Highlights from the OPNT test results at a US Tier-1 telecom lab

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Marc Weiss, presenter
A. Savencu, C. van Tour, M. Johnson, J.C.J. Koelemeij

opnt. TIME PROVISIONING

What was done

- Work in lab of a Tier-1 US telecom carrier simulates their actual network
- Measured the accuracy and stability of OPNT White Rabbit (WR) time signals
- Equipment from four different WDM vendors used
- WR inserted onto networks using OPNT filters to mix WR signals with other wavelengths
  - Using the Optical Supervisory Channel (OSC) with one vendor– allows insertion of filters without service disruption, but only certain equipment provides the connection
  - Also using S band wavelength for the WR
  - Equipment Calibration (back-to-back) and Link Calibration (delay asymmetry due to chromatic dispersion)
- Measurements made with and without Optical Amplifiers
- Results reported here: Phase plot, Stats, ADEV, TDEV (emphasized)

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1. Overview of Measurements & Measurement Setup, Schematic Overview & Results

Overview of the measurements

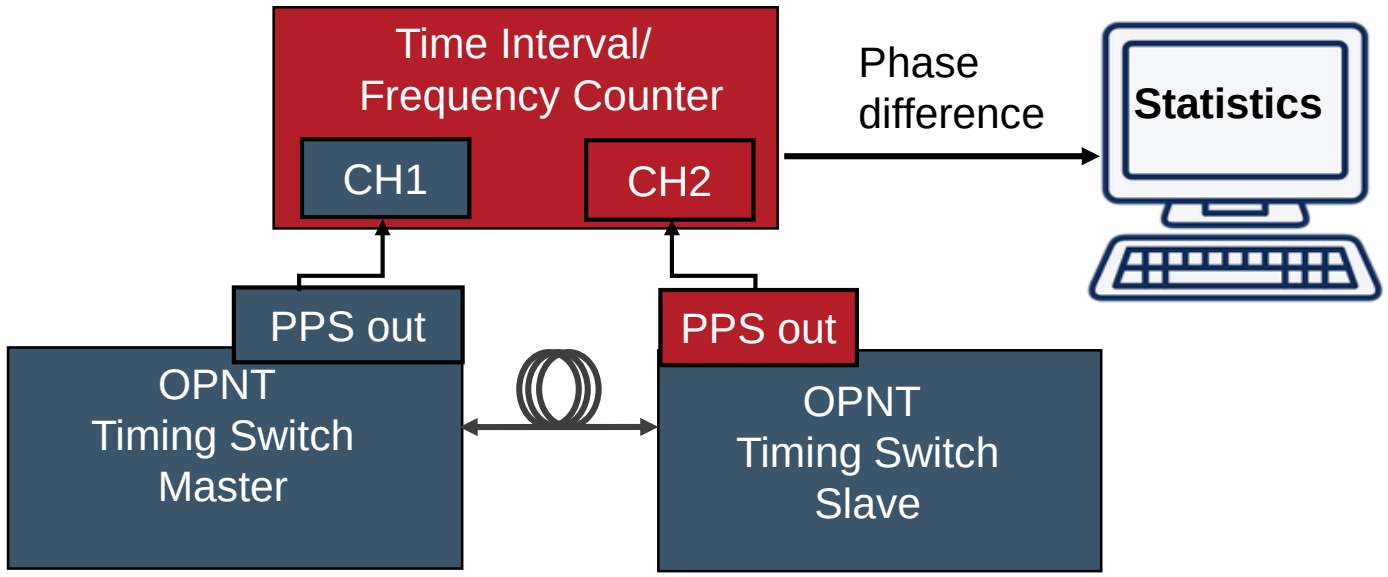
WDM System	Wave-lengths	Fiber Length (km)	Optical Amplifier
V1	OSC	140	Without
V1	OSC	140	With
V1	S band	140	With
V2	S band	100	Without
V3	S band	80	Without
V4	S band	90	Without

The OPNT Timing Switches make use of the White Rabbit (WR) protocol developed at CERN (https://www.ohwr.org/projects/white-rabbit).

* The wavelengths of the OPNT Timing signals are:
- OSC: 1511.81 nm/1511.05 nm (ITU DWDM Grid)
- S band: 1470 nm/1490 nm

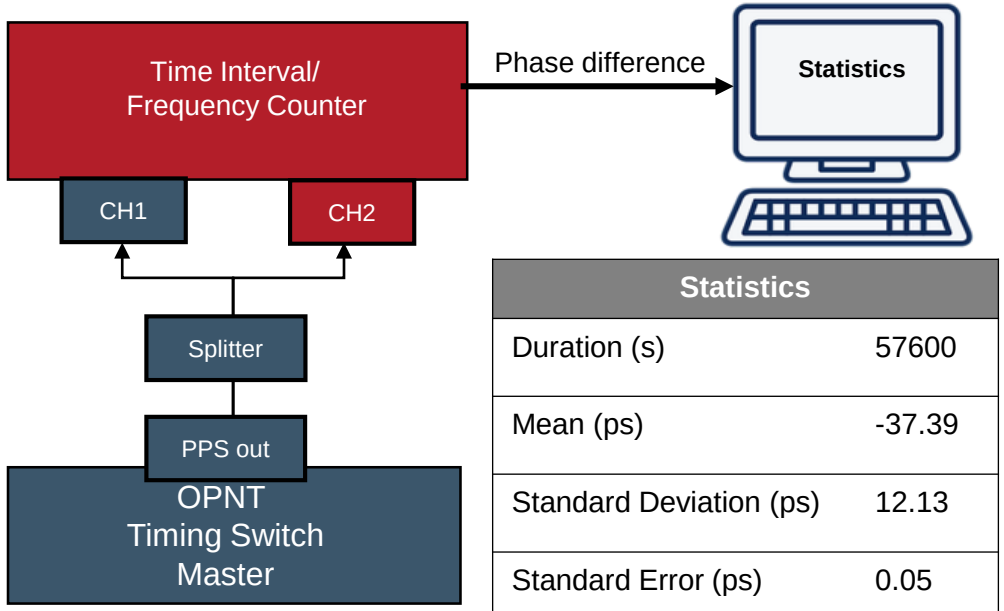
** The OPNT Timing signals can be amplified with an OPNT Bi-Directional Optical Amplifier

