High speed Pockels Cell shutter and the Herstmonceux MCP-PMT detector

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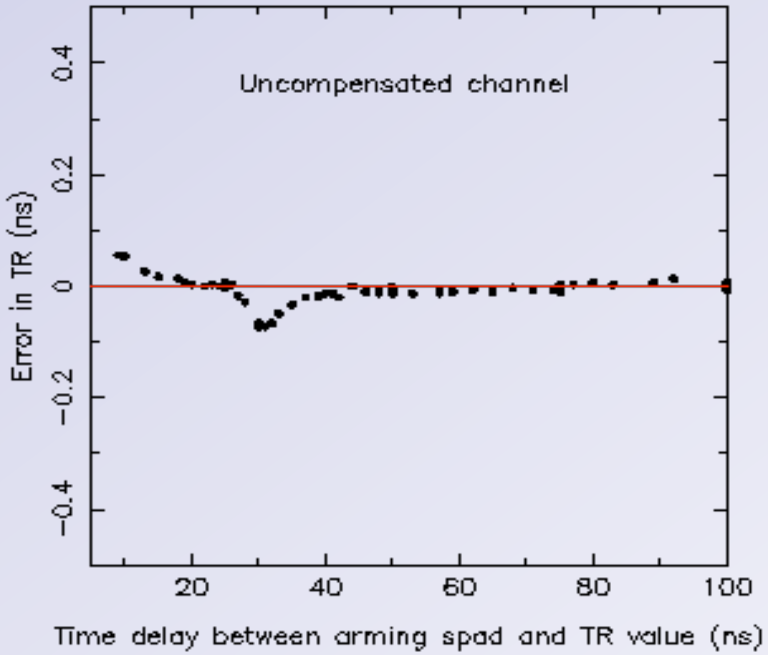
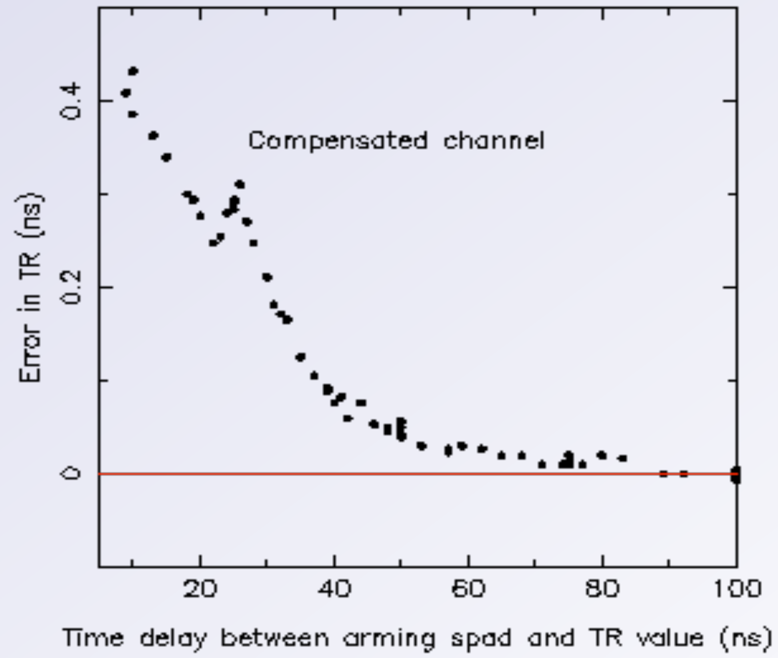
Wednesday, October 15
Session 7 - High repetition-rate systems

Introduction

The NSGF SLR system uses a C-SPAD detector and consequently makes only one detection per laser fire. Also the C-SPAD must be armed 50-100ns before an observation to avoid any bias.



