

Photon counting detector for both passive and active space debris optical tracking

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G. Kirchner et al, Int. Work. on Space Debris .., Canberra, Australia Nov. 2018

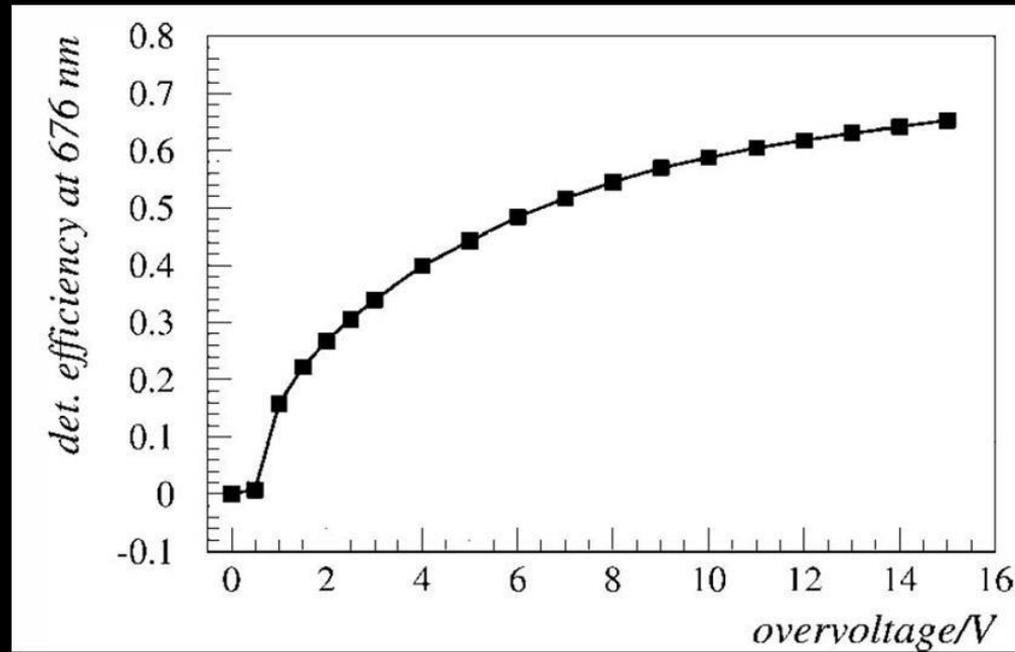
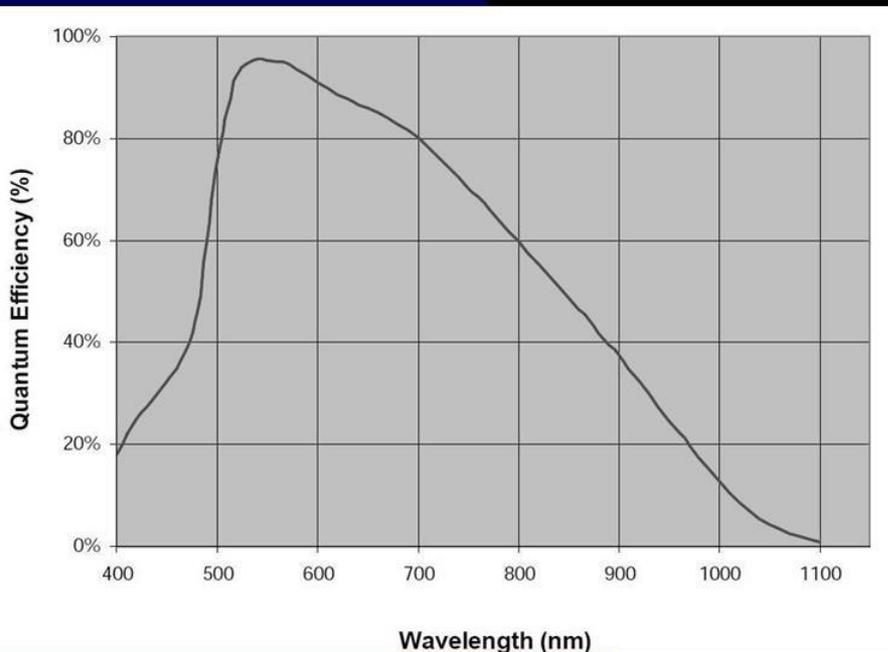
Content