General Measurement Setup

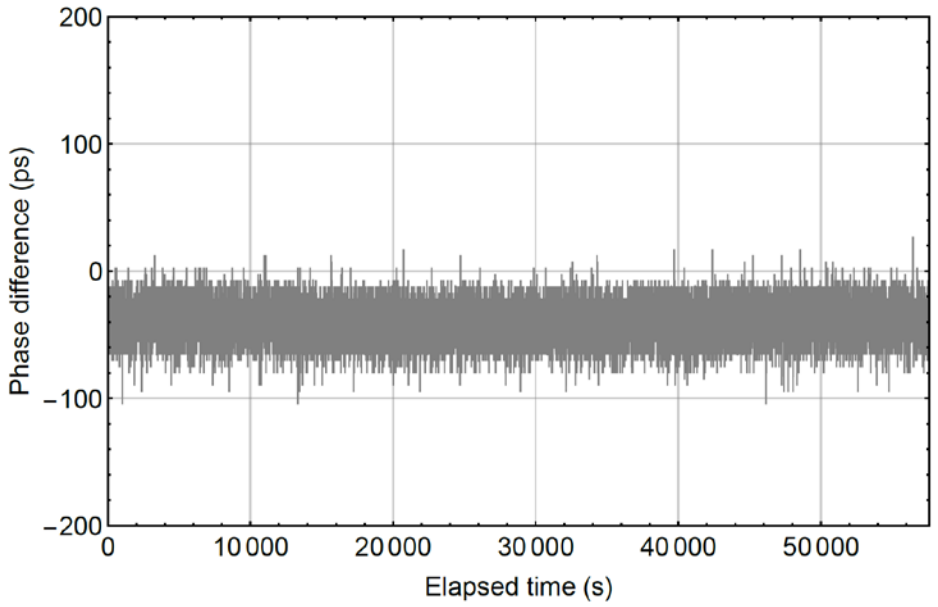


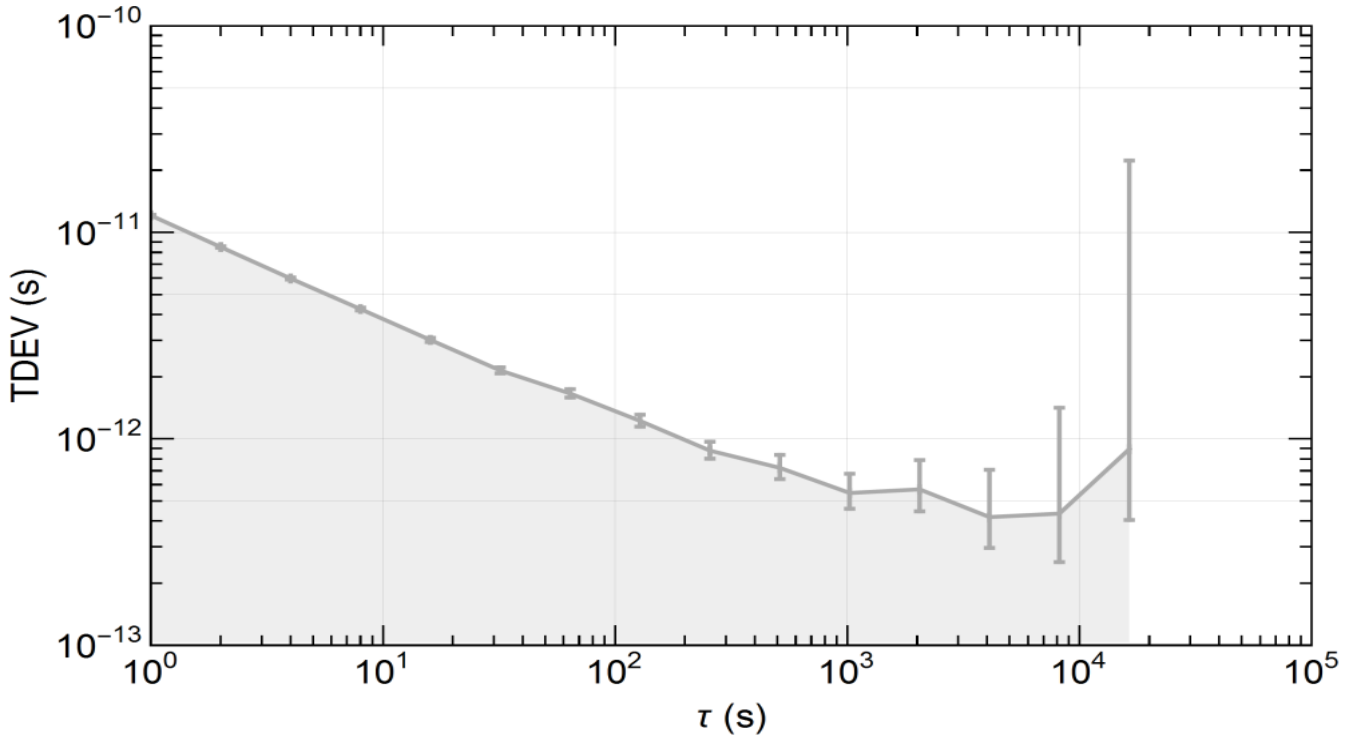
The pulse-per-second (PPS) output of the Master Timing Switch and the Slave Timing Switch are directly compared with each other using a Time Interval/Frequency counter.

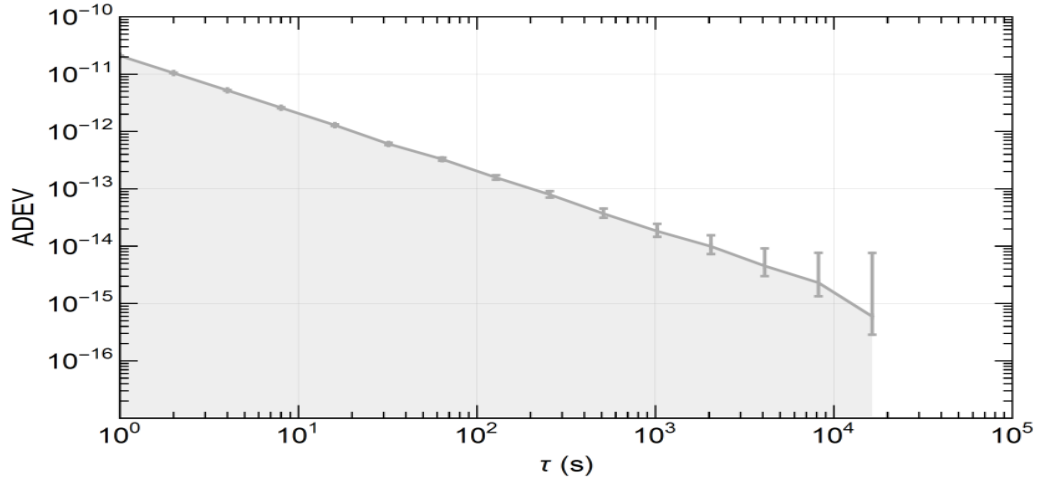
2. Noise Floor Measurement, Schematic Overview & Results



Statistics	
Duration (s)	57600
Mean (ps)	-37.39
Standard Deviation (ps)	12.13
Standard Error (ps)	0.05