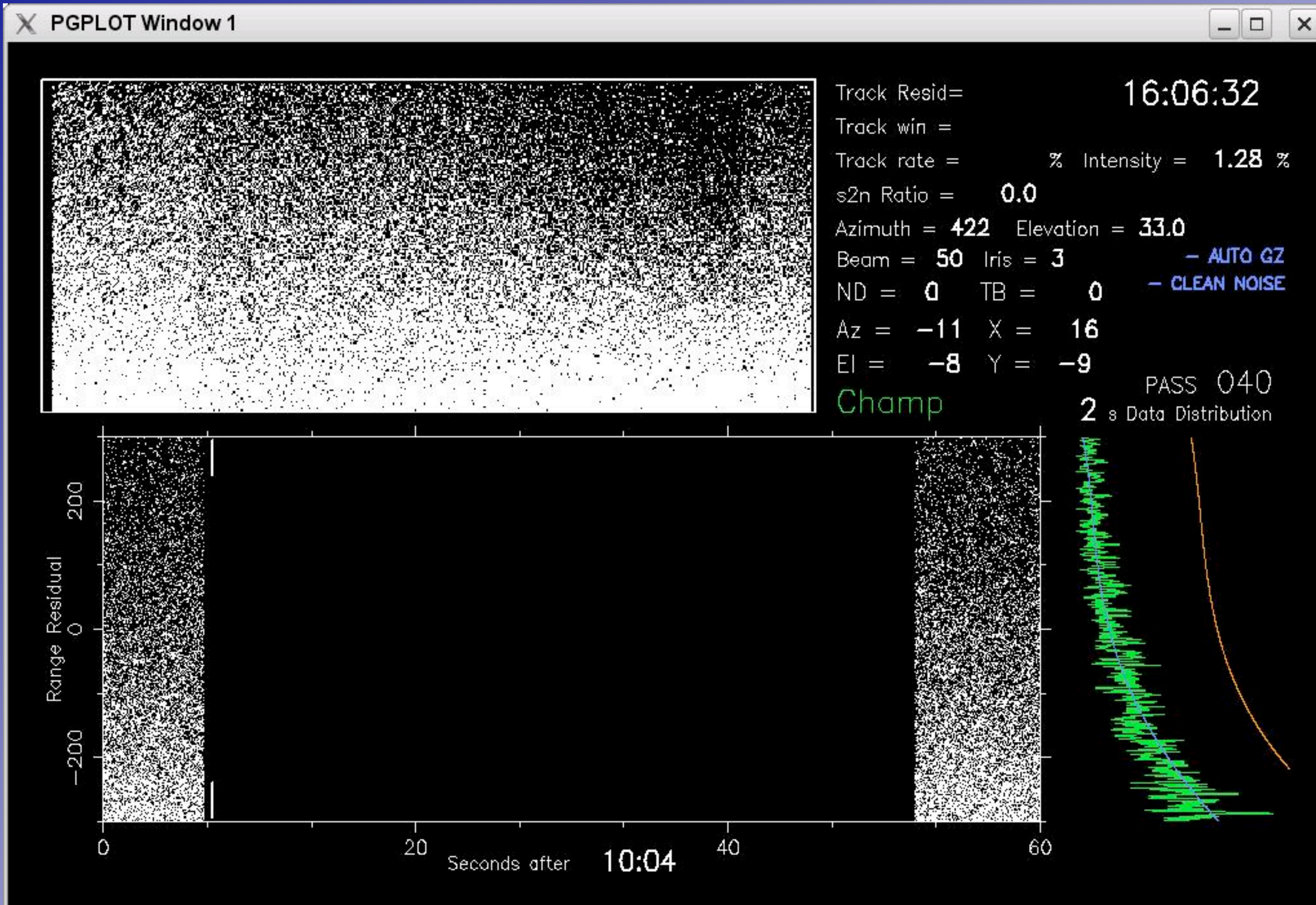


Introduction

If the C-SPAD detects a noise point before the arrival of the satellite return signal then the opportunity to observed the satellite for that shot is lost.

In comparison to the Nd:YAG laser, the new kHz laser system has a greatly reduced signal to noise ratio with much more sampling.

Therefore, daylight noise is much more apparent in the range gate window and has a more significant impact on observing.