- GOAL
To develop a photon counting detector optimized for optical tracking of orbiting space debris
- Detector concept
 - based on SAP500 APD chip by Laser Components
 - using an existing HQE – SPAD design
 - modified control electronics to enable both CW and gated operation
 - electronic switching between two operation modes
- Detector main parameters
- Summary and Conclusion

SPAD detector chip SAP500



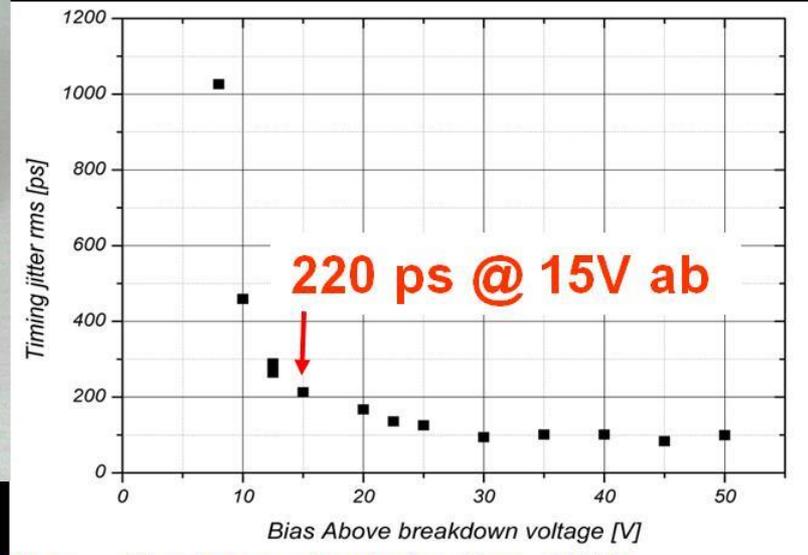
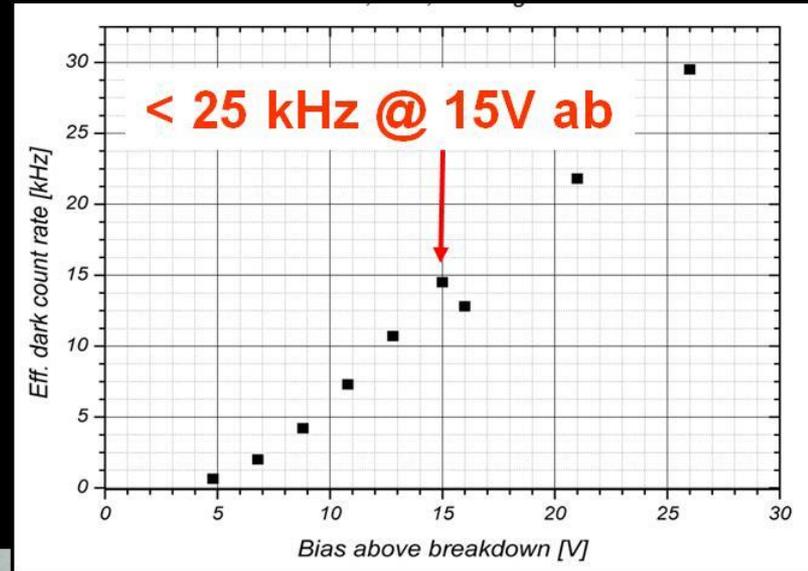
- SAP500 detector by Laser Components
- APD on Si, 0.5 mm diameter, ~ 100 V break
- High Photon Detection Efficiency typically 70 % @ 532 nm (M.Stipcevic, 2011)



HQE - SPAD detector package

version 2015

- SAP500 Single TE cooling to -8°C
- Active gating and passive quenching control circuit
- Operational on several SLR sites worldwide



