National White Rabbit Network

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SIG-TFN
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Outline

- CZ Infrastructure for Time and Frequency – CITAF
- Time Distribution in CESNET Network – 2024
- National White Rabbit Network

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CITAF

Czech Infrastructure for Time and Frequency

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CITAF

- To be a national platform for cooperation in research and development of methods of time and frequency transmission in optical networks;
- To establish a permanent national optical infrastructure for the transmission of time and frequency and interconnect it to the follow-up European infrastructure;
- To support joint publishing activities of partners and cooperation in national and international projects and grants;
- Present the results of cooperation and develop an awareness of the possibilities and use of the distribution of very accurate time and stable frequency.

ÚFE

CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE

ISI CAS

FJFI

IPP

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CITAF has currently 6 partners

- three institutes
- two faculties
- CESNET

http://citaf.org

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Time Distribution in CESNET Network - 2024

Accurate White Rabbit service in CESNET network (2024)

- Service available in 6 nodes at university or research institute
- WR-LEN are beeing replaced by WRS technology
- Operate a reliable distributed WR system is a challenge
  - monitoring
  - resilience

Optical network infrastructure

- Shared with data services
- Bidirectional transfer over dedicated channel in commercial DWDM
- Bidirectional amplifiers in telecom huts

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Standard WRS

- https://white-rabbit.web.cern.ch/

- **Modes: BC (boundary clock), GM (grand-master), FR (free running)**
- **Modes are configurable but fall down to FR in case of reference issue**
  - Sometimes do not return back to BC / GM - difficult to reproduce
- **No possibility to switch from GM to BC in case of RF signal fail**
- **No direct indication of mode or mode change (i.e. LED change)**
  - Mode and other running parameters accessible by SNMP

White Rabbit Switch

Several issues of standard WRS that complicate use for 24/7 service or in large heterogeneous and multidomain setup:

- **Only one port port might be configured as slave**
- **No possibility to switch from GM to BC in case of RF signal fail**
  - Box requires reconfiguration in case of lost reference
- **Identification of network failure requires active monitoring**
- **SFP calibration parameters tied with #PN**
  - Impossible to calibrate more SFP of the same type

Modernization of CESNET Optical Network

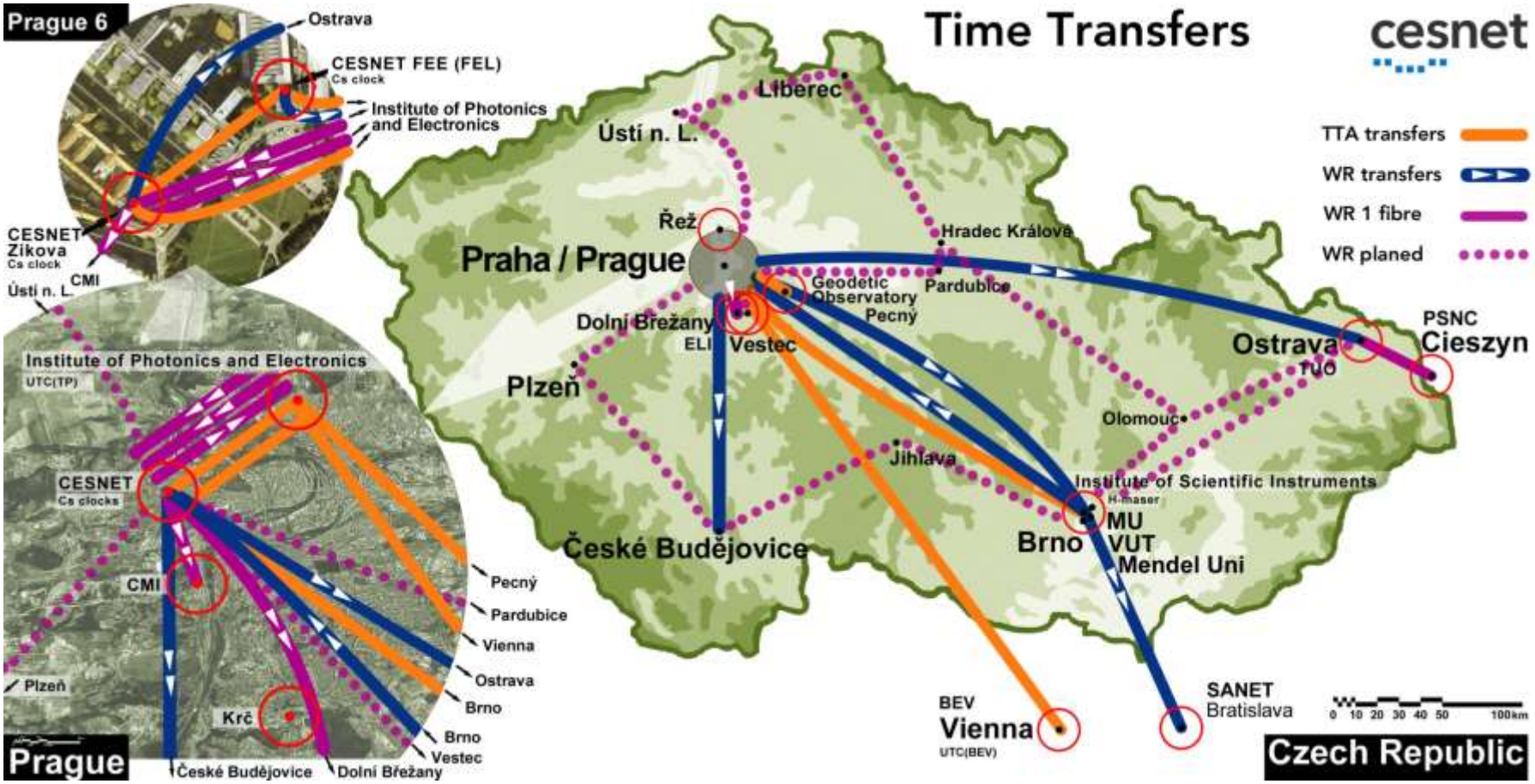
In 2024 started a large national project aimed at modernization of CESNET optical network

