Advances in Laser Ranging Technology

at CTU in Prague and new SLR Applications

I. Prochazka[1], J. Kodet[1,2], J. Blazej[1]

Presented at

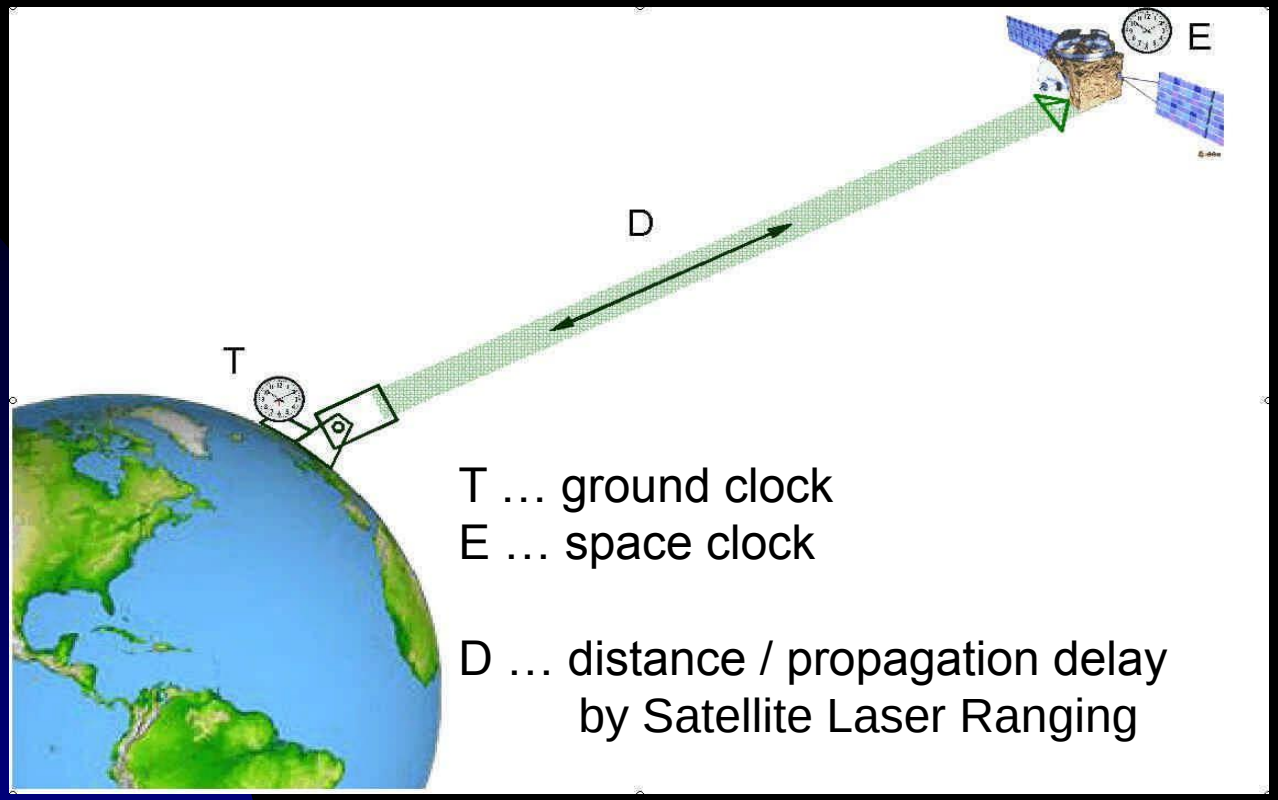
20th International Workshop on Laser Ranging, GFZ Potsdam, Germany
October 9-14, 2016

[1]Czech Technical University in Prague, Prague, Czech Republic
[2]TU Munich, Geodetic Observatory Wettzell, Bad Kötzting, Germany

OUTLINE

- New SLR application:
- Laser Time Transfer
- New SLR system characterization TDEV
- SLR hardware optimization to minimize TDEV
- Start detector
- Epoch timing device NPET
- SPAD detectors for ground & space
- One-way laser ranging
- Orbiting space debris laser ranging
- New SLR systems characterization
  one-way calibration constants
- Conclusion

Laser Time Transfer



OPERATIONAL missions	Compass LTT 4x	
	T2L2 Jason-2	
	Glonass-M series	
PLANNED missions	ACES – ELT	2018
	I-SOC	2023
	Gallileo test	?

