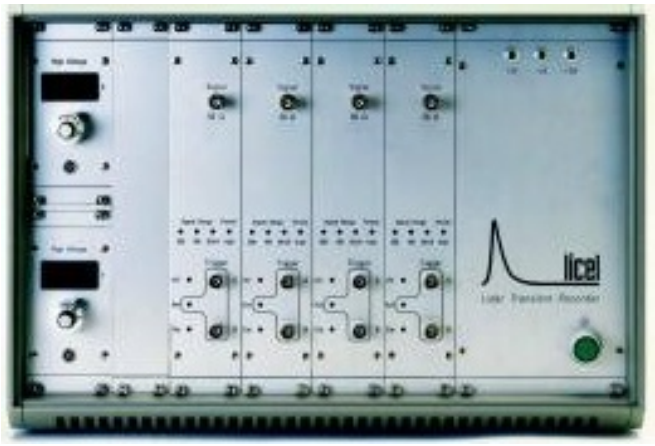
# DIFFERENTIAL ABSORPTION LIDAR

# Optical Transient Recorders




# & Photodetectors

## Photon-Counting PMTs for 160 to 850 nm
## Silicon APD Modules <650 to >1064 nm

licel
lidar computing and electronics

BostonElectronics

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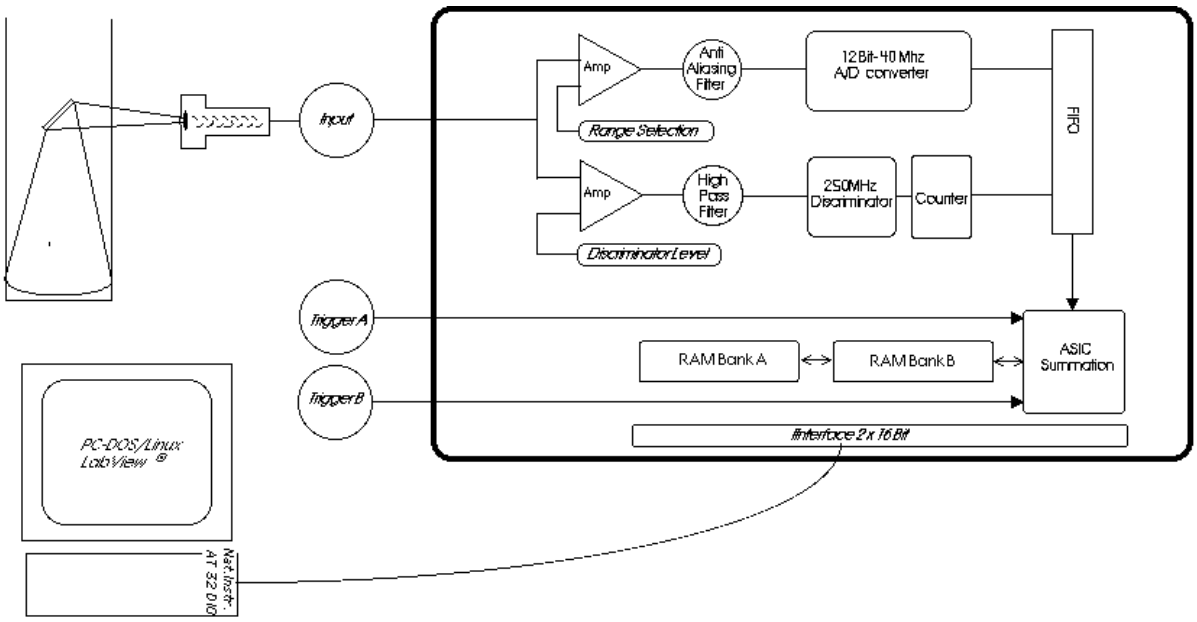
# The Licel Transient Recorder

## Concept

The Licel transient recorder is a powerful data acquisition system, especially designed for remote sensing applications. To meet the demanding requirements of optical signal detection, a new concept was developed to achieve the best dynamic range together with high temporal resolution at fast signal repetition rates.




For the first time analog detection of the photomultiplier current and single photon counting is combined in one acquisition system. The combination of a powerful A/D converter (12 Bit at 40 MHz) with a 250 MHz fast photon counting system increases the dynamic range of the acquired signal substantially compared to conventional systems. Signal averaging is performed by specially designed ASIC's which outperform any CISC- or RISC-processor based solution. A high-speed data interface to the host computer allows readout of the acquired signal between laser shots. The implementation of this concept makes the Licel transient recorder the state of the art solution for all applications where fast and accurate detection of photomultiplier, photodiode or other electrical signals is required at high repetition rates.

# Applications:

- LIDAR (Light Detection and Ranging)
- LIF (Laser induced fluorescence)
- TDLAS (Tunable Diode Laser Absorption Spectroscopy)
- and other pulsed optical signal techniques.

# Principle of operation

The Licel transient recorder is comprised of a fast transient digitizer with on-board signal averaging, a discriminator for single photon detection and a multichannel scalar combined with preamplifiers for both systems. For analog detection, the signal is amplified according to the input range selected and digitized by a 12-Bit-20/40 MHz A/D converter. A hardware adder is used to write the summed signal into a 24-Bit wide RAM. Depending on whether trigger A or B is used, the signal is added to RAM A or B, which allows acquisitions of two repetitive channels if these signals can be measured sequentially.

At the same time the signal part in the high frequency domain is amplified and a 250 MHz fast discriminator detects single photon events above the selected threshold voltage. 64 different discriminator levels and 2 different settings of the preamplifier can be selected by using the acquisition software supplied. The photon-counting signal is written to a 16-Bit wide summation RAM that allows averaging of up to 4094 acquisition cycles.

# Detection of light signals ranging over 5 orders of magnitude

In remote sensing applications like LIDAR (Laser Radar) a photomultiplier looking at a laser pulse sent out into the atmosphere is driven close to saturation by the backscattered light from the near field, but a few hundred microseconds later it is required to detect single photons returning from a distance of 40 to 80 km. This high dynamic range of up to five orders of magnitude is one of the challenges in the detection of LIDAR signals as well as in other techniques like LIF (Laser Induced Fluorescence) or CARS (Coherent Anti Raman Scattering).

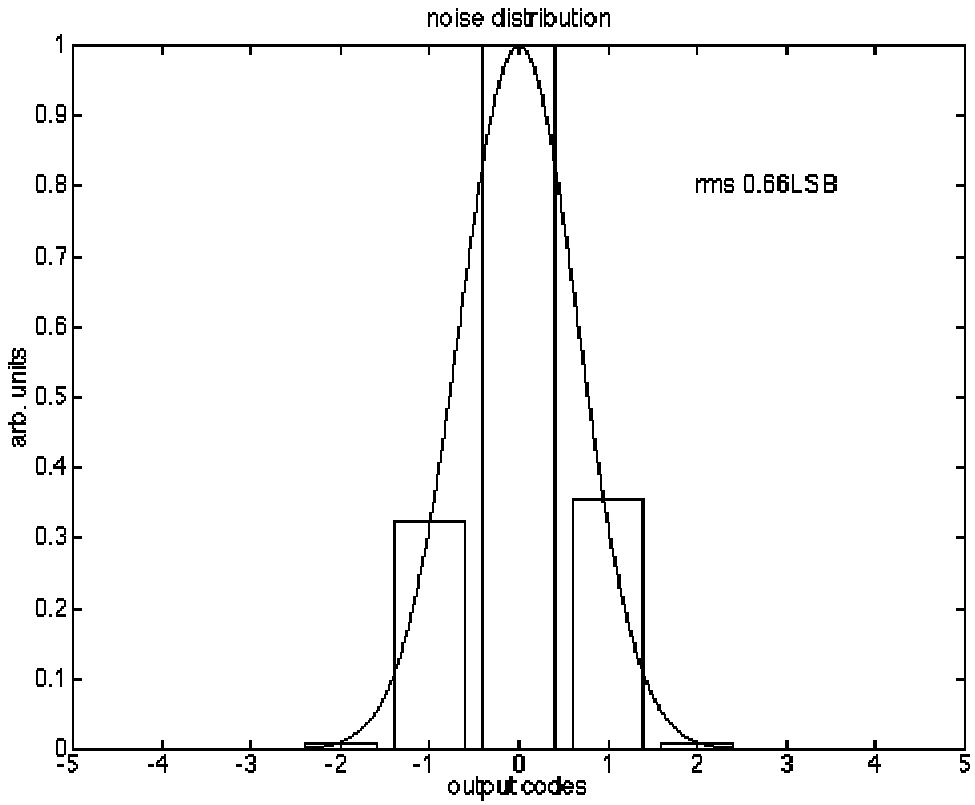
Usually, the detection system is optimized for measuring low-level light intensities using the single photon counting technique, but at higher light levels this approach results in nonlinear signal response. Analog measurement of the photomultiplier current is therefore necessary to increase the dynamic range.

# Combined analog and photon counting acquisition

Analog and photon counting detection techniques require different signal conditioning. High speed and high gain amplification is needed for photon counting, whereas a strictly linear amplification below the Nyquist frequency of the A/D converter is necessary for analog measurement. Only the integration of two complete acquisition chains from the preamplifier to the summation memory will therefore enable one to combine both techniques for increased linear dynamic range. This has been done in the Licel transient recorder.

# High end analog acquisition

The best 12-Bit A/D converter available at 40 MHz sampling frequency was used to build a high end transient digitizer with a signal to noise ratio greater than 74 dB up to the Nyquist frequency of 20 MHz. Carefully shielded preamplifiers for three different input ranges and a fast hardware adder can average up to 4094 shots of 200 µs or 400 µs (800µs at 20 MHz) signals to attain a maximum resolution of 0.03 µV (500 µV input range). Each sample is checked for overrange to control clipping in the average signal.