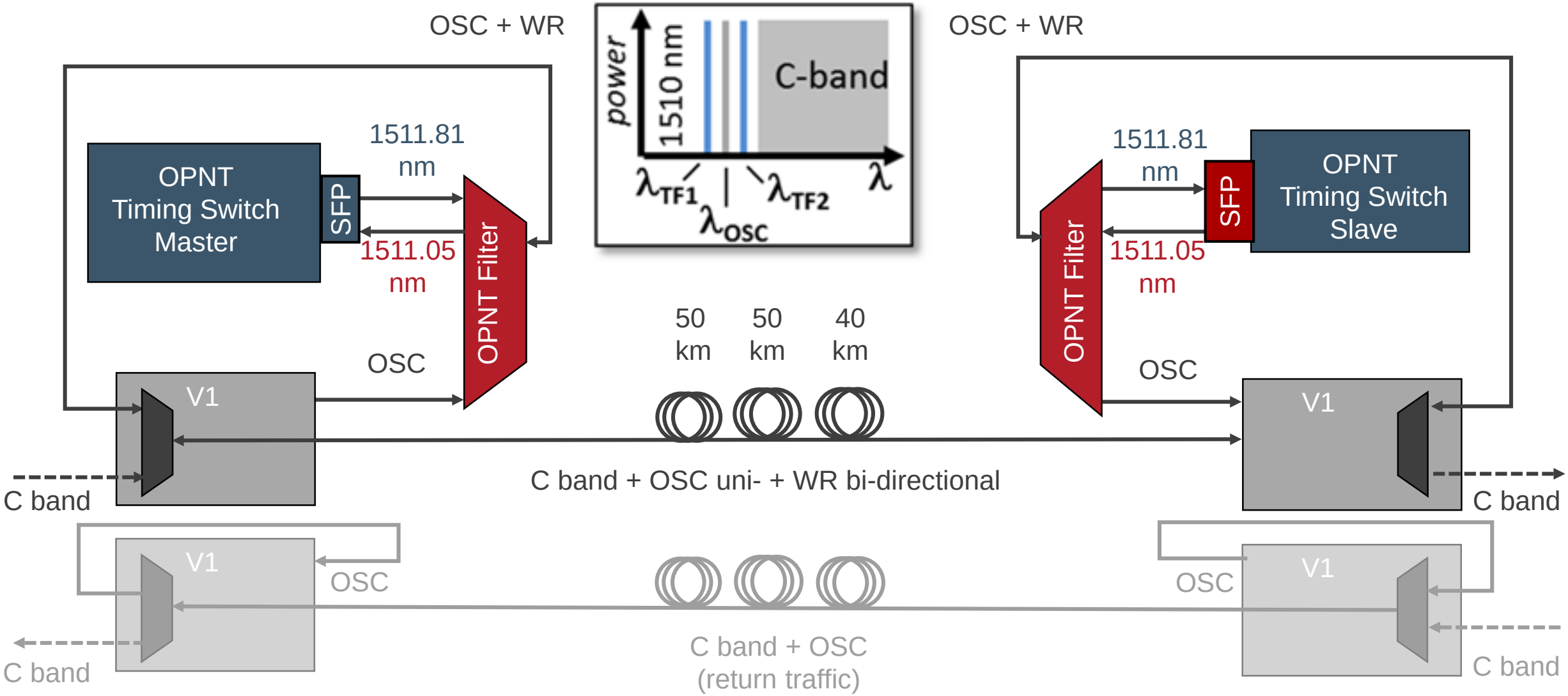






3. Vendor 1 (V1) – OSC Wavelength – 140 km – Without Optical Amplifier

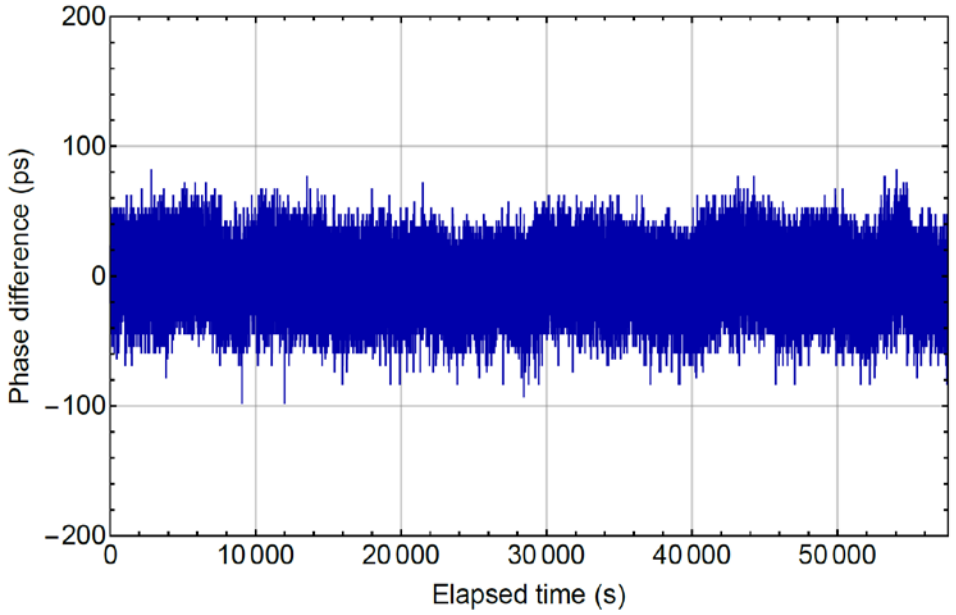
Schematic Overview

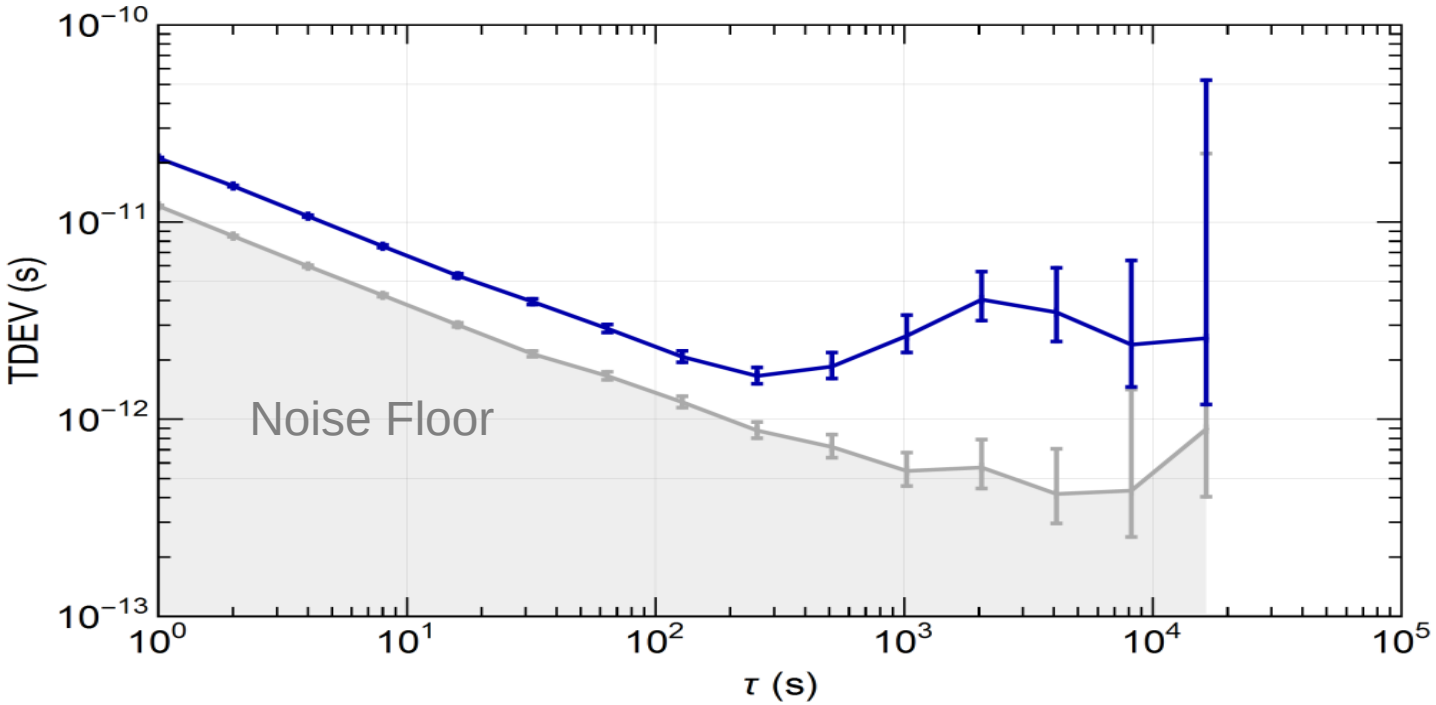


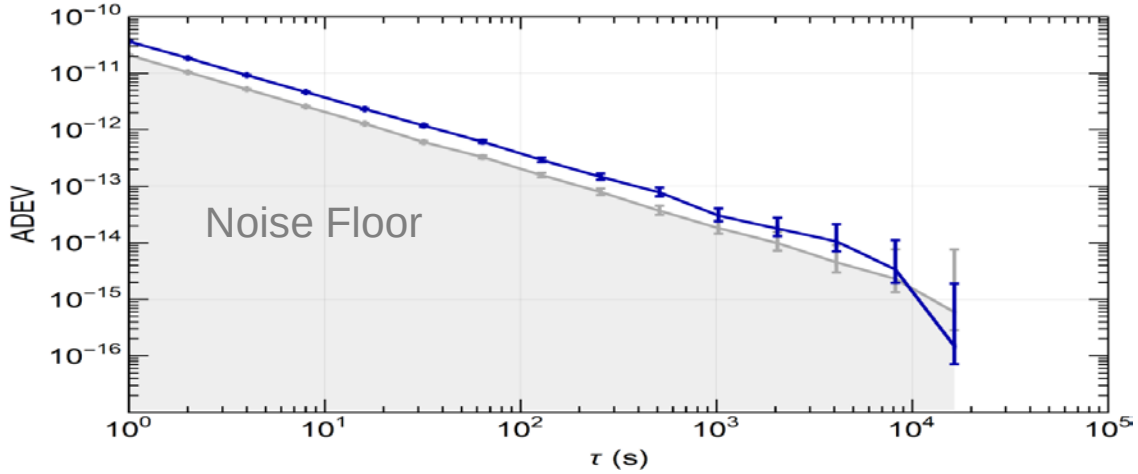
This OSC method is covered by a patent: US Patent 9331844 B2, R.J.W.M Nuijts, J.C.J. Koelemeij

3. V1 – OSC Wavelength – 140 km – Without Optical Amplifier, Results

Statistics	
Duration (s)	57600
Mean (ps)	0.04
Standard Deviation (ps)	22.16
Standard Error (ps)	0.09