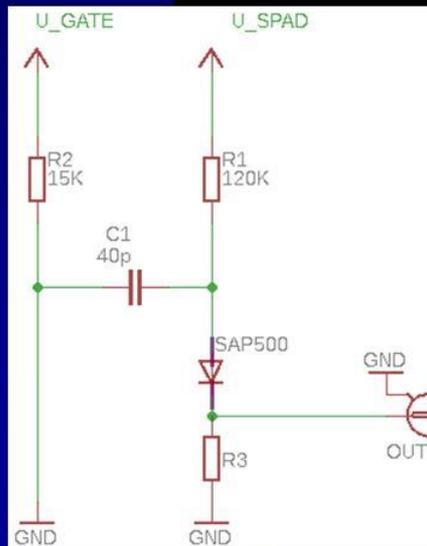
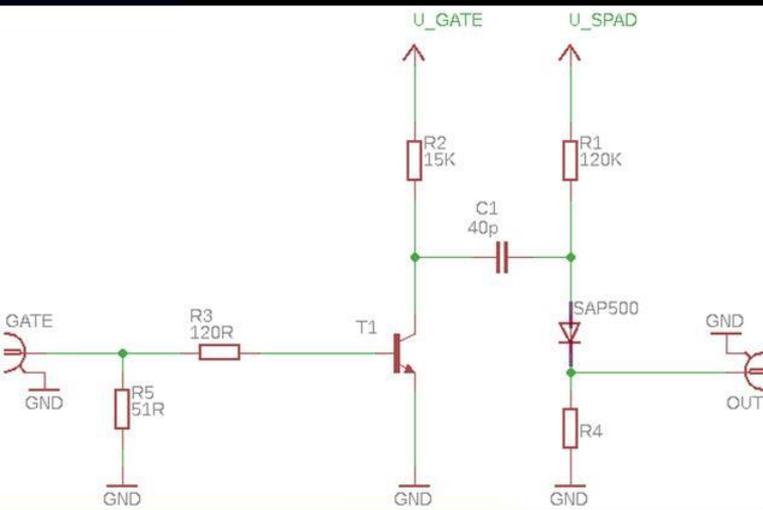
Prochazka I, et al, *Journal Advances in Space Research*, JASR11779

G. Kirchner et al, Int. Work. on Space Debris .., Canberra, Australia Nov. 2018

Why to add CW counting capability ?

- To enable to track passively Sun illuminated space debris and to record a time series of diffused light intensity. This time series will provide information about debris orientation and spinning.
- The CW counting mode will be optimized for maximum photon count rate dynamic range.
- The gated mode will be optimized for laser ranging of orbiting space debris.
- The detector development and tests is supported by ESA project P3-SST-I

SPAD Control Circuit Modification



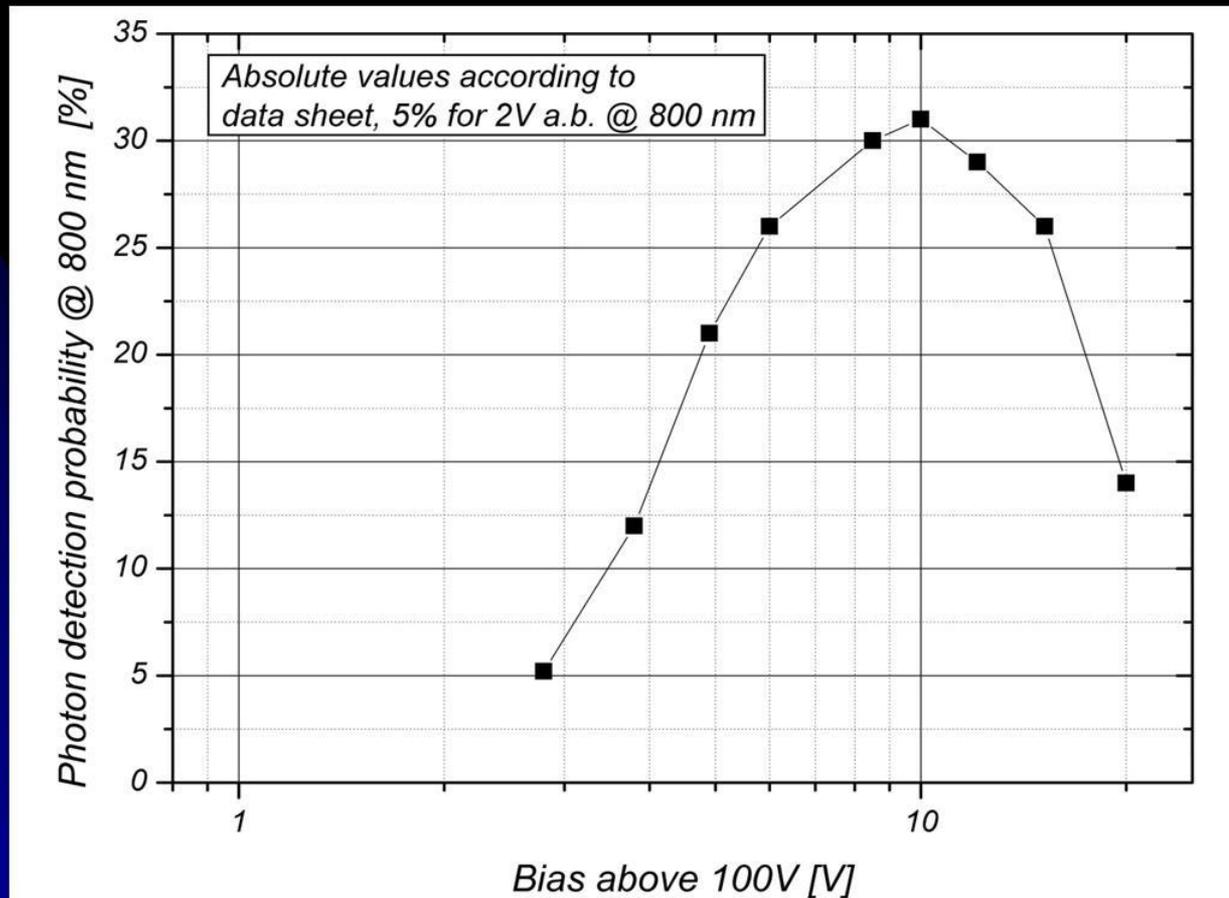
- Gated mode
- SAP500 active gating and passive quenching circuit
- CW mode
- The operating modes are switched by a simple external electrical control

