Photon Counting Module
for Laser Time Transfer Space Mission

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GOALS

- Fast photon counting detectors for the Laser Time Transfer space mission, China
- BACKGROUND
  the K14 SPAD detectors have been launched onboard MARS 96 (Russia) and NASA Mars Polar Lander (USA) space missions
- REQUIREMENTS
- low — mass, power, bias voltage
- high — radiation in - sensitivity (> 5 years in space)
- high — temperature range
- extreme — optical damage threshold (full Solar flux, no shutter)

„LTT Module in Space", China, 2007-2008

- GOALs
- to synchronize the rubidium clocks in space, hydrogen masers in a future.
- Laser Time Transfer (LTT) between space and ground
- employing the existing China Satellite Laser Ranging network consisting of 5 fixed and 2 mobile systems

- required ~ 100 ps timing accuracy
- expected accuracy improvement >> 10x over RF techniques

Detector Requirements - version LTT China

- single photon timing — K14 SPAD chips
  two channels

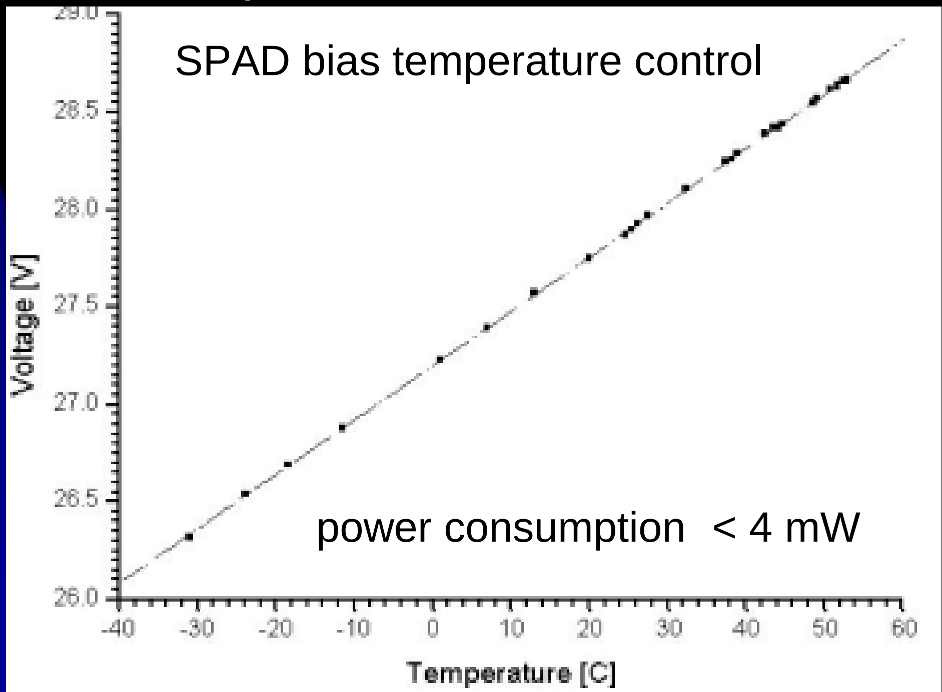
- aperture — 25 µm each
- timing resolution — < 100 psec
- power, mass — < 2 W , 100 grams
- operating temperature — -30 …+60^{o}C
- lifetime in space — > 5 years

- high opt. damage threshold — direct exposure to the Sun (!!)
  in a focal plane of 2 mm aperture collecting optics
  no Sun safety shutter will be installed

