Recent progress in SPAD detectors for SLR and laser time transfer

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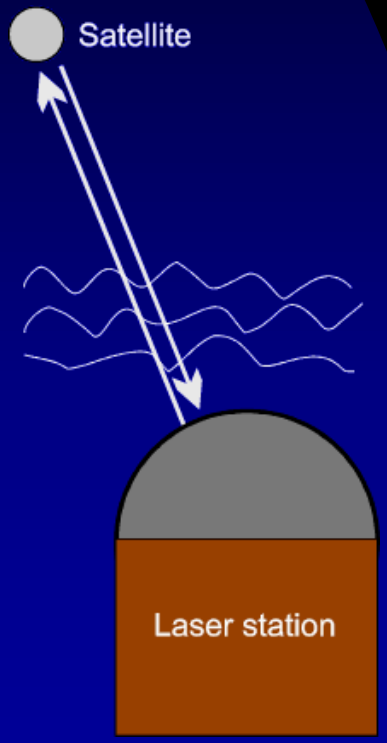
Outline



- K14 SPAD detector package 100um TE1
  detection delay temperature drift reduction
- InGaAs/InP SPAD detector package for SLR
  at 1064 nm
- active quenching and gating version
  key timing parametrs
  comparison to passive quenching
- Summary and Conclusion