- **Sub-goal: Infrastructure for accurate time distribution**

Parameters White Rabbit Network

- **20 Points-of-Presence with WR switch**
  - including WR PoPs in neighboring countries: AT (Vienna), Poland (Cieszyn), SK (Bratislava)
- **Advanced WR boxes**
  - multiple switchable references
  - redundant power supply
- **Reserved bandwidth (move to “near” L-band)**
- **Dedicated bidirectional amplifiers**
- **Two independent sources of accurate time traceable to UTC(TP)**
  - H-masers in Cesnet (Prague) and UPT (Brno)

White Rabbit Network



White Rabbit with Multi-source Reference

WR boxes with several reference inputs

- **Specified priority of inputs (SFP ports and RF)**
- **Holdover mode with defined duration**
- **Automatic switching to another input in case of signal failure**
- **Recovery once higher priority signal is available again**
- **Switching as fast as possible**
  - No box with immediate switching yet available ??

WR-Z16

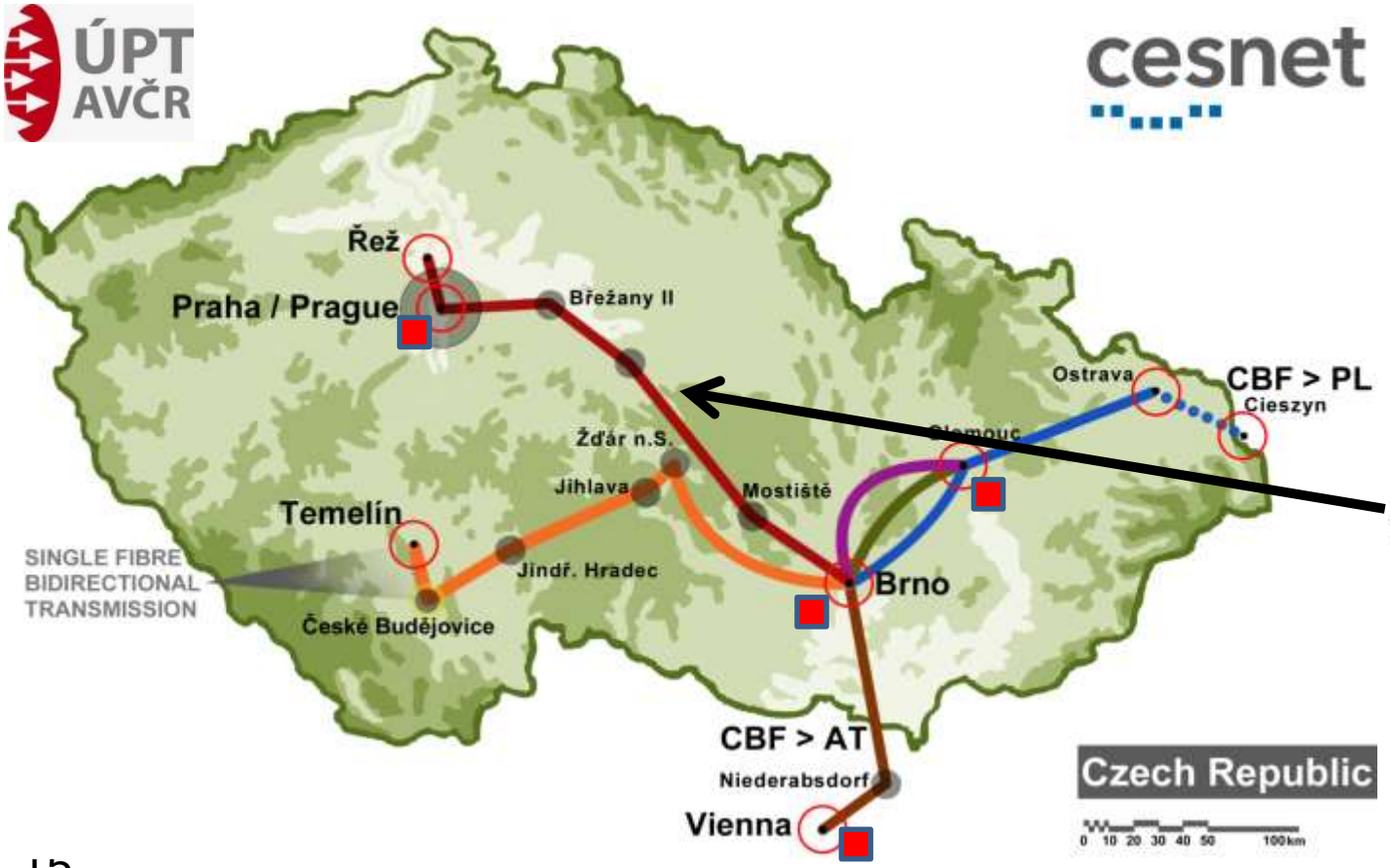
Example: WR-Z16 from Safran/ SevenSolutions

