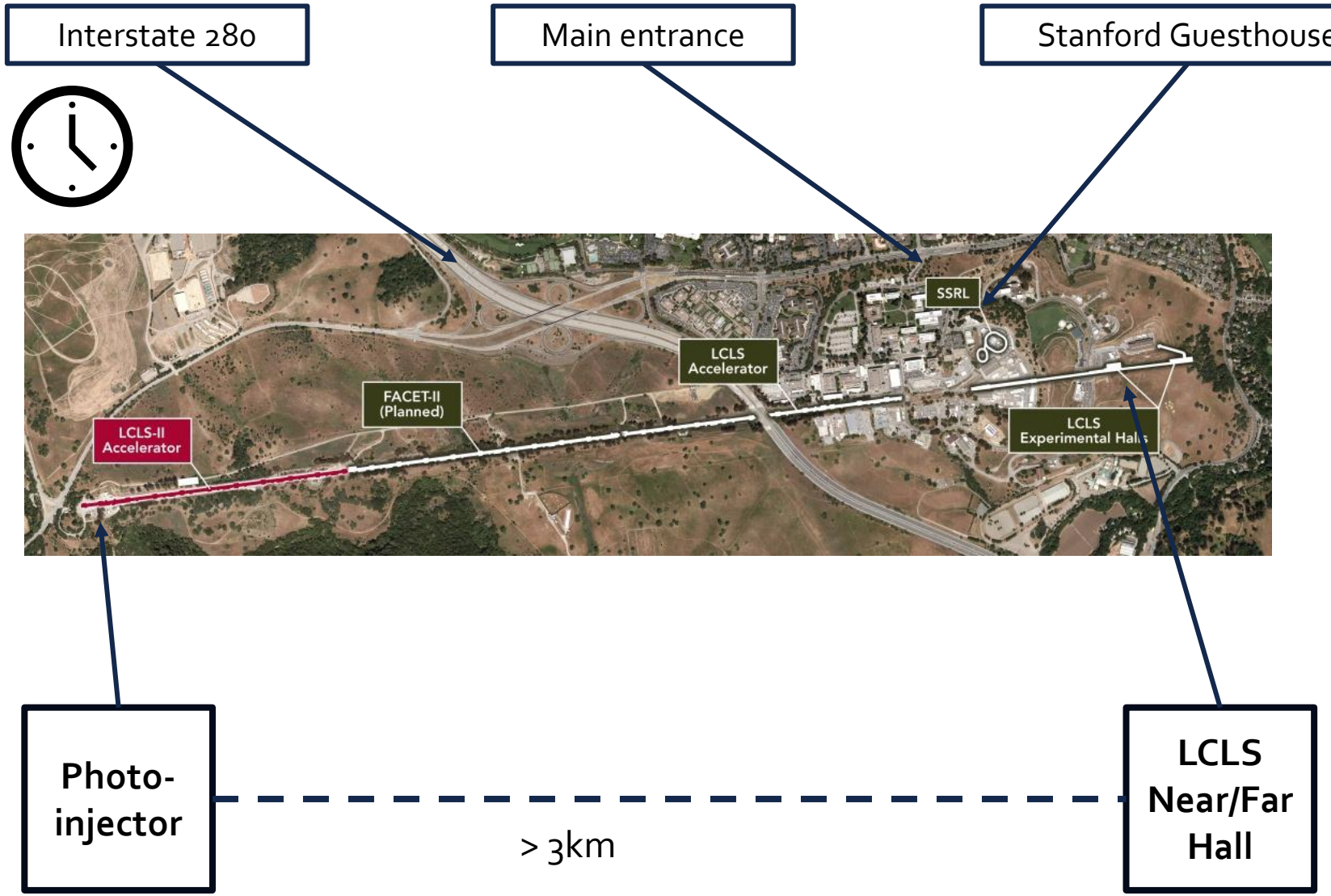
24 people
from
Germany, China,
Turkey, India,
Pakistan, Ukraine,
Poland, Russia
Bulgaria, and
Bavaria

Timing & Frequency Measurement & Distribution



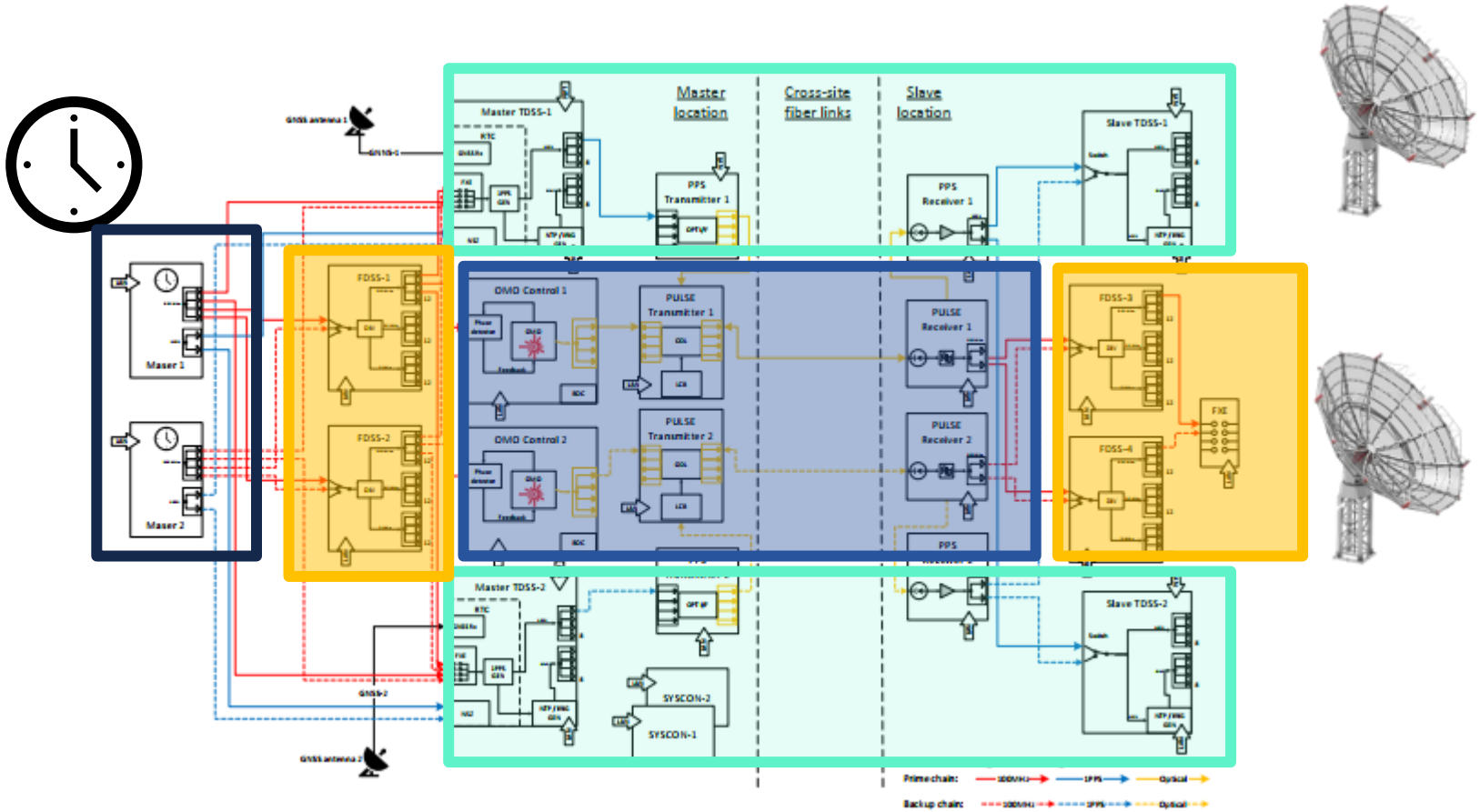
Timing & Frequency Measurement & Distribution