SPAD Power Supply Circuit Modifications

- Additional functionalities added:
 - SPAD bias / gate switching for two operational modes
 - providing additional control signal for SPAD control circuit
- CW mode
operation SPAD chip typically 12V above breakdown
- Gated Mode
biasing SPAD chip typically 5V below breakdown,
within the gate opening, the chip is pulse biased
25 V above breakdown
- The operating modes are switched by a simple external
electrical control

CW mode of operation

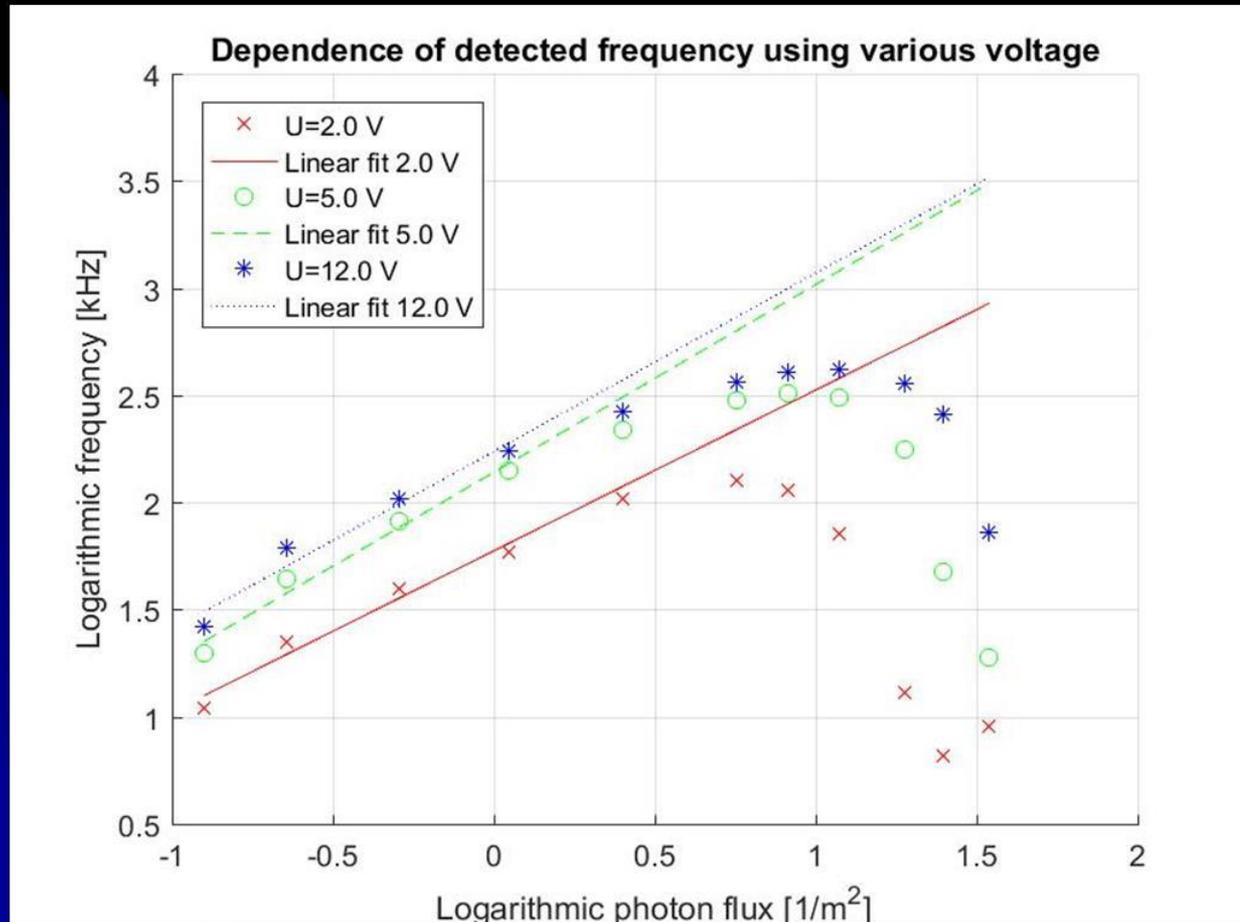
Photon counting probability



- The SPAD chip is CW operated typically 12 V ab
- Considering the QE graph (M. Stipcevic, 2011) the photon detection probability $> \sim 45\%$ @ 532 nm is achieved in this configuration

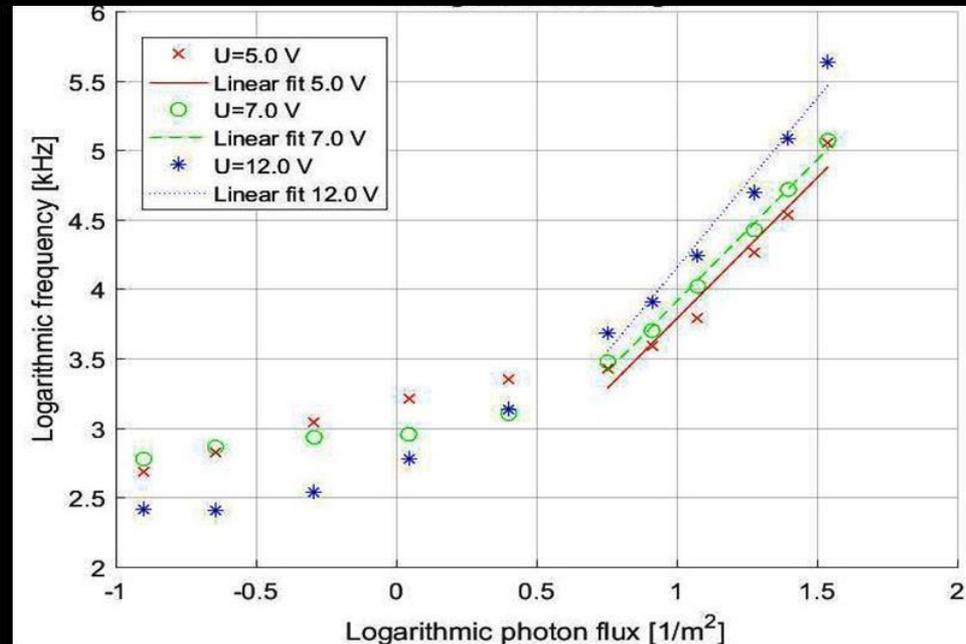
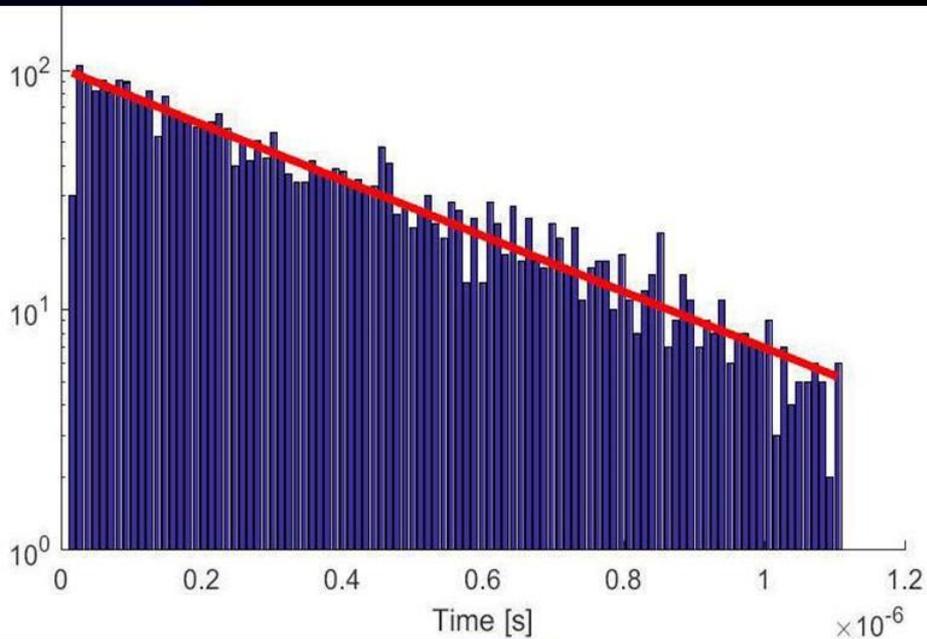
CW mode of operation