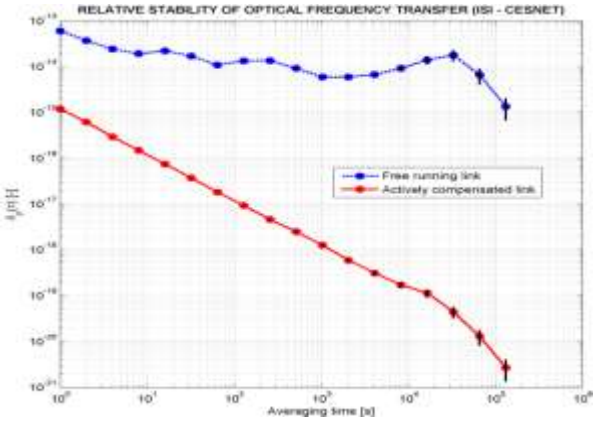
- two reference SFP ports
- 1PPS / 10 MHz inputs
- input switching takes tens of seconds

Outline cont.

- **Design Considerations**
  - Spectrum shared - among DATA, COF and WR
  - OADMs
  - WR regeneration or amplification
  - Common EDFAs for T and F or distinct
  - Synchronisation and Quantum
- **Monitoring**
  - White Rabbit
  - Bidi EDFAs
  - Coherent Optical Frequency