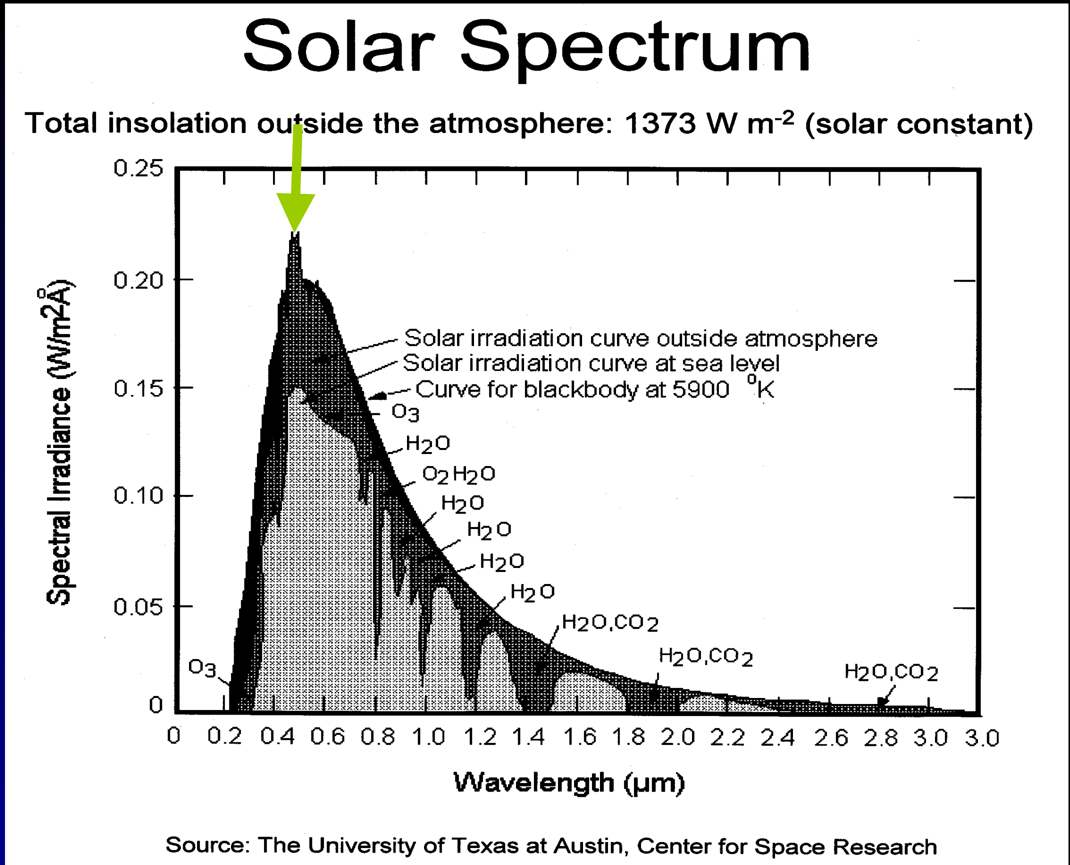
- design & construction — 3 months (!)

SPAD Bias Temperature Control

- SPAD break down voltage 29 Volts
- bias accuracy required 100 mV
- temperature range requested -30 …+ 60º C
  no temperature control or cooling
- SPAD break voltage temperature drift - 30 mV / K
- => temperature controlled <u>bias circuit</u>



Optical Damage Threshold



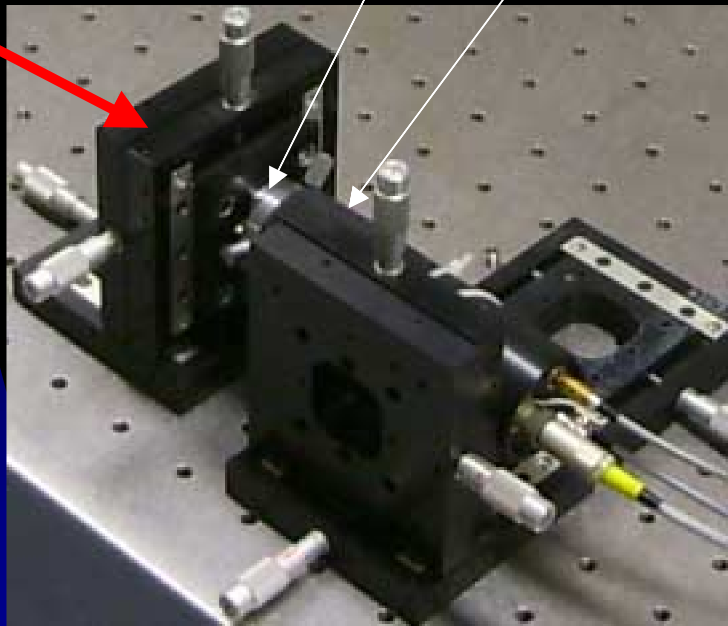
- Irradiance 0.2 W/m²/0.1 nm @ 532nm wavelength
- receiver
  - aperture 2 mm
  - f / d ~ 1.0
  - field of view ~ 0.5°
  - entire Solar disc
- bandwidth 100 nm blocking glass filter
- => 1 mW max. on SPAD

