Photon Counting Module for Laser Time Transfer Space Mission

Ivan Prochazka, Karel Hamal, Lukas Kral 1) Yang Fumin 2)

presented at:
the 15 International Workshop on Laser Ranging
Canberra, Australia, October 2006

1) Czech Technical University in Prague, Czech Republic
2) Shanghai Observatory, Chinese Ac.of Sci., Shanghai, China
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)
GOALs

1. to synchronize the rubidium clocks in space, hydrogen masers in a future.

2. Laser Time Transfer (LTT) between space and ground

3. 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

Prochazka, Hamal, Kral, Yang Fumin, Canberra, October 2006
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°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 (!) 😡

Prochazka, Hamal, Kral, Yang Fumin, Canberra, October 2006
SPAD Bias Temperature Control

- SPAD break down voltage: 29 Volts
- Bias accuracy required: 100 mV
- Temperature range requested: -30 …+ 60°C
  - No temperature control or cooling
- SPAD break voltage temperature drift: -30 mV/K

=> temperature controlled bias circuit

Power consumption: < 4 mW
Optical Damage Threshold

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

- Laser diode & beam shaping optics
- 2 mW cw, red
- SPAD with electronics on XYZ stage
- microscope objective
- spot 12 x 20 um 1 mW

- 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)

Prochazka, Hamal, Kral, Yang Fumin, Canberra, October 2006
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
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
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°C
- **operating temp.**: -30 … +60°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

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