SLAC



Time & Frequency Measurement & Distribution

ESA
Deep Space



MASERs | Distribution | Time | Frequencies

Achieved milestones:

2017: first system installed

2019: Delivery of a timing system for an X-ray laser

2020: project kickoff, timing system for deep space antennas

Dalian China, 2017

Stanford USA, 2019

ESTRACK ESA, 2020 – 2025

IN COLLABORATION WITH

esa

The view expressed herein can in no way be taken to reflect the official opinion of the European Space Agency.

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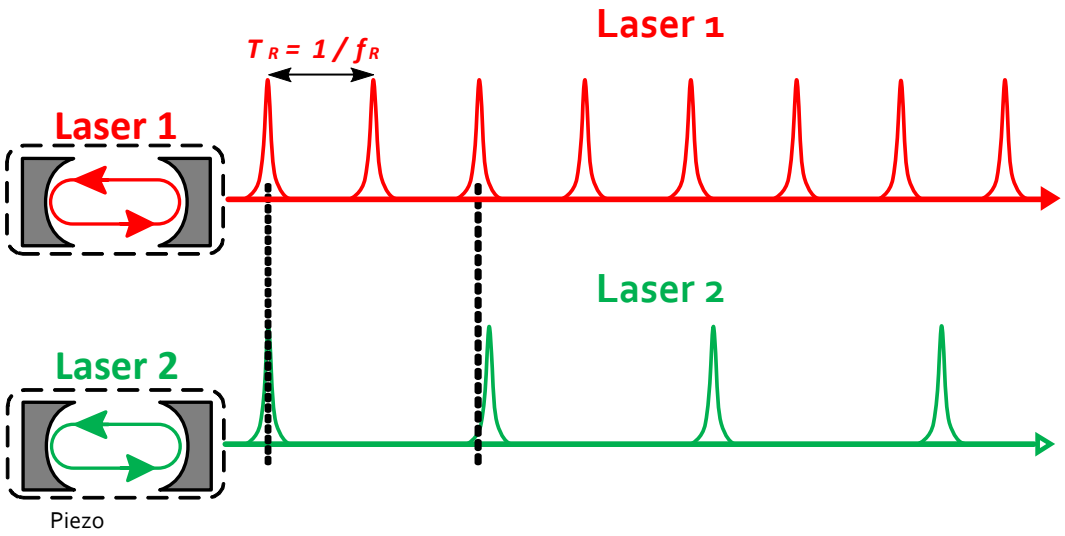
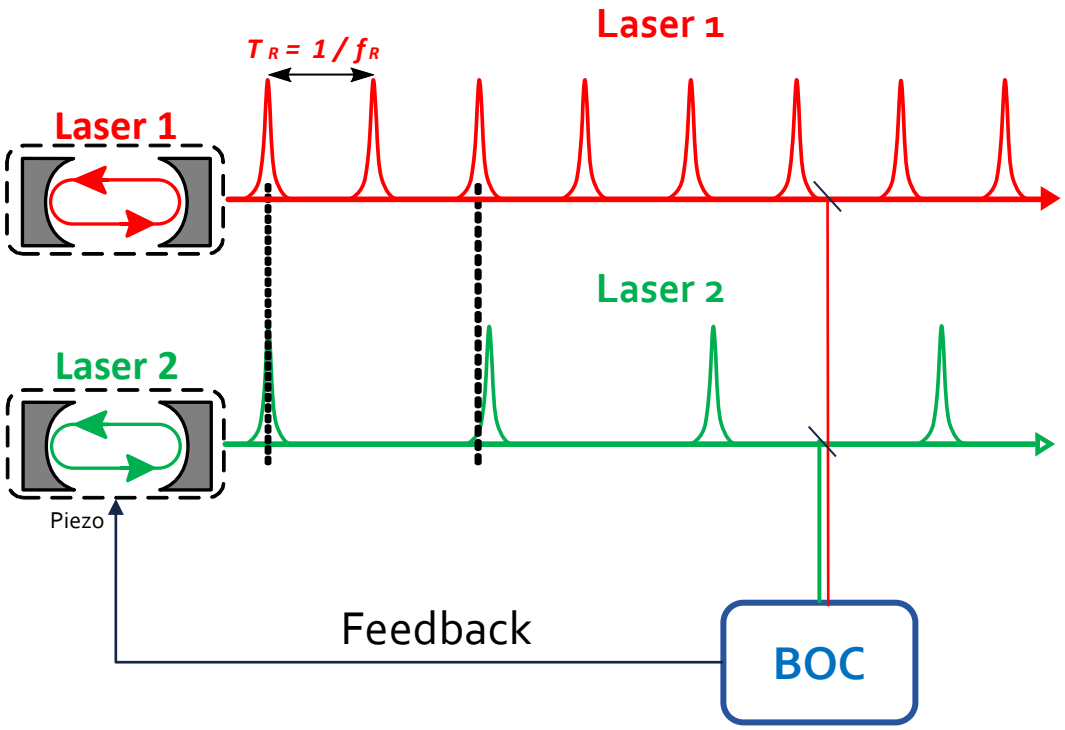
Synchronizing two mode locked lasers