# Fast Photon Counting

The photon counting acquisition system includes a fast three-stage preamplifier and a discriminator with 64 threshold levels, controlled by the host computer. With a maximum count rate of 250 MHz, single photon counting is pushed to new limits when the selected photomultipliers are used. A time resolution of 50 ns without any dead time or overlap between two memory bins is reached by using a continuous counter together with a multichannel scalar burnt into the silicon of a custom designed ASIC.

# Complete acquisition software

The Licel transient recorder is completely software controlled. Input ranges for analog and photon counting acquisition, discriminator levels and the Number of active bins can be selected. The acquired analog and photon counting signals for both summation memories can be read out separately. Data are transferred via a 2 x 16 Bit interface to a National Instruments DIO-32-HS family (PC) interface card.

Support of NuBus-cards has been discontinued, as they are not listed anymore in the NI catalog. The data transfer rates are 800 KB (PC/486 DX2-66) using DOS and 500 KB using LabVIEW. Up to 16 Transient recorders can be controlled by one interface card. A ready-to-use LabView Interface comes with each Licel transient recorder. It can be run on the PC/Windows platforms. Software drivers and acquisition programs for PC/Linux are supplied.

# Specifications

| | |
|---|---|
| In/Outputs: | |
| Signal input: | BNC, 50 Ohm, front panel |
| Trigger A: | BNC, 50 Ohm, front panel |
| Trigger B: | BNC, 50 Ohm, front panel |
| Host I/O: | 50-pol bus, back panel |
| Indicators: | -Analog input range |
| | -Signal overrange |
| | -Trigger and Host I/O |
| **Environmental:** | |
| Power: | 230V/50 Hz or 110V /60Hz, 12 W per transient recorder. |
| Operating temperature: | +10º to + 40º C |
| Storage Temperature: | -30º to + 70º C |

| | |
|---|---|
| Spurious free dynamic range: | 74 dB |
| S/N single shot: | 66 dB@ 100 mV input range (100mV) |
| Memory depth: | 8192 or 16 384 bins |
| Summation memory: | 2 channels |
| | 4094 acquisitions |
| Repetition Rate: | 150 Hz for 400µms signals, |
| | 75 Hz for 800µs signals |
| Protection: | Diode clamped |
| Input impedance: | 50 Ohm |
| Coupling: | DC |
| Trigger Delay and Jitter: | 50 ± 12.5 ns |

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| | |
|---|---|
| Humidity: | 0 to 95%, non-condensing. |
| Dimensions: | Each transient recorder is mounted in a RF-shielded cassette 50.4x262x232mm. Systems up to 6 channels are mounted in a 448.6x 311.5 x 361mm housing for 19" rack mounting. |
| **Analog acquisition:** | |
| Signal input range: | 0... -20, -100, -500 mV |
| A/D Resolution: | 12 Bit |
| Sampling rate: | 20 MSPS/40 MSPS |
| Lidar spatial resolution: | 7.5 m / 3.75 m |
| Bandwidth: | DC-10/20 MHz |
| A/D differential nonlinearity: | typ. 0.65 LSB |
| | max. 1.25 LSB @25º C |
| A/D integral nonlinearity: | typ. 1 LSB @25º C |

| **Photon Counting Acquisition:** | |
|---|---|
| Max. count rate: | 250 MHz |
| Threshold: | 0... -20 mV |
| | 0... -100 mV |
| Discriminator: | 64 levels for each input range, software controlled |
| | 4094 acquisitions |
| Input impedance: | 50 Ohm |
| Bandwidth: | 10 MHz - 250 MHz. |
| no dead time or overlap between bins. | |
| Trigger: | |
| 2 Trigger inputs to acquire signals in 2 separate summation memories. | |
| Impedance: 50 Ohm | |
| Threshold and slope 2.5 V, positive | |

# Optical Transient Recorder

Simultaneous analog and photon counting acquisition for detection of optical signals


- 12 bit–40 MHz A/D acquisition
- 250 MHz single photon count rate
- Up to 18 kHz repetition rate
- 800 KB/s data transfer
- Integrated preamplifiers
- $10^5$ dynamic range by combination of A/D and photon counting detection
- 4094 shots on board summation
- 2 alternate summation channels
- Complete acquisition software

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## Combined acquisition

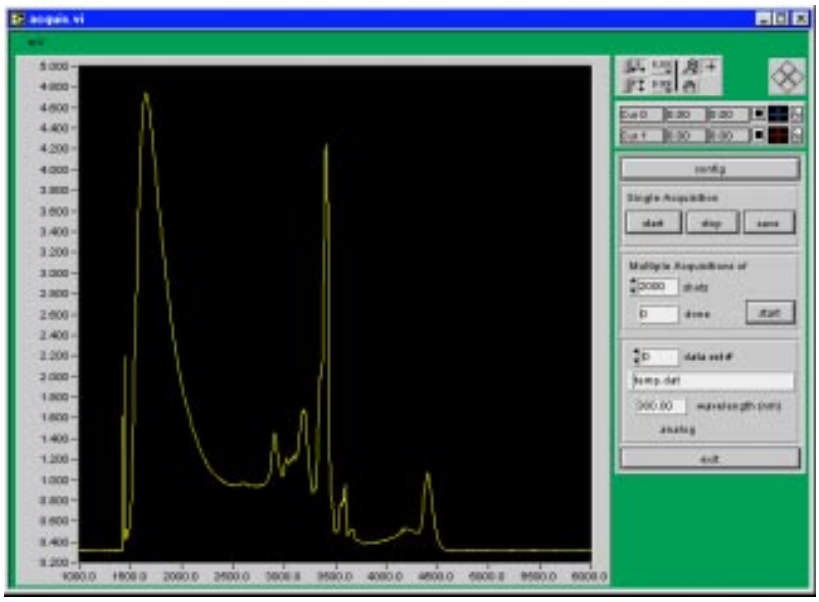
Analog and photon counting detection techniques require different signal conditioning: a high-speed, high-gain amplification for photon counting and a strictly linear amplification below the Nyquist frequency of the A/D converter for analog measurement. Only the integration of two complete acquisition chains from the preamplifier to the summation memory will therefore enable you to combine both techniques for increased linear dynamic range. This has been done in the licel transient recorder.

## High-end analog acquisition

The best 12-bit A/D converter available at 40MHz sampling frequency was used to build a high-end transient digitizer with a spurious free dynamic range of 81dB up to the Nyquist frequency of 20MHz. Carefully shielded preamplifiers for three different input ranges and a fast hardware adder can average up to 4094 shots of 200µs or 400µs signals to a maximum resolution of 0.03µV (500mV input range). Each sample is checked for overrange to control clipping in the average signal.

## Fast photon counting

The photon counting acquisition system includes a fast three-stage preamplifier and a discriminator with 64 threshold levels, controlled by the host computer. A maximum count rate of 250MHz pushes the limits of single photon counting when selected photomultipliers are used. A time resolution of 25ns without any deadtime or overlap between two memory bins is achieved by using a continuous counter together with a multichannel scaler burnt into the silicon of a custom-designed ASIC.



## Complete acquisition software

The licel transient recorder is completely software-controlled. Input ranges for analog and photon counting acquisition, discriminator levels and the number of active bins can be selected. The acquired analog and photon counting signals for both summation memories can be read out separately.

Data are transferred via a 2 x 16-bit interface to a National Instruments interface card (AT, PCI or PCMCIA). Up to 16 transient re-corders can be controlled by one interface card.

A ready-to-use LabView® Interface comes with each licel transient recorder. C-software drivers and acquisition programs for DOS or Linux are supplied.

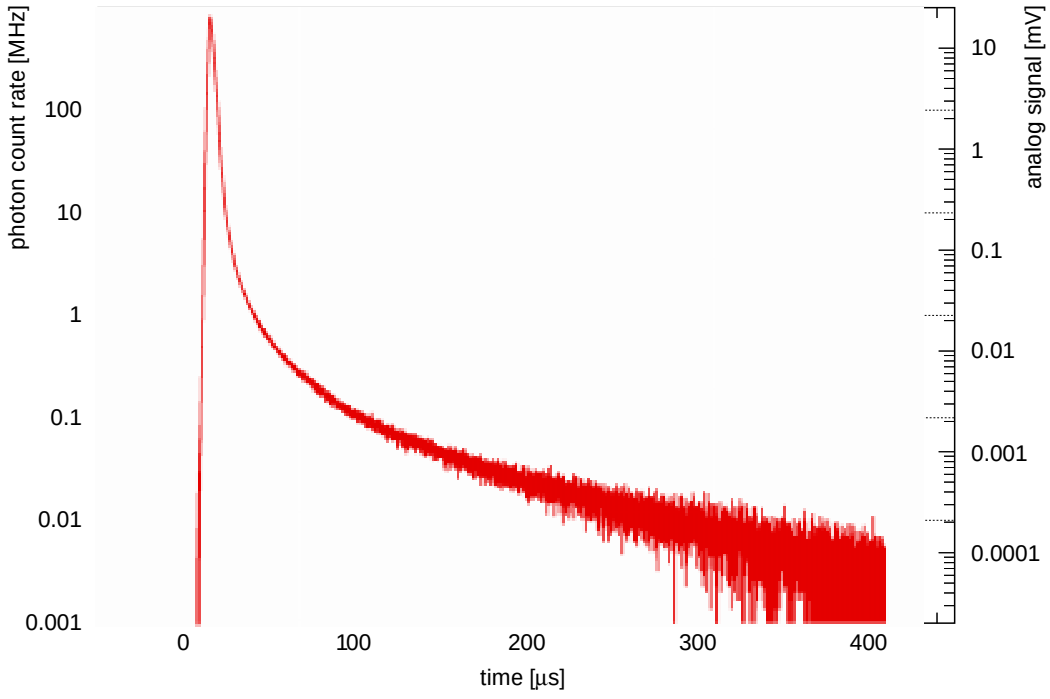
## Concept

The licel transient recorder is a powerful data acquisition system, designed especially for optical signal detection. A new concept was developed to reach the best dynamic range together with high temporal resolution at fast signal repetition rates. For the first time, analog detection of the photomultiplier current and single photon counting are integrated into one acquisition system. The licel transient recorder comprises a fast transient digitizer with on-board signal averaging, a discriminator for single photon detection and a multichannel scaler together with preamplifiers for both systems.