Coherent Frequency Transfers

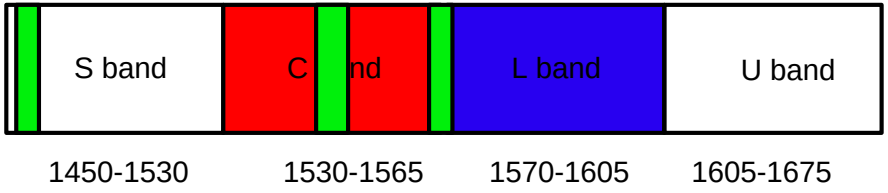


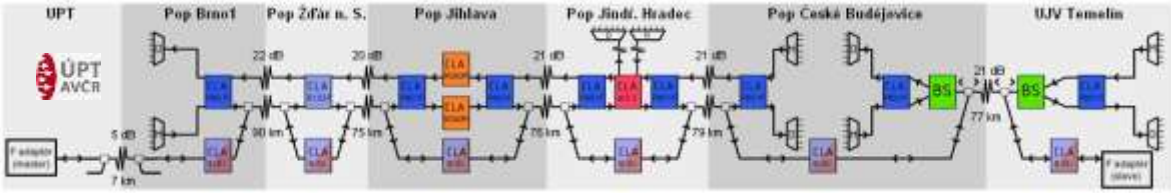


CESNET Praha - UPT Brno 306 km, ADEV 10^{-18} @10^{3} s

Shared Spectrum

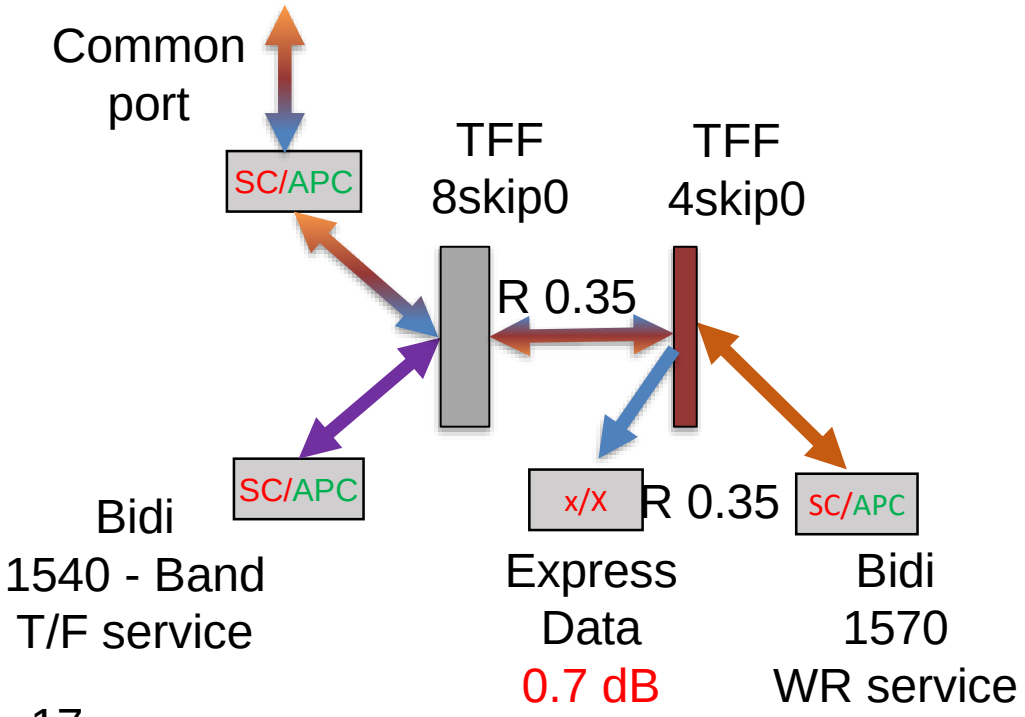
- Fibre infrastructure 5800 km approx., coherent 100-400Gbps per lambda
- For time and frequency dedicated all-optical bidirectional bandwidth reserved (skipping telco equipment)
- 120 pcs. of OADMs deployed mainly in 2021
- Dual window OADMs installed: 46-39ch and 9-6 ch
- COF hannels 44+46, ready for ch 7
- One line with 1458nm COF transfer (Ca+ clocks)
- Bidi EDFAs used to compensate losses (cca 28 pcs. now)





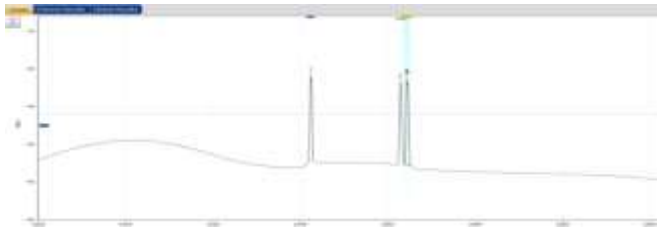
Multi-service TF Infrastructure

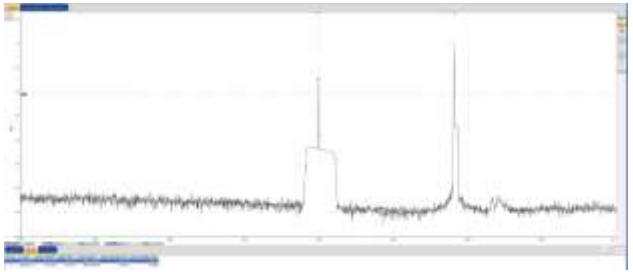
- Dual band OADMs

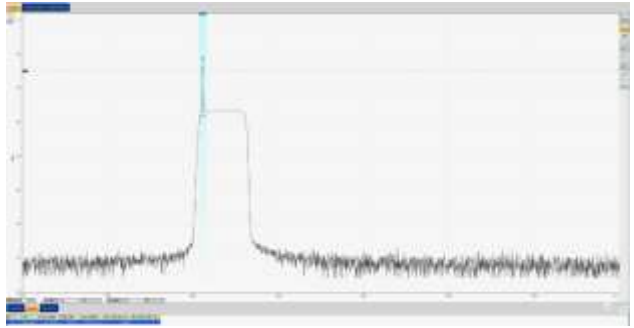


Shared Amplification between COF and WR

- Established shared channel 2015
- 308 km, 5 and later 6 bidiEDFAs
- Possible however…..
- Noise accumulates in bidi channel fast
  - COF - lower OSNR is acceptable
  - WR - need decent OSNR