Surprisingly, the total flux on the detector aperture is not exceeding 1 mW /100 nm for any aperture (!), due to the field of view limitation.

Larger telescope is not capable to focus all the incoming Sun light onto small SPAD aperture.

Prochazka,Hamal, Kral, Yang Fumin, Canberra, October 2006

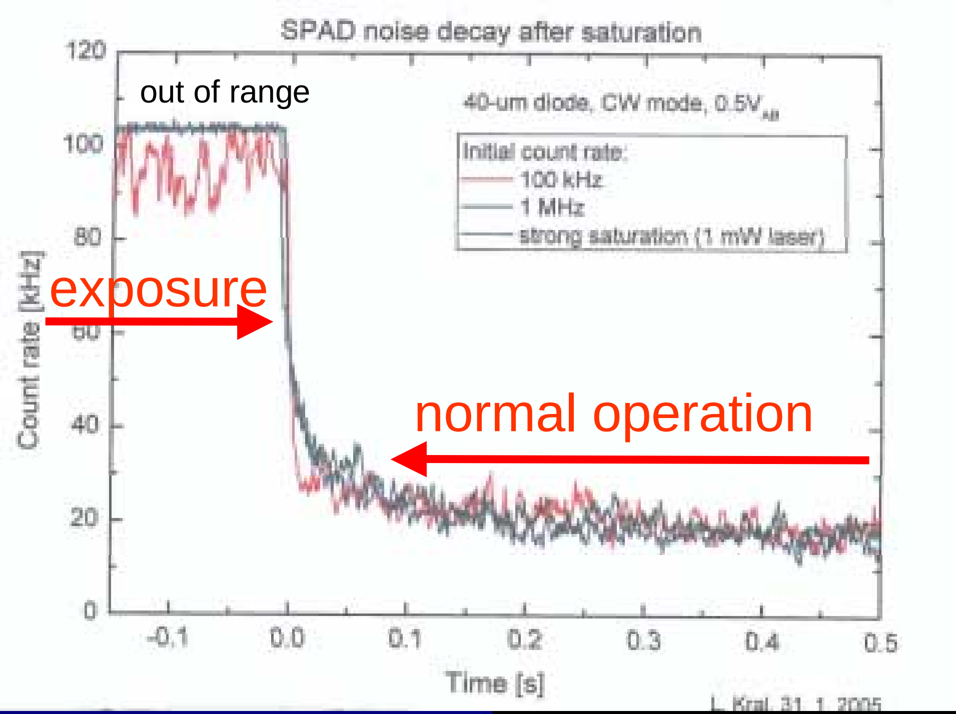
Optical Damage Tests

- exposure tests :
- no bias 3 x 8 hr
- biased 3 x 8 hr

- NO detectable detector degradation after all optical irradiation tests
- Any size telescope with SPAD detector may be pointed toward the Sun without the damage (< 100 nm bandwidth)

