New SPAD detector package for SLR and laser time transfer

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Outline

- Why new SPAD detector(s) ?
- Detector parameters requirements
- Detector design construction
- Key parameters
  - timing resolution
  - timing drift
  - dark count rate
  - single – multiple photon response
- Summary & Conclusion
Why new SPAD detector(s)?

- #1
  The supply of TE3 cooled 200um diameter chips is approaching zero 😞

- #2
  New applications, namely Laser Time Transfer require extremely high timing stability ~ 100 fs

- #3
  New wavelengths (1064 nm, 1540 nm,...) see our poster
New SPAD detector package

- K14 SPAD chips 100um diameter
- AVAILABLE
- TE1 cooling, NO temperature sensor (!!)

- New active quenching and gating circuit
- Analogy to ELT+ space segment
- Very simple, compact, space qualified
- SPAD max 2.5 Volts above 😊

Optimized for high temperature stability

*Rev. of Sci.Instruments* **87**, 056102 (2016);
Built in SPAD bias control circuit is adjusting bias above break versus temp. and also tunes detection delay.

- Key components (SPAD, comparator) positive temperature coefficient $\sim 1$ ps/K
- SPAD chip detection delay vers. bias coefficient is negative $-0.12$ ps / mV
- SPAD bias control may compensate all the (smooth !) temperature contributors.

Rev. of Sci. Instruments 89, 056106 (2018)
New SPAD detector package
Passive compensation of temperature delay dependence

![Graph showing temperature dependence of SPAD chip and Comparator]
New SPAD detector package
Passive compensation of temperature delay dependence

SPAD Detection delay

- drift 40.7 mV/K; $U_{AB} = 1.6$ V
- drift 38.6 mV/K; $U_{AB} = 1.9$ V
- drift 36.5 mV/K; $U_{AB} = 1.7$ V

Drift ADJUSTABLE

Relative detection delay (ps)

Temperature (°C)
Thermoelectric cooling TE1 of SPAD chip

PROBLEM – No temperature sensor inside

- No chance to stabilize the chip temperature
- Stabilize the cooling current => fixed temperature step
- Compensate the detection delay of the entire device by its body temperature (hot side of TE1)
- It works (!) Delay stability is OK
- BUT the detector is more noisy in summer time 😊
Thermoelectric cooling TE1 of SPAD chip

Dark count rate

New gating logic, Terminate the windows
Worst case estimate, rather noisy test chip

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Passive compensation of temperature delay dependence

Detection delay stability TE1

SPAD100um 2.5Vab Start NPET2 400Hz 10%

DELAY [ps]

0 2 4 6 8 10 12 14 16 18 20

hours after Power ON ; Oct.17 2018

+/- 500 fs @ day complete loop
Passive compensation of temperature delay dependence

Detection delay stability TE1

TDEV 60 fs @ hours

TIME STABILITY

SPAD 100um compensate laser hamamatsu Start NPET2

600Hz 8% mean of 256 2.2+sigma editing
Passive compensation of temperature delay dependence
Response to multiphoton echoes

C-SPAD operation of 100um chip is difficult

Detection delay constant
Ret. Rates 0 … 50%

ELT calibration tests Wettzell, Feb. 13, 2014
Passive compensation of temperature delay dependence

New SPAD detector package 100um TE1

- Standard SPAD housing, compact power supply
- New aspheric lens collecting optics, 12 mm diam. beam
- Standard Gate and output signals
- 1 : 1 replaceable with C-SPAD and/or HQE SPAD pack.

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SUMMARY
New SPAD detector package 100um TE1
Passive compensation of temperature delay dependence

- Detector package for SLR and laser time transfer optimized for high detection delay stability

PARAMETERS

- Active area: 100 um diameter
- Photon det. Effi.: > 35 % @ 532 nm
- Jitter: < 18 ps rms
- Temp.drift: tunable, abs.< 250 fs /K
- Stability: < 100 fs @ hours

- Few photons / echo data rate up to 50% are acceptable for ideal targets and LTT

- Thanks for your attention

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