Photon counting linearity for various biases above the breakdown voltage
Dynamical range of ~ 2 orders of magnitude



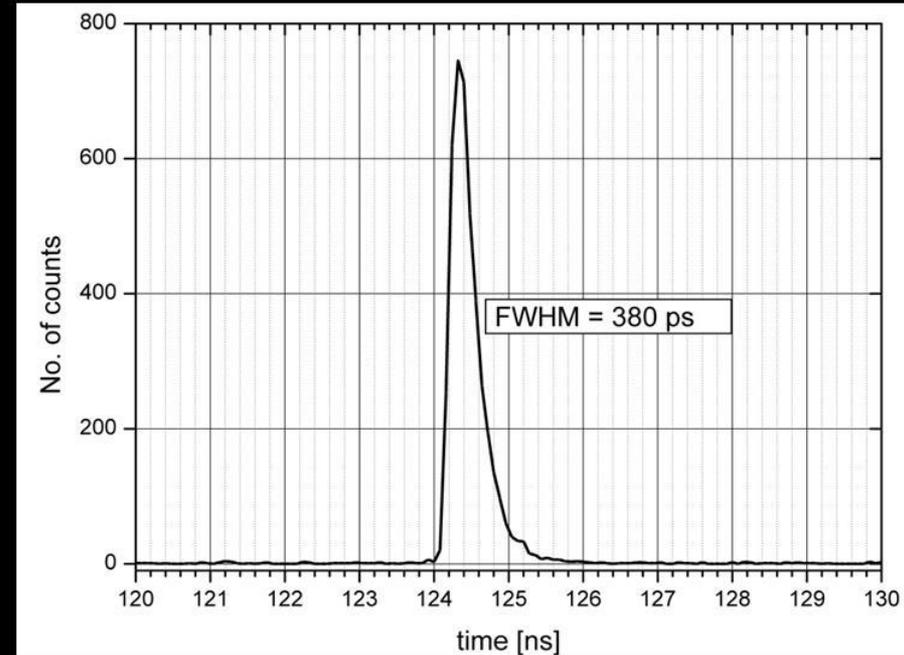
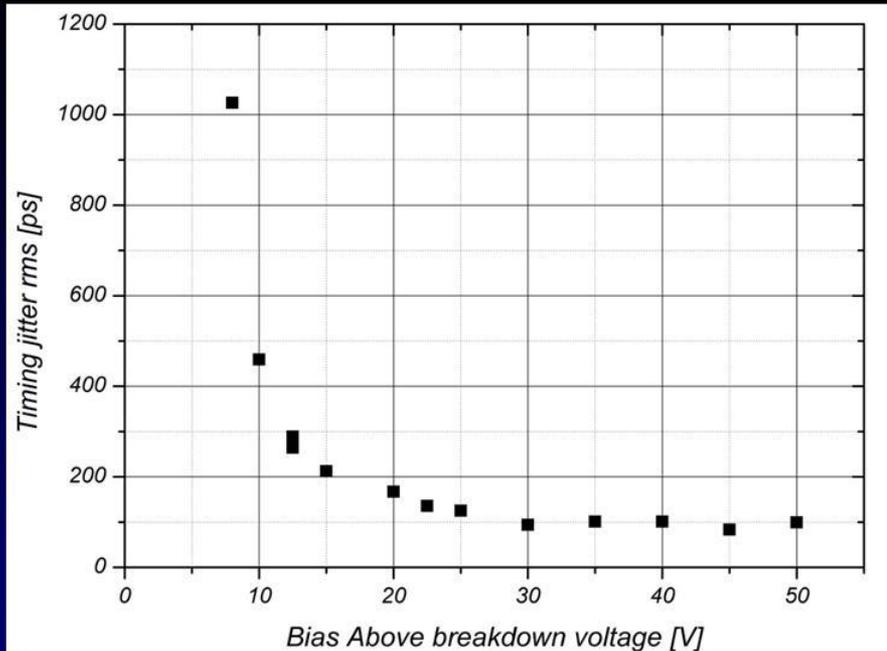
Gated Mode Operation