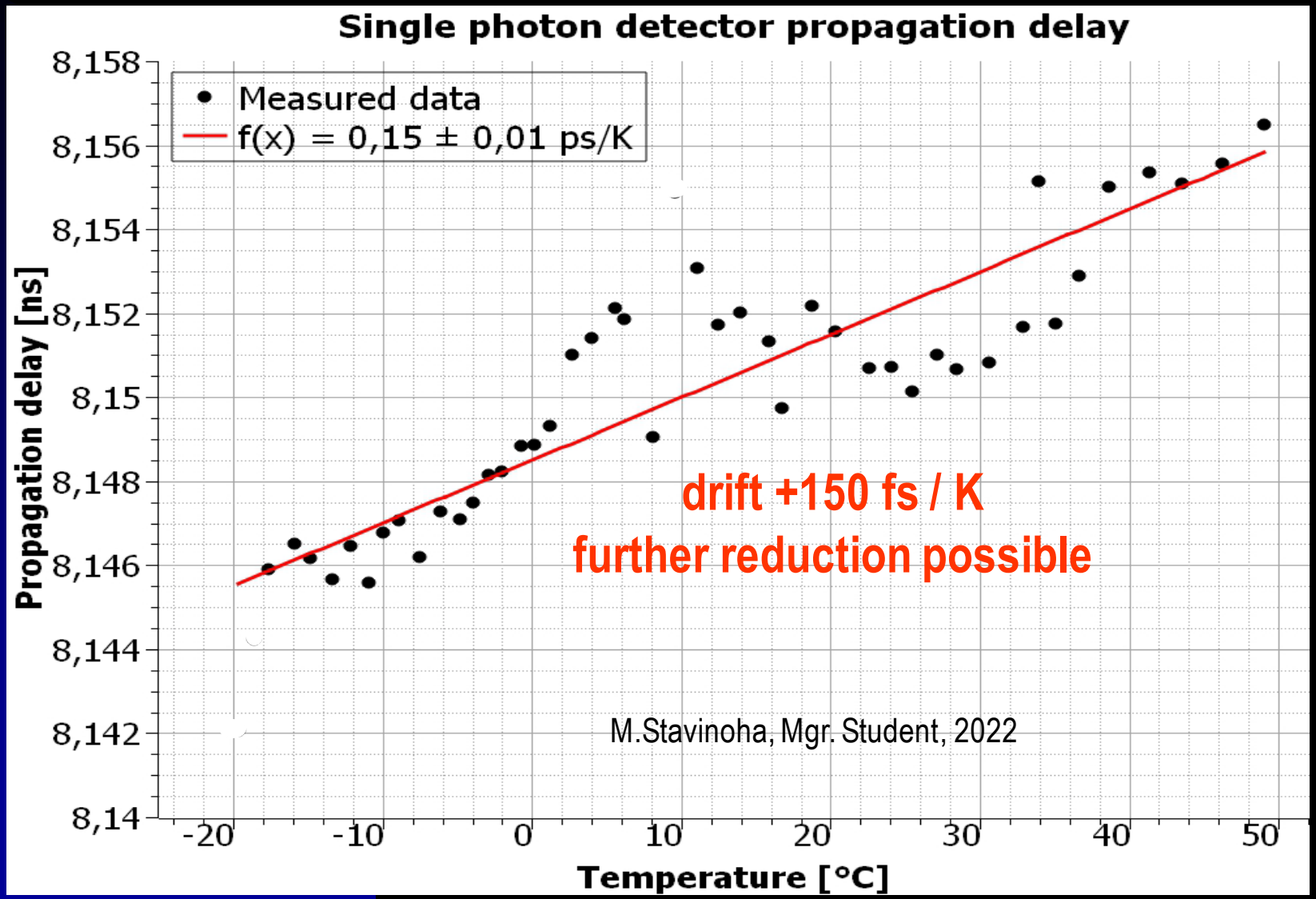
Si SPAD Detector 100um TE1 Upgrade

- New SPAD detector for SLR and laser time transfer ground segment

https://cddis.nasa.gov/2019_Technical_Workshop/docs/2019/

- Based on 100um diameter SPAD chip K14 TE1 cooled to reduce its DCR
- The passive compensation of the detection delay temperature dependence
- New comparator was implemented
  => "flat" temperature delay dependence
- = > The over all temperature delay drift
  < 100 fs / K is possible

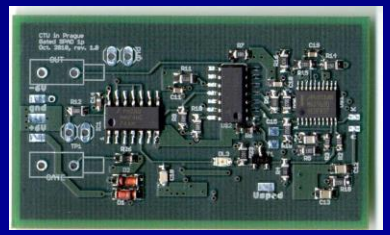
New comparator - temperature drift reduction the very first results



InGaAs/InP SPAD detector package

for SLR at 1064 nm

- Commercial InGaAs/InP detection chip
  Princeton Lightwave PGA-200-1064
  active area diam. 80 um, TE3, 1064 nm window
- Its application in LLR pioneered by
  C. Courde et al, 2016 and J. Eckl, 2017
- Our goal was to develop a detector package
  providing mm accuracy and ps stability
- Operating range gates 0.1 - 10 us wide
- = > development & tests of an
  ACTIVE QUENCHING and gating circuit



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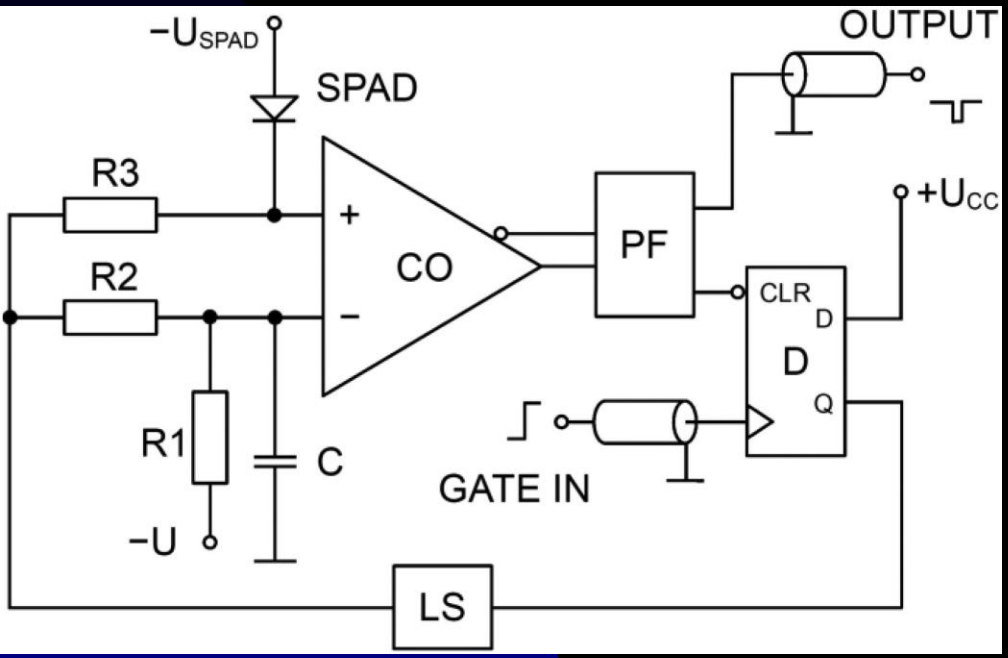
InGaAs/InP SPAD detector package