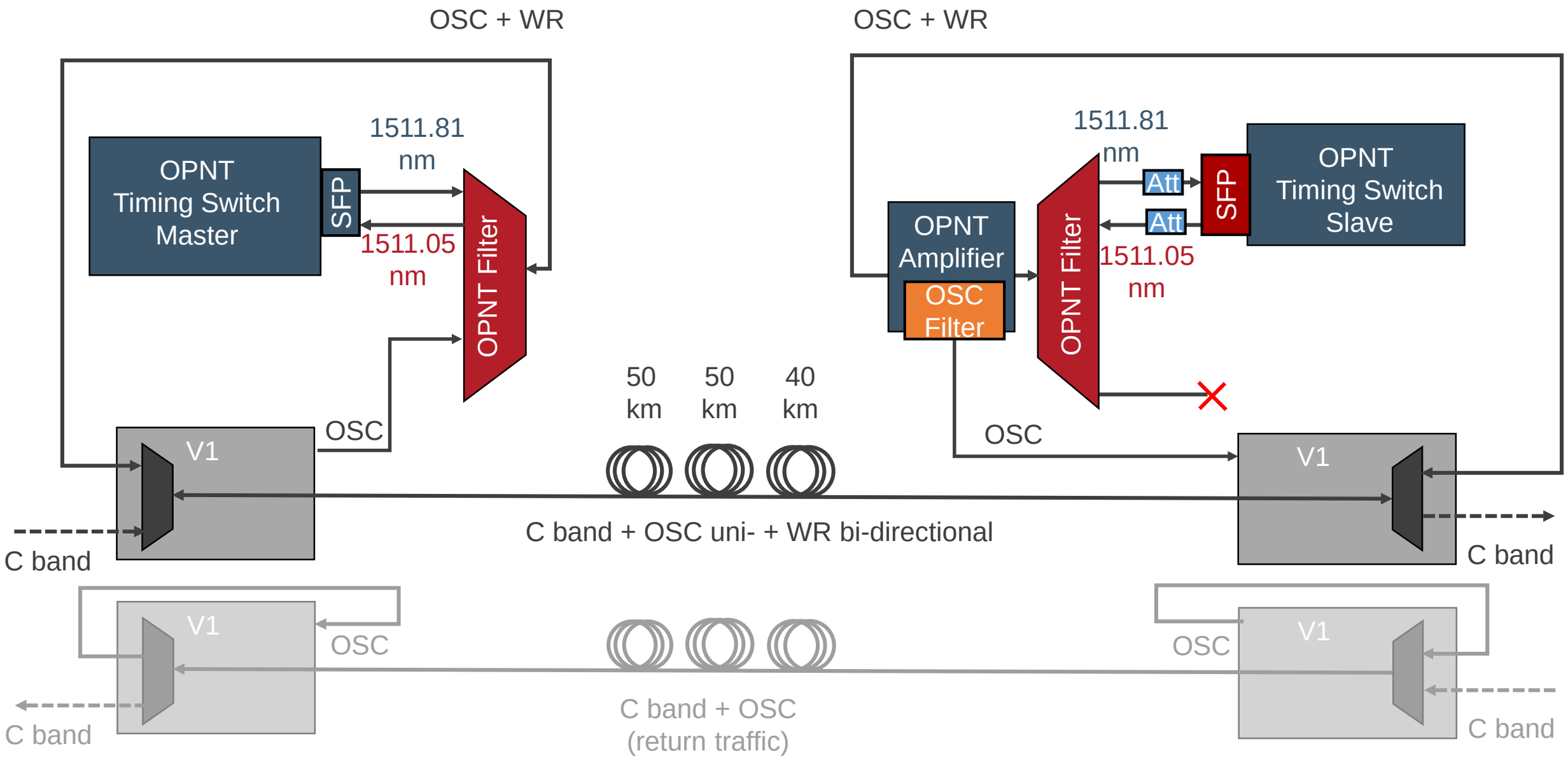






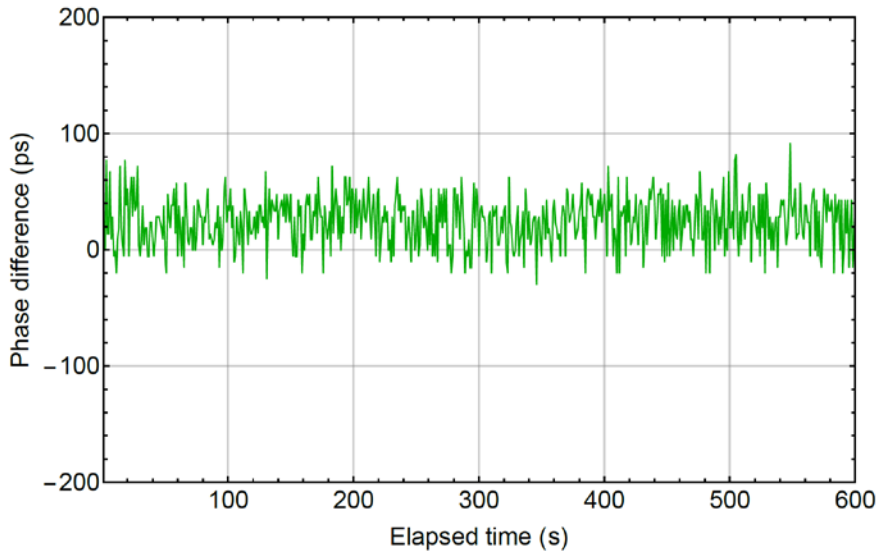
4. Vendor 1 (V1) – OSC Wavelength – 140 km – With Optical Amplifier

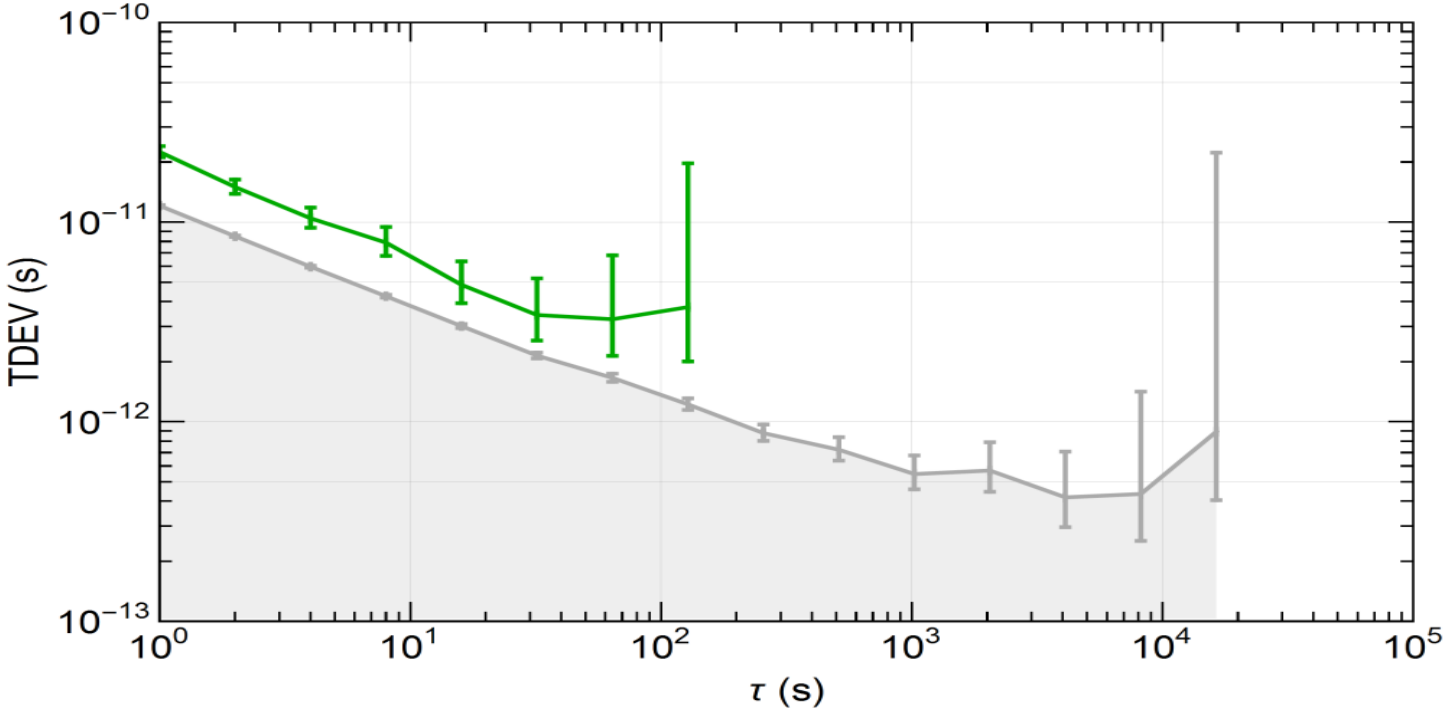
Schematic Overview

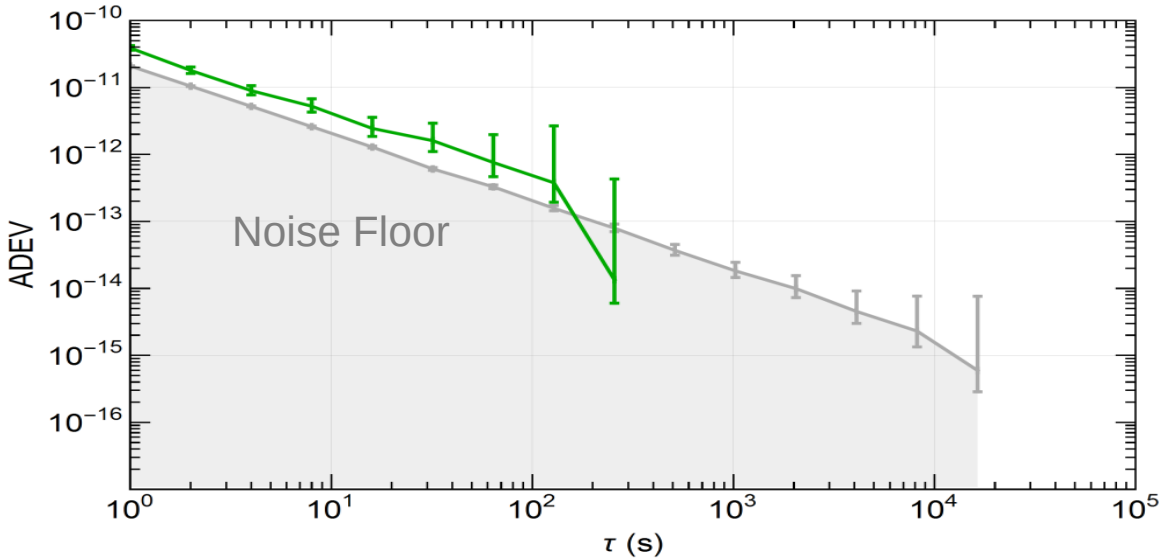


4. V1 – OSC Wavelength – 140 km – With Optical Amplifier, Results

Statistics	
Duration (s)	600
Mean (ps)	24.62
Standard Deviation (ps)	21.85
Standard Error (ps)	0.89