## Detection of light signals ranging over five orders of magnitude

In remote sensing applications like LIDAR (Light Detection and Ranging) a photomultiplier looking at a laser pulse sent out into the atmosphere is driven close to saturation by the backscattered light from the vicinity, but a few hundred microseconds later it is required to detect single photons returning from 50 or 100km apart. Such a high dynamic range of up to five orders of magnitude is one of the challenges in detection of LIDAR signals as well as in other techniques such as LIF (Laser Induced Fluorescence) and many other optical methods.

Usually, the detection systems are optimized for measuring low-level light intensities using the single photon counting technique, but at higher light levels this approach gives a nonlinear signal response. An analog measurement of the photomultiplier current is therefore necessary to increase the dynamic range.




*Combined analog and photon counting signal. Analog detection allows signal acquisition up to virtual count rates of 1GHz. Nonlinearities in the photon counting mode become significant at count rates between 1 and 10MHz. At this signal level the photomultiplier is still far below the maximum cw-anode current of 100µA (5mV at 50□) and analog detection can therefore increase the dynamic range significantly.*

# Specifications

## Analog acquisition (TR 20–xx):

| | |
|---|---|
| Signal input range: | 0...–20, –100, –500mV |
| A/D resolution: | 12bit |
| Sampling rate: | 20MSPS |
| Bandwidth: | DC–10MHz |
| A/D differential nonlinearity: | typ. 0.3LSB<br>max. 1.0LSB @ 25°C |
| A/D integral nonlinearity: | typ. ±0.75LSB @ 25°C |
| Spurious free dynamic range: | 81dB |
| S/N single shot: | 66dB @ 100mV input range (50µV) |
| Memory depth: | 256 to 16384bins |
| Summation memory: | 2 channels<br>4094 acquisitions |
| Max. repetition rate: | 300Hz for 16Kbin signals,<br>10kHz for 512bin signals |
| Protection: | Diode clamped |
| Input impedance: | 50 Ω |
| Coupling: | DC |
| Trigger delay and jitter: | 25 ±7ns |

## In/Outputs:

| | |
|---|---|
| Signal input: | BNC, 50□, front panel |
| Trigger A: | BNC, 50□, front panel |
| Trigger B: | BNC, 50□, front panel |
| Host I/O: | 50-pol. bus., back panel |

## Photon counting acquisition:

| | |
|---|---|
| Max. count rate: | 250MHz |
| Temporal resolution: | 25ns |
| Threshold: | 0...–25mV |
| Discriminator: | 64 levels for each input range, software-controlled |
| Memory depth: | 8192 or 16384bins |
| Summation memory: | 2 channels,<br>4094 acquisitions |
| Input impedance: | 50Ω |
| Bandwidth: | 10MHz–250MHz<br>no deadtime or overlap between bins |

## Trigger:

2 trigger inputs to acquire signals in 2 separate summation memories

| | |
|---|---|
| Impedance: | 50Ω |
| Threshold and slope | 2.5V, positive |

# Product Selection Chart

| Application | Sample rate | Number of bins | Signal length | Max. repetition rate | Model number |
|---|---|---|---|---|---|
| High repetition rate | 10MHz | 512 | 5.12µs | 11kHz | TR 10-05 |
| High temporal resolution | 40MHz | 8192 | 204.8µs | 600Hz | TR 40-80 |
| Long signal duration | 20MHz | 16384 | 819.2µs | 300Hz | TR 20-160 |

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# Photomultiplier module

## *High dynamic range detectors for analog + photon counting measurements*


### The best choice for pulsed dynamic signals

The High Dynamic Range Photomultiplier from Licel has been specifically optimized to enhance the results of your measurements in pulsed applications. The compact design combines a stabilized dynode chain for strong light pulses with fast rise times and narrow pulse widths for high single photon count rates. This combination allows high dynamic range measurements by using both analog and photon counting measurements together, thus extending the linear dynamic range to 5 orders of magnitude. Additional advantages are reduced space charge effects and higher light levels that can be measured without suffering from nonlinearities. These qualities make the Licel High Dynamic Range Photomultiplier your ideal detector for applications such as Lidar, fluorescence detection and other spectroscopic methods

### Features:

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- stabilized dynode chain
- overcurrent protection
- single photon pulse width <2.2 ns
- high pulse load stability
- HV remote control option
- compact design
- interface to lens tube system


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# *Specifications*

**Detector:**

| | |
|---|---|
| cathode diameter: | 8 mm |
| spectral sensitivity./dark counts: | |
| Bialkali cathode-06: | 160-650 nm/ 500cps |
| Bialkali cathode-03: | 185-650 nm/ 80 cps |
| Multialkali cathode-01: | 300-850 nm/ 80 cps |
| Multialkali cathode-02: | 300-880nm |
| Multialkali cathode-04: | 185-850 nm/ 500 cps |
| max. average anode current: | 0.1 mA |
| gain: | $10^5$-$10^6$ |

**Signal specs:**

| | |
|---|---|
| single photon rise time: | <1.3 ns |
| single photon width (FWHM) | <2.2 ns |
| pulse load stability, HV=850V, 100mV signal / 60µs | <0.15% |

**HV supply:**

| | |
|---|---|
| voltage range: | -100...-1kV |
| max. current: | 2 mA |
| voltage ripple: | <1mV (DC to 20 MHz) |
| remote control voltage | 0..+5V |

**Mechanics:**

| | |
|---|---|
| PMT module size: | 60.7 x 25mm |
| PMT module weight: | 50 g |
| Optical interface: | O-ring sealed mount or adapter for 1" Thorlabs lens tube system |
| High voltage supply: | 50.5x128.4x103mm 3 height units, 10 width units standard cassette |

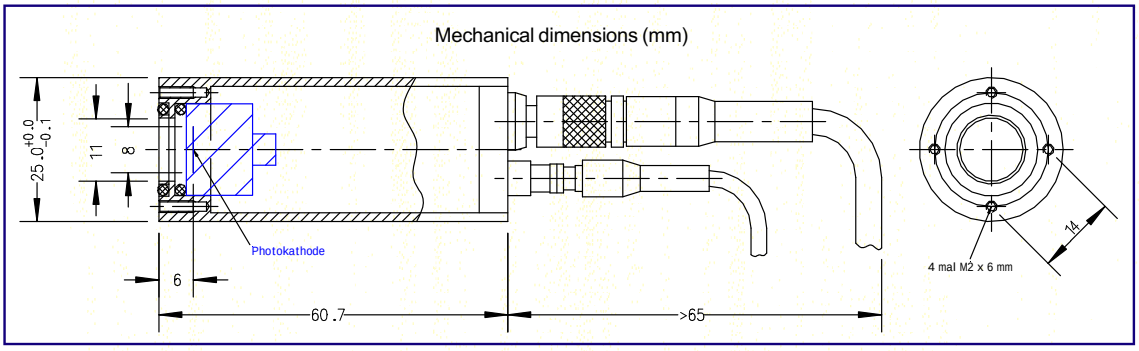
**Connectors:**

| | |
|---|---|
| Signal out: | Minax/BNC |
| HV to PMT: | Lemo Camac |
| HV power supply: | H11 connector |

**Power supply:** 15V DC, 250mA

**Environmental conditions:**

| | |
|---|---|
| Operating temperature: | 0°C to 30°C (non condensing) |
| Storage temperature: | -40°C to 70°C |




**International distribution:**

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# Si-Avalanche Photodiode module

## *Low noise - high speed detector @ 400 nm-1100nm*

## High NIR Quantum Efficiency

Now you can measure optical signals in the near IR with high quantum efficiency, comparable to UV-Vis detectors. Our Si-APD Module consists of a TE-cooled detector, a high-speed low-noise preamplifier and HV supply. Signals can be acquired using analog detection as well as single photon counting mode.

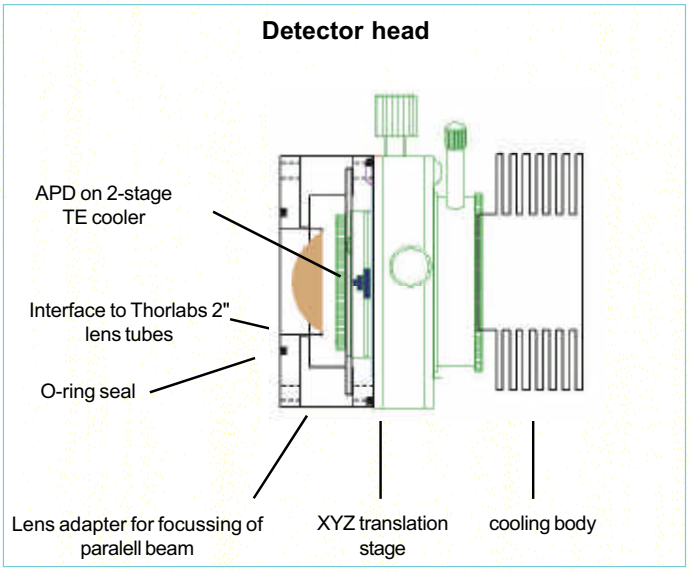
Integrated focussing optics and alignment mechanics allow easy integration into your optical setup.The increased sensitivity in the near infrared is a major advantage compared to photomultipliers.