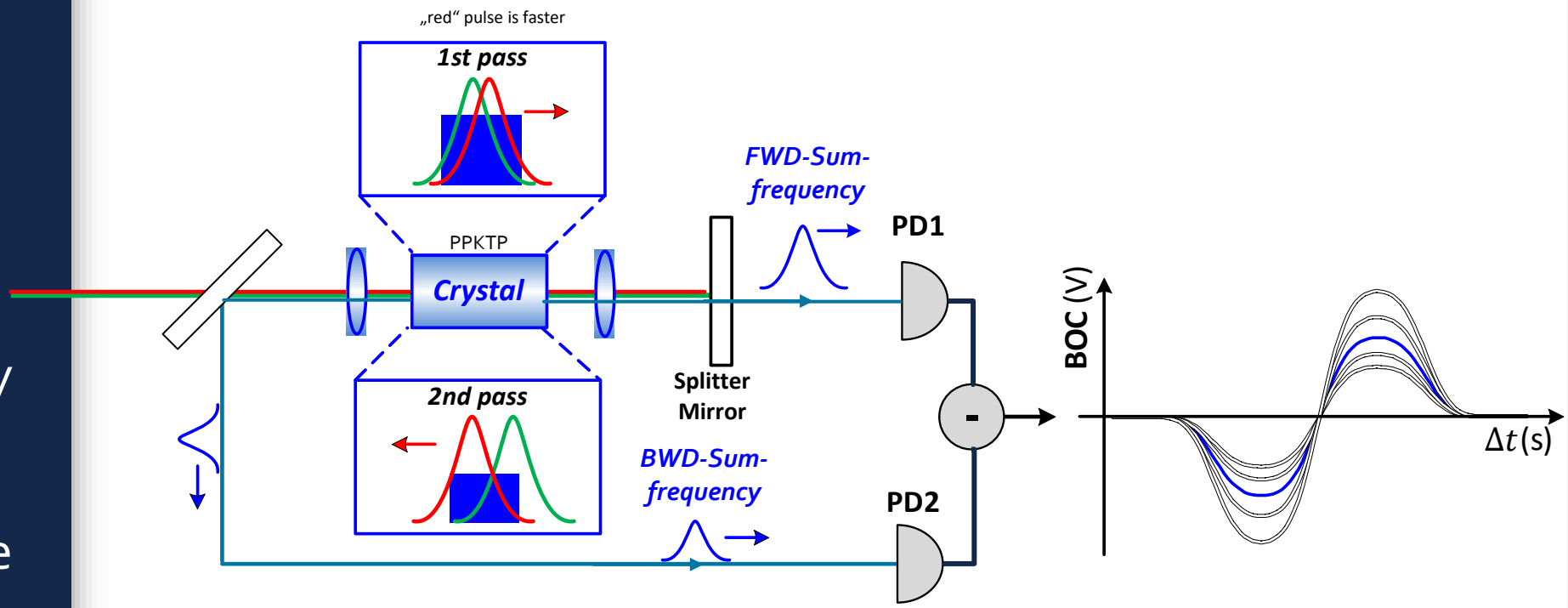


BOC
Synchronizing two mode locked lasers



BOC

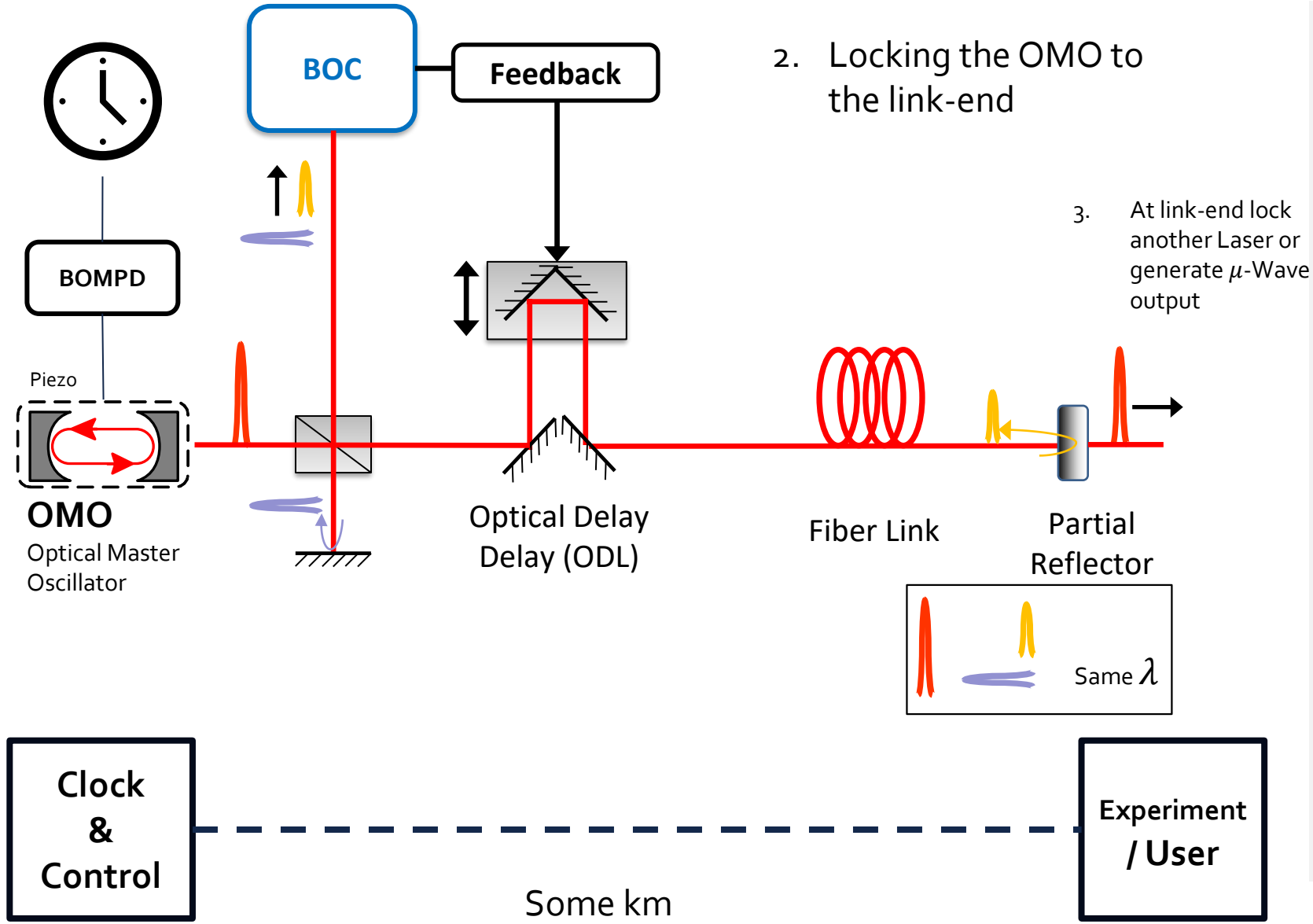
Balanced optical cross-correlation with an additional, time-delayed sum frequency generation suppresses optical intensity fluctuations around the zero crossing.