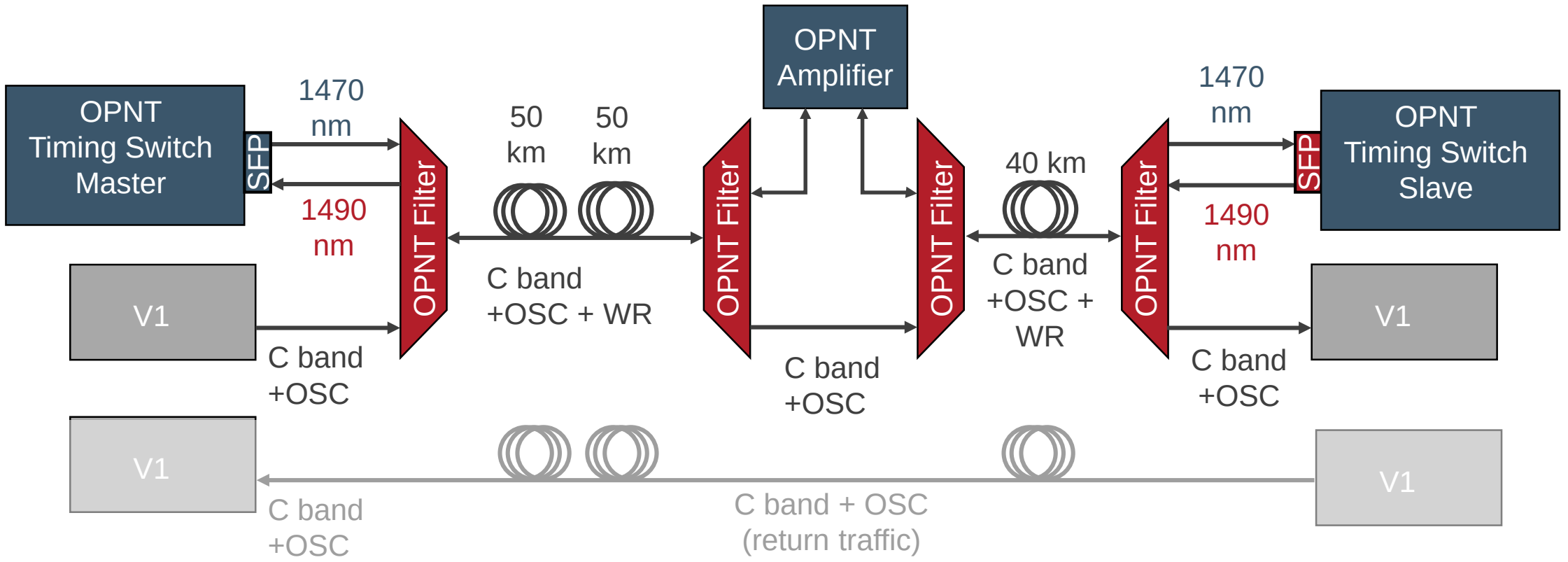






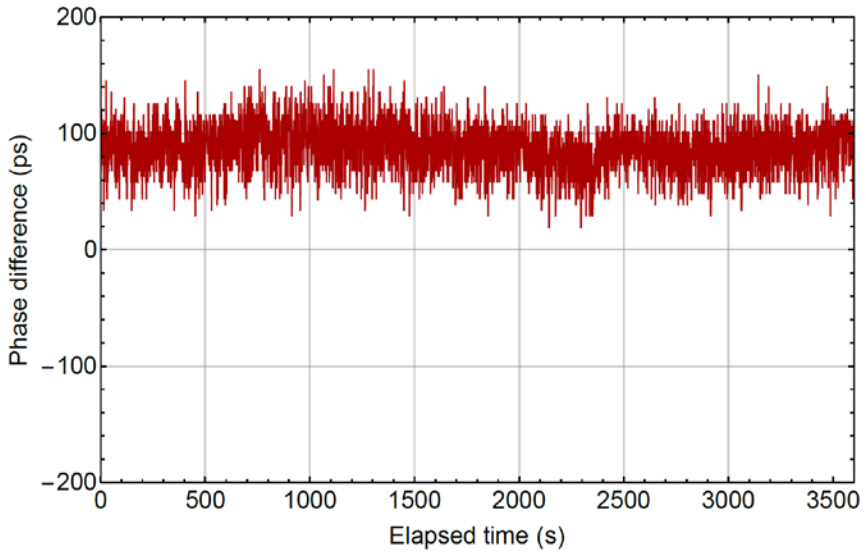
5. Vendor 1 (V1) – S-Band Wavelength – 140 km – With Optical Amplifier