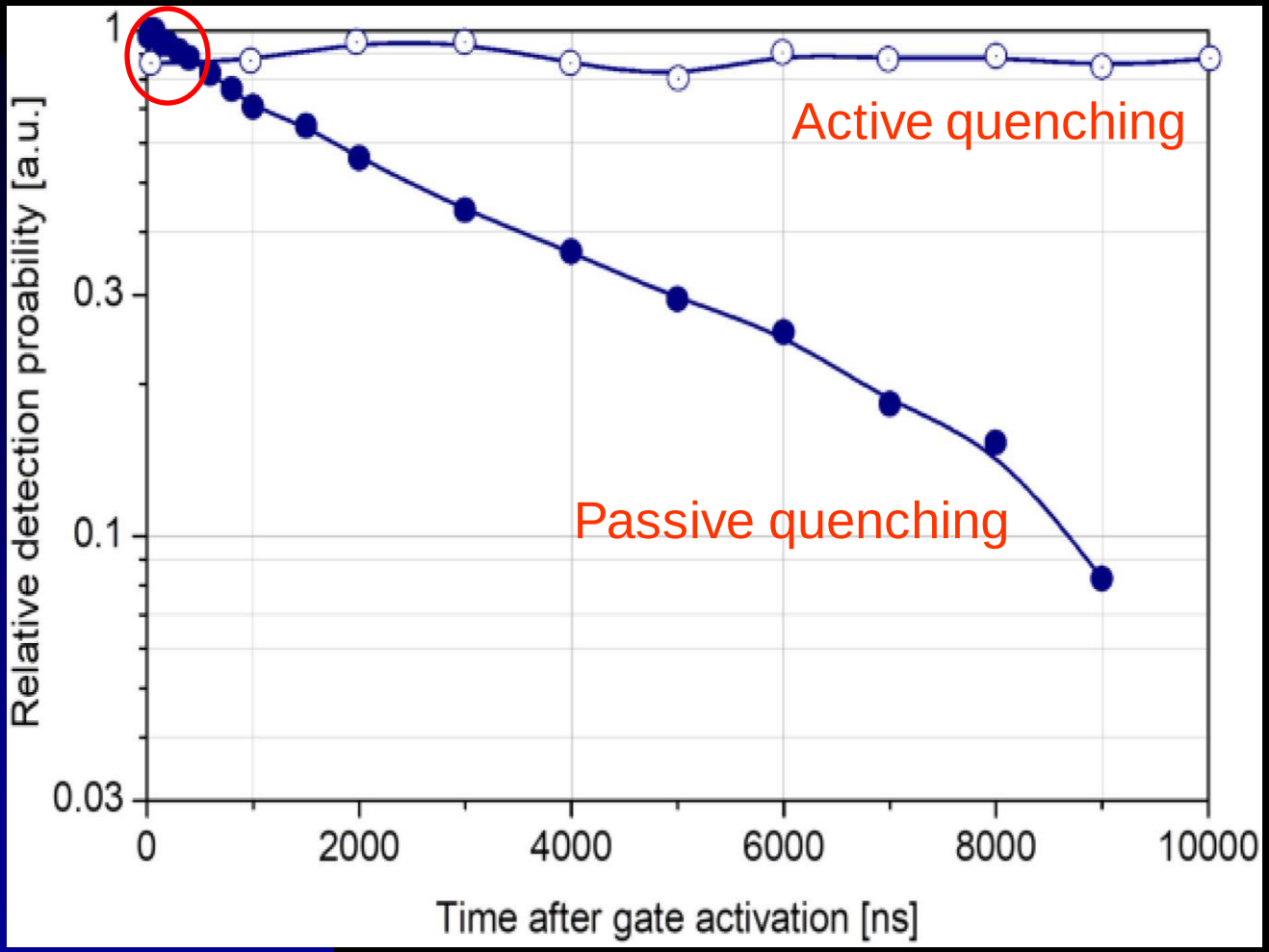
Active Quenching and Active Gating Circuit