Sensitivity

Up to some 10 $\frac{mV}{fs}$

PULSE

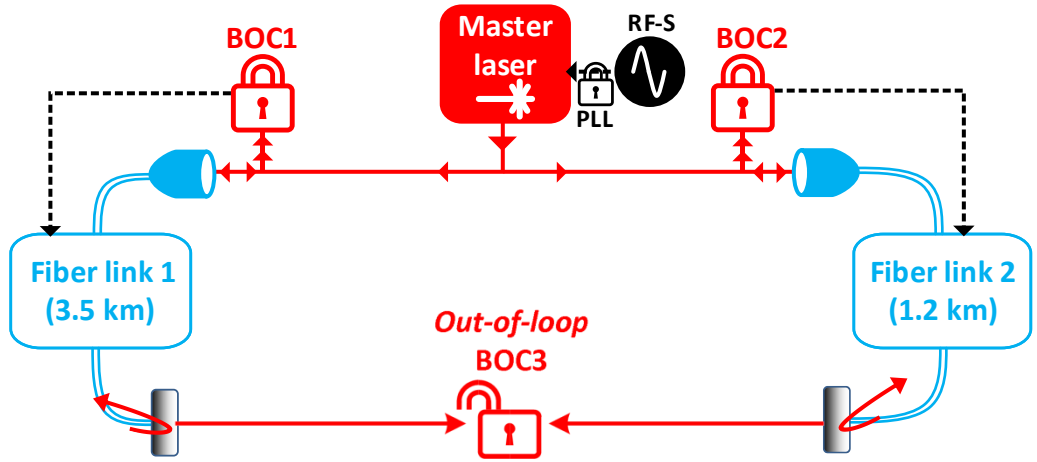


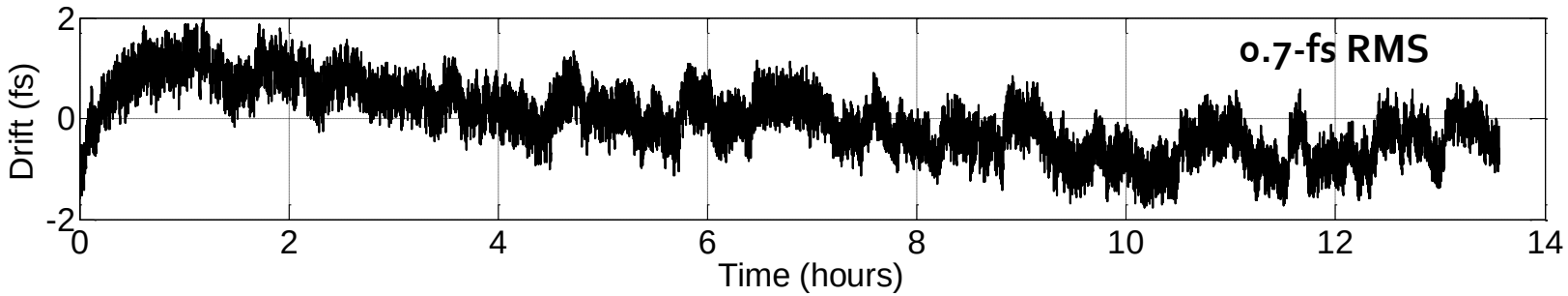
2. Locking the OMO to the link-end

3. At link-end lock another Laser or generate μ-Wave output

PULSE

sub-femtosecond jitter and timing drift