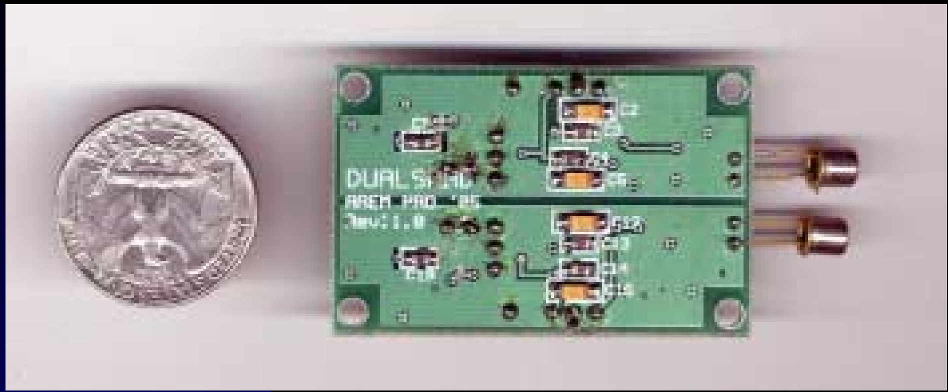
Optical Saturation Recovery



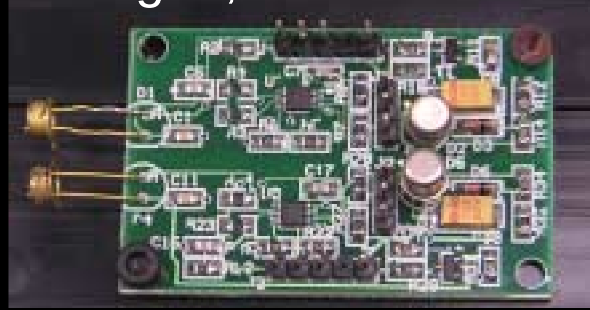
- Detector operation recovery after strong optical signal exp.
- detector illumination
- ambient light 100 kHz
- attenuated laser 1 MHz
  out of range when illuminated
- full laser 1 mW NA
  out of range when illuminated
- instrument time constant ~ 0.02 s

- Detector recovery time after saturation is well below 100 ms
- within this time, the dark count rate drops to 1.1 times the standard value

Photon Counting Module for Space Mission LTT



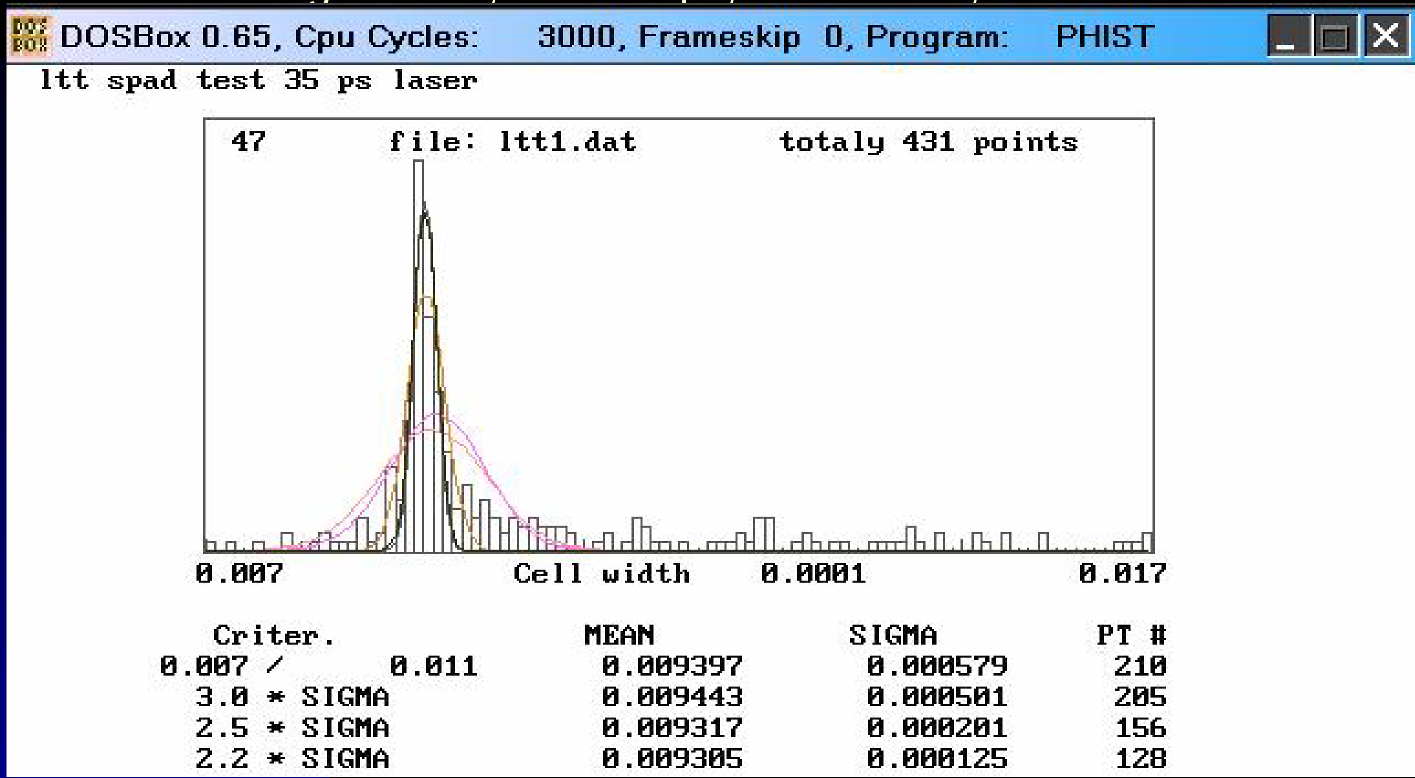
Technology demonstrator
Prague, March 2005