- analogy of K14 SPADs control circuit
- PROBLEM
  high speed – ns delays - and
  higher bias steps are needed
  typ. 10 – 20 V instead of 2 - 3 V
- SOLUTION
  We optimized the existing circuit to maximum possible biasing above breakdown voltage.
- NEW POWER SUPPLY
  - high stability of SPAD bias
  - high stability of chip temperature

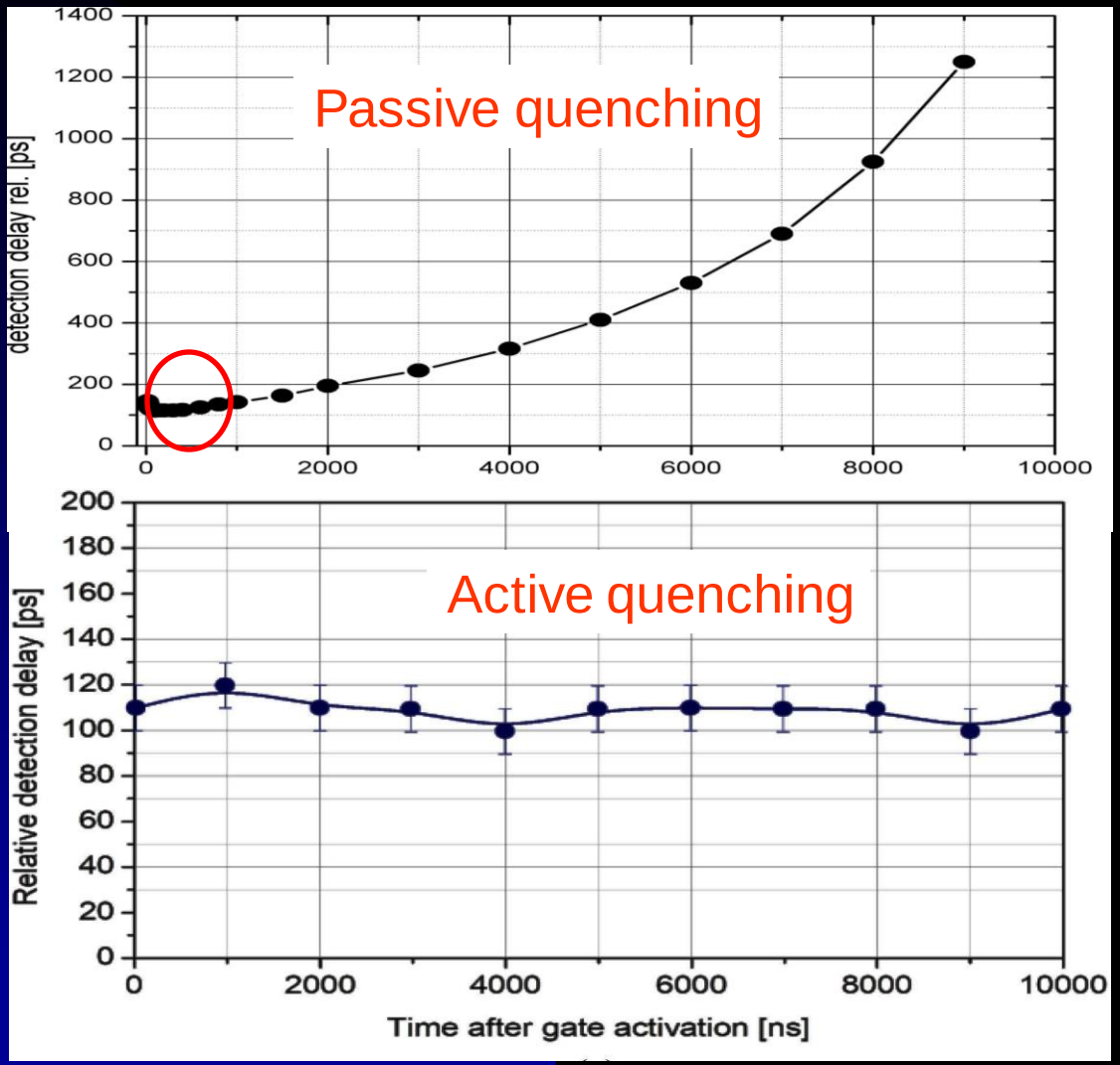
InGaAs/InP SPAD detector package, active quenching circuit

