Use of a Hybrid Photo Detector (HPD) in the MAGIC micro power LIDAR system

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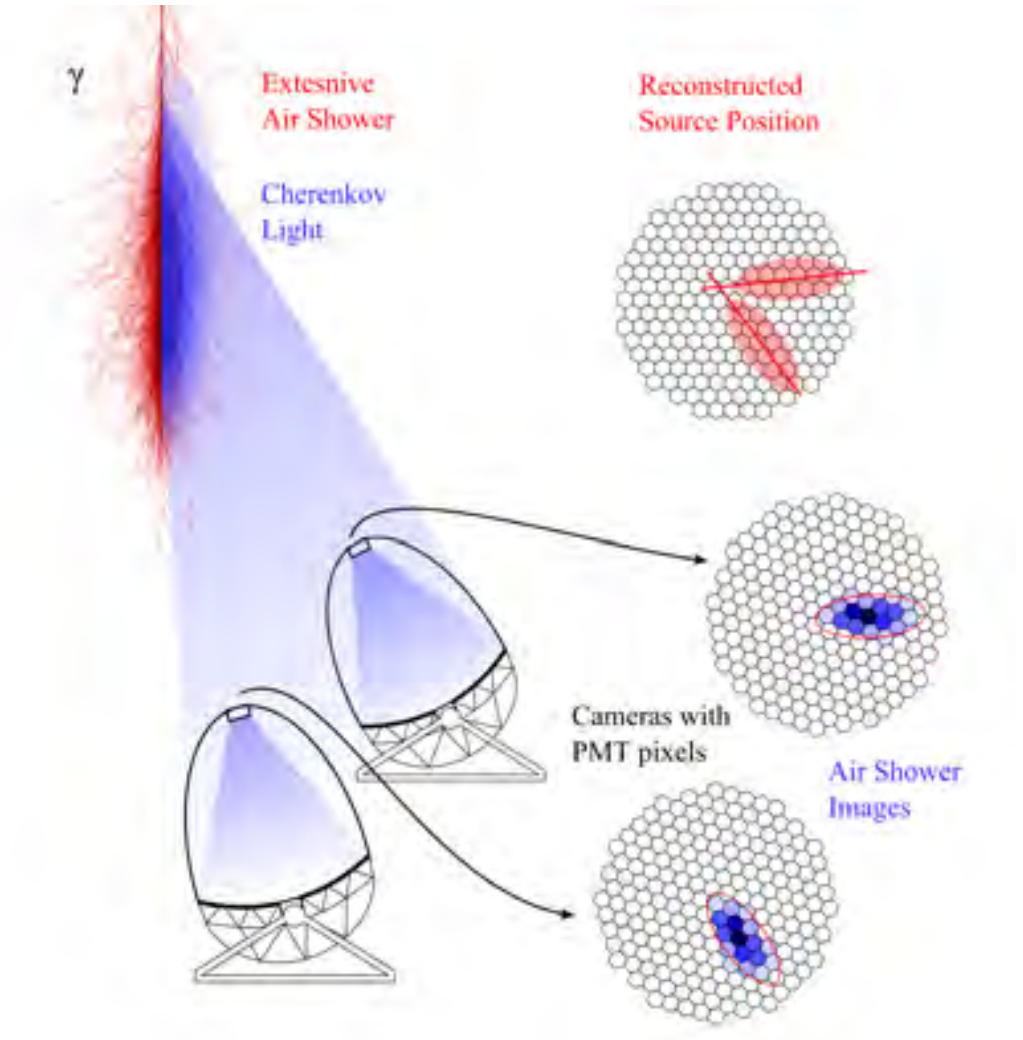
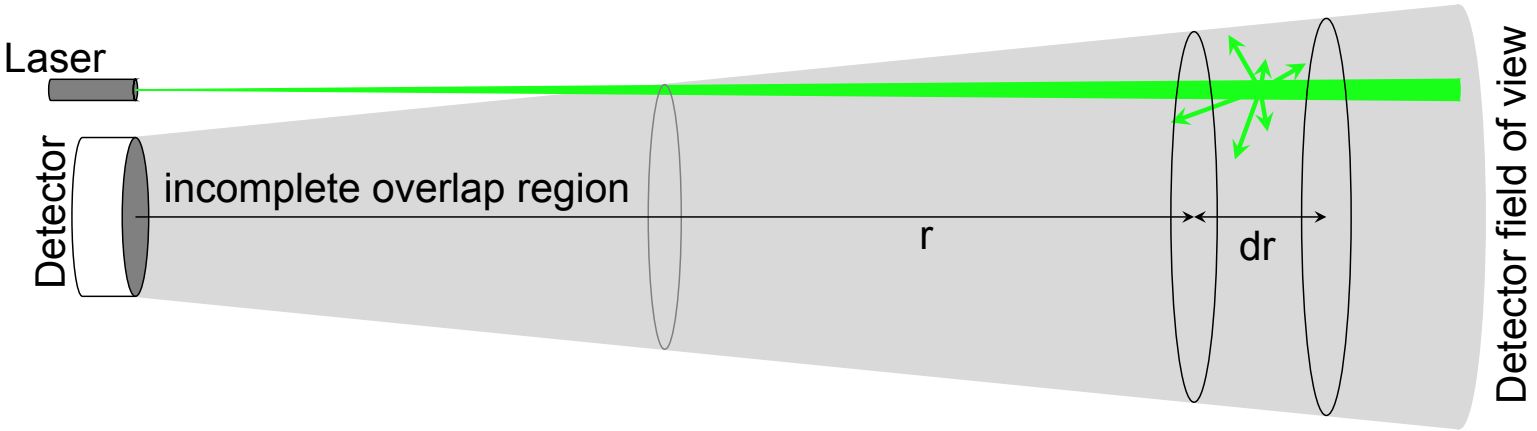
Overview