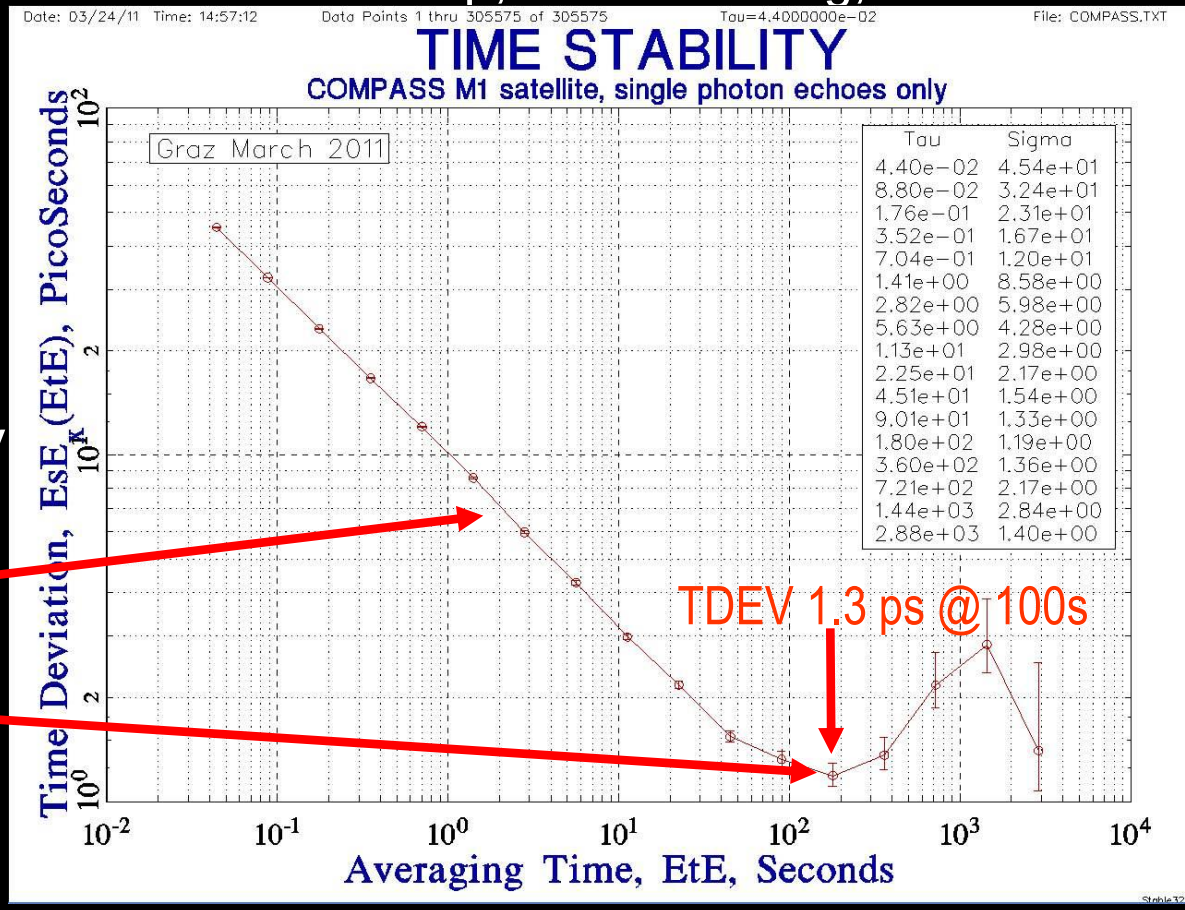
Prochazka, Kodet, Blazej, 20th Workshop, GFZ Potzdam, Oct. 2016

New SLR system characterization
Time Deviation TDEV

- Used in time & frequency community (Allan formulas, Rilley et al, Stable32)
- TDEV expresses the system stability, ultimate precision, data statistics
- TDEV in SLR was presented on 17th Workshop, Bad Koetzting, 2011