## Features:

- 0.8,1.5 or 3 mm dia. detector size
- thermoelectric cooled up to -20° C
- low noise, high gain preamplifier
- easy system integration with integrated alignment optics and mechanics
- integrated HV- and AC-power supply

## Applications:

- LIDAR (Light Detection and Ranging)
- fluorescence detection
- replacement for photomultipliers >800nm



# Specifications

**Detector:**

| | |
|---|---|
| detector size: | 0.8, 1.5 or 3 mm dia. |
| QE @650 nm: | > 80% |
| QE @ 900 nm: | 85% |
| responsivity @ 1060 nm: | 34 A/W typ., QE=38% |
| dark current @22°C: | 50 nA (0.8 mm dia), |
| | 100 nA (1.5 & 3 mm dia.) |
| spectral noise current: | 1 pA/√Hz typ., |
| @10kHz | 2 pA/√Hz max. |

**Mechanics:**

The compact APD/preamp/TEC controller unit is mounted in a XYZ translation stage for easy integration and alignment in detection systems.

| | |
|---|---|
| XY axis travel: | 5 mm |
| Z-axis travel: | 6 mm |
| precision: | 4µm |

**Preamplifier for analog detection:**

| | |
|---|---|
| bandwidth: | DC-10 MHz |
| gain: | 11mV/µA into 50 Ω |
| spectral noise current: | |
| DC...1MHz | 2 pA/√Hz |
| DC...10 MHz | 7.2 pA/√Hz |
| output polarity: | negative |
| output signal: | 0...-1V (max), 0...-100mV |
| | (typ. operation) into 50 Ω |

**Integrated TE cooler and temp. controller:**

| | |
|---|---|
| Detector temperature: | +0°C (+25°C for 3mm APD) |
| Temperature stability: | <0.5 K |

**Power supply:**

| | |
|---|---|
| input: | 230V/50 or 110V/60 Hz |
| output: | +5V, -5V, +15 V, linear |
| | regulated. |

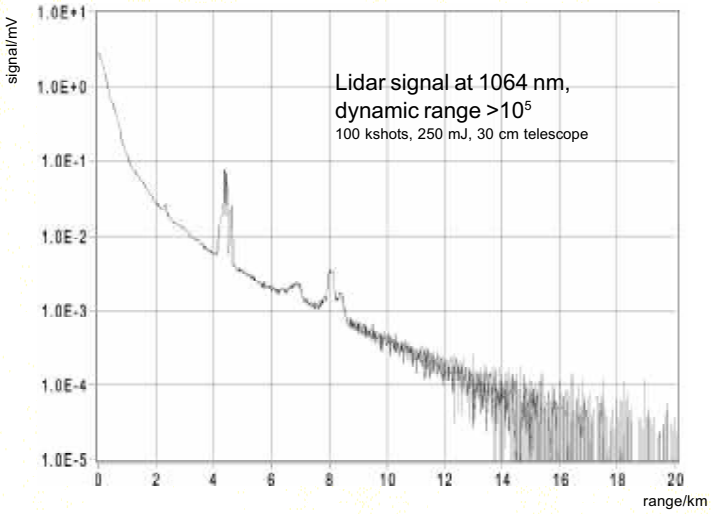
**HV supply:**

| | |
|---|---|
| voltage range: | 0...+450V |
| max. current: | 0.6 mA |
| voltage ripple: | <0.005% |

**Environmental conditions:**

| | |
|---|---|
| Operating temperature: | 0°C to 30°C (non condens.) |
| Storage temperature: | -40°C to 70°C |

# Signals

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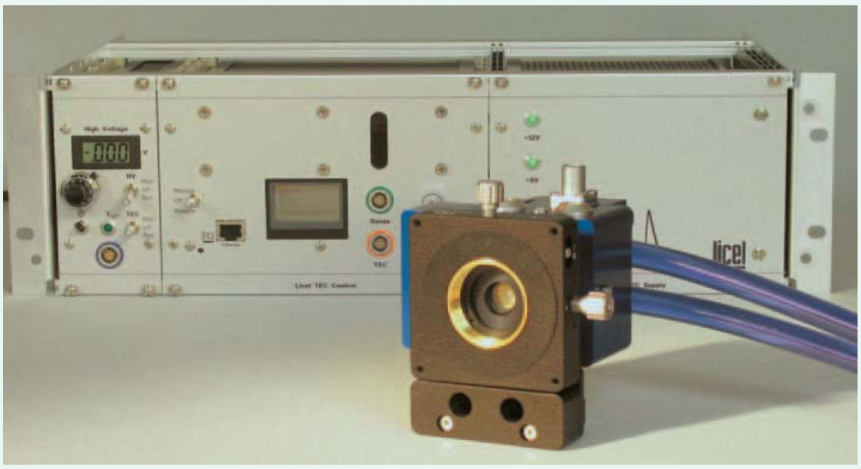
# InGaAs-APD module

## *Detector for eye-safe lidars @ 1100 nm-1700nm*

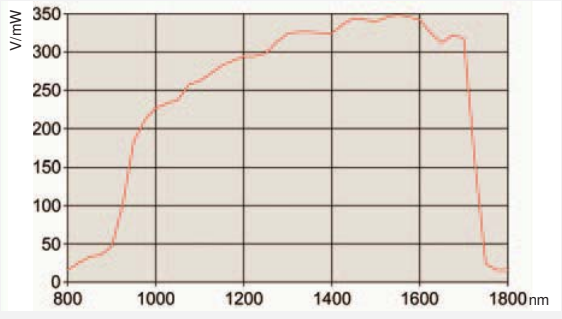



### Concept:

The Licel InGaAs APD module is an integrated detector solution for eye-safe lidar systems. The detector head comprises a thermoelectrically cooled detector and preamplifier in a XYZ-translation stage.

The APD high voltage supply , water to air cooler and AC/DC power supply are mounted in a 3 or 4 height unit 19" crate.

### Spectral Sensitivity:




### Features:

- 0.2 mm detector size
- detector temperature -10° C
- temperature stability 0.2° C
- signal bandwidth 40 MHz
- integrated alignment optics and mechanics
- integrated preamplifier
- HV supply, water to air cooler, AC/DC supply


LICEL GmbH, Chausseestr. 34/35, D-10115 Berlin, phone/fax +49.30.283.917.37/38, info@licel.com

# *Specifications*

**Detector:**

| | |
|---|---|
| detector size: | 0.2 mm dia. |
| responsivity @1550nm: | 5 A//W |
| TIA gain: | 68 V/mA |
| NEP @ 100kHz: | 1.3 E-13 W/√Hz |
| spectral noise density @ 100kHz: | 45nV/√Hz |

**Preamplifier for analog detection:**

| | |
|---|---|
| bandwidth: | DC-40 MHz |
| gain: | 68mV/µA into 50 Ω |
| output polarity: | negative |
| output signal: | 0...-1V (max), 0...-500mV (typ.) into 50 Ω |

**HV supply:**

| | |
|---|---|
| voltage range: | 0...+100V |
| max. current: | 0.6 mA |
| voltage ripple: | <0.005% |

**Mechanics:**

The compact APD/preamp/TEC controller unit is mounted in a XYZ translation stage for easy integration and alignment in detection systems.

| | |
|---|---|
| XY axis travel: | 6 mm |
| Z-axis travel: | 6 mm |
| precision: | 4µm |

**Integrated TE cooler and temp. controller:**

| | |
|---|---|
| Detector temperature: | -10°C |
| Temperature stability: | <0.5 K |

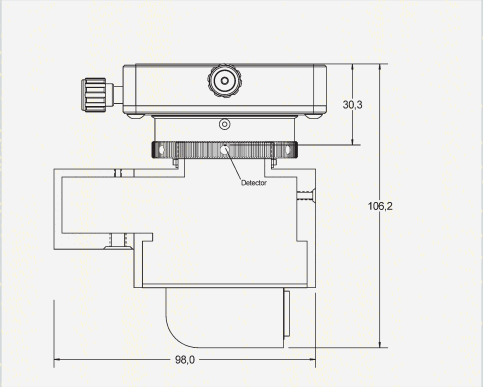
**Power supply:**

| | |
|---|---|
| input: | 100V,110V or230V, 50/60 Hz |
| output: | +5V, -5V, +15 V |

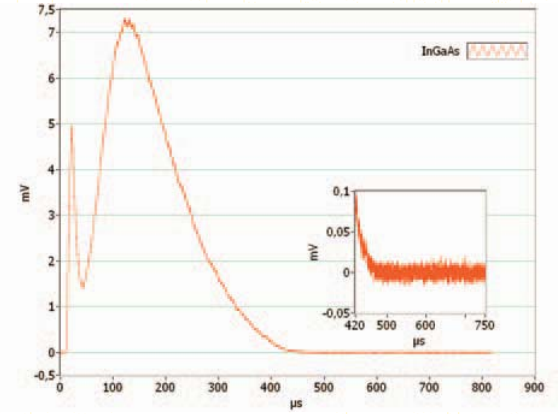
**Environmental conditions:**

| | |
|---|---|
| Operating temperature: | 0°C to 30°C (non condens.) |
| Storage temperature: | -40°C to 70°C |

**Detector head mechanical dimensions**




**LED simulated lidar signal**

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# Operators manual





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## 1. Principle of operation

The Licel Si-Avalanche Photodiode Module is based on the EG&G C3095xE series of avalanche photodiodes. These Si-diodes are manufactured using a double-diffused "reach through" structure. By using this technique the detectors are designed such that their long wave response (i. e. $\lambda > 900$ nm) has been enhanced without introducing any undesirable properties. At the same time, the desirable properties of the double diffused "reach through" structure (such as low noise, low capacitance, and fast rise and fall times) have been retained. The increased sensitivity in the near infrared is a major advantage as compared to photomultipliers. The quantum efficiency at the Nd:YAG fundamental wavelength at 1064 nm is still about 38%.

## 2. System description

The Licel Si-Avalanche Photodiode Module consists of the detector head and the power supply unit. The detector head contains the APD and the preamplifier. The APD is mounted on a temperature stabilized thermoelectric cooler inside a hermetically sealed housing. This detector head is mounted in a XYZ translation stage for easy optical alignment.