Detection probability within gate



InGaAs/InP SPAD detector package, active quenching circuit

Detection delay within gate

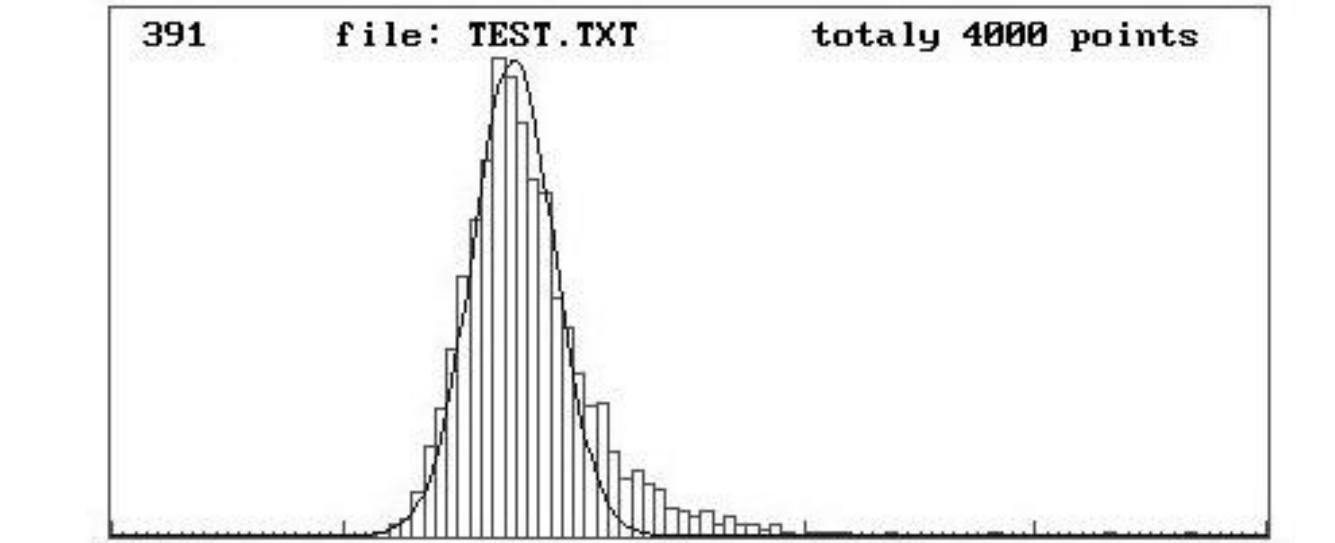


Acceptable stability only 0 – 0.5 us

Stable within entire gate 0-10 us

InGaAs/InP SPAD detector package, active quenching circuit

Detection jitter – equal within entire gate



Criter.	MEAN	SIGMA	PT #
5.000 / 7.001	5.725481	0.130785	3967
3.0 * SIGMA	5.710350	0.092925	3834
2.5 * SIGMA	5.701108	0.080471	3659

- Overall timing jitter 80 ps RMS
- Deconvoluting the laser pulse 60 ps FWHM
- = > SPAD jitter 52 ps RMS