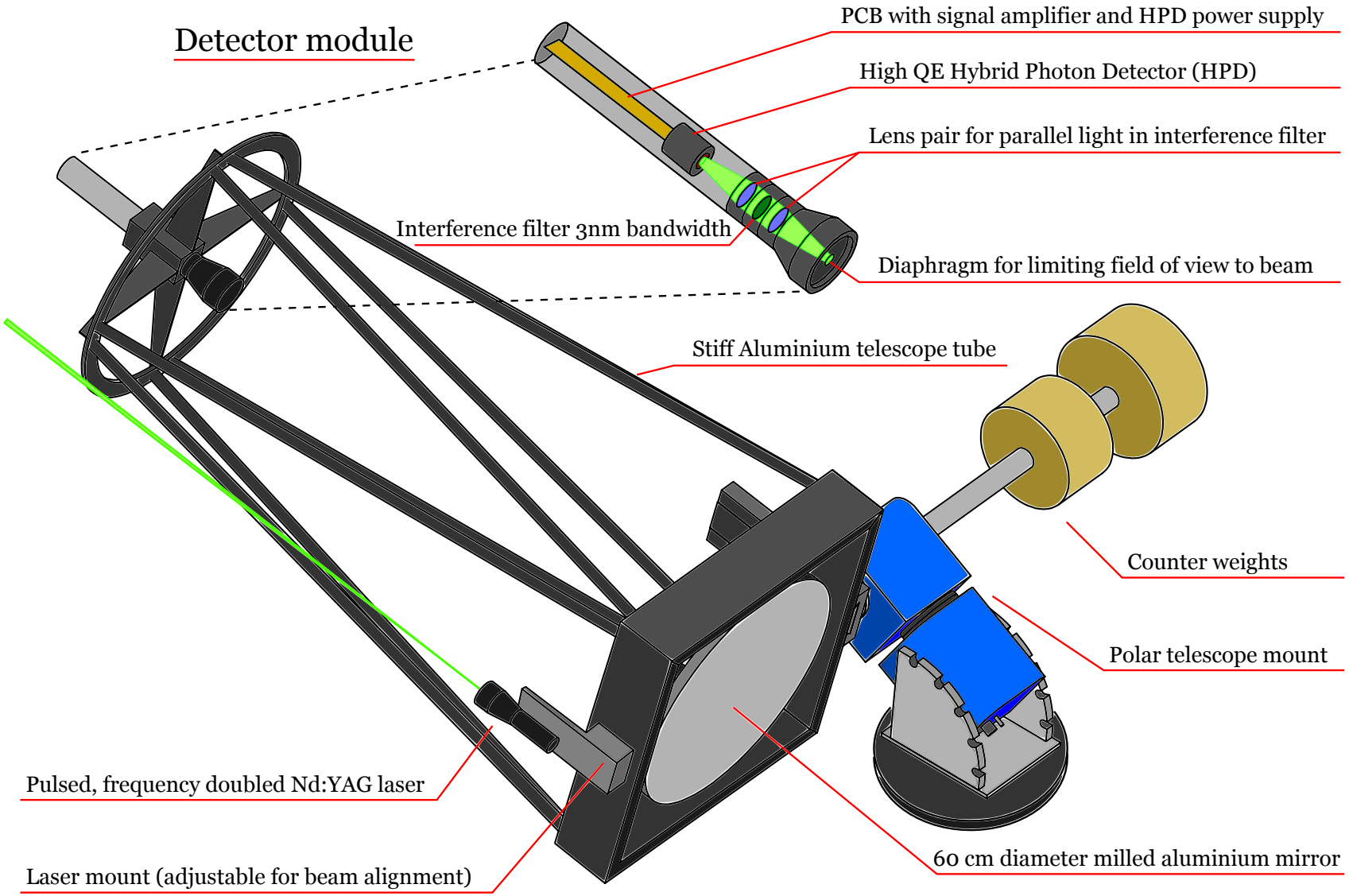
- MAGIC uses the Imaging Airshower Cherenkov Technique (IACT)
- Light produced in atmospheric particle shower
- LIDAR (LIght Detection And Ranging) for determining the atmospheric attenuation
- 'micro power' LIDAR ($5\,\mathrm{mW}$) to not disturb observations on the Roque