One way timing
Graz, March 2011

- Single photon echoes only
- Precision ~ 1/ SQR(N)
- Limiting precision



Prochazka, Kodet, Blazej, 20th Workshop, GFZ Potzdam, Oct. 2016

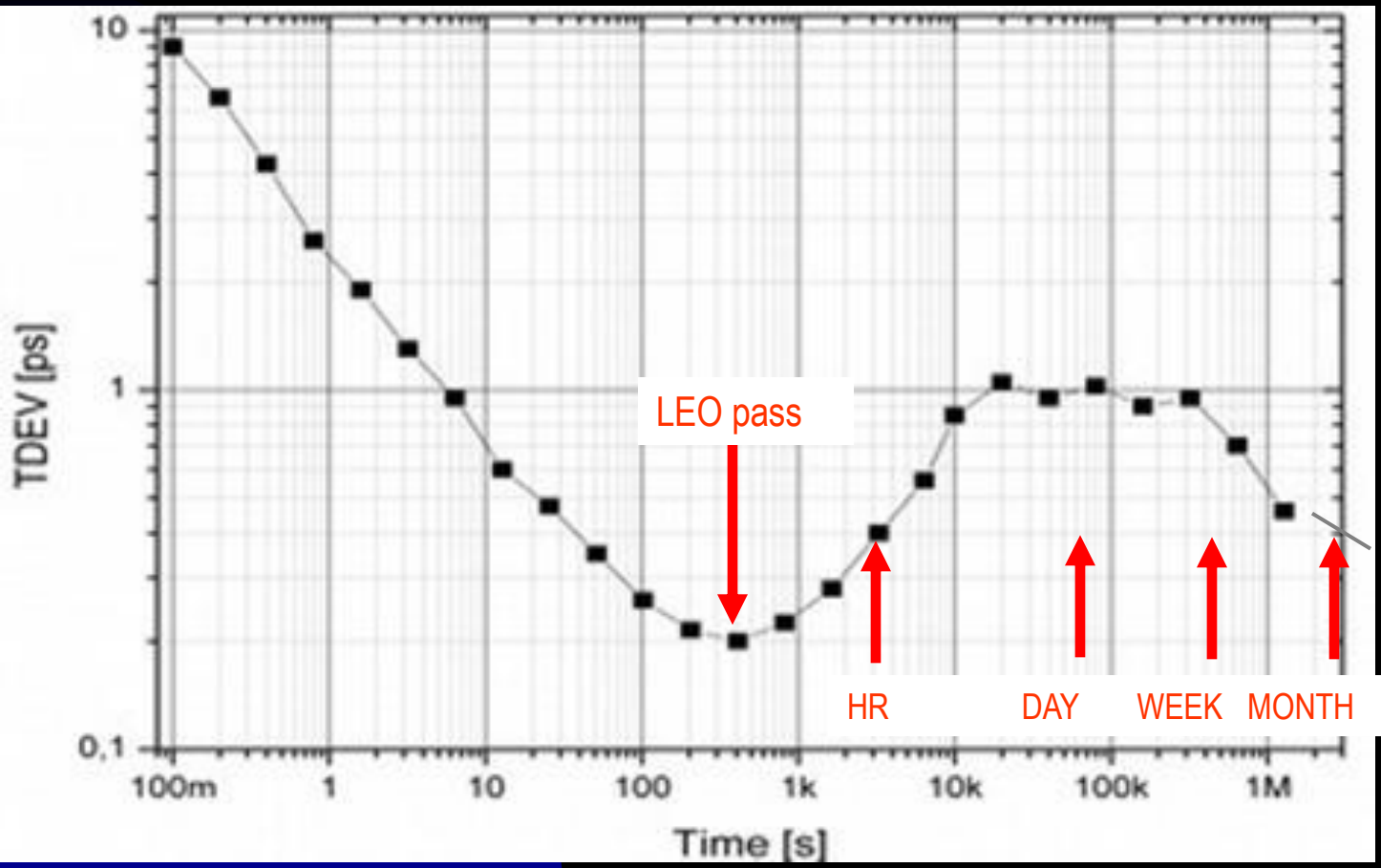
Laser time transfer performance TDEV

- EXISTING missions
- Compass 20 ps @ 500 s (2007)
- T2L2 Jason 2 10 ps @ 200 s (2008)
- Glonass ? (2011)

- READY to launch
- ACES – ELT 3 ps @ 100 s (2018)

- FUTURE missions requirements
- I-SOC 0.3 ps @ 100 s (2023)
- GNSS 0.2 ps @ 200 s (?)