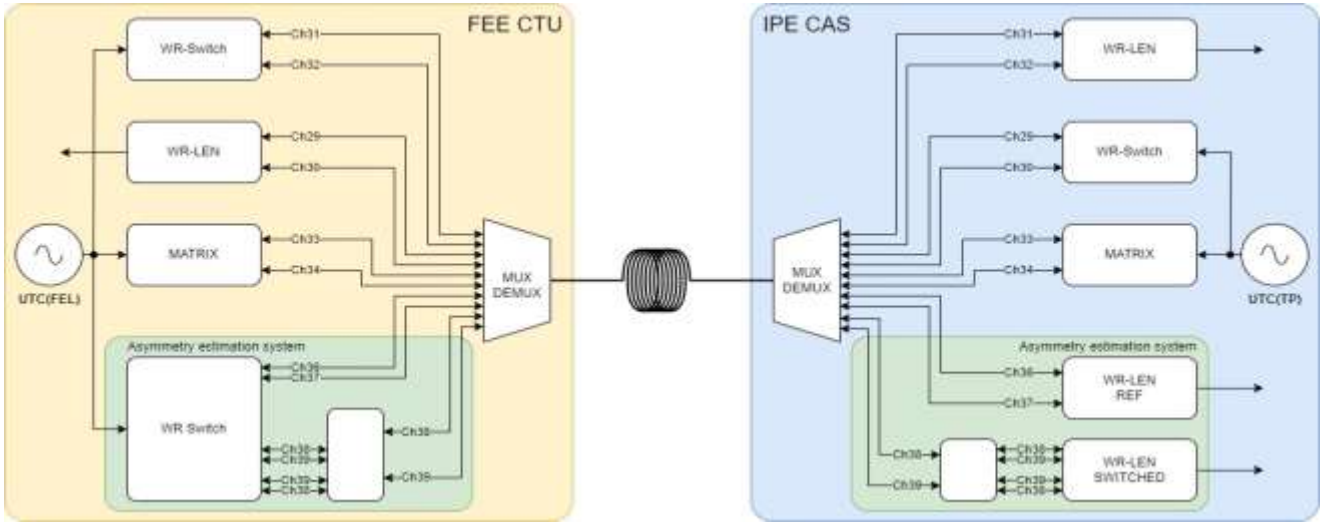






Multiple T Transfers - Benefits

Multiple transfers in single fibre



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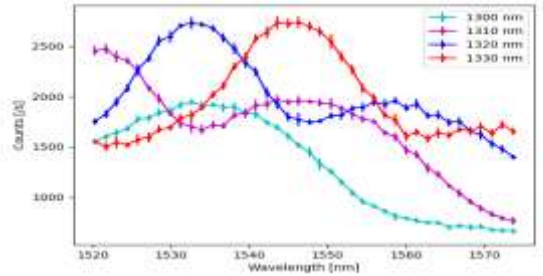
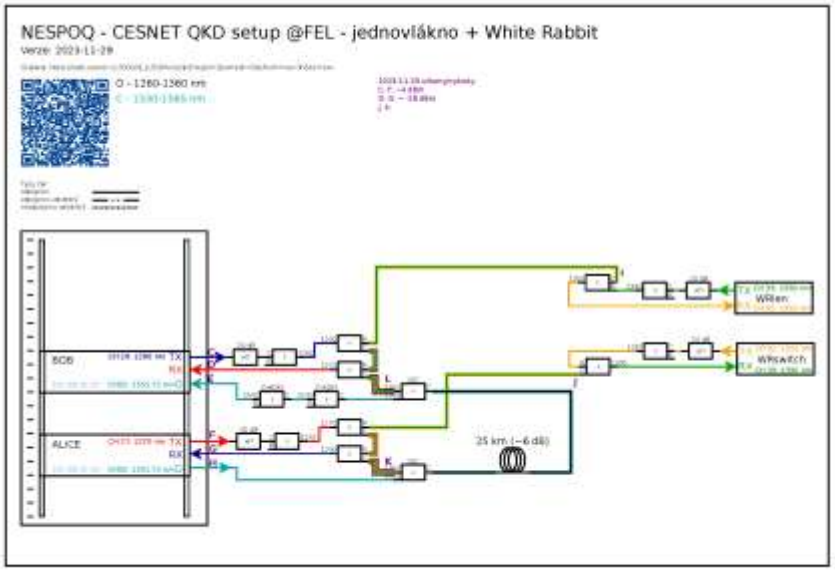
Michal Špaček et al. "System for continuous evaluation of optical path asymmetry"; https://doi.org/10.1117/12.2678936

Line calibration described by E. Dierikx and Y. Xie, White Rabbit Good Practice Guide, May 2019

- **Parallel transfer – doable but….**
- **WR – relativelly strong signals**
- **Q channel 1550 nm – spont. Raman photons**
- **Q channel 1310 nm**
  - 1.6 times short reach
  - 90km instead 150km





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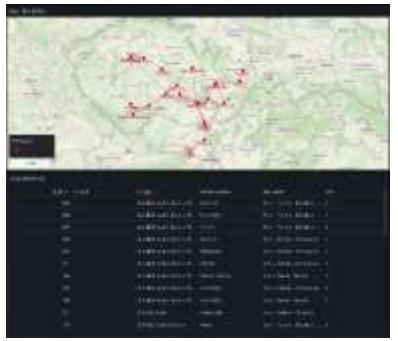
MONITORING

- **Goals**
  - Monitoring and control of bidi EDFAs (1600km already in operation)
  - Monitoring of complete WR network status
  - Monitoring of COF transfer status
  - Check for failures and network changes



- **Integration with currently deployed monitoring solution**
  - Grafana
  - Victoria Metrics
  - Telegraf