- Unavoidable sub-fs drift source **correlated with link power fluctuations**

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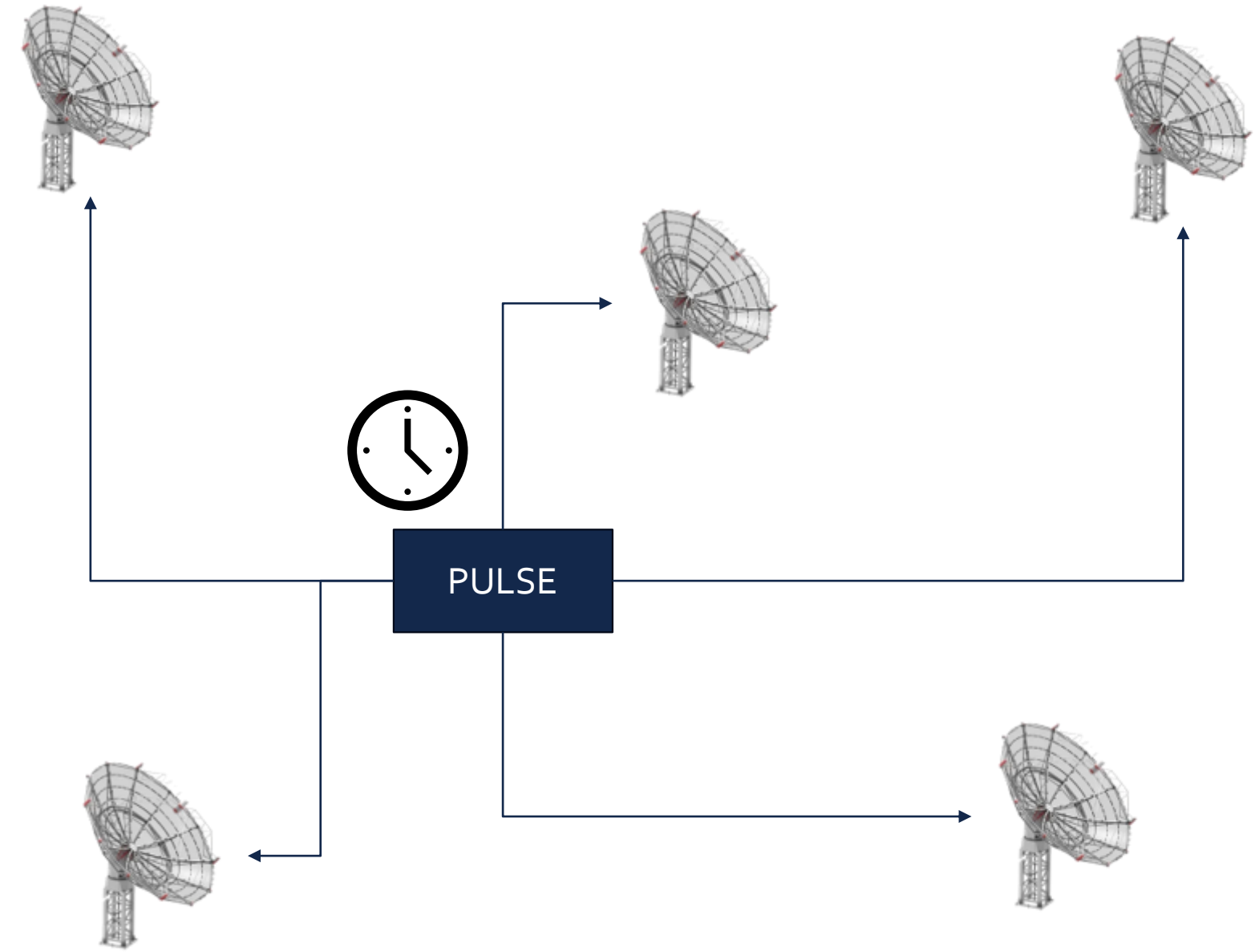
PULSE

typical 8-16 links each
with own BOC and ODL



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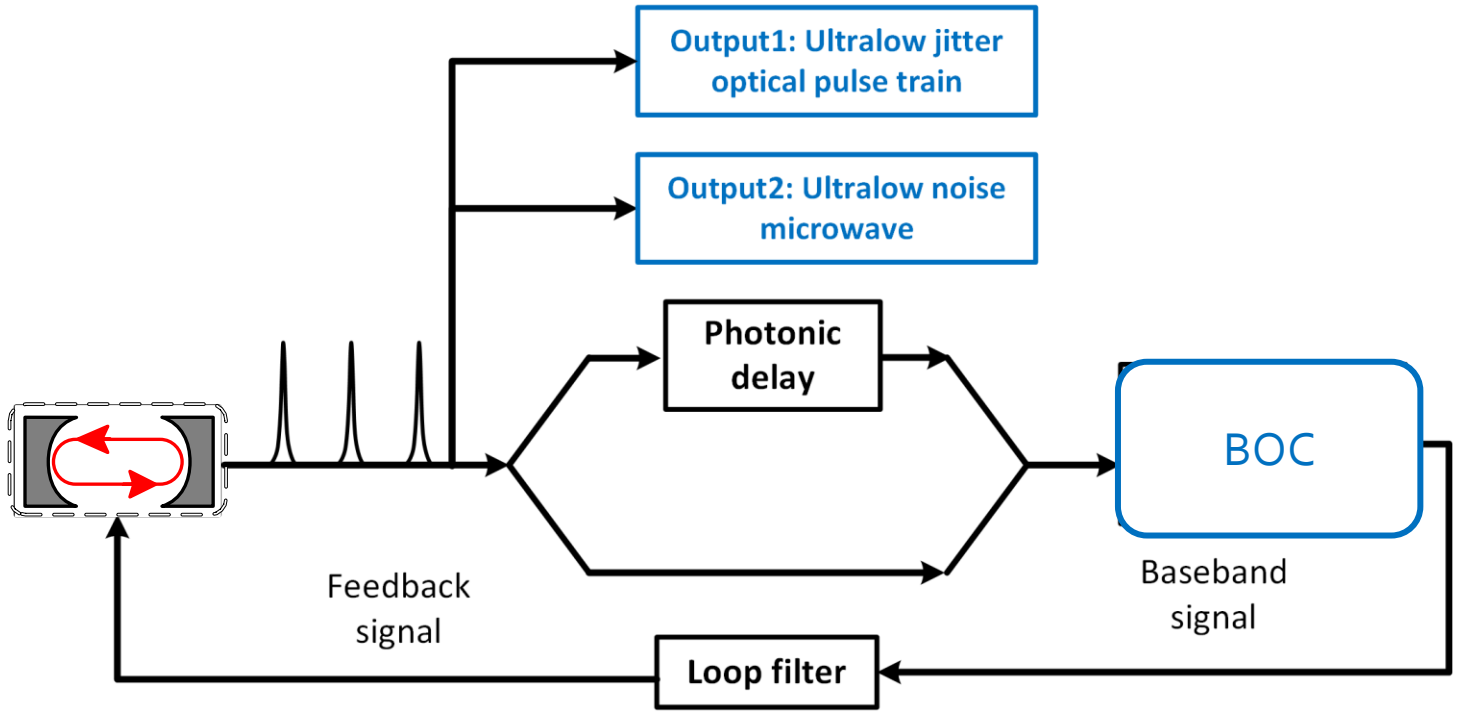
R&D PRESTO[1]:

Photonically Reference Extremely STable Oscillator



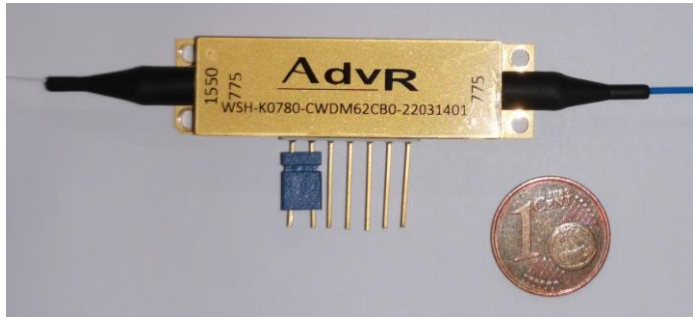
- Pulse repetition rate is locked to the delayed optical pulse train.
- The long fiber delay serves as the reference for the stabilization.
- The timing jitter is measured with highly sensitive BOCs
- First prototype:

[1]**Patent pending:** EP 21 17 1191 & US 17/731 233

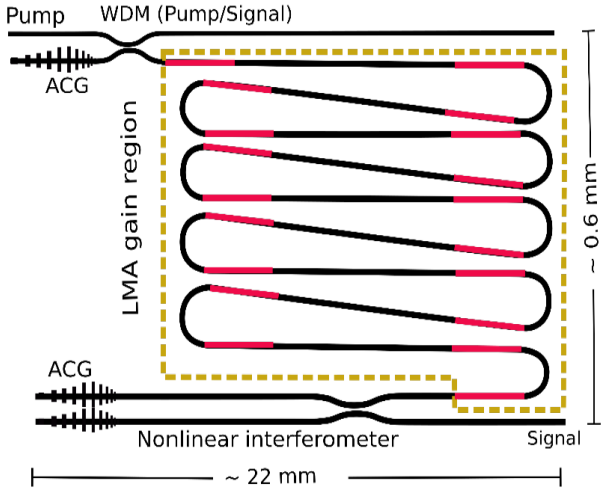
R&D PRESTO

We want to make it smaller.

- The WDM as a fiber-coupled dichroic beam splitter
  - directing the input pulses into the PPKTP waveguide
  - Separating the backward generated second harmonic signals
- Dichroic coating at the end facet
  - Highly reflecting for the fundamental signals
  - Anti-reflecting for the second harmonic signal



- ✓ Compact footprint 45 mm x 10 mm footprint
- ✓ Compatible with chip technology
- ✓ **Increased timing sensitivity (up to 100 x)**
- ✓ Alignment free



Mode-locked laser on chip
Image courtesy [11]

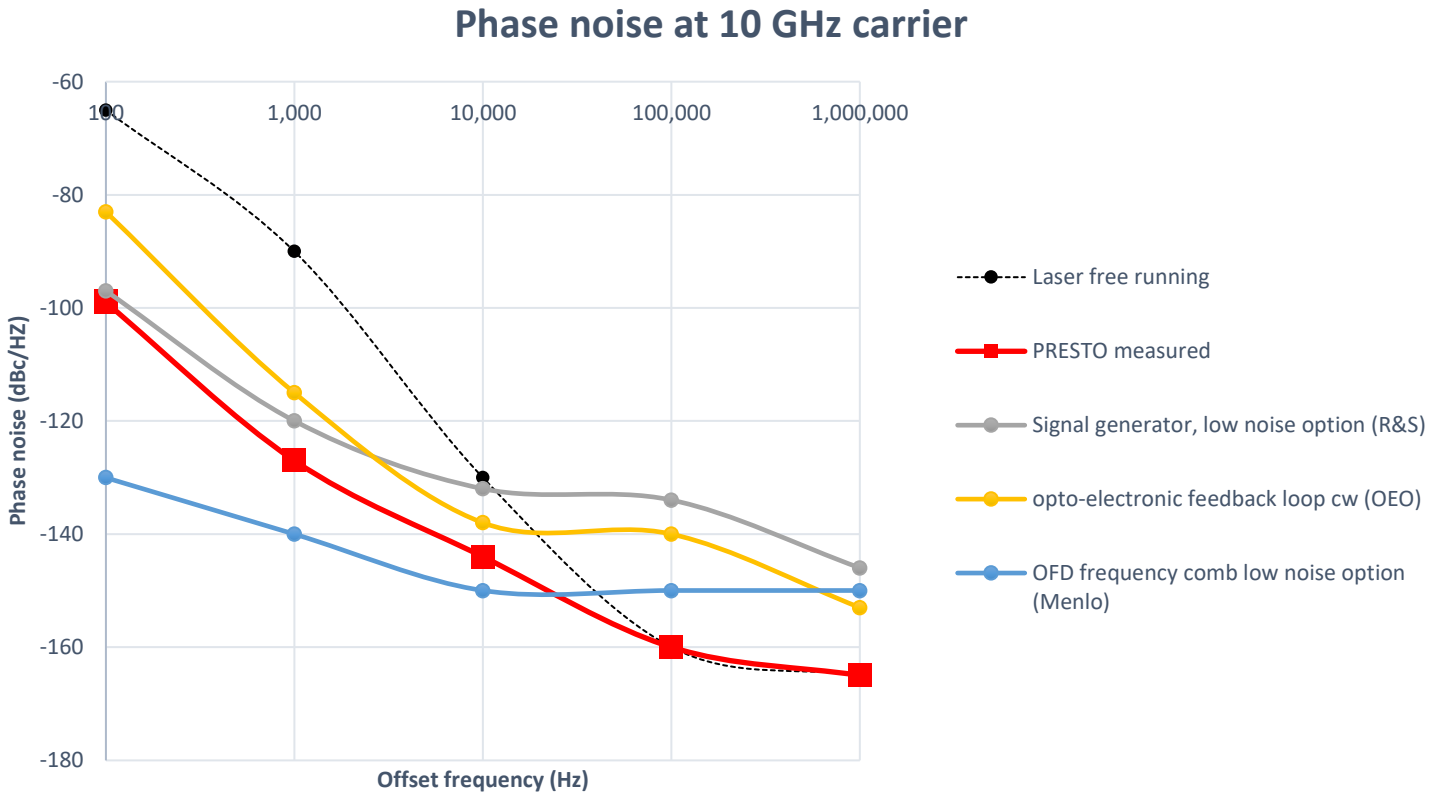
Emerging miniaturized lasers (on chip)