New SLR system characterization – TDEV
Calibration (long term) stability



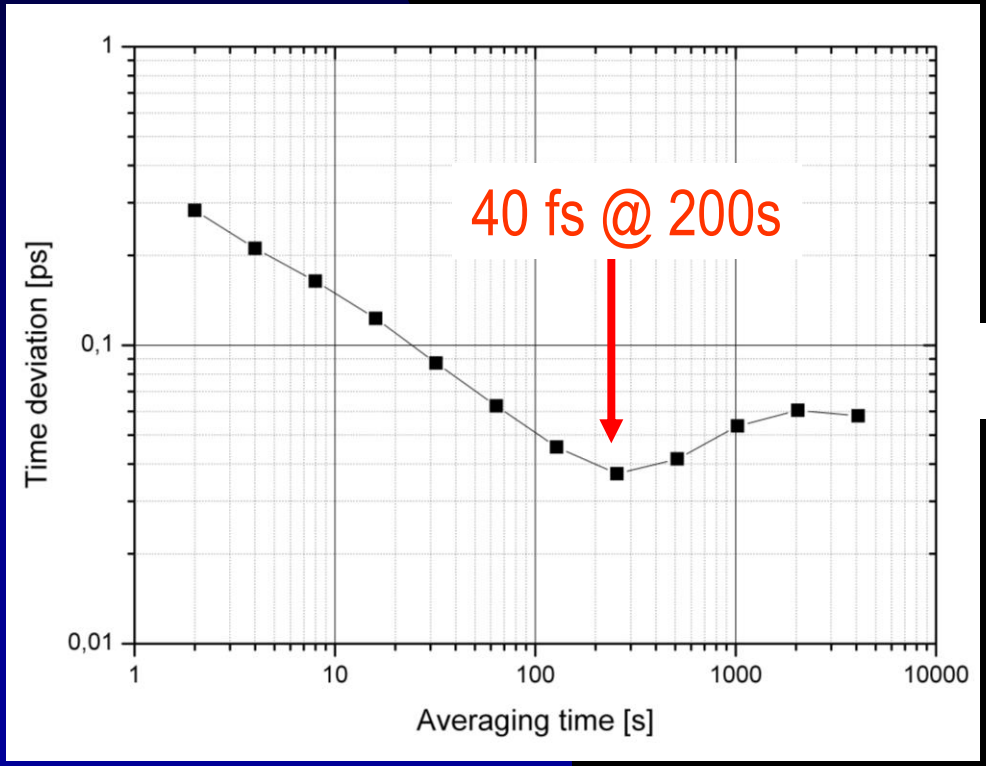
- The SLR systems improve their TDEV much faster than RMS ….
- Graz improved TDEV from 1 ps @ 300s (2010) to 0.2 ps (2016)
- WLRS improved TDEV from 12 ps @ 100s (2010) to < 1 ps (2016)

Prochazka, Kodet, Blazej, 20th Workshop, GFZ Potzdam, Oct. 2016

New SLR hardware to minimize TDEV #1
START detector

- Compact construction, RF resistant
- Jitter 900 fs rms
- Drift < 300 fs / K
- output fall times ~< 50 ps

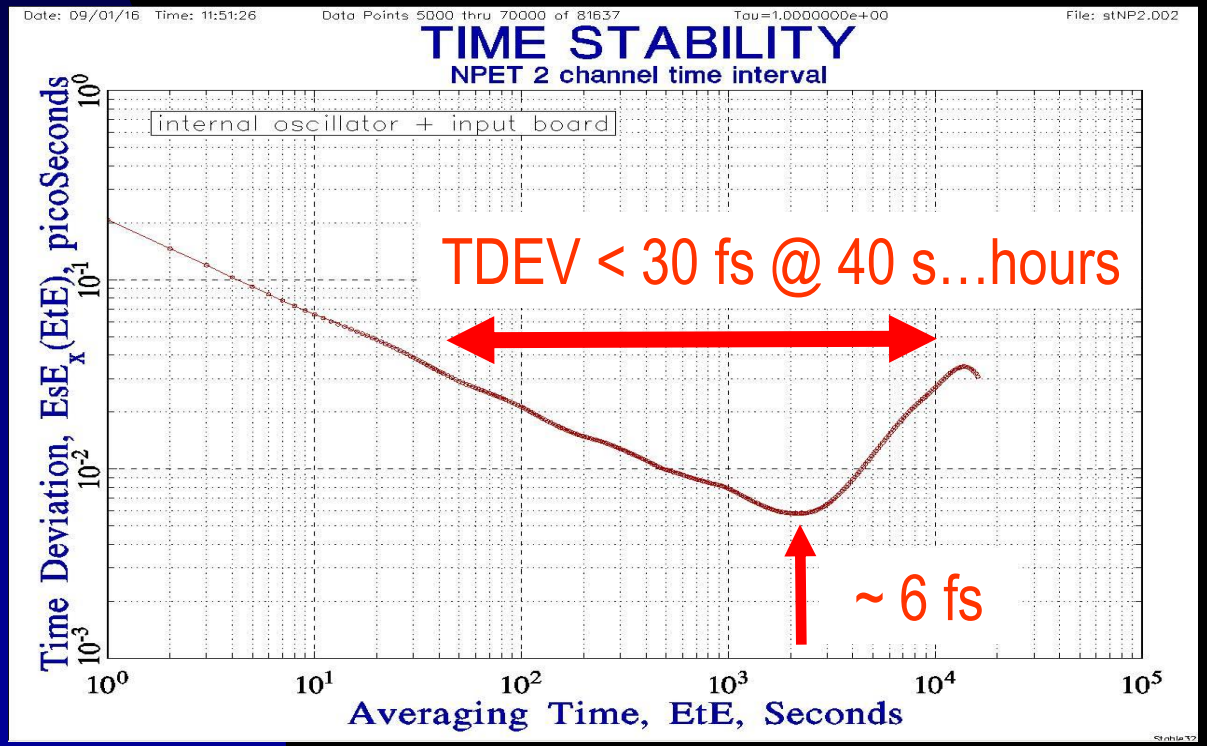
J. Kodet et al, ***Rev. of Sci. Instruments****. 2012, Vol.83/3*