- **Centralized dashboard for both Open HW and Z16 variants of the WR Switch**

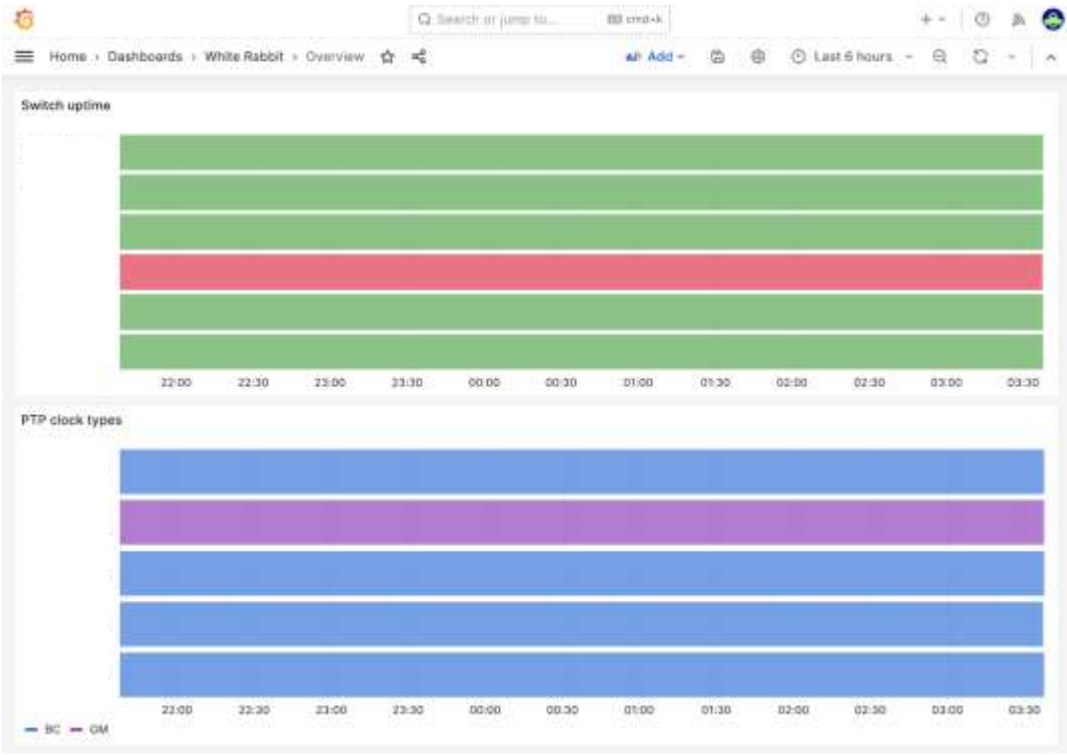
White Rabbits Monitoring

Open Hardware WRS

- Data collection through SNMP
- Directly using SNMP plugin in Telegraf

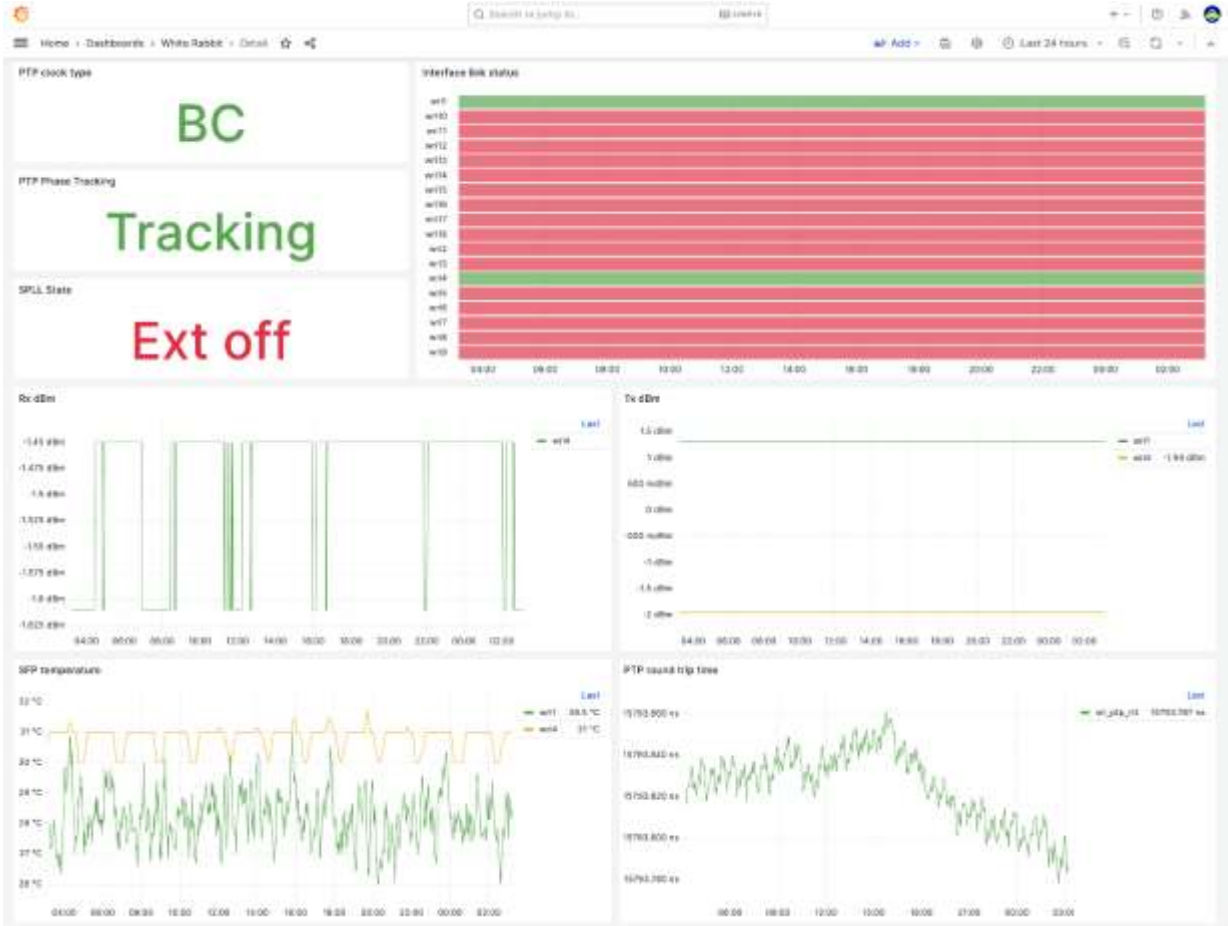
WRS-Z16

- Data collection through REST API
- Python script feeding data into Telegraf
- Acquired data mapped to corresponding WRS values to ensure full compatibility



White Rabbits Monitoring

- Collected data
  - Clock type
  - WR status
  - SFP link status
  - SFP Rx and Tx power
  - SFP temperature
  - PTP round trip time



BidiAmplifiers Monitoring

- Data acquisition protocols

SNMPv2/3 – many data from optical layer & system
SSH – some system data by Ansible playbooks