CW photon flux intensity monitoring, 1kHz gating, 10us



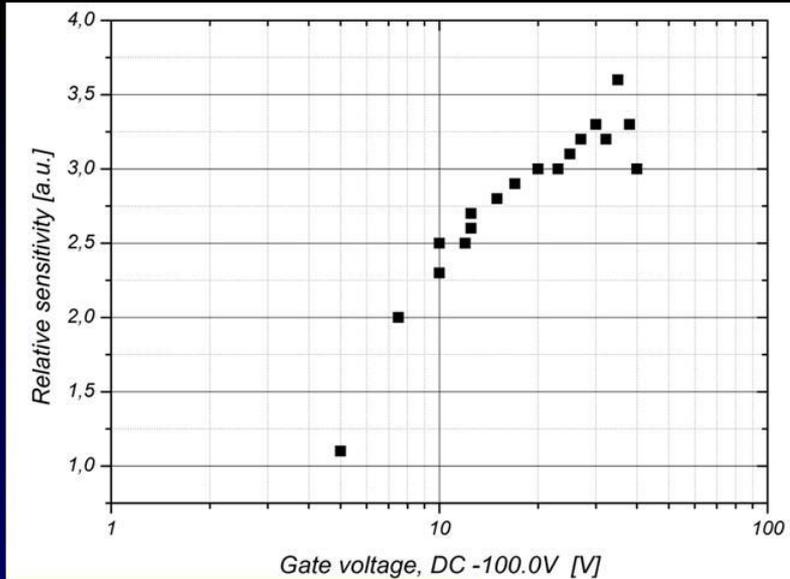
- Operating the detector at 1kHz rate, gate width $\sim 10\mu s$, the cw photon flux intensity may be monitored also
- Applicable for strong fluxes $> \sim 1$ MHz, slowly varying intensities
- This scheme extends the photon flux intensity monitoring range

Gated Mode Operation 1

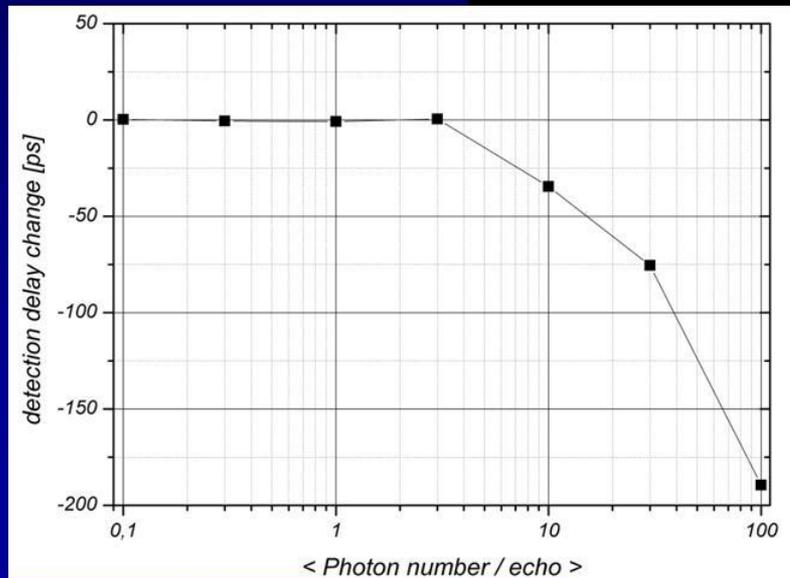


- Timing jitter in Gated mode, no signal focusing
- Typical bias above break is 15V , it corresponds to a jitter of 220 ps rms
- Focusing the optical signal to an active area center, the jitter might be reduced below 100 ps rms.

