CTU
CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF NUCLEAR SCIENCES AND PHYSICAL ENGINEERING CTU IN PRAGUE

Technologies for single photon counting and laser time transfer in space

I. Procházka, J. Blažej

presented at

Space Colloquium, June 23-24 2022, Prague

CTU in Prague - FNSPE

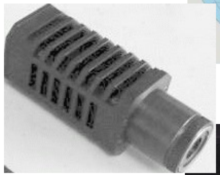
- Time-resolved detection of single photons in VIS and IR – millimeter satellite laser ranging, picosecond laser time transfer and time-scale synchronization, sub-picosecond event timing
(this presentation)
- X-ray photonics (June 23, 16:40, Pína, X-ray optical systems)
- Sensorics (June 23, 15:50, Jirsa, Radiation-tolerant semiconductors...)
- Nuclear chemistry (June 23, 14:40, Drtinová/Němec, Analysis of extraterrestrial materials and cosmogenic nuclides)
- Nuclear reactors (June 24, 9:40. Frýbort, Competence for Space Power Sources)

Space-related activities

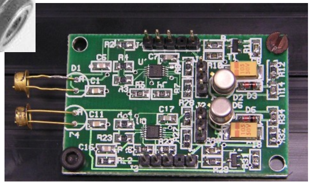
CTU in Prague, FNSPE, Advanced Space Research Lab

- Satellite laser ranging — 1973 – 1991
  development and operation of worldwide SLR network
  INTERKOSMOS, single photon detection technology dev.

- Single photon detectors for SLR — 1989 – now
  ground segment installed 25× on 5 continents



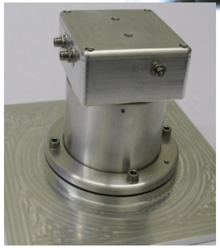
- Single photon detectors for space segment — 1990 – now
  Russia, NASA, China, ESA, CNES, S. Korea



- Altimeter for Mars probe, Russia — 1991 – 1995
  LIDAR for mission NASA Mars Polar Lander — 1993 – 1998

- Picosecond event timer for ground segment — 1997 – now
  Japan, China, Germany, NASA, ESA, S. Korea, …

- Laser Time ,Transfer (detectors, timing, ...) — 2002 – now
  China, CNES, NASA, ESA, Russia



Si SPADs for Space Applications

developed at CTU in Prague

- World unique feature
  <u>space qualified </u>up to <u>extremely high radiation doses </u>
  (up to Jupiter moons environment…)

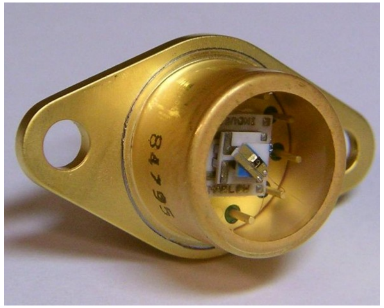
- Insensitive to high background photon fluxes

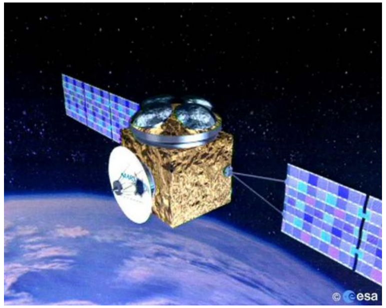
- 11 units launched to space, no problems reported

- Low power (< 0.5 W), low voltage (U < 35 V)

- Operating <u>temperature range −100 to +50 °C </u>

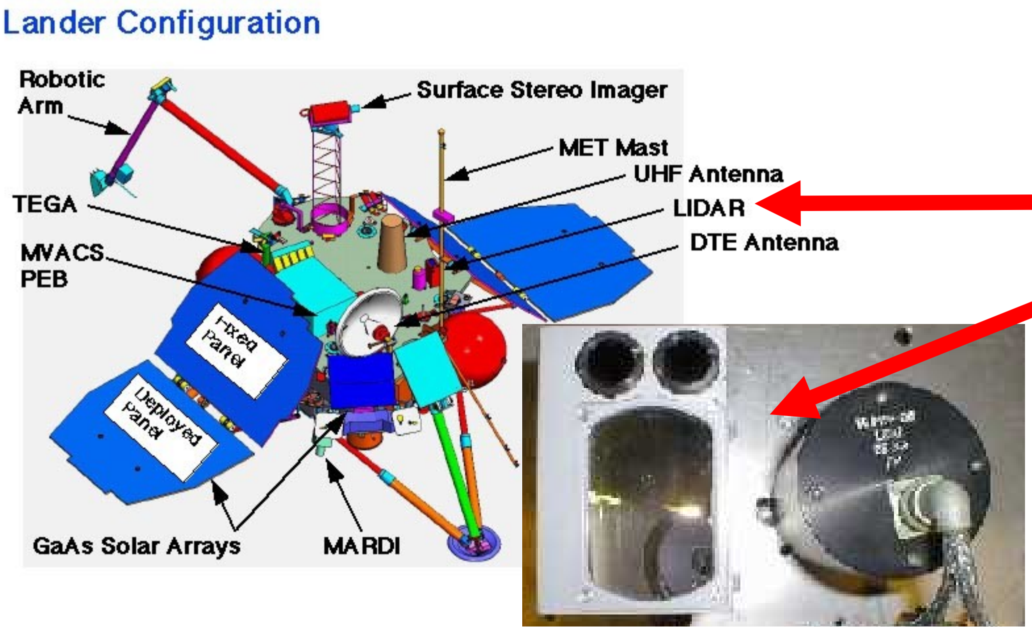
- Extremely high timing stability TDEV < 50 fs