- Data storage

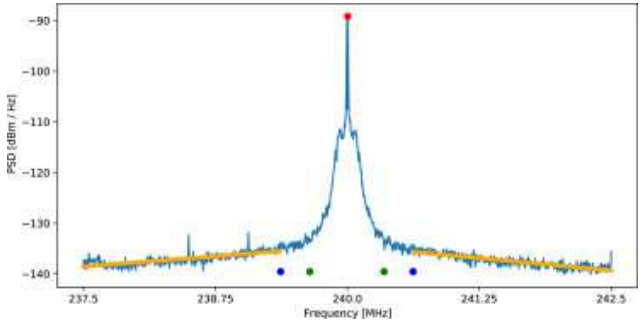
VictoriaMetrics – lightwave powerfull time series database:
possitive experience (6 months ~
436 M datapoints; 59 MB space on disk
for (optical power levels,attenuations, wavelengths, . . .)

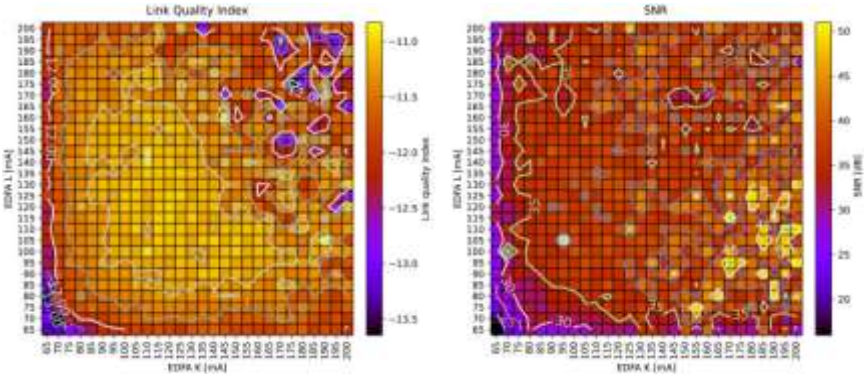
- Data view

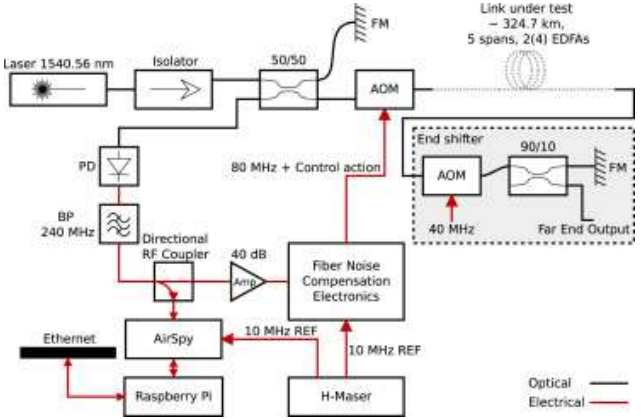
CLManager – in-house developed CMS for CzechLight boxes
Grafana – interactive, powerfull and highly customizable dashboard system

COF Transfer Monitoring

- Evaluation of beatnote signal at RLS
- Link Quality Index (LQI) proposed
- The goal of LQI is to determine the state of the link before undesired lasing or transfer drop emerge.
- Used for balancing of gain of EDFA amplifiers cascade.