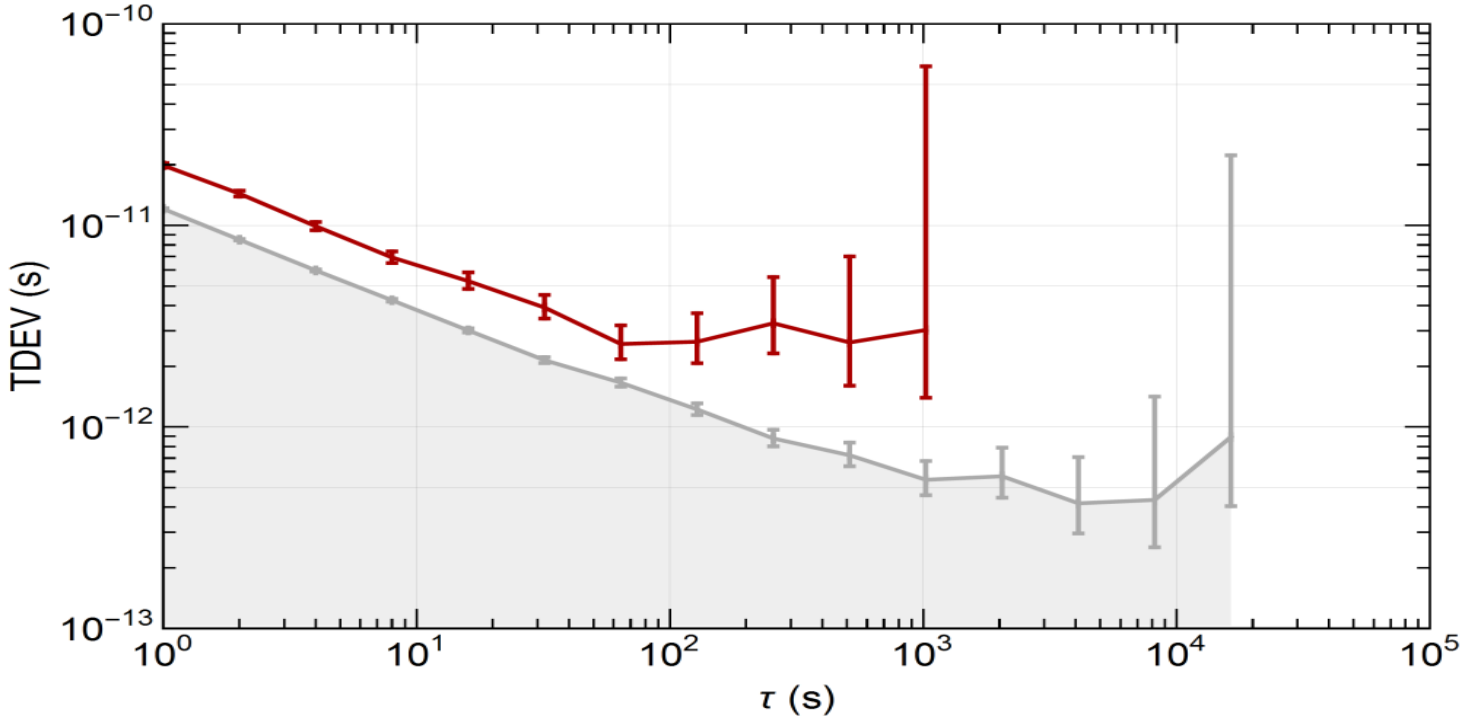
Schematic Overview

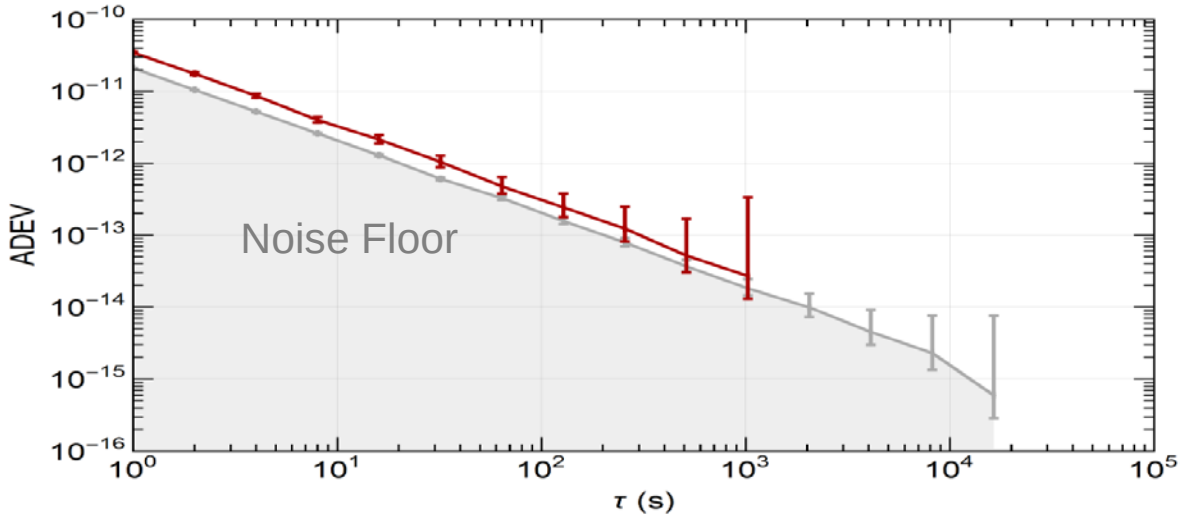


5. V1 – S-Band Wavelength – 140 km – With Optical Amplifier, Results

Statistics	
Duration (s)	3600
Mean (ps)	87.31
Standard Deviation (ps)	20.74
Standard Error (ps)	0.35

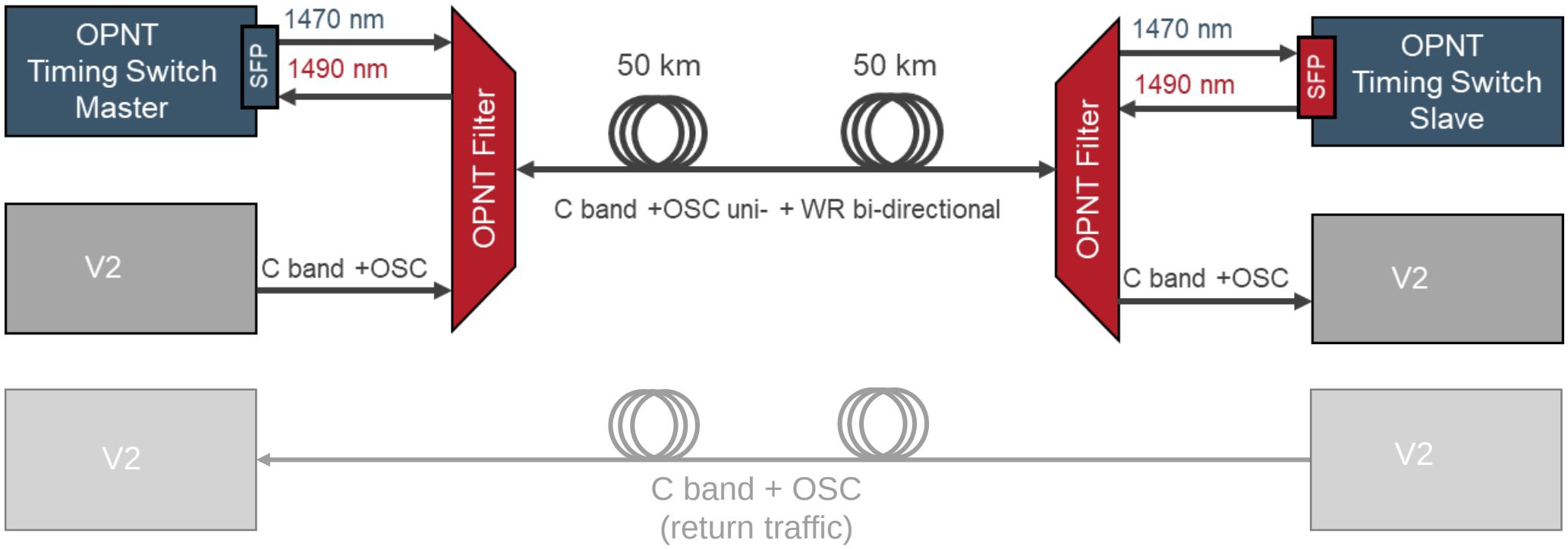






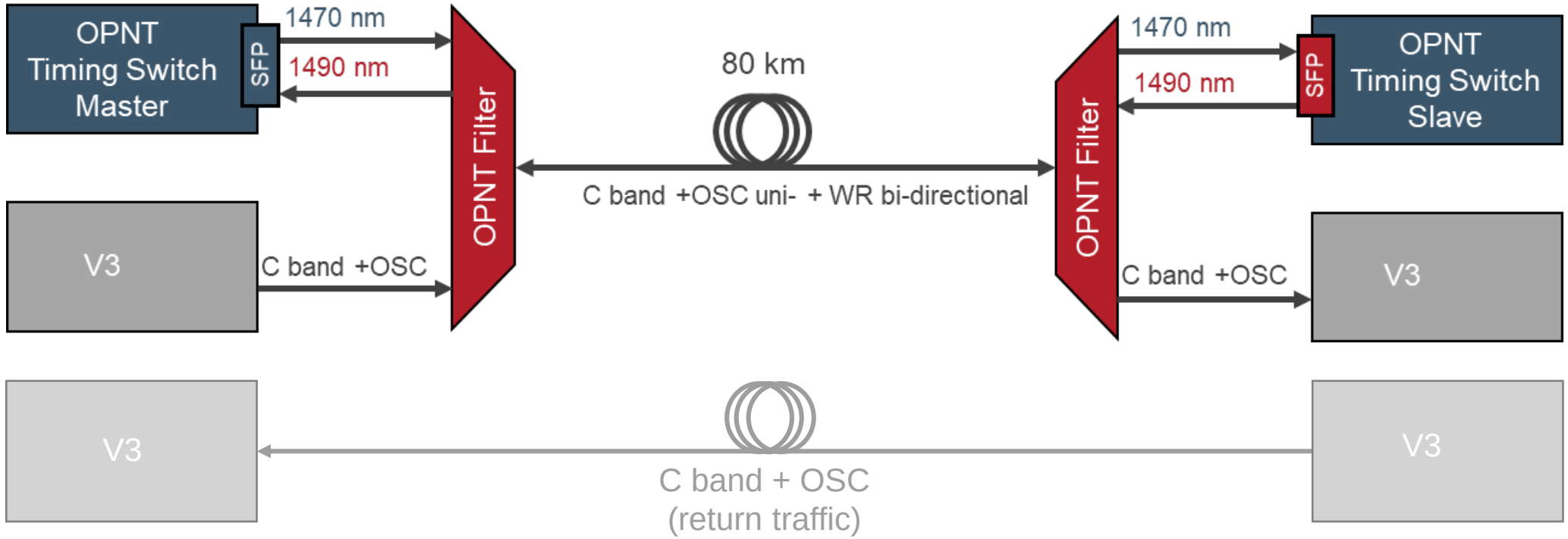
6. V2 – S-Band Wavelength – 100 km – Without Optical Amplifier
See results in summary