Detector package sample
for pre-flight tests
Shanghai, China, July 2006

SPAD Timing Resolution Tests, Shanghai July 2006

Shanghai SLR, laser 35 ps, HP counter, Detector # 1

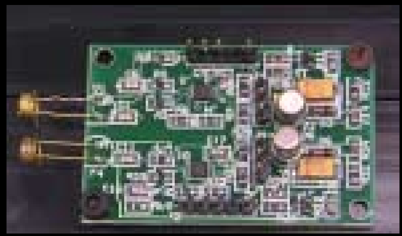


- Jitter detector # 1 125 psec
- detector # 2 120 psec
- Detection delay difference 440 +/- 20 psec

Dual Single Photon Counting Module

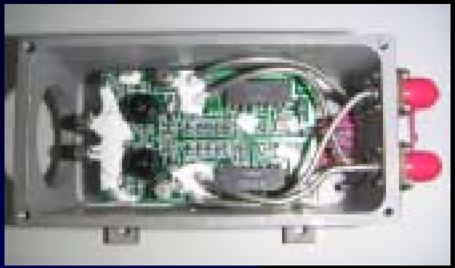
Detector Technology Demonstrator - Specifications

▪ configuration	dual photon counting detector based on Silicon K14 SPAD
▪ quenching	active
▪ active area	circular 25 um diameter
▪ quantum efficiency	~ 10 % @ 532 nm
▪ timing resolution	75 psec
▪ dark count rate	< 8 kHz @ +20^{o}C
▪ operating temp.	-30 … +60^{o}C no cooling, no stabilisation
▪ power consumption	< 400 mW
▪ mass	4 grams
▪ optical damage th.	full Solar flux 100 nm BW, > 8 hr
▪ lifetime in space	> 10 years



CONCLUSION
Photon Counting Module for Space Mission LTT

- the Technology Demonstrators have been completed Prague, March 2005



- the Flight Unit detector version has been completed Shanghai, July 2006
- Solar flux resistant using moderate wavelength filtering
- radiation resistant, 100 kRads without parameter change
  => lifetime in space > 10 years
- pre-flight tests, Shanghai, Beijin , fall 2006