Gated Mode Operation 2



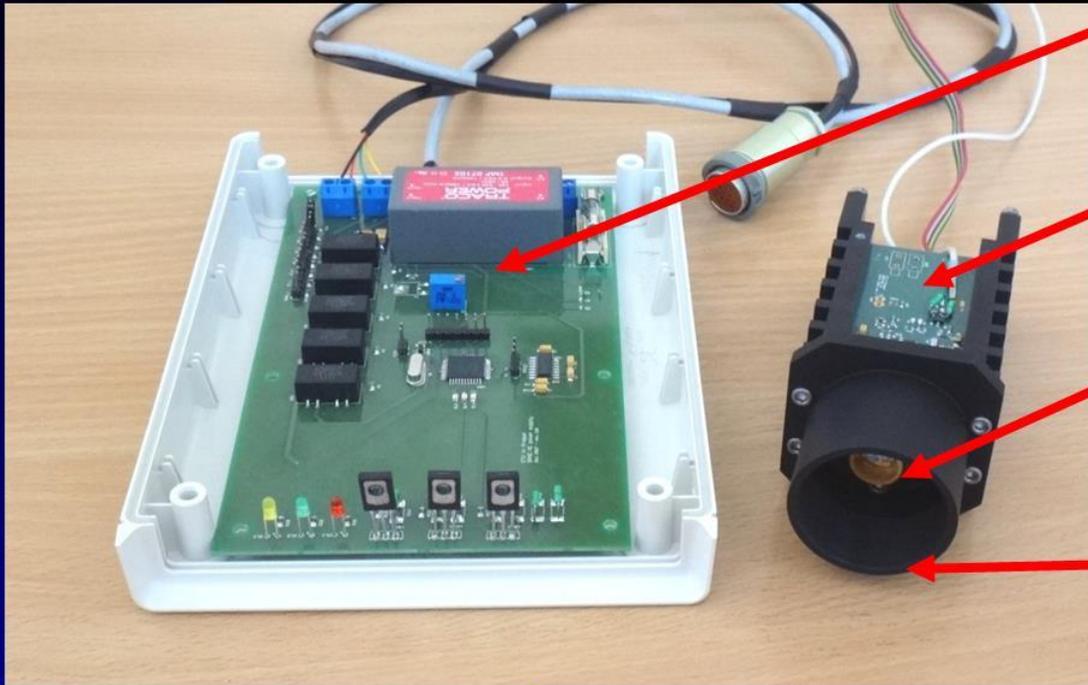
- Relative photon counting sensitivity
- Considering the spectral curve and Stipcevic 2011 data, photon detection probability is
 - ~ 80% @ 532 nm 25 V ab
 - ~ 65% @ 532 nm 15 V ab



- Detection delay time walk
- Laser 42 FWHM @ 789 nm

Device final assembly

WP2210 SPAD detector R&D



Detector modified power supply and cooling control

Detector new gating control board in a new housing

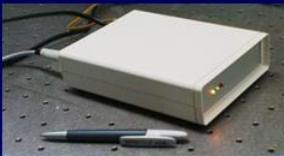
SAP500 detection chip in a TE cooled housing

New collecting optics F/D=1 (single aspheric lens) will be installed here

- Final assembly is expected to be completed by November 2018
- Final parameters tests are planned for December 2018

Photon counting detector for both passive and active space debris optical tracking

Summary – Conclusion



Expected final shape

- The new photon counting detector for both passive and active space debris optical tracking was designed, developed and tested.
- It enables two operating modes
CW mode to track passively Sun illuminated space debris and to record a time series of diffused light intensity
Gated mode to perform laser ranging to orbiting space debris
- The device was developed as a part of Bc thesis of CTU in Prague student R. Bimbova,
- The support of P3-SST-I project ESA is appreciated