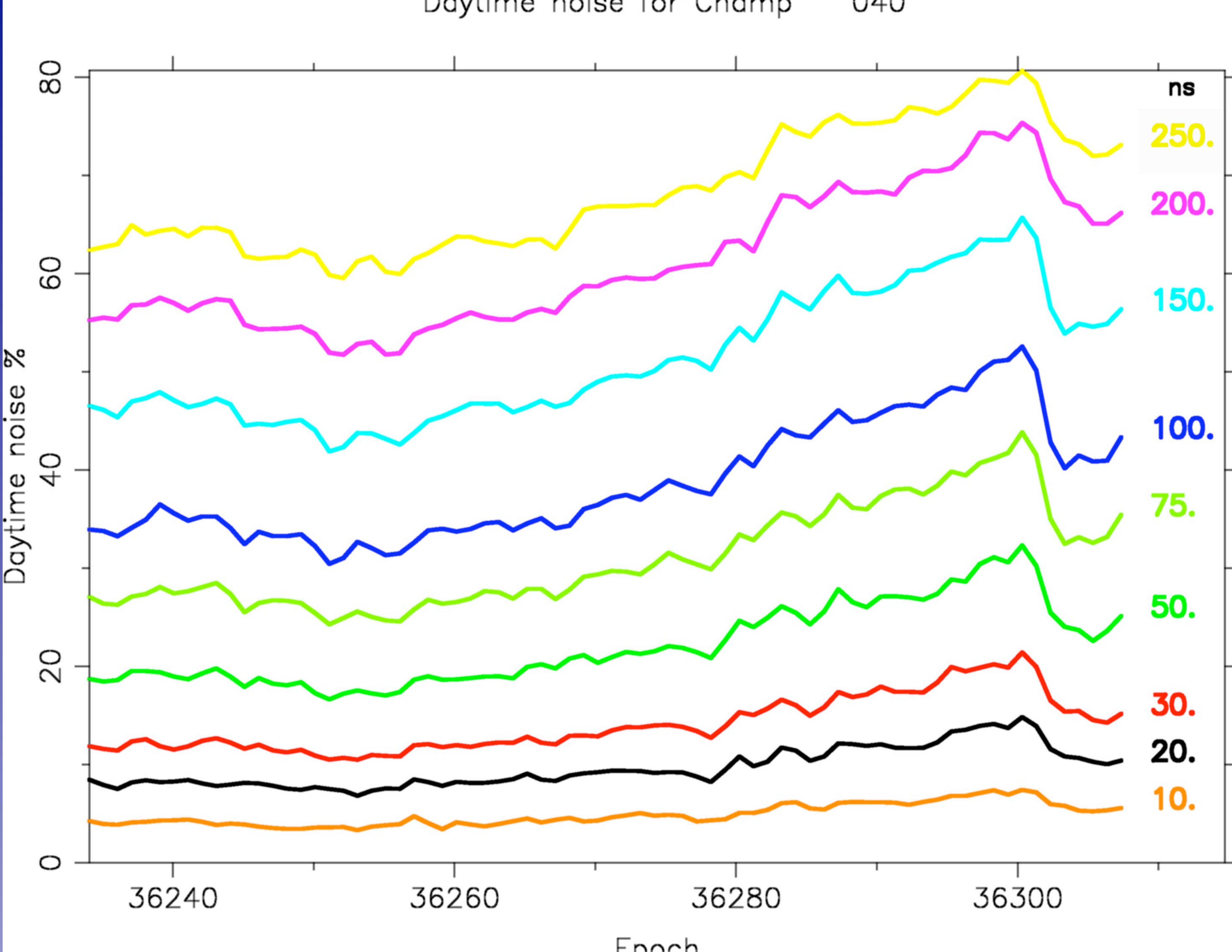

PGPLOT Window 1
Track Resid=
16:06:32
Track win =
Track rate = %
Intensity = 1.28 %
s2n Ratio = 0.0
Azimuth = 422
Elevation = 33.0
Beam = 50
Iris = 3
– AUTO GZ
– CLEAN NOISE
ND = 0
TB = 0
Az = –11
X = 16
El = –8
Y = –9
PASS 040
Champ
2 s Data Distribution
Range Residual
200
0
–200
0
20
40
60
Seconds after 10:04

Daylight noise in the range gate

The C-SPAD will make a detection within a few hundreds of nanoseconds during normal daylight operations.