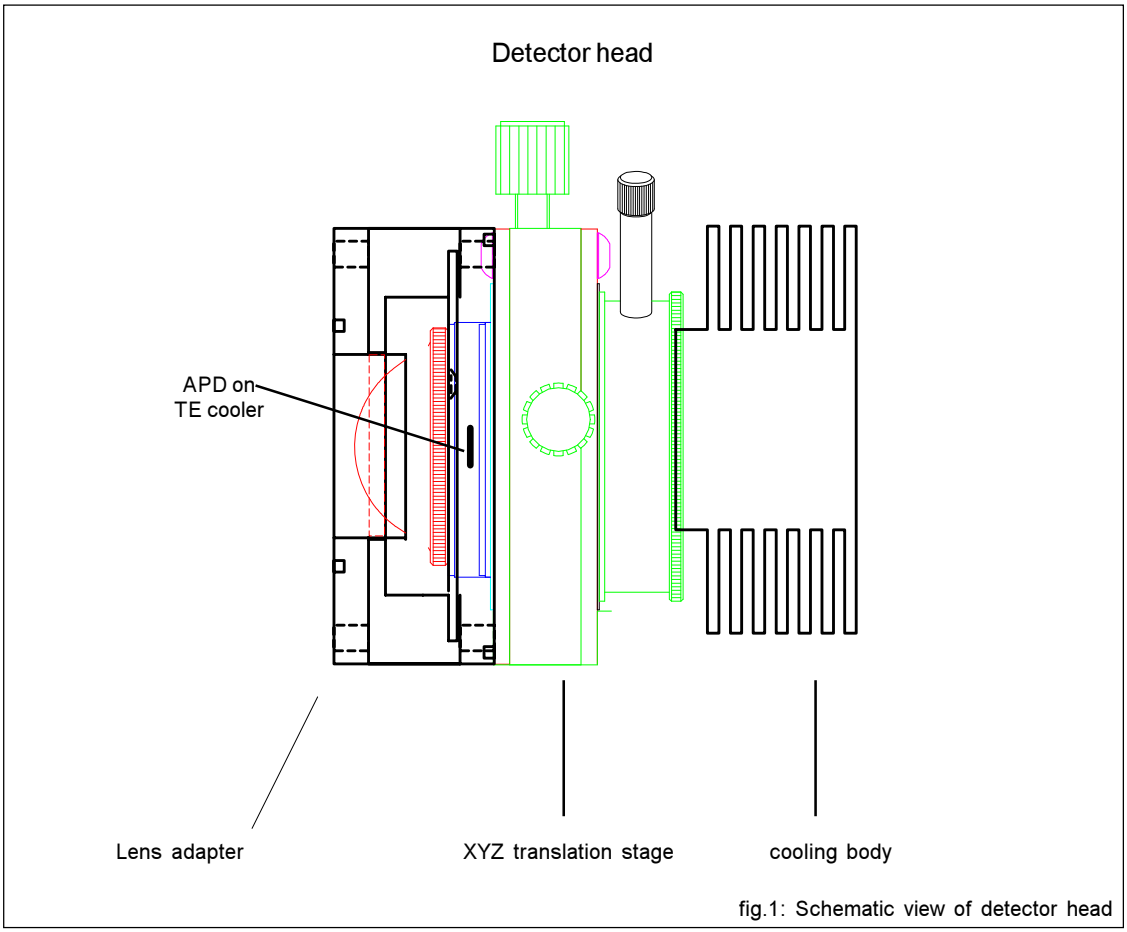



fig.1: Schematic view of detector head

The power supply unit contains a linear regulated +5V and +/-15 V power supply and a 0...+400 V high voltage supply. This provides the voltages for the temperature controller and preamplifier as well as the variable reverse voltage for the APD.

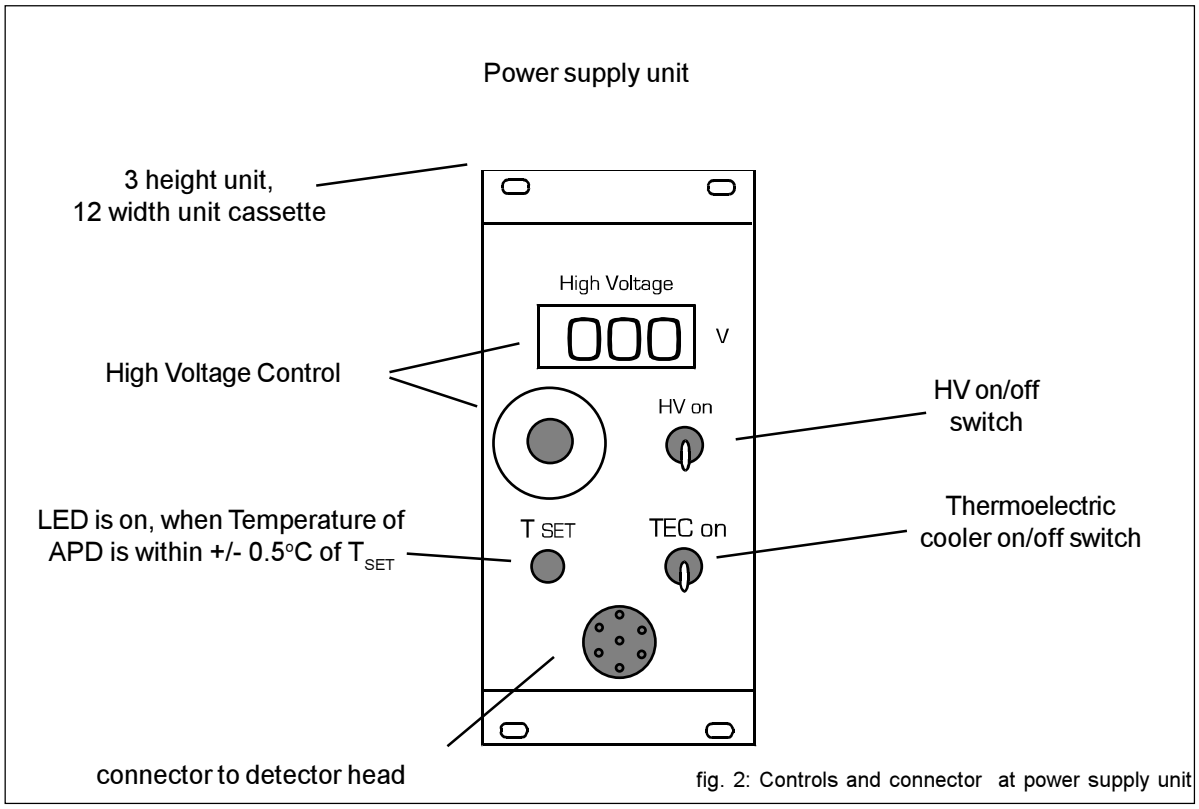



fig. 2: Controls and connector at power supply unit

## 3. Operating instructions

Avalanche photodiodes are highly sensitive photodetectors that show a strong dependance of gain and photocurrent on the DC reverse voltage. Similar to photomultpliers, exceeding the absolute maximum ratings of photocurrent can lead to permanent damage of the diode. When approaching the breakthrough voltage the reverse current will drastically increase and can lead to a current which will destroy the photodiode. Since the breakthrough voltage at room temperature is decreased by about 80 V when cooling to -20° C be sure to reduce the high voltage through the photodiode to a safe operation region before turning on the TE-cooler. Exact values of the breakthrough voltage for each individual detector can be found in the datasheet supplied with your diode.

At very low light levels (i.e. in lidar systems using narrowband daylightfilters) the high voltage can be increased up to 10 V below the breakthrough voltage. The variation of gain with respect to the reverse voltage is shown in fig. 3. The recommended voltage $V_R$ is given in the datasheet supplied with your diode.

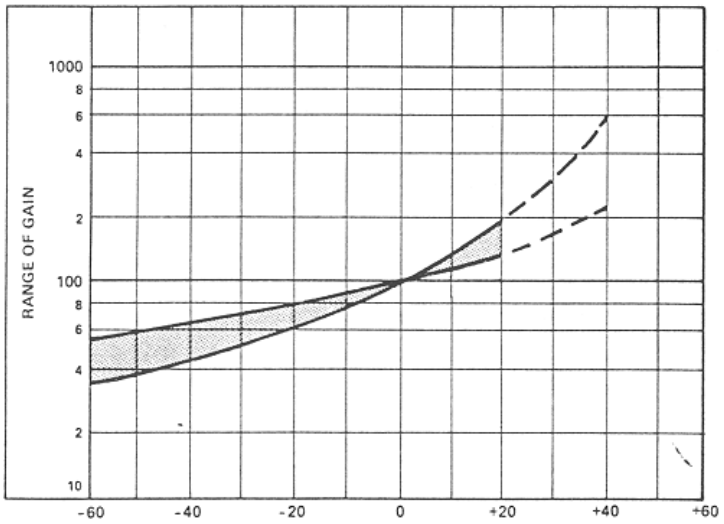



fig. 3: Variation of gain as a function of difference between actual applied operation voltage and recommended operation voltage (adapted from EG&G C30955 datasheeet).

The following procedure is a suggestion to operate the APD and find the best high voltage setting for your measurement::

**1. HV and TEC off:**

Turn the HV potentiometer counterclockwise into the zero position. Turn the HV on/off switch off. (The switches are a locking type, pull the switch to unlock).Turn off the TE cooler by switching the TEC on/off switch to the lower position.

**2. Power on:**

Turn on the main power supply using the switch on the back side of the power supply cassette.

**3. TEC on:**

Turn on the TE cooler by switching the TEC on/off switch to the upper position. After 5-10 seconds the green LED will turn on, indicating that the temperature of the APD is within 0.5° C of the set temperature.

**4. HV on:**

Turn the HV on/off switch on.