TDEV =< 60 fs @ days

New SLR hardware to minimize TDEV # 2
NPET epoch timing

- Two channel epoch timing device
- Jitter ~< 900 fs rms
- Drift ~ < 500 fs / K
- TDEV < 30 fs @ 40 s ... hours



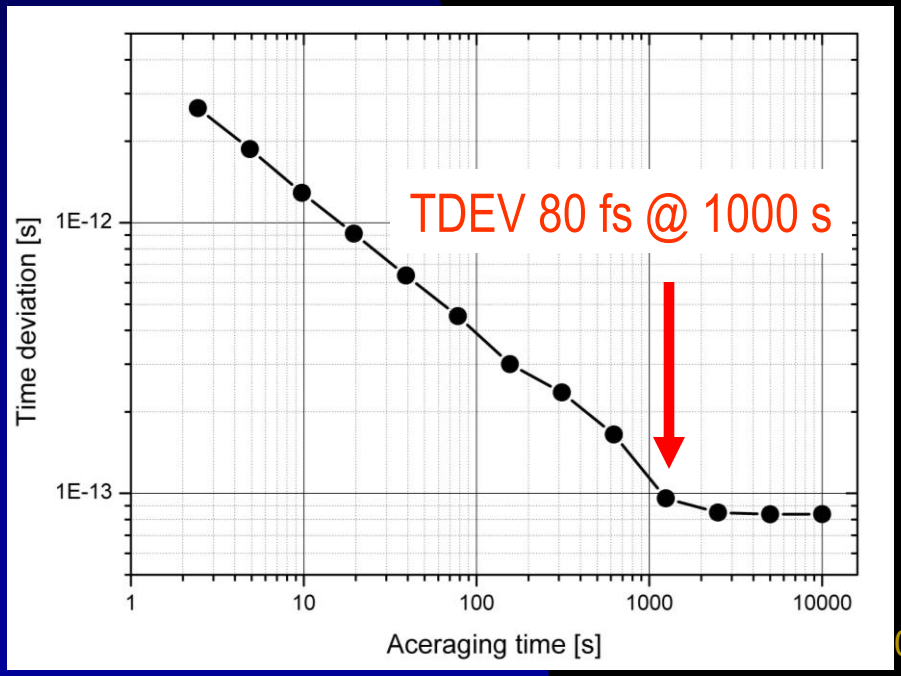
Prochazka, Kodet, Blazej, 20th Workshop, GFZ Potzdam, Oct. 2016

New SLR hardware to minimize TDEV # 3
SPAD detector package modifications

SLR ground

LTT space

- Faster control electronics (6GHz)
- Optimized PCB & connectors
- Optimized cooling
- Jitter < 15 ps rms
- Drift < 500 fs / K