To reduce daytime noise the return path includes an oven controlled daylight filter that allows a narrow spectrum of 0.14nm FWHM centred at 532.1nm. Peak Transmission is 68.04%.

The following plot shows the daylight detections for the Champ pass as a proportion of laser fires.


Daytime noise for Champ 040
Daytime noise %
Epoch
0
20
40
60
80
36240
36260
36280
36300
ns
250.
200.
150.
100.
75.
50.
30.
20.
10.

Very Fast Shutter

Introducing a shutter before the C-SPAD will allow it to fully arm in darkness. The shutter can then be opened much closer to the satellite track (~10ns).

This could turn a 50% loss to a 10% loss.

Suitably Fast Shutters

Physical **-** Spinning disc or resonant forks opening and closing a physical barrier matched in phase.

Liquid Crystal Display **-** Cell containing long molecules aligned at each surface and 90 degrees apart. Polarised light is rotated through the cell with no applied voltage. Cell becomes opaque when a voltage is applied as the molecules align to the electric field.

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Suitably Fast Shutters

**Electro-optic - ** Pockels cell shutter using fast switching of polarisation to block and transmit light.

**Acousto-optic - ** A piezoelectric device transmits a sound wave through a quartz crystal to produce a diffraction grating. This grating then deflect light.

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Acousto-optic **-** A piezoelectric device transmits a sound wave through a quartz crystal to produce a diffraction grating. This grating then deflect light. **However, the speed of the shutter is limited to the speed of sound in the crystal and it is only fast enough if the return signal beamwidth is very small ~ 1 micron.**

Pockels Cell Shutter

Example

Wavelength range:

0.3 – 1.2μm

Optical Rise time:

< 1.0ns

Contrast:

> 1000:1

Pockels cell picture taken from website www.leysop.com

Pockels Cell Shutter

Example

Insertion loss:
< 4%

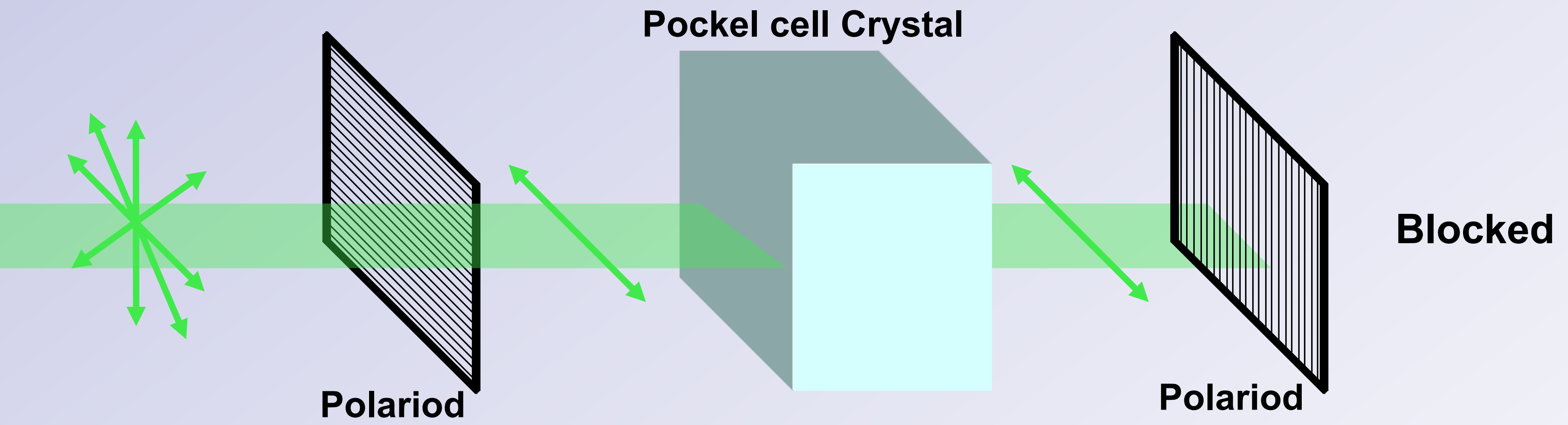
Physical diameter:
35mm

Physical length:
42mm

Pockels cell picture taken from website www.leysop.com

Pockels Cell Shutter

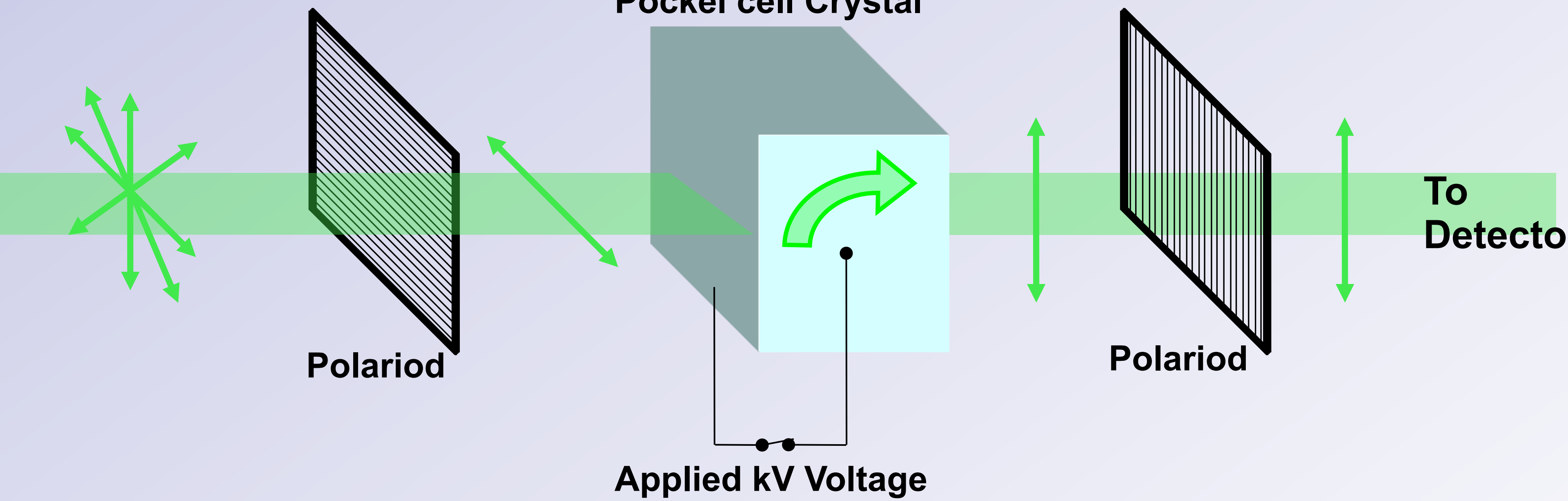
Schematic



Light is polarised before entering the Pockels cell crystal. With no applied voltage the light is blocked.

Pockels Cell Shutter

Schematic



With an applied high voltage the polarisation of the light is rotated. The light can then pass through the second polariod a reach the detector.

Malus's Law

The major disadvantage of introducing a Pockels cell shutter before the C-SPAD is the loss of signal intensity due to Malus's Law.

For a perfect polariser aligned by θ to polarised light of intensity I_0, the output intensity equals:

$$I = I_0 \cos^2\theta$$

Only the intensity component that is parallel to the polariser's transmisson axis is transmitted.

Malus's Law

Unpolarised light consists of a random mixture of polarisations. The average over this random mixture is the average of $\cos^2\theta$ from 0 to 90^o, which equals ½.

Therefore the intensity of unpolarised light through a perfect polariser is reduced by half.

Polarisers are not perfect and so transmission is less than 50%, although this is small using calcite glass polarisers.

Further issues

The Pockels cell must be electronically switched at high voltage. This reduces gating time to 10-15ns.

The Pockels cell will not block all wavelengths of light so it is positioned after the dichroic mirror in the return path and experiences mostly green light.