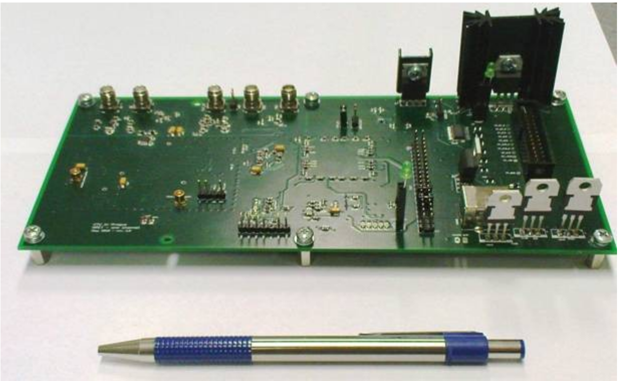
Si SPADs for Space Applications

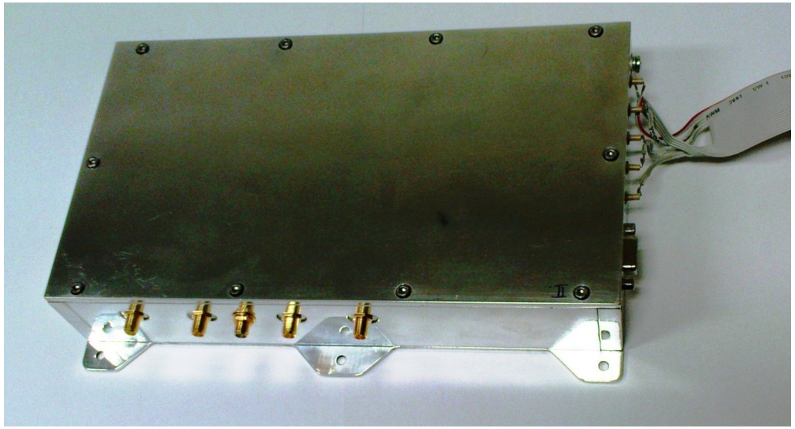
- MARS 92 (USSR / Russia, 1992-96) — Photon counting laser rangefinder, Mars baloon altimetry
- NASA Mars Polar Lander, (USA, 1998) — Photon counting Lidar, Mars surface atmospheric studies



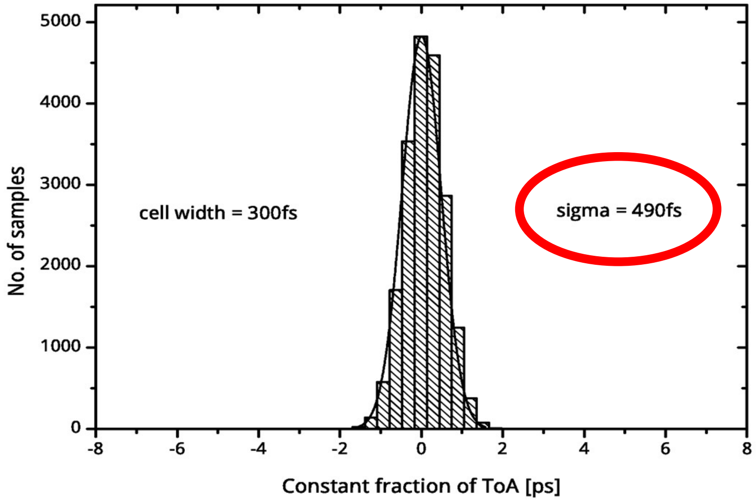
CTU Prague & IKI Moscow

Sub-ps Timing system NPET2 version 3.0





- SAW filter based timing
- Jitter & non-linearity < 500 fs
- temperature drift < 100 fs/K
- measurement rate > 4 kHz

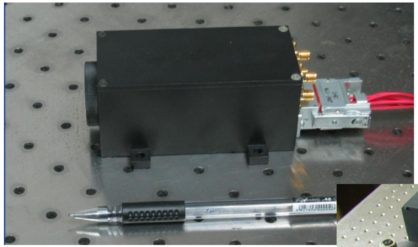
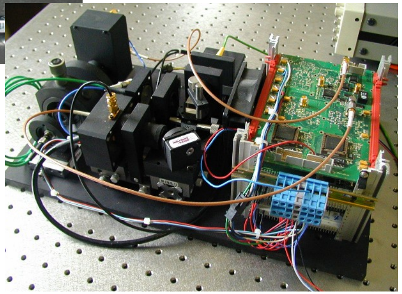


- U.S. Patent 7,057,978 B2, Jun. 2006.
- Panek, P. Time-interval measurement based on SAW filter excitation. IEEE trans. on instr. and meas. 57(11), 2582-2588, 2008.
- https://doi.org/10.1063/1.3155510

Laser Time Transfer ground – space
History & Concepts & Performance & Requirements

CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE

• LTT Compass (2003/2007)	single photon - precision / accuracy	achieved TDEV 30ps@500s / NA
• T2L2 CNES (2003/2008)	multiphoton - precision / accuracy	achieved TDEV 10ps@200s / ~100 ps
• ELT ACES (2010/2018)	single photon - precision / accuracy	required TDEV 5 ps@100s / ~20 ps
• ELT+ ISOC (2017/ ????)	single photon - precision / accuracy	required TDEV 0.5 ps@100s / ~20ps

Lab capabilities

- picosecond lasers (532, 778, 1550, ... nm)
- sub-picosecond event timers (jitter < 1 ps)
- single-photon detectors (jitter 20 – 80 ps), not only Si
- optical trigger devices, delay lines, ...
- frequency sources, analyzers, ...
- cables with calibrated delay

Thank you.