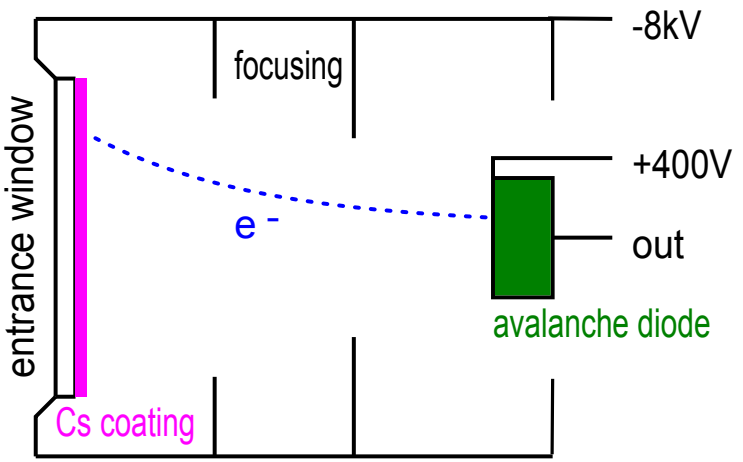
$$\mathrm{d}N(r) = N_0 \; C \; G(r) \; \frac{A}{r^2} \; \beta(r)\mathrm{d}r \; \exp\left(-2\int_0^r \sigma(r')\mathrm{d}r'\right)$$

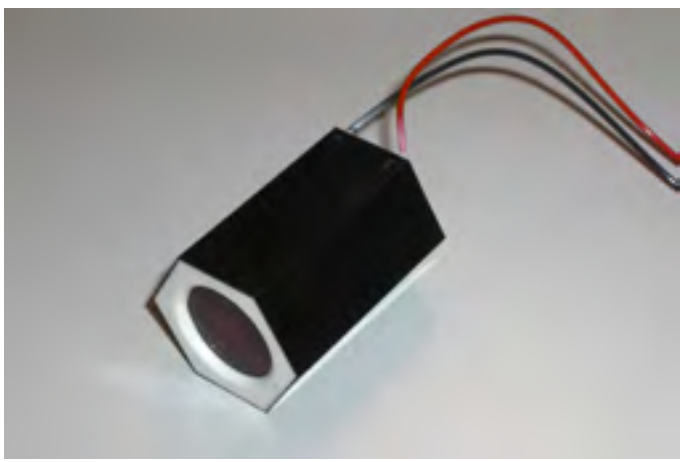
- N_0,$\mathrm{d}N(r)$: photons: in laser pulse, in range bin
- C,$G(r)$: overall efficiency, overlap (laser-FOV) and focus effects
- $\frac{A}{r^2}$: solid angle (detector seen from location of scattering)
- $\beta(r)\mathrm{d}r$: volume backscattering coefficient times range bin length
- $\exp\left(-2\int_0^r \sigma(r')\mathrm{d}r'\right)$ total attenuation on the way
- two unknown functions: $\beta(r)$ and $\sigma(r)$
- $\frac{1}{r^2}$ dependency demands for high dynamic range


Detector module
PCB with signal amplifier and HPD power supply
High QE Hybrid Photon Detector (HPD)
Lens pair for parallel light in interference filter
Interference filter 3nm bandwidth
Diaphragm for limiting field of view to beam
Stiff Aluminium telescope tube
Counter weights
Polar telescope mount
Pulsed, frequency doubled Nd:YAG laser
Laser mount (adjustable for beam alignment)
60 cm diameter milled aluminium mirror

The light detector HPD

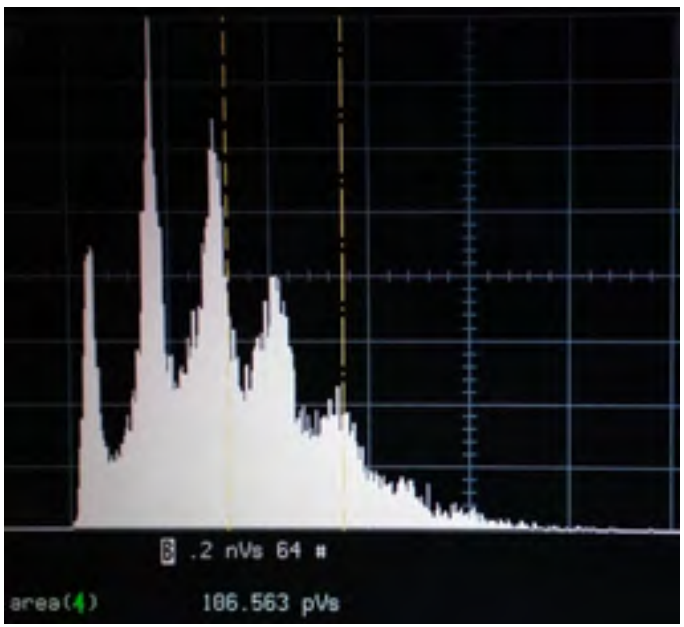
- HAMAMATSU R9792U-40
- GaAsP entrance window coated with Cs for reducing the work function
- operated at 6.5kV and 400V
- charge gain $\approx$ 1000 (bombardment gain) $\times$ 100 (avalanche gain)
- high dynamic range (single ph.e. and integrating)