Altimetry or LEO satellites could have a sloping track in a narrow a range gate and searching is difficult. Therefore this technique works best for Lageos or HEO satellites.

Conclusion? Install a Pockels cell?

A very fast shutter would benefit Lageos and HEO SLR by reducing daytime noise.

The best shutter option is a Pockels cell and all of the obstacles encountered in planning for the installation have been overcome.

The **disadvantage** of this shutter is a 50% loss of return signal.

The **advantage** is the close gating that reduces the number of lost shots due to daytime noise.

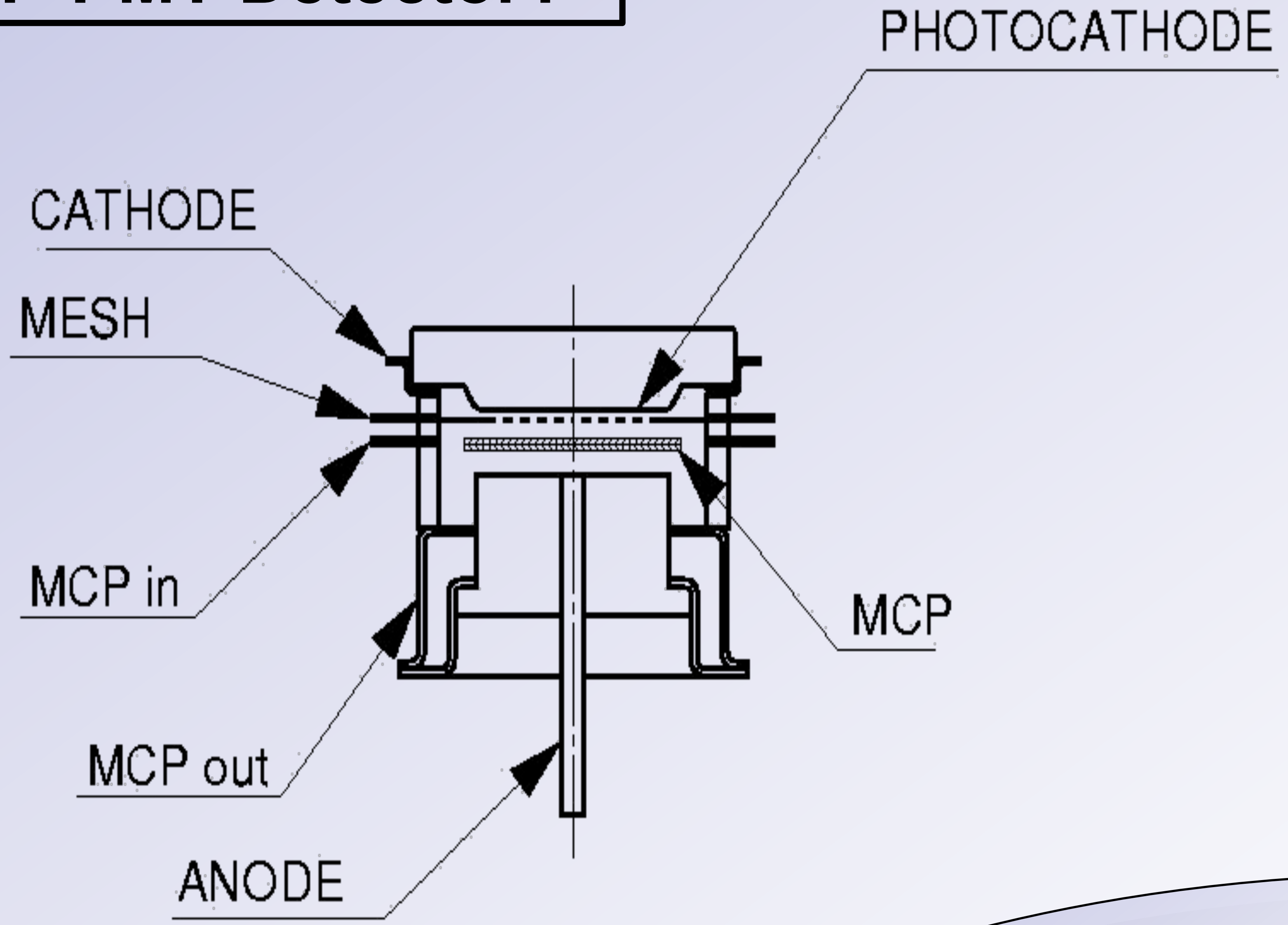
Alternative Detector?