- **Chip size** millimeter scale
- **Typical rep. rate** 10 GHz
- **Typical average power** 10 mW
- **Typical pulse energy** 1 pJ
- A factor of 100 – 1000 less pulse energy
- Weak pulse energy budget

[11] N. Singh et al. Opt. Exp. 28, 22562 (2020)

R&D PRESTO

First experimental results are promising



Phase noise (dBc/Hz) at 10 GHz carrier frequency

Offset Frequency (Hz)	Laser free running	PRESTO measured	Signal generator, low noise option (R&S)	opto-electronic feedback loop cw (OEO)	OFD frequency comb low noise option (Menlo)
100	-65	-99	-97	-83	-130
1.000	-90	-127	-120	-115	-140
10.000	-130	-144	-132	-138	-150
100.000	-160	-160	-134	-140	-150
1.000.000	-165	-165	-146	-153	-150

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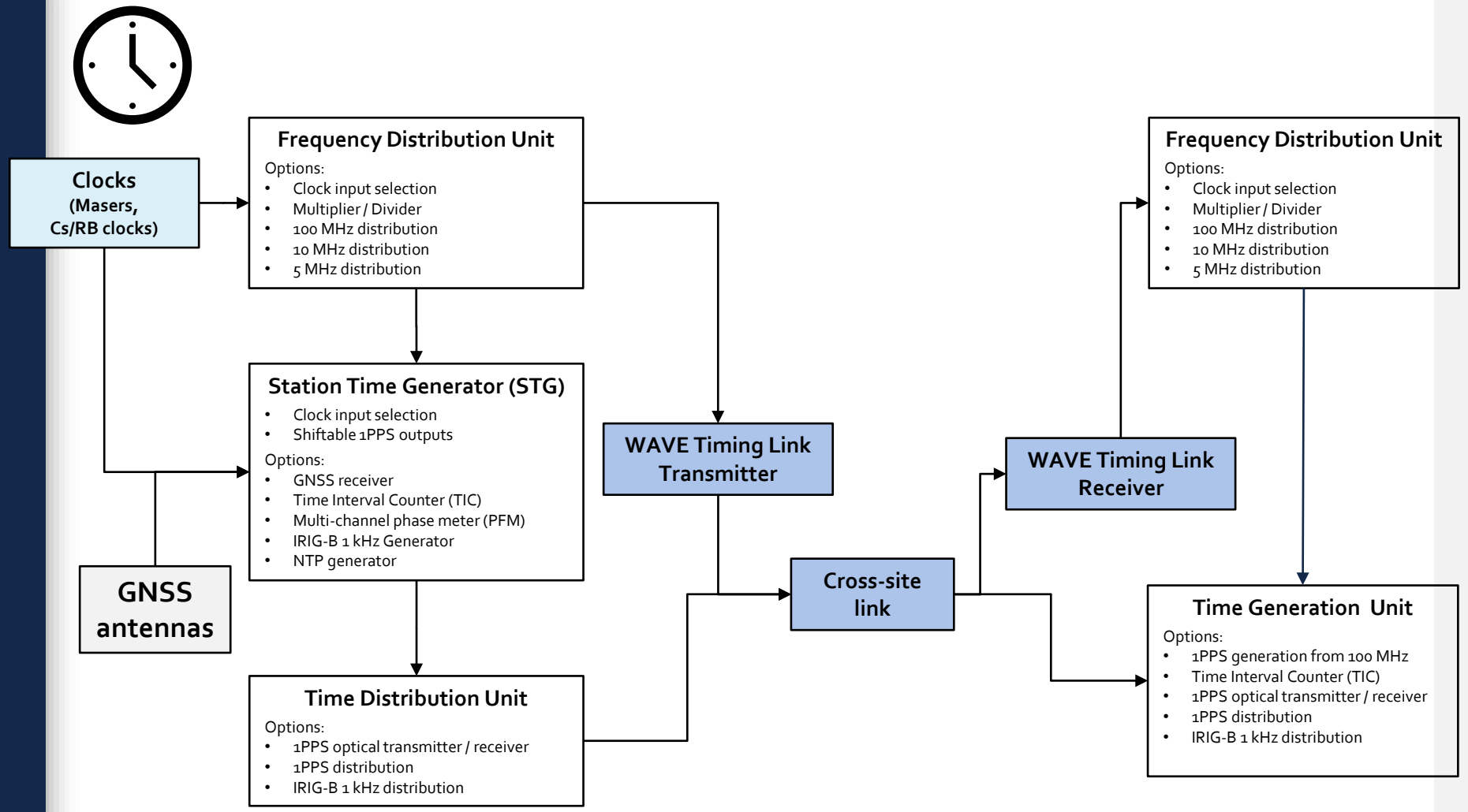
R&D