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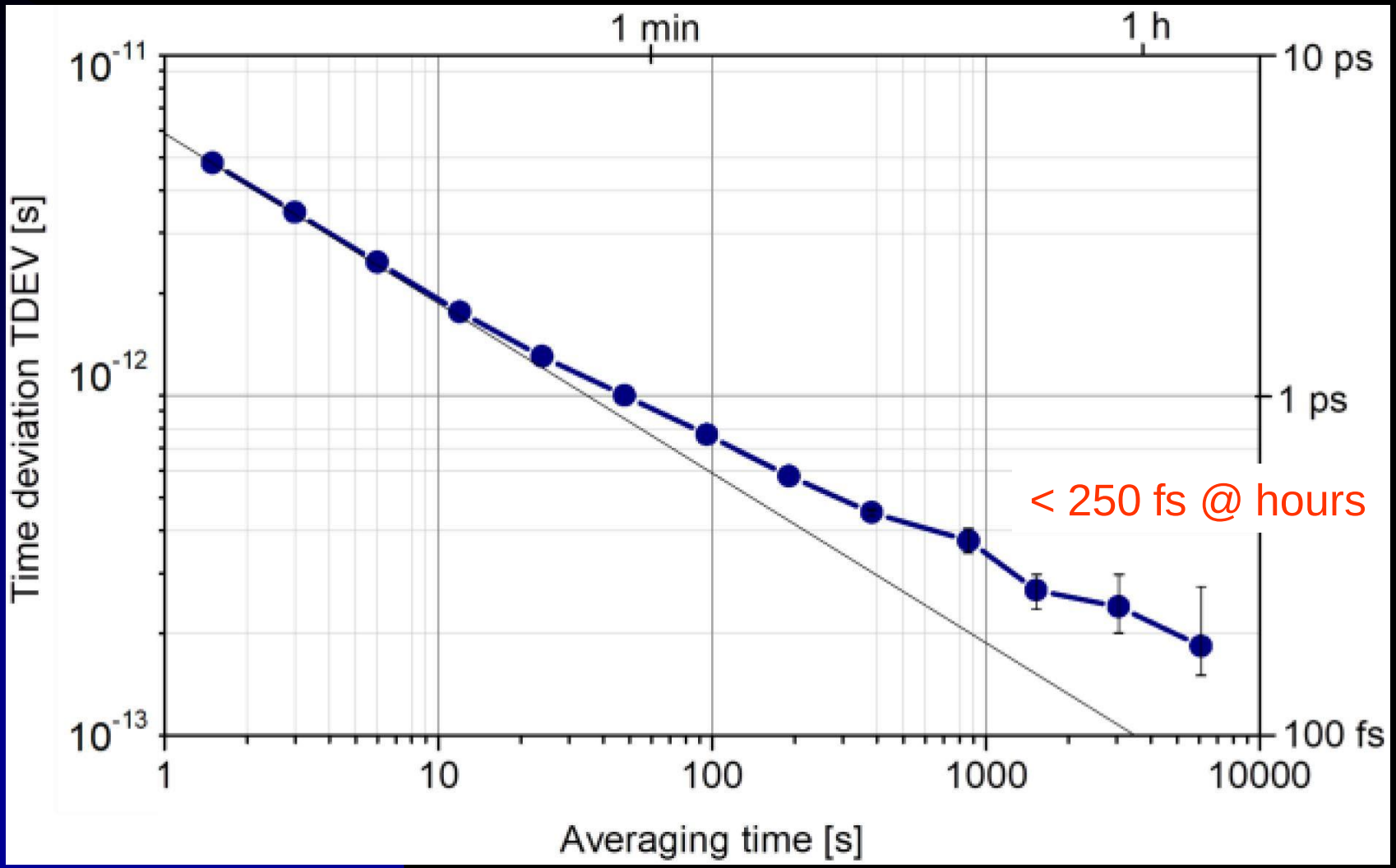
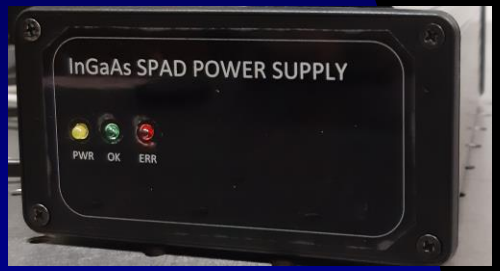
InGaAs/InP SPAD detector package, active quenching circuit

Detection overall stability TDEV



InGaAs/InP SPAD detector package, active quenching circuit

Detector package + Power supply



- Standard SPAD detectors housing
- TE3 chip cooling to -40 +/- 0.2 °C
- Bias above break max 4.5 V
- Key parameters

jitter		< 60 ps RMS
det.probability		> 20 % @ 1064nm
effective DCR		< 160 kHz
gate	active	0.1 to 10 us
	signal	TTL , 50 Ohms
output	NIM	fall time < 200 ps
temp drift		< 0.8 ps / K
stability TDEV		< 0.3 ps @ hours

Conclusion

- K14 SPAD detector package 100um TE1
  detection delay temperature drift was reduced well below 200 fs /K
- InGaAs/InP SPAD detector package for SLR at 1064 nm
  was optimised for SLR and space debris laser ranging. Top stability over range gates of 0.1 to 10 us.
- The costs are timing resolution single shot (30 -> 60 ps) and photon detection probability (30% - > 20%)
- The detector was developed for SLR and space debris laser ranging at 1064 nm
- Thank you for your attention