Schematic Overview



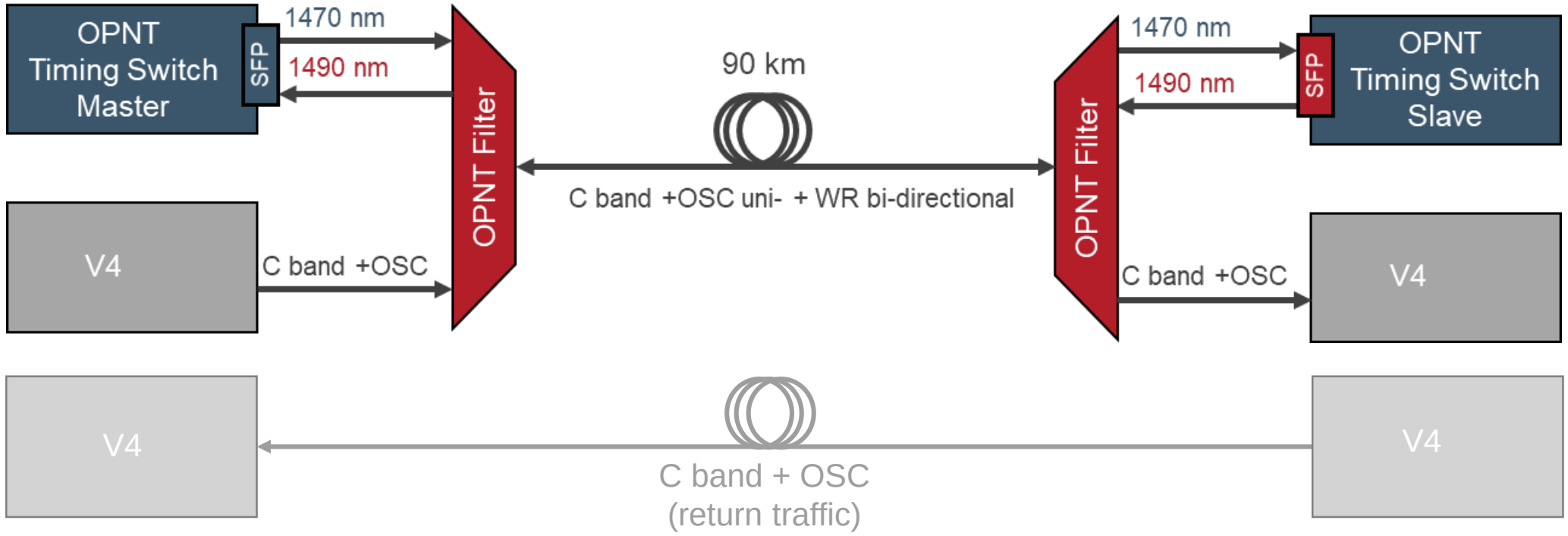
7. V3 – S-Band Wavelength – 80 km – Without Optical Amplifier
Similar to case 6, but with different vendor and fiber length – see results in summary

Schematic Overview



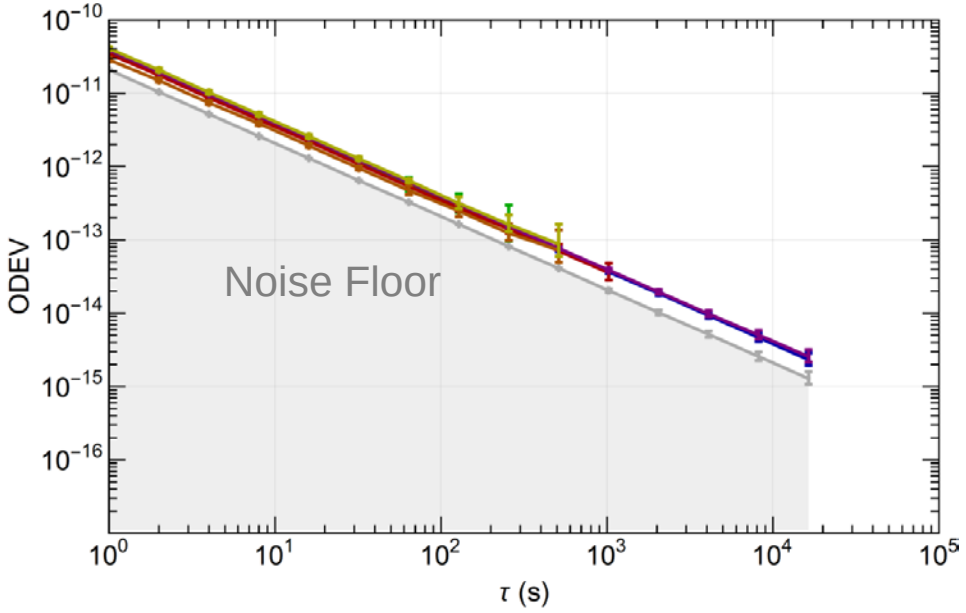
8. V4 – S-Band Wavelength – 90 km – Without Optical Amplifier
Similar to case 6, but with different vendor and fiber length – see results in summary