**5. Set HV:**

Observe the APD signal (50 Ω, DC coupling, -100 mV full scale) and increase the HV. Be sure not to exceed the absolute maximum rating of 200 μA reverse bias current and 0.1 W total power dissipation. (By using the preamplifier gain of 11mV/μA, 0.1W total power dissipation is reached at -2.75 V output signal, when a HV of 400V is applied. A 200 μA reverse current would result in an output signal of -3.3 V).

***System Specifications:***

**APD type: EG&G C30954/5E**

**Detector:**

| | |
|---|---|
| detector area: | 0.8 or 1.5 mm dia. |
| QE @650 nm: | > 80% |
| responsivity @ 1060 nm: | 34 A/W typ. |
| dark current @22° C: | 50 nA (0.8 mm dia), 100 nA (1.5 and 3 mm dia.) |
| spectral noise current density: | 0.3 pA/sqrt (Hz) typ., 0.5 pA/sqrt (Hz) max. |

**Preamplifier:**

| | |
|---|---|
| bandwidth: | DC-200 MHz |
| gain: | 11mV/µA into 50 Ω |
| output polarity: | negative |
| output signal: | 0...-1V (max), 0...-100mV (typ. operation) into 50 Ω |

**Geiger mode operation:**

| | |
|---|---|
| single photon rise time: | <5ns |

**HV supply:**

| | |
|---|---|
| voltage range: | 0...+400V |
| max. current: | 0.6 mA |
| voltage ripple: | <0.005% |

**Integrated TE cooler and temperature controller:**

| | |
|---|---|
| Detector temperature: | -20°C |
| Temperature stability: | <0.5 K |

**Power supply:**

| | |
|---|---|
| input: | 110...230V/50 or 60 Hz |
| output: | +5V, -5V, +12 V, linear regulated. |

**Mechanics:**

The compact APD/preamp./TEC controller unit is mounted in a XYZ optical mount for easy integration and alignment in detection systems.

| | |
|---|---|
| XY axis travel: | 5 mm |
| Z-axis travel: | 6 mm |
| precision: | 4µm |

**Absolute maximum ratings:**

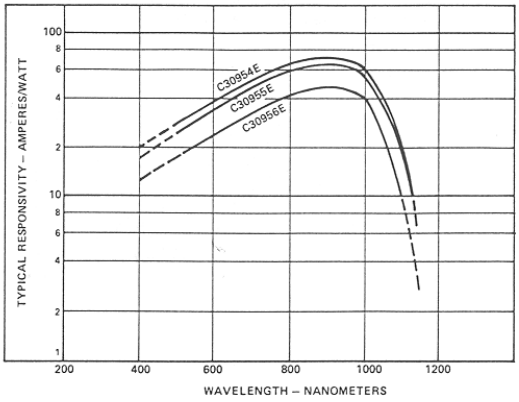
| | |
|---|---|
| Reverse Bias Current: | 200 µA |

Max. APD power dissipation at 22°C: 0.1 W

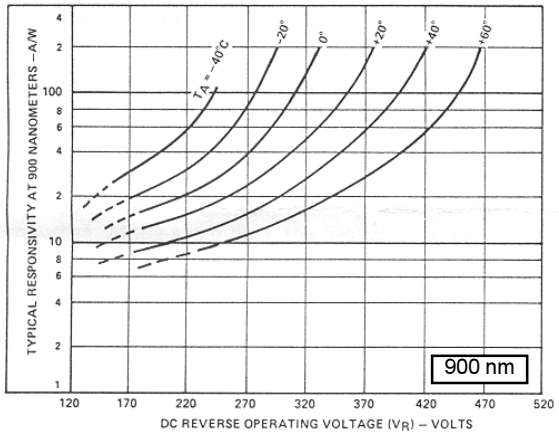
| | |
|---|---|
| Operating temperature: | 0°C to 35°C (non condensing) |
| Storage temperature: | -40°C to 70°C |

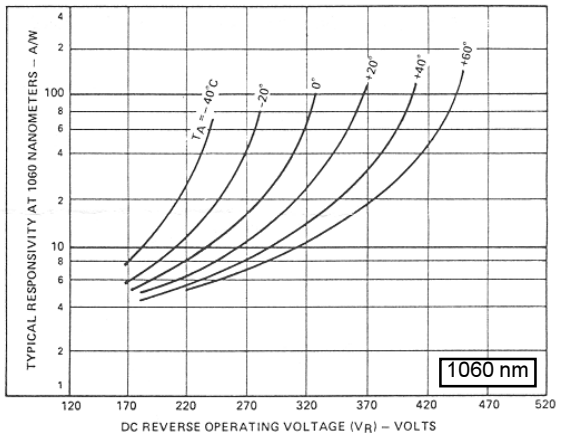
The following data and figures are adapted from the EG&G C30954/5/6E datasheet:

Typical spectral responsivity characteristics

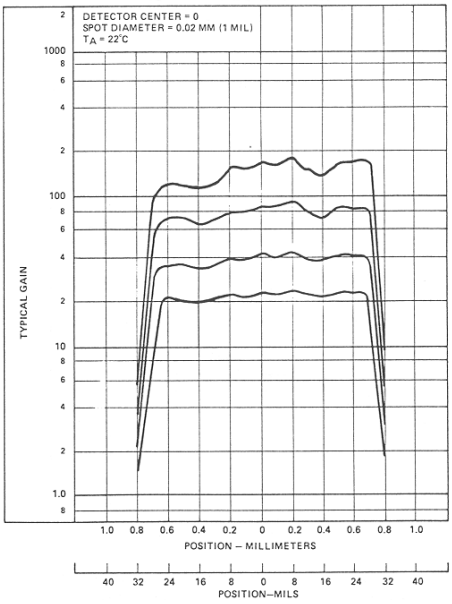



Typical respositivity at 900 and 1060 nm (detector size 1.5mm, light spot size 1 mm)



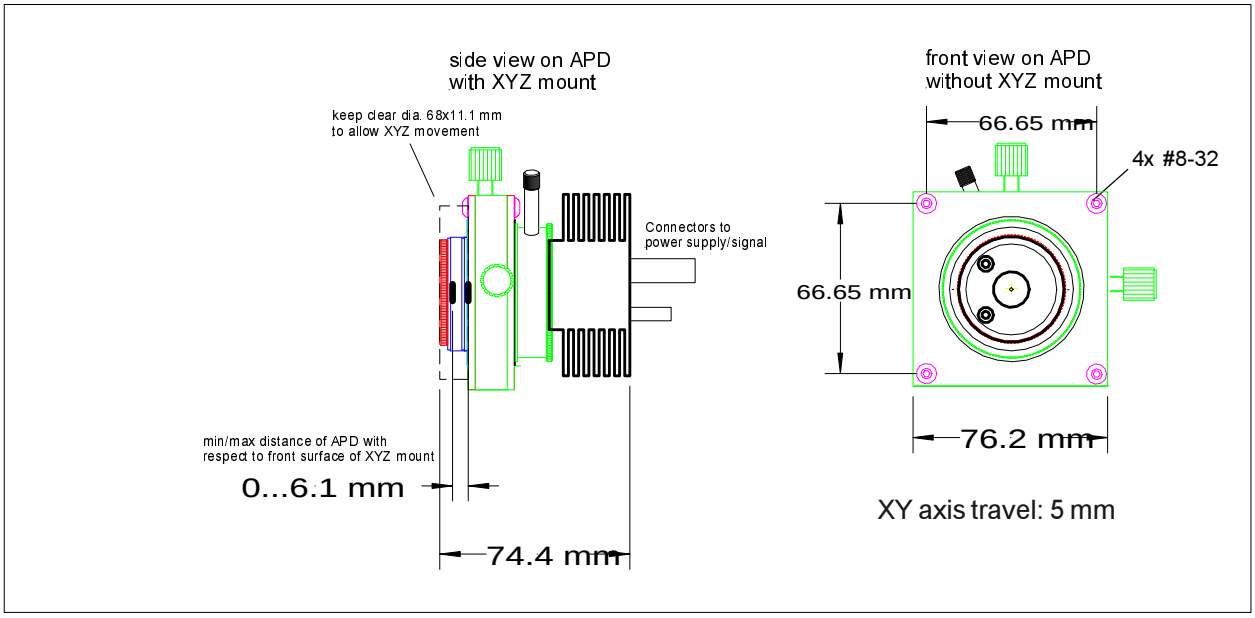




gain variation across detector surface:



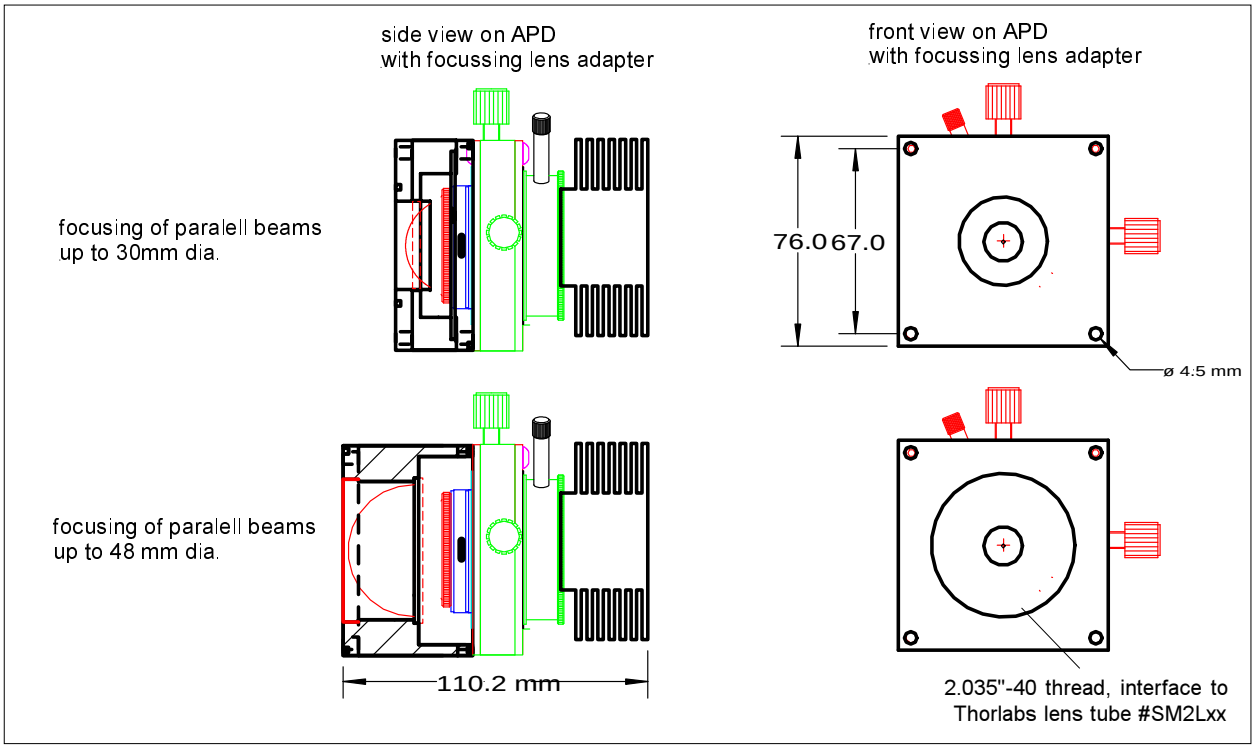
## Mechanical specifications:

1. Mounting the APD module without lens adapter



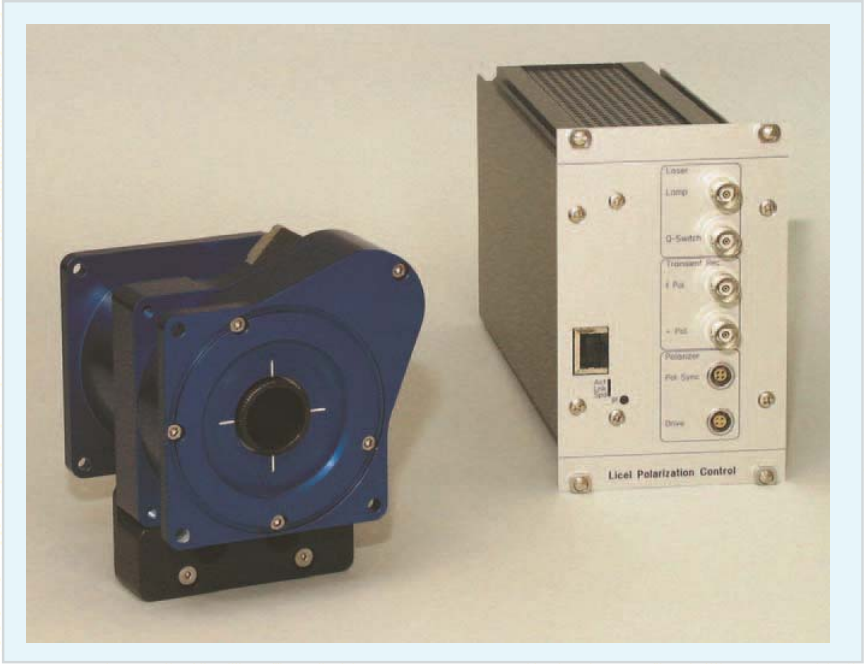

2. Mounting the APD module with lens adapter

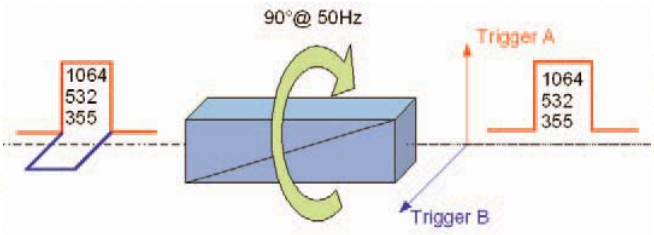
Two different lens adapters are availabe to focus paralell beams up to 30 mm and up to 48 mm onto the diode. Both lens adapters are compatible with the Thorlabs lens tube system.



# Rotating Polarizer

## *Multispectral polarization measurements*




## Concept:

The Licel Rotating Polarizer adds (de-)polarization measurements to multispectral detection systems.

A rotating Glan Thompson prism is used to separate p- and s-polarized signal contributions.

The integrated trigger generator synchronizes the laser flashlamp and Q-switch pulses.

## Features:

- optical transmission 210 nm to 2.3 µm
- extinction $5x10^{-5}$ - $5x10^{-6}$
- 20 mm clear aperture
- integrated trigger generator for
  - laser flashlamp
  - acquisition
  - Q-switch
- Ethernet interface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# *Specifications*

## Optics:

| | |
|---|---|
| Polarizing material: | α-BBO or Calcite |
| Optical transmission : | 200 nm - 2µm |
| Extinction: | $5x10^{-6}$ @220..900nm α-BBO |
| | $5x10^{-5}$ @350..2300nm Calcite |
| Acceptance angle: | >15° (full angle) |
| clear aperture: | 20 mm |

## Mechanics:

| | |
|---|---|
| Rotation speed: | 0.08 Hz - 12.5 Hz |
| Minimum step: | 0,1° |

Interface to Thorlabs 2" lens tube system

## Trigger generator:

| | |
|---|---|
| Laser lamp out : | 5V into 50 Ω, BNC |
| Lamp out frequency: | 0,32 Hz - 50 Hz |
| Acquisition out : | 5V into 50 Ω, BNC |
| Acquisition out delay: | 0.2 µs - 13104 µs |
| Q-switch out: | 5V into 50 Ω, BNC |
| Q-switch out delay: | 0.013 µs - 819 µs |

## Software:

| | |
|---|---|
| LabView source code: | Adjustable trigger for laser and acquisition control. Individual trigger enable for each polarizer orientation. Absolute angular positioning. |

## Data Interface:

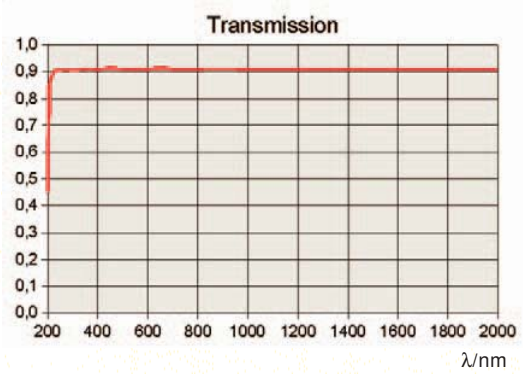
| | |
|---|---|
| Ethernet: | 10/100 MB/s |

## Power supply:

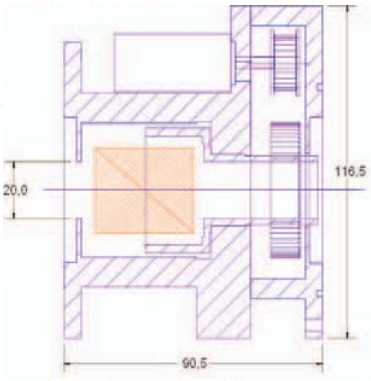
85-240V, 43-67 Hz

## Environmental conditions:

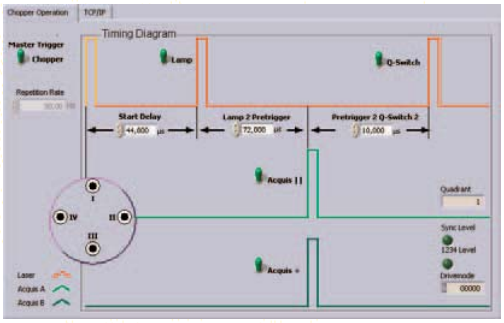
| | |
|---|---|
| Operating temp.: | 0°C to 30°C (non condensing) |
| Storage temperature: | -40°C to 70°C |




Mechanical dimensions (mm)




Software

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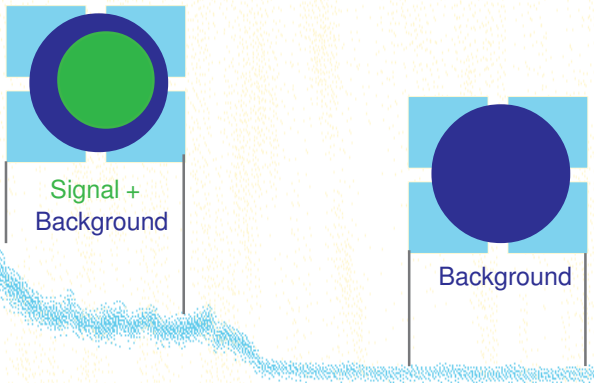
# Boresite Alignment Sensor

## *4- quadrant, range resolved photon counting detector*

Signals on Multi Anode PMT



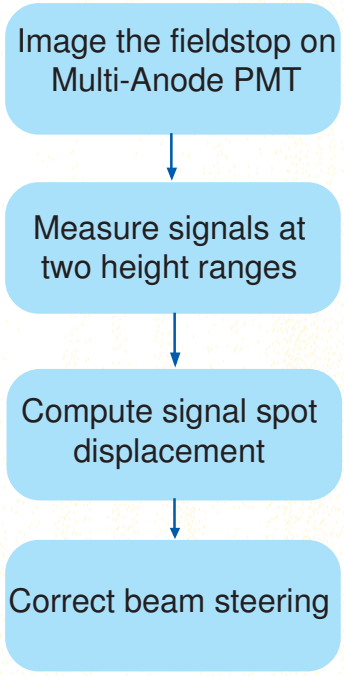

## Continous alignment control:

In many LIDAR applications, daylight is among the major limiting parameters for the achievable signal range.

By implementing a continuous monitoring and correction of the alignment, the telescope field of view can be reduced close to the laser beam divergence. This can improve operation of narrow field of view Raman or micropulse lidars and unattended operation.