M. Slapak at al: Stabilization of super coherent frequency transfers via amplifier cascade balancing. Oct 2024 https://doi.org/10.1016/j.yofte.2024.103910

We are open and looking for cooperation and experience Exchange. Thank You very much for kind attention! Questions?

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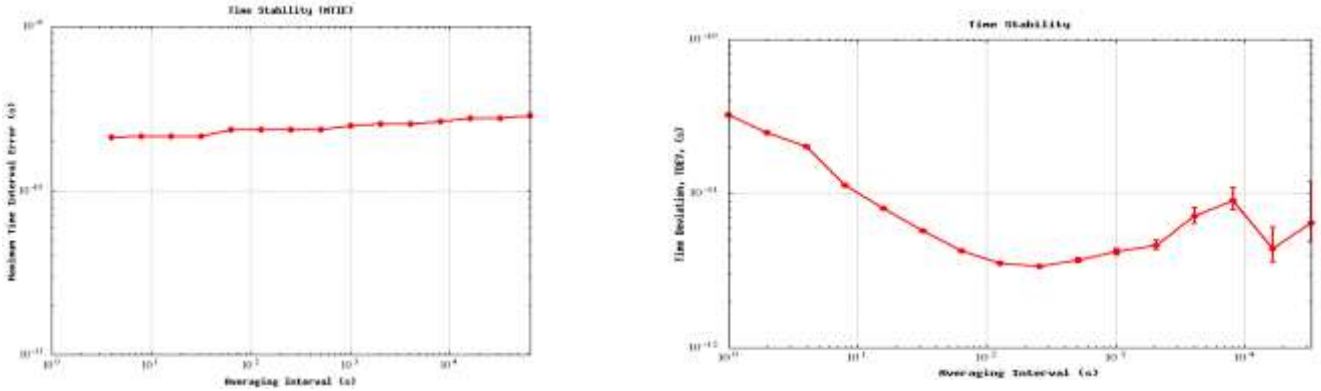
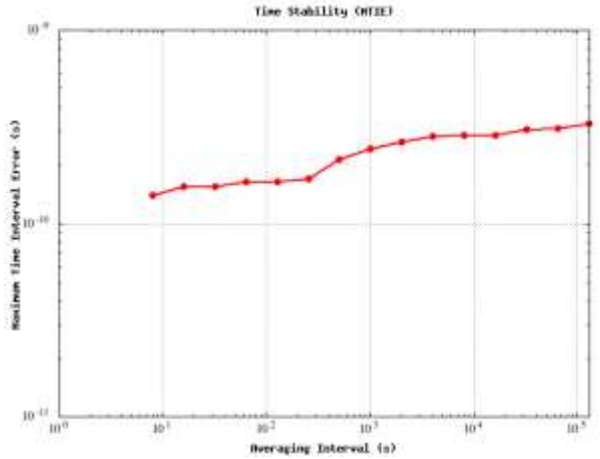
Amplification vs. Regeneration

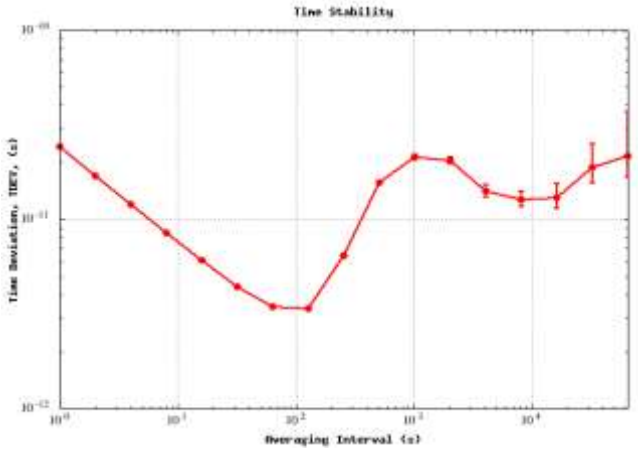


Left maximal time interval error (MTIE), right time deviation (TDEV), 1570 nm band, ch 8+9, **three 100km** spans, 2× amplified by Bi-di EDFA

J. Vojtech et al., "Long Haul Single Fiber Reamplified-Reshaped White Rabbit Transmission," 2021 Joint Conference of the European Frequency and Time Forum and IEEE International Frequency Control Symposium (EFTF/IFCS) doi: 10.1109/EFTF/IFCS52194.2021.9604245.

Amplification vs. Regeneration





Left maximal time interval error (MTIE), right time deviation (TDEV), 1570 nm band, ch 8+9, **three 100km** spans, 2× 2R speed and protocol agnostic **regenerator**

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