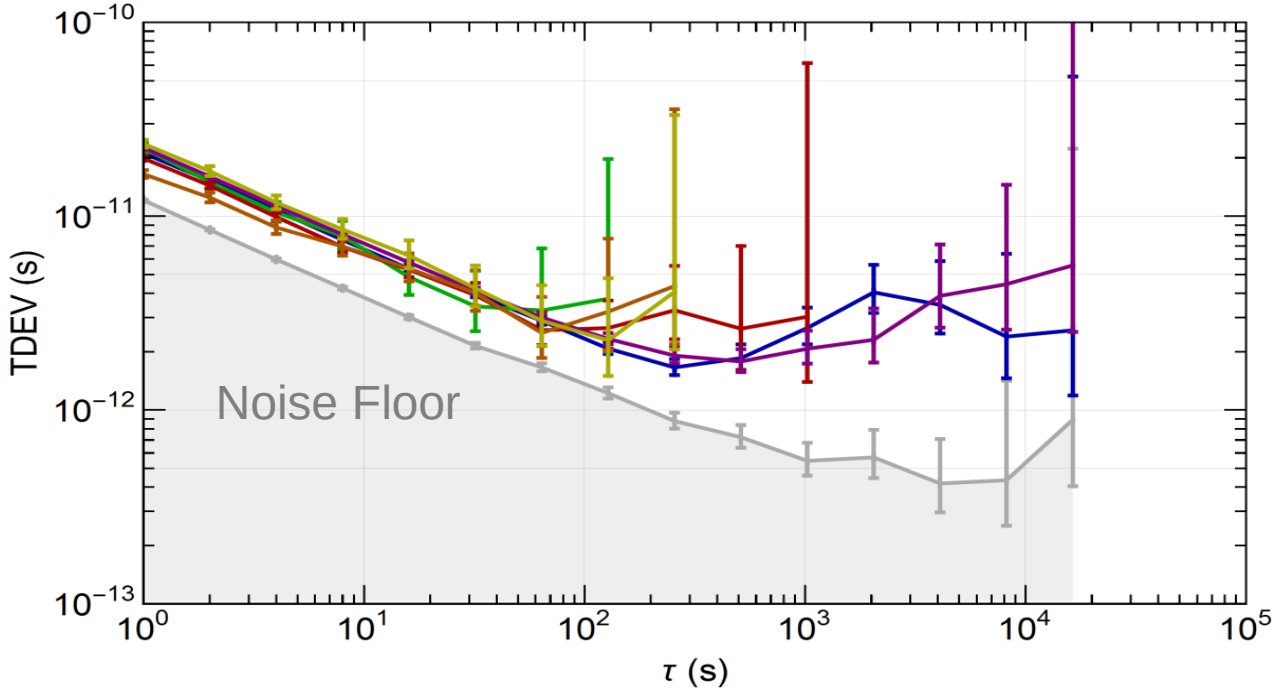
Schematic Overview



9. Overview of Results

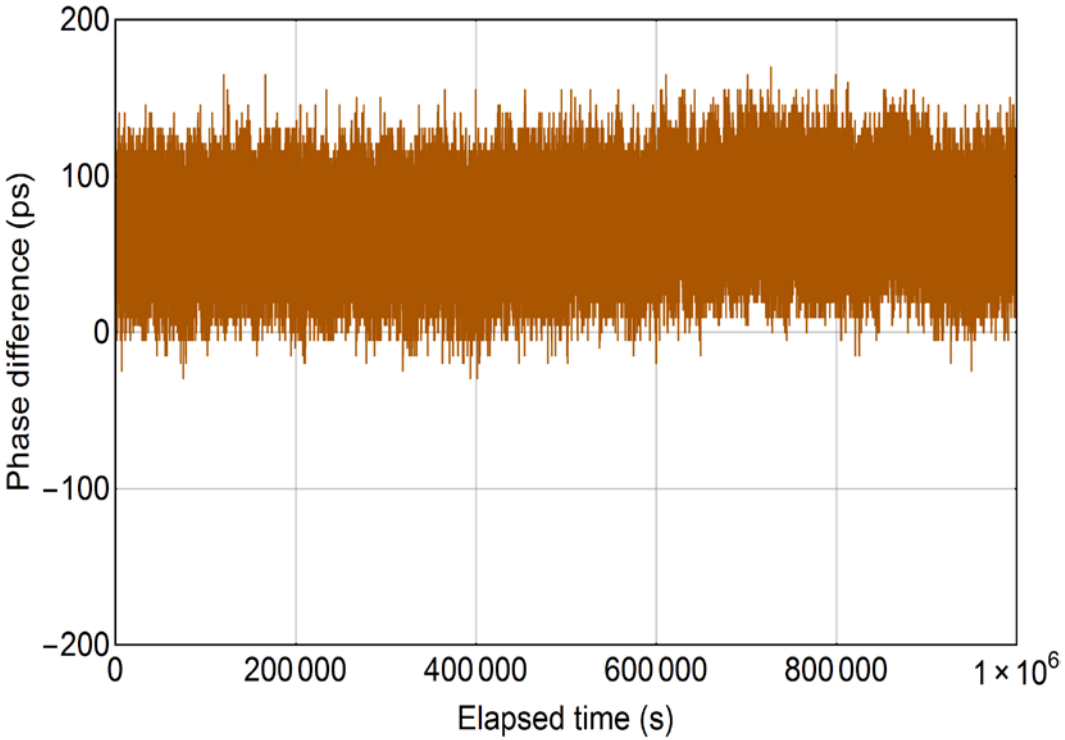
Color Index	WDM System	Wavelengths	Fiber Length (km)	Optical Amplifier	Duration (s)	Mean (ps)	Standard Deviation (ps)
—	V1	OSC	140	Without	57600	0.04	22.16
—	V1	OSC	140	With	600	24.62	21.85
—	V1	S band	140	With	3600	87.31	20.74
—	V2	S band	100	Without	1200	-54.44	24.25
—	V3	S band	80	Without	57600	30.78	24.03
—	V4	S band	90	Without	1200	67.85	19.82

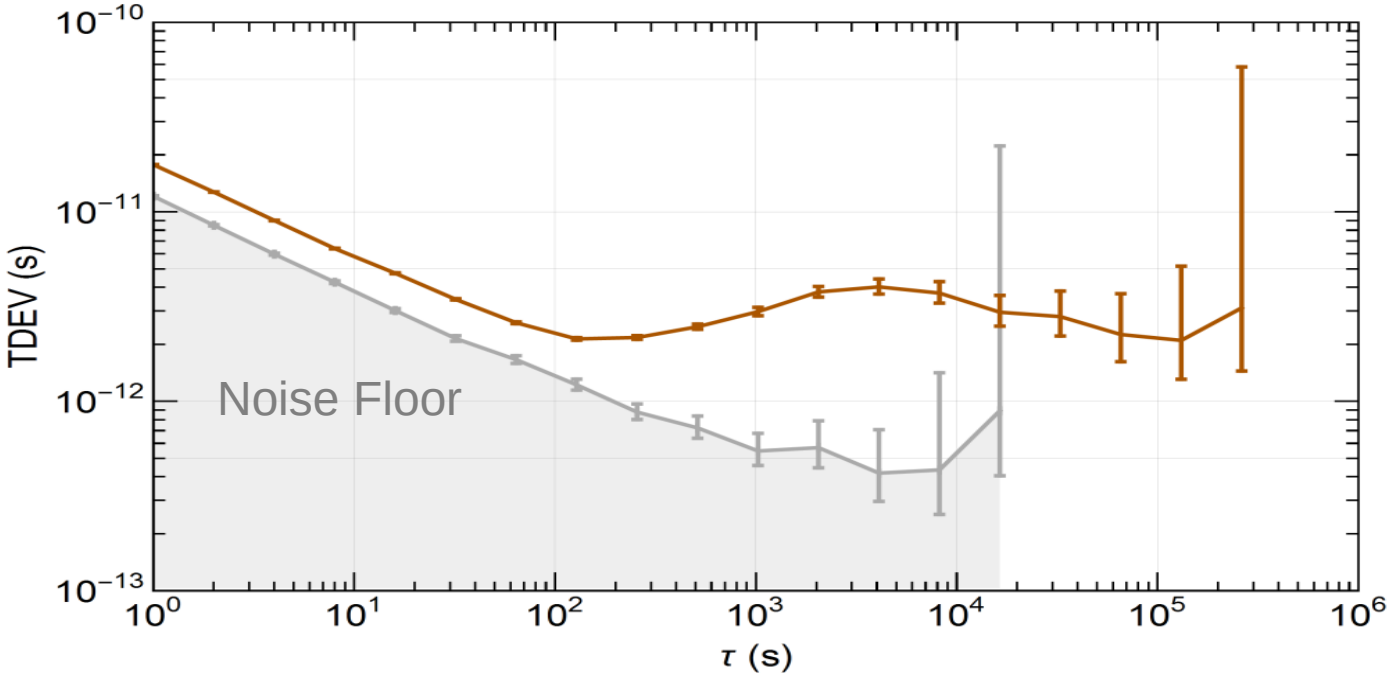


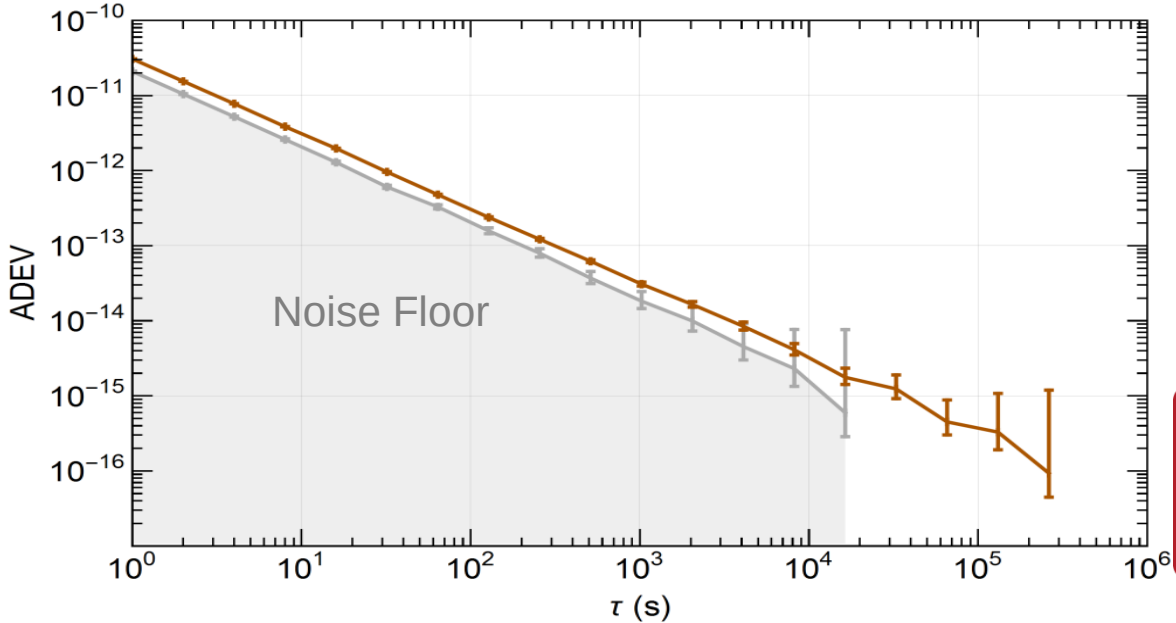


10. V4 – S-band Wavelength – 90 km – Without Optical Amplifier, Results 11 day run

Statistics	
Duration (s)	999999
Mean (ps)	70.14
Standard Deviation (ps)	20.11
Standard Error (ps)	0.02







Conclusions

- We have shown that accuracies in the 10’s of ps are possible over up to 140 km in a US tier-1 telecom network
- Using the OSC
  - Allows insertion of filters without disruption of service
  - Seems to have the best accuracy, at least in this test
  - Requires that equipment have this available
- TDEV stabilities under 10 ps after a few seconds
- ADEV frequency stability under 1 part in 10^{15} at about 1 day
- WR provides not only time and frequency, but also 1 Gb/s connectivity and switching!