## Method:

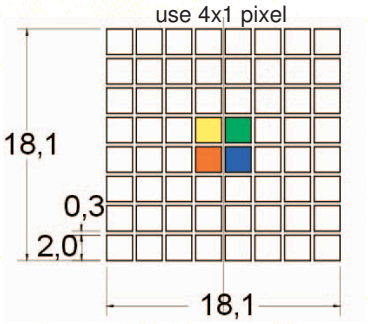
The LICEL bore sight alignment controller evaluates the image of the laser return from two user defined height ranges on a multi anode photomultiplier. It computes correction parameters for the beam steering.

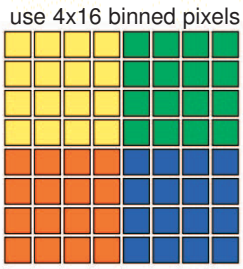


# *Method and Specifications*

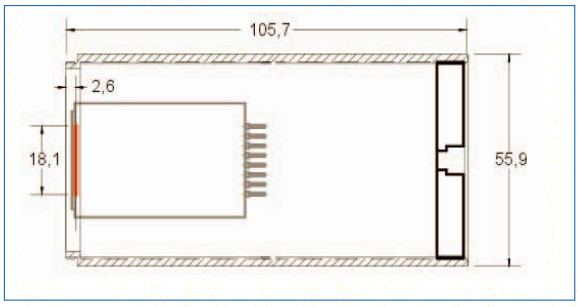
### Pixel size configuration:

The pixels on the Multi Anode PMT can be binned to achieve 4 sensitive surfaces from 2x2mm up to 9,2x9,2mm.




### Mechanics:




### Detector:

| | |
|---|---|
| PMT: | Hamamatsu H7546B |
| spectral sensitivity : | 300 nm - 650 nm |
| Pixel size: | 64x 2x2 mm |

### acquisition:

| | |
|---|---|
| signal start height $h_1$: | 15m-15.36 km |
| signal stop height $h_2$: | $h_1$ + 15m-15.36 km |
| background start $h_3$: | $h_2$ + 15m-15.36 km |
| background stop $h_4$: | $h_3$ + 15m-15.36 km |
| max. count rate: | 180 MHz |
| max. integr. counts: | 8192 photons/signal |

### Mechanics:

| | |
|---|---|
| Detector assembly: | 56 x 106 mm, 350 g |
| Ethernet Controller: | 55 x 128 x 100mm, 400 g |

Interface to Thorlabs 2" lens tube system

### Software control:

- set $h_1$ to $h_4$with 15m resolution
- set discriminator level
- set HV
- variable number of shots to average
- height scan
- single photon pulse height distribution
- integrated number of photons for each pixel
- LabView source code supplied

### Data Interface:

| | |
|---|---|
| Ethernet: | 10/100 MB/s |

### Power requirements:

DC supply (not incl.): +5V, 1A, -5V, 0.2A, +15V, 0.2A

### Environmental conditions:

| | |
|---|---|
| Operating temp.: | 0°C to 40°C (non condensing) |
| Storage temperature: | -40°C to 70°C |

### International distribution:

**USA**:
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# Lidar Automation

## *Ethernet based lidar components*

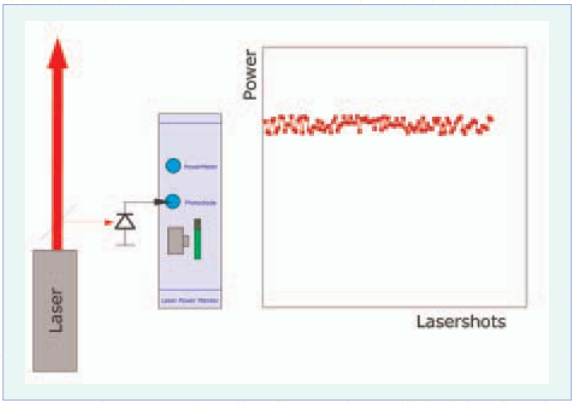
### Overview:

The Ethernet based components for Lidar automation provide remote control for laser monitoring, timing parameters, detectors and transient recorders. The modules are building blocks for highly integrated detection systems.

Ethernet is a modern, easy to use and very scalable system control technology. It fits perfectly to any PC. You can run your whole system from a laptop with an internet connection.

### Laser Power Monitor:

Monitoring every laser shot is the optimum approach to detect laser pulse energy fluctuations, SHG and THG efficiency changes and flashlamp degradation of your laser .
A laser spot reflection can measured using a photodiode or a laser power meter.

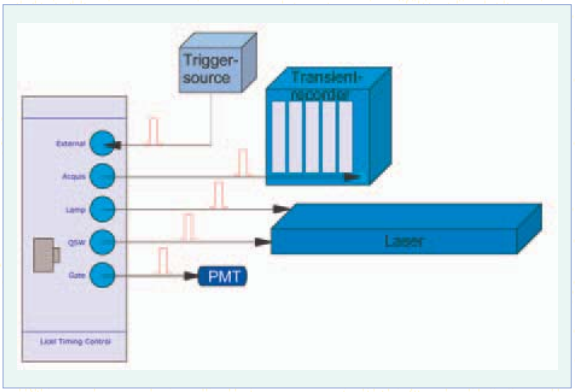



specifications:

| | |
|---|---|
| input: | photodiode/power meter |
| resolution: | 10bit |
| max. rep. rate | 100Hz |

### Timing Control:

Control the laser, the transient recorder and the gating from a single integrated module instead of using an external pulse generator. The module provides all necessary trigger signals: laser flashlamp, laser Q-switch, transient recorder and gating. Use these signals to setup a pretrigger solution where the laser can be either master or slave.




specifications:

| | |
|---|---|
| Laser lamp out : | 5V into 50 Ω, BNC |
| Lamp out frequency: | 0,32 Hz - 50 Hz |
| Acquisition out : | 5V into 50 Ω, BNC |
| Acquisition out delay: | 0.2 µs - 13104 µs |
| Q-switch out: | 5V into 50 Ω, BNC |
| Q-switch out delay: | 0.013 µs - 819 µs |
| Gate out delay: | 0.013 µs - 819 µs |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# Ethernet based lidar components

## PMT/APD Control:

Remote controlling the detectors helps to optimize automated lidars. You can prevent signal saturation (low clouds), react on high or low solar background.

Without manual controls more compact systems can be built.

**PMT Remote 8:**

Remote control for PMT modules.

| | |
|---|---|
| No. of PMTs to control: | up to 8 |
| high voltage set/read accuracy: | +/-1V |

**APD Remote 4:**

Remote control for APD modules.

| | |
|---|---|
| No. of . APDs to control: | up to 4 |
| high voltage set/read accuracy: | +/-1V |
| APD cooling control: | on/off |
| Temp. in range monitor | |

## Transient Recorder Control:

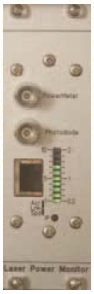
Controlling the transient recorder over Ethernet allows to place the acquisition rack as close as possible to the detectors. The PC can be located anywhere in the LAN.

Older systems can be upgraded with this module, the software structure is very similar to make the transition smooth.

**Transient recorder control:**

| | |
|---|---|
| No. of transient recorders: | up to 16 |
| trigger: | global trigger input |

compatible to DIO-32HS interface



**Specifications for all Ethernet modules:**

**Data Interface:**

| | |
|---|---|
| Ethernet: | 10/100 MB/s |
| Ethernet adress: | DHCP or manual |

**Mechanics:**

All Ethernet modules can be mounted into 3 height unit cassettes or on the rear panel of the transient recorder rack.

**Software:**

Executables and LabVIEW software source code is supplied. An additonal C-based driver is available.

**Environmental conditions:**

| | |
|---|---|
| Operating temperature: | 0°C to 30°C (non condens.) |
| Storage temperature: | -40°C to 70°C |

**International distribution:**

**Asian Pacific Rim:**
Electronics Optics Res., Ltd.
3-fl., Onoda Building,
4-26-19, Koenzi-Minami-Ku
Tokyo 166, Japan
phone 03-3314-5699
fax 03-3314-2333
email eor@tkd.att.ne.jp
www.eor.jp

**USA:**
Boston Electronics Corp.
91 Boylson Street
Brookline MA 02445
phone (800)347-5445
fax (617)731-0935

e-mail: boselec@boselec.com
www.boselec.com

**United Kingdom:**
Photonic Solutions PLC
Gracemount Business Pavillons,
40 Captains Road,
Unit A2/A3, Edinburgh, EH17 8QF
phone: 0131 664 8122
fax: 0131 664 8144
email: sales@psplc.com
www.psplc.com

**other countries:**
Licel GmbH
Chausseestr. 34/35
D-10115 Berlin

phone +49.30.283 917 37
fax +49.30.283 917 38
e-mail: info@licel.com
www.licel.com

# Gated Photomultiplier module

## Specifications

**Detector:**

| | |
|---|---|
| cathode diameter: | 8 mm |
| spectral sensitivity: | |
| Bialkali cathode-06: | 160-650 nm |
| Bialkali cathode-03: | 185-650 nm |
| Multialkali cathode-01: | 300-850 nm |
| Multialkali cathode-04: | 185-850 nm |
| Multialkali cathode-02: | 300-880nm |
| Multialkali cathode-20: | 300-900nm |
| max. av. anode current: | 0.1 mA (5mV into 50Ω) |
| gain: | $10^5$-$10^6$ |

**Signal specs:**

| | |
|---|---|
| Single photon rise time: | <1.3 ns |
| Single photon width (FWHM) | <2.2 ns |
| Pulse load stability, HV=850V, 100mV signal / 60µs | <0.15% |

**Gating:**

| | |
|---|---|
| Active ON type | |
| Gate Pulse Input | >2.5V into 50Ω |
| Suppression, Gate OFF | < $10^{-3}$ |
| Rise time: | <10 ns |
| Settling time (