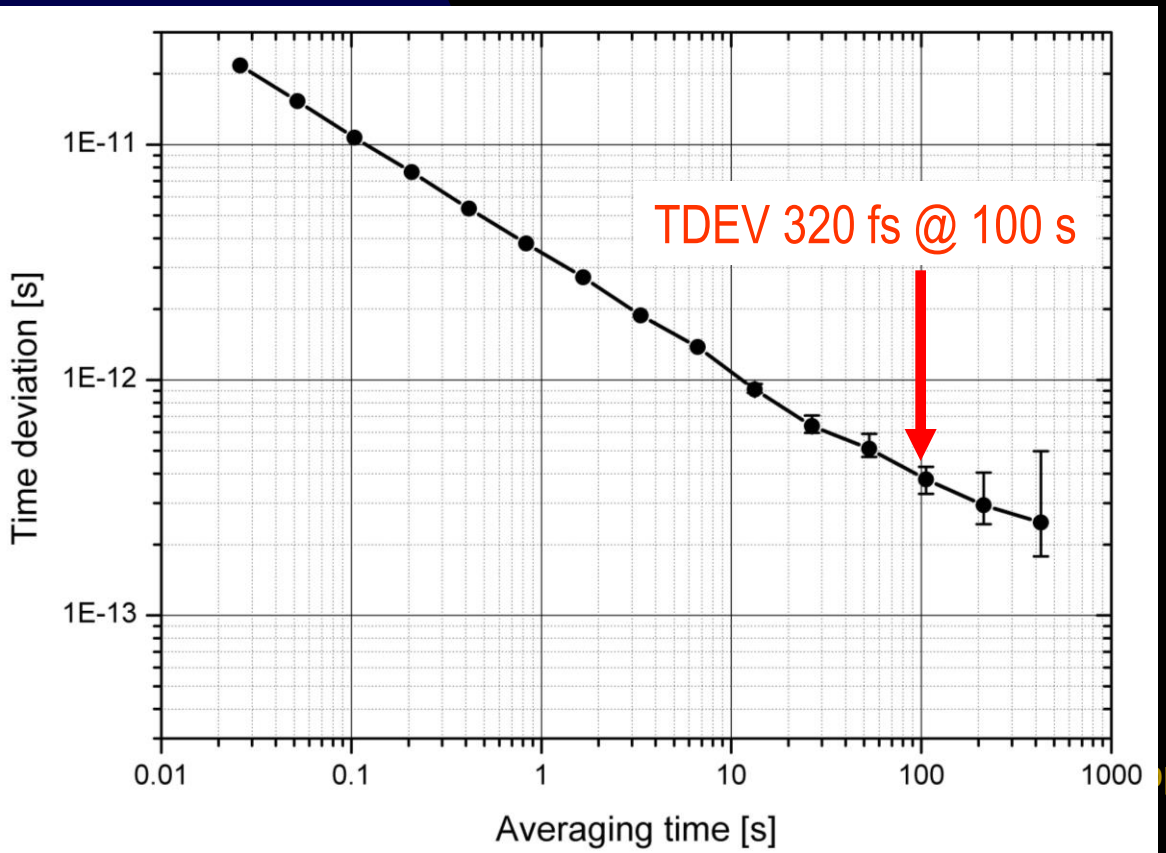


- Complete LR loop, indoor +/- 0.5K
- laser
- NPET timing
- Start detector
- SPAD detector, 1 photon, 8 %

Timing stability over all
TDEV 80 fs @ hours

New SLR hardware to minimize TDEV # 4
Laser Time Transfer field demonstration

- Graz SLR , August 2016
- Graz standard SLR hw configuration Start, GrazET
- ELT-EM detector package, 1 ph, 8%
- NPET timing ELT, 500 Hz



Even lower TDEV (=< 250fs) of Laser Time Transfer may be achieved for longer averaging time or higher rep. rates

New SLR applications:
- one way laser ranging
- space debris multi-static laser ranging

- See dedicated sessions for details
- Common problem: one-way biases and their calibration
- Problem is common to Laser Time Transfer
- Procedure and HW was developed and
  T and R biases were measured by our group
- More details in session related to biases

Calibration device to determined one way SLR system biases

CONCLUSION

- GOOD NEWS - New SLR applications are coming

- Laser Time Transfer (ACES-ELT, I-SOC, GLONASS, GALILEO, …)
- => new SLR hw characterization should be added: TDEV
- => message - improve your SLR; goal TDEV < 0.3 ps @ 100s

- One Way Laser Ranging
- Space Debris Laser Ranging
- calibration of one–way delays is needed
  the calibration hw and procedure was developed

- Thanks for your attention