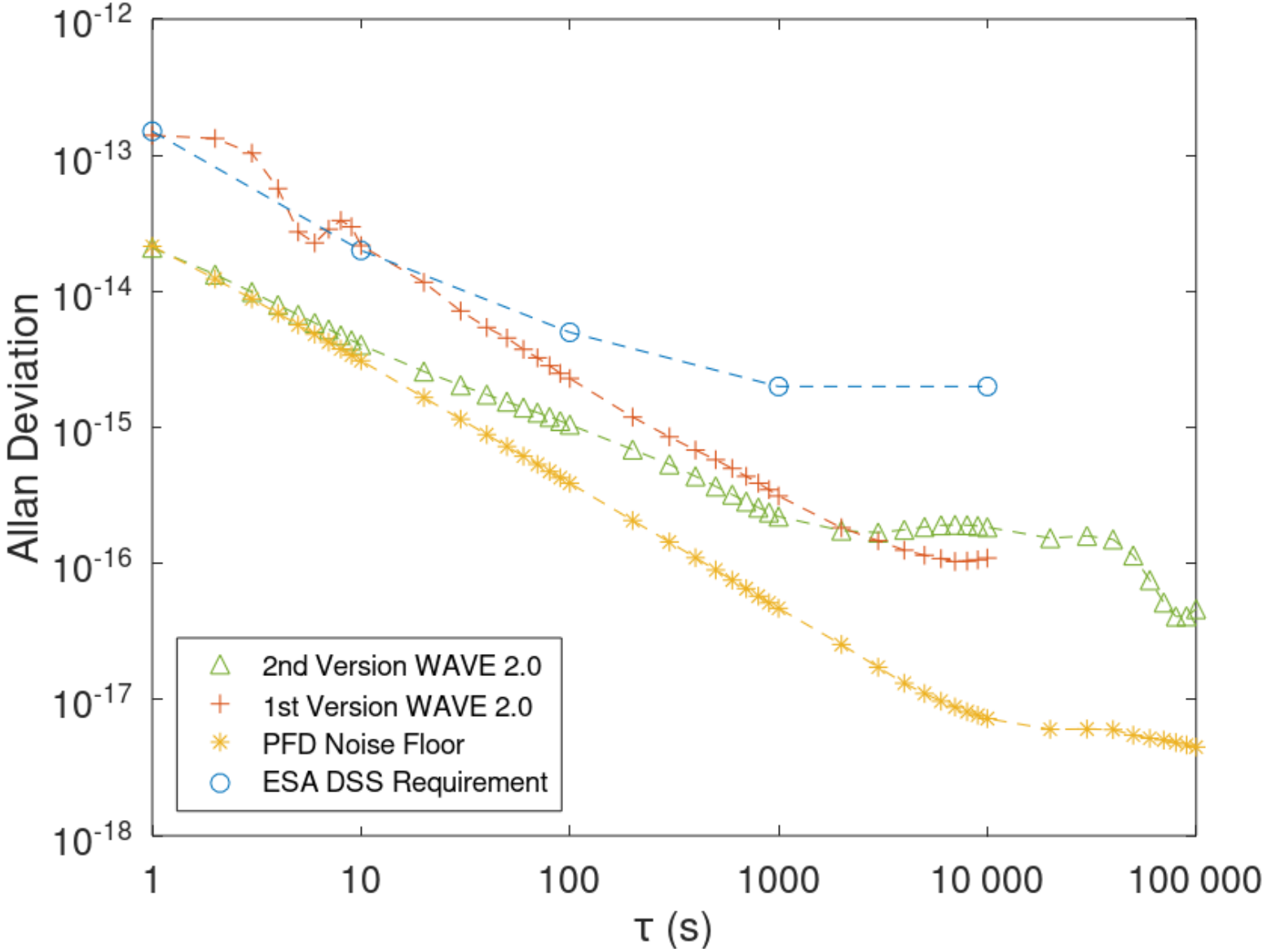
Wave 2.0 & Time Distribution



R&D

Wave 2.0

First demo device is being tested.



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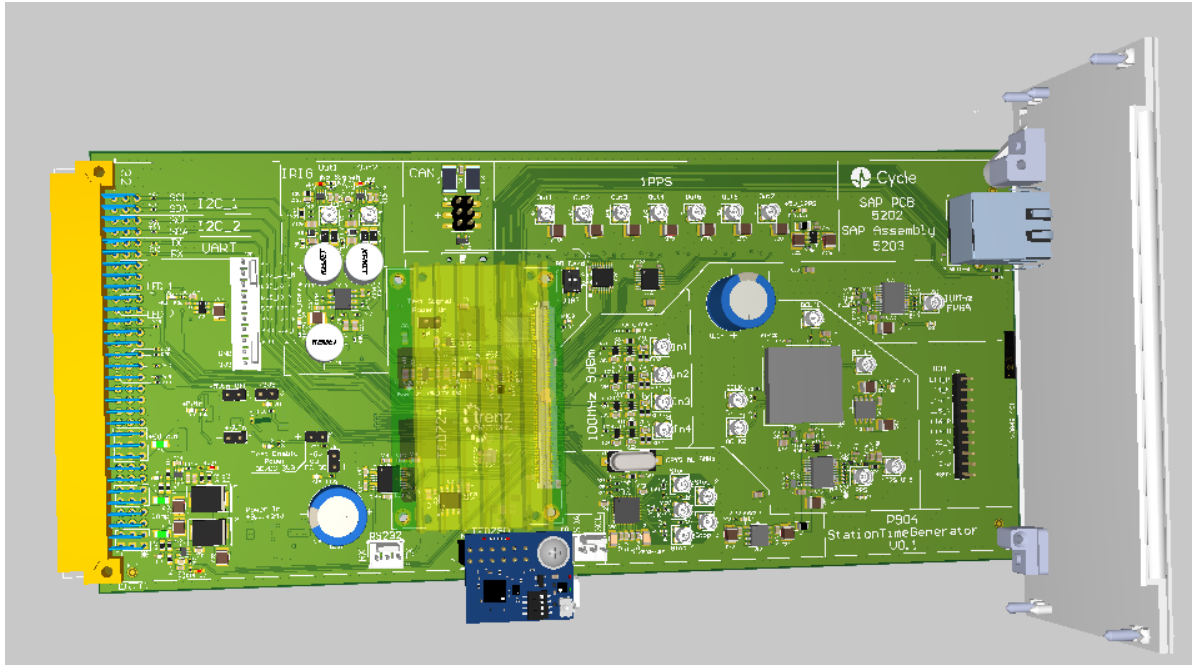
R&D

Time Distribution

Station Time Generator:

- Phase-shift measurements
- 8 phase-shiftable 1PPS from 100 MHz
- Alignment to UTC with GPS
- 1PPS
- IRIG
- EuroCard



Conclusions

Conclusion

- Technology Development Collaboration
  - Miniaturization, integrated optics
  - Microwave generation for Radar, Lidar, RF equipment
  - Reliability & Compactness of timing & frequency systems
- Other R&D Interests
  - Frequency conversion (proposal with Lukasiewicz)
  - Ultra-stable MLL
  - High Power Laser

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