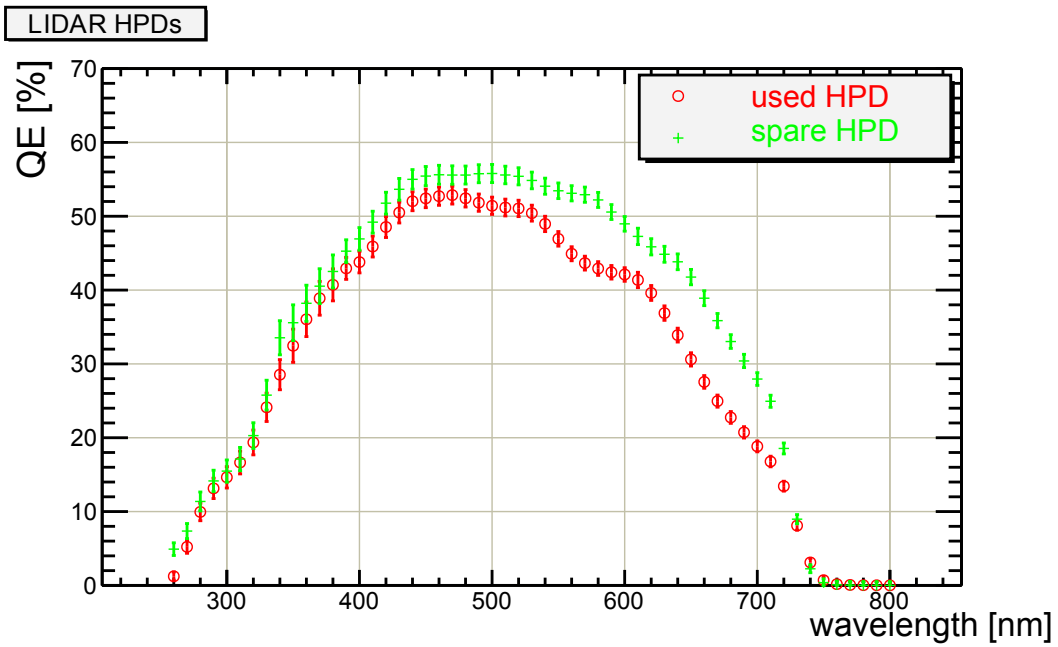


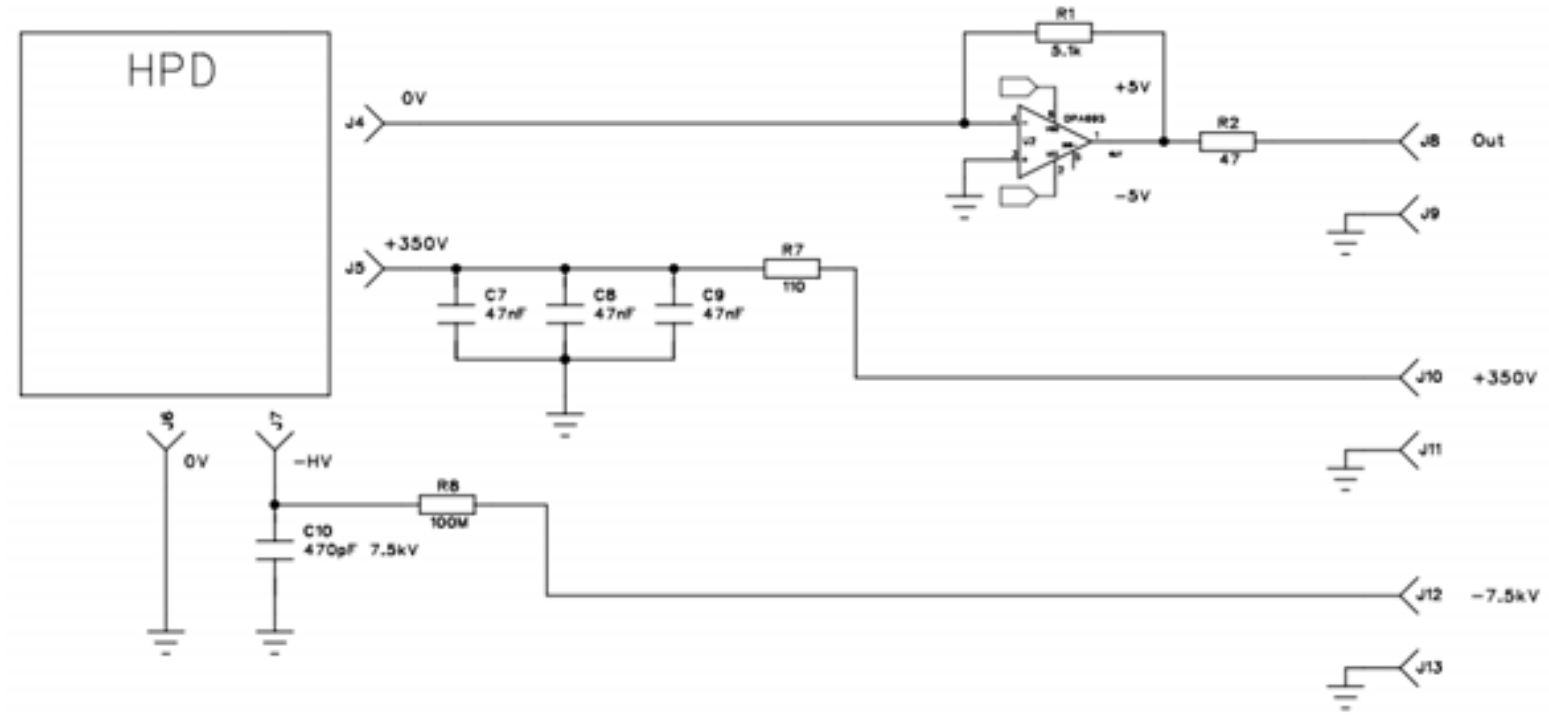


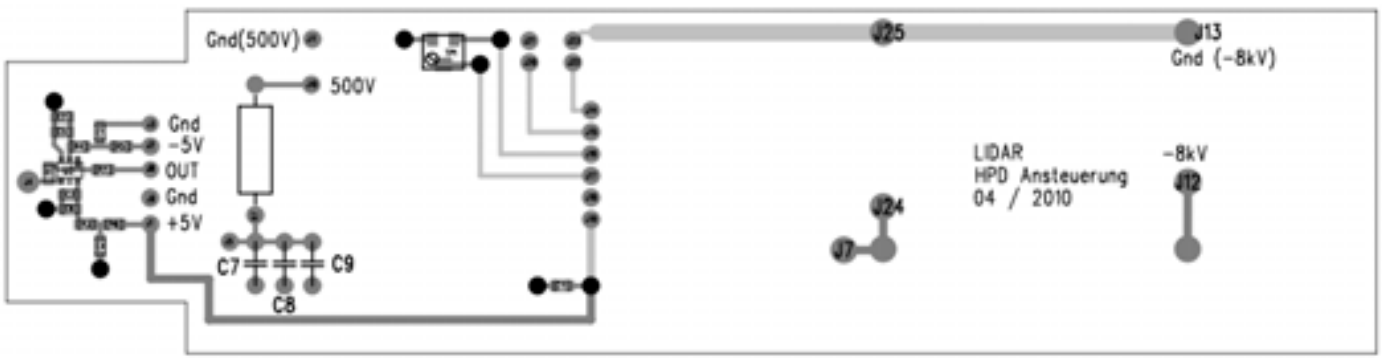
The light detector HPD

- good single ph.e. resolution
- QE $\approx 50\,\%$ at 532nm

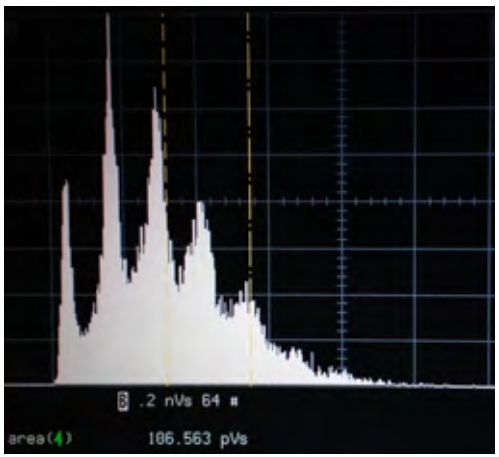


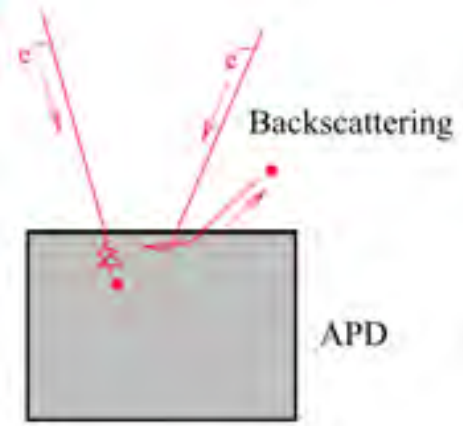



HPD
J4
0V
R1
5.1k
+5V
-5V
R2
47
J8
Out
J9
J5
+350V
C7
47nF
C8
47nF
C9
47nF
R7
110
J10
+350V
J11
J6
0V
J7
-HV
R8
100M
C10
470pF 7.5kV
J12
-7.5kV
J13

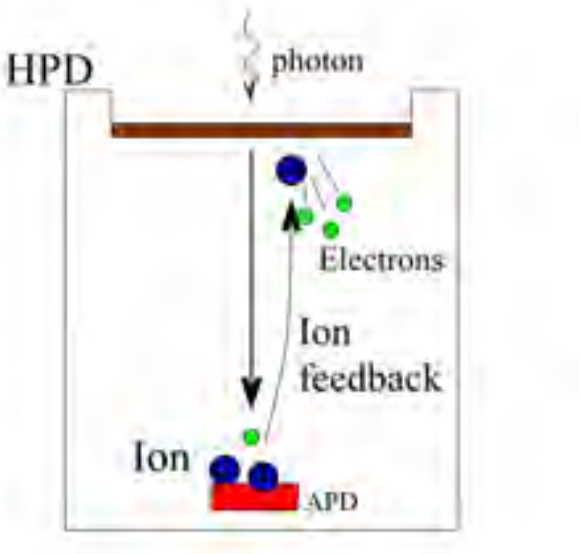

Gnd(500V)
500V
Gnd
-5V
OUT
Gnd
+5V
C7
C8
C9
J25
J13
Gnd (-8kV)
LIDAR
HPD Ansteuerung
04 / 2010
-8kV
J12
J24
J7

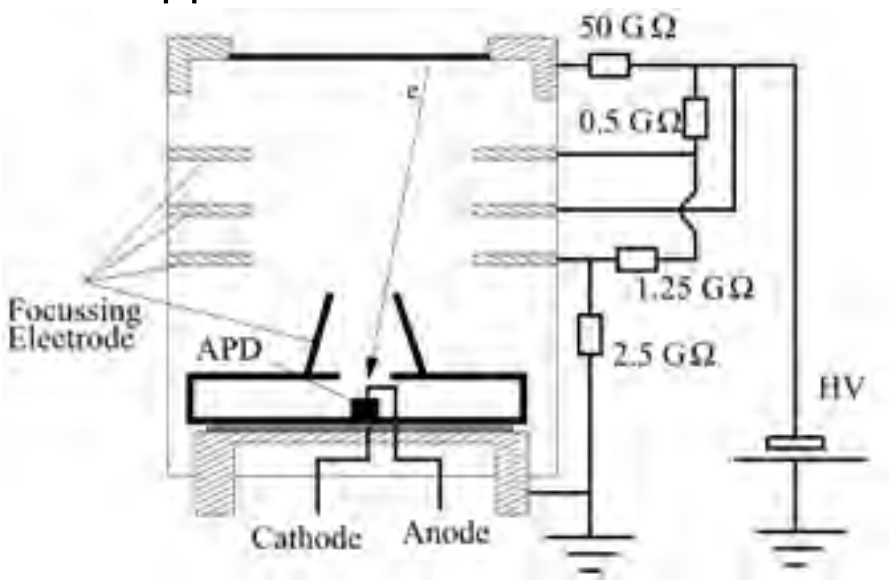
backscattering:



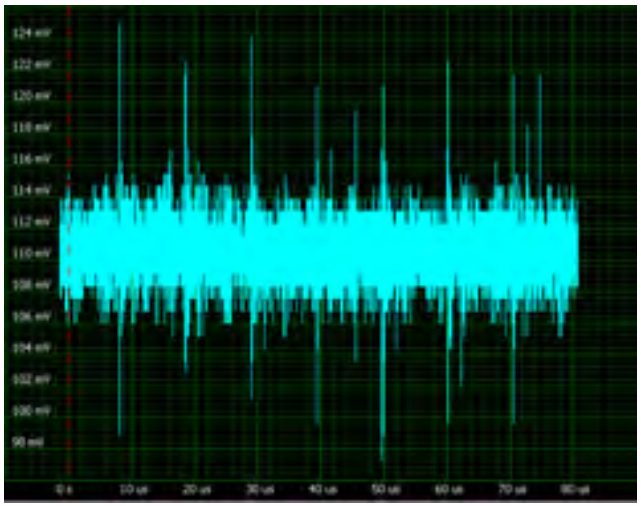


ion feedback suppression:

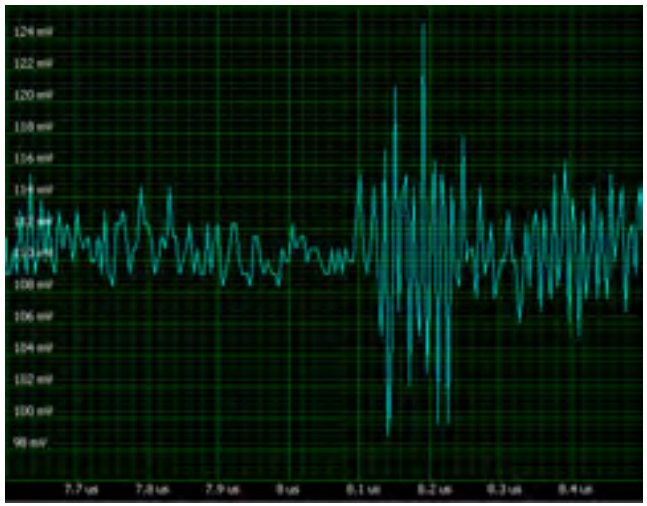




detector noise

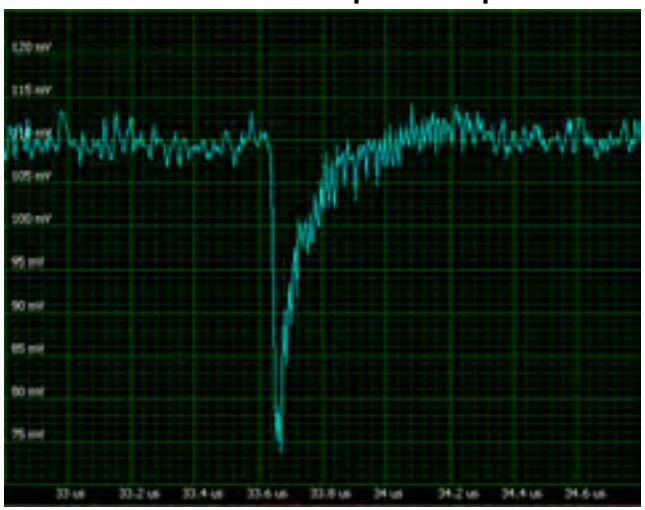


zoomed out



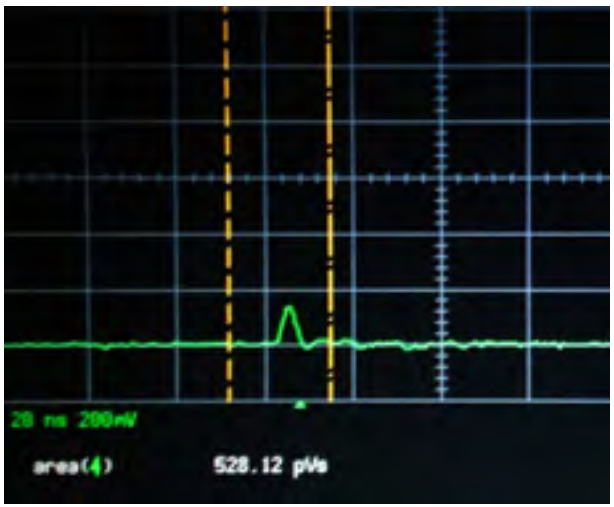
pick up noise

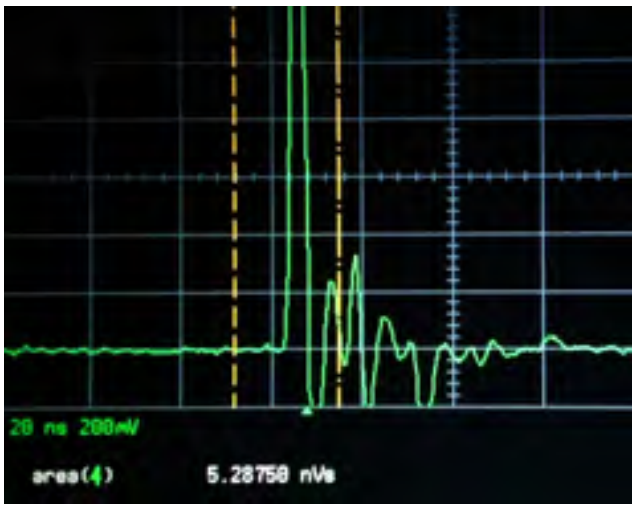
single photon



"spark"

noise sources





- ion feedback (even if reduced by deflection system)
- X-rays from the anode impact
- scintillation caused by backscattered e^-
- cosmic muons / radioactivity
- signal pickup on large capacitance

Noise reduction

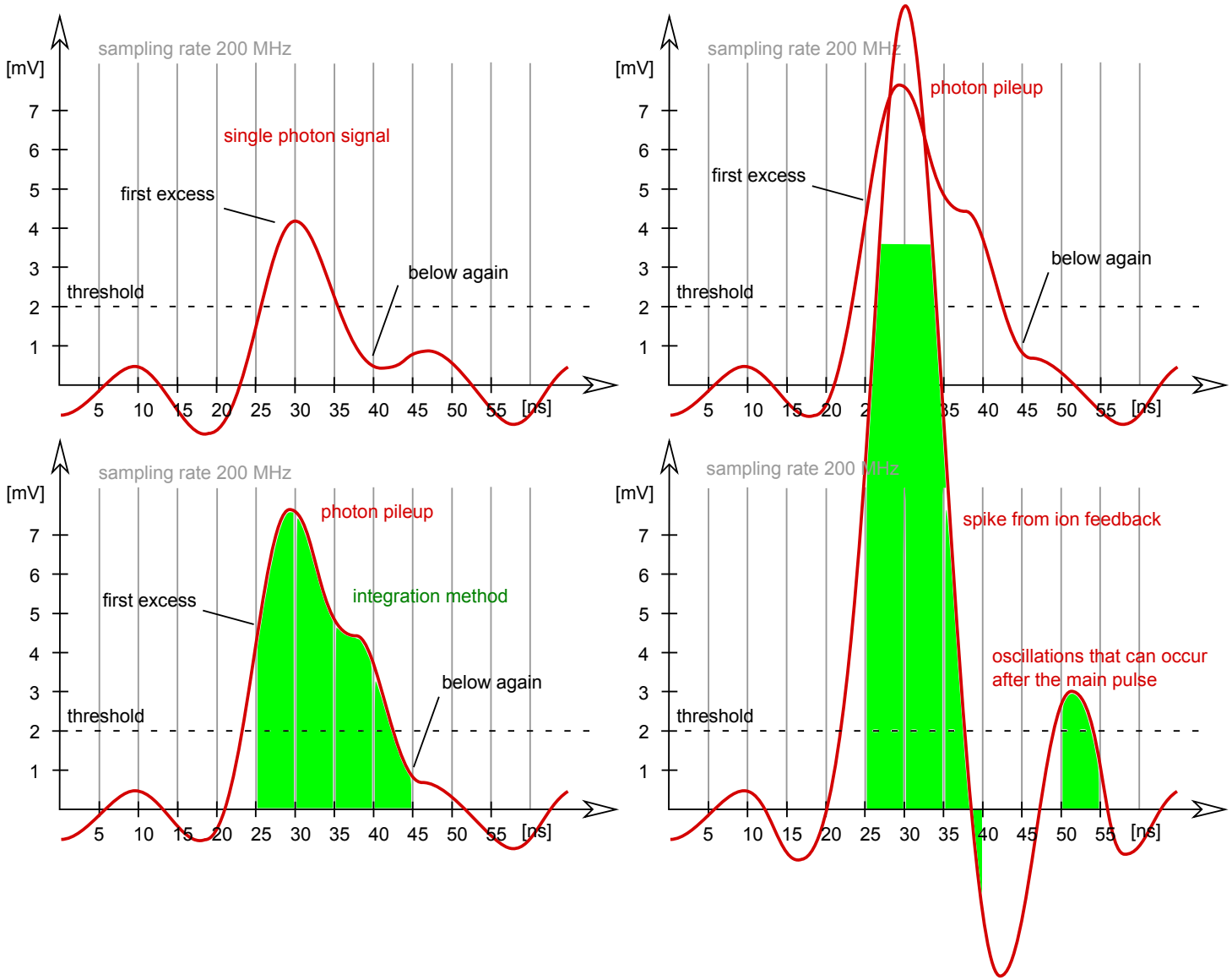
by Hardware:

- screening from noise signals (Al tube)
- short connection to first amp. ($<$ 1cm)
- limited bandwidth ($\approx$ 50 MHz) for reducing HF pickup

by Software:

- subtraction of background rate
- single photon counting mode for for weak signals
- reduction of the effect of oscillating noise

Photon counting modes:



- counting photons via threshold excess
- photon peaks have all the same sign while pick up noise is random
- include second threshold and count negative

Comparison with other detector types

PMT:

- low dark rate
- lower HV needed, less problematic to handle
- lower QE
- no good single ph.e. resolution
- high rate of afterpulses

Comparison with other detector types

HPD:

- practically no dark rate
- high QE
- good single photon resolution
- lower rate of high amplitude background events (ion feedback)
- more HV related problems due to higher voltage
- more problems with pickup noise due to high capacitance
- sensitive to accidental exposure to stronger light

Comparison with other detector types

SiPM:

- high QE
- only low voltage needed
- easy handling
- allows to build very compact detector
- but: high dark noise
- crosstalk

Conclusions

- the HPD is a very sensitive photo detector for single photon counting
- there are some problems that could be treated by optimizing the system
- HPD has proven to be well suitable for the micro power LIDAR application