SIGNAL STRENGTH MONITOR FOR C-SPAD RECEIVER

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Goals:

- to estimate the echo signal strength in laser ranging based on C-SPAD detector

- the SPAD chip current pulse risetime depends on photon number (Kirchner, Koidl, 1995)

- C-SPAD circuit provides two output timing pulses, their interval corresponds to the detected signal energy

- to construct the Time to Digital Converter to record the interval and hence the echo signal energy
C-SPAD Detector Package # 0406

Measured: Delay (Comp-Uncomp Output) with PPET

Time Walk [ps] relative to Single-Photon-Level

Delay: 210 ps; ==> 280 Photons

Compensated Output [ps]
UN-Compensated Output [ps]

Number of received Photons

- avalanche build up time effect expanded by built-in circuit (G.Kirchner, F.Koidl)
- large data sets averaging

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SLR with Photon Number Estimate

RMS vs. Received # of Photons
Rec. Energy: Meas. by PPET (Compens.Delay)

Single-Shot RMS [mm] for specific # of photons

- LAG-1: All Rets: 9.4 mm
- LAG-2: All Rets: 9.3 mm
- ERS-2: All Rets: 4.3 mm

Number of received Photons/Return

<Graz, 1998-09-11>

G. KIRCHNER¹, F. KOIDL¹, I. PROCHAZKA², K. HAMAL², 11th WLRI, Deggendorf, 1998

SLR data post processing, data averaging

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Photo Number Estimate
Indoor Calibration Tests

- compensated versus un-compensated output
- shot by shot data processing
- PET4 timing, NdYAG 32 ps @ 532 nm, indoor

- data spread ~ 50 ps rms
- = > ultimate photon number resolution 3 x

Time to Digital Converter for C-SPAD Based Energy Monitor

- REQUIREMENTS:
  - resolution: 20 ps
  - range: 8 bits / ~ 1.6 ns
  - dead time: < 400 us

- DESIGNED CIRCUIT
  - time expander, capacitor charge / discharge
  - expansion factor: ~ 2000 x
  - digital counter 30 / 15 ns on Programmable Gate Array
Time to Digital Converter Calibration

- ~ 100 channels / 1.6 nsec

I. Prochazka, May 25, 2004
Indoor Laser Ranging Test

Prague, June 2, 2004, 2 kHz, 32 ps laser diode, C-SPAD, PET2k

- 1 PE: 23 ps rms dark count
- 1 ~ 10 PE: 23 ps
- ~ 100 PE: 12 ps
- ~ 1000 PE: 8 ps
Ground Target Laser Ranging Energy Spectrum

Graz, May 5, 2004, 2 kHz, 8 ps laser, C-SPAD, PET2k

Dark counts / stability
2 series, 24 hour apart

1 m ground target ranging
1 - 10 PE, 15 ps rms

4 km ground target ranging
~ 1000 PE, 6 ps rms
Conclusion

- the C-SPAD based receiver package energy monitor has been constructed and tested

- FEATURES:
  - built in the PET2k
  - 7 energy levels resolution / shot - by - shot
    1-3, 3-10, 10-30, 30-100, 100-300,300-1000, > 1000
  - self - calibrating /via dark counts on 1 PE/
  - temperature & temporal stability < 0.1 ch / day

- STAND BY device of the C-SPAD energy monitor has been constructed and is available for SLR stations operating C-SPAD