An alternative option that would give the same advantage of close gating would be to switch to an MCP-PMT detector.

An MCP-PMT detect can be gated even quicker than a Pockels cell shutter.

Also this detector has much less dark noise compared to the SPAD.

MCP-PMT Detector?



MCP-PMT Detector?

Choice of MCP-PMT from Photek or Hamamatsu:

Photek **PMT210 S2**

Very fast gating
Quantum efficiency = **12%**
Jitter = **30ps**

Testing at Herstmonceux

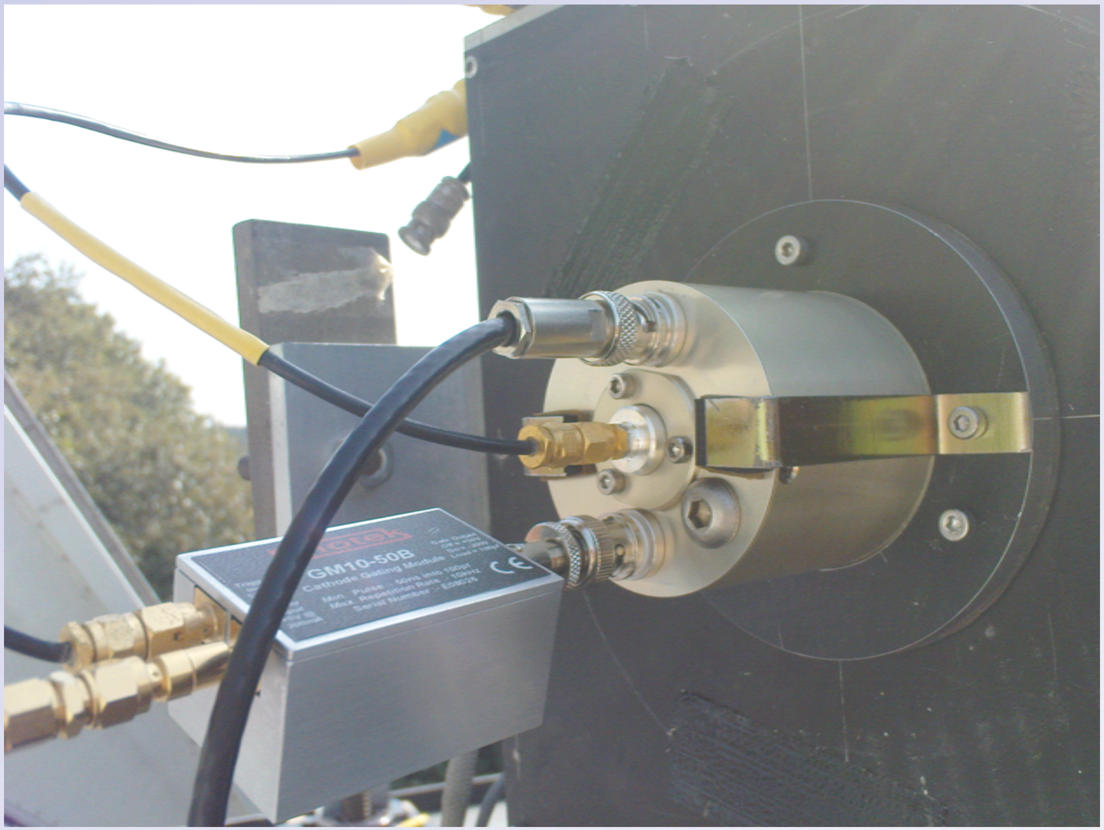
Hamamatsu **MCP-PMT R5916U-64**

Very fast gating
Quantum efficiency = **40%**
Jitter = **110ps**

Installed at Borowiec

MCP-PMT Detector?

Photek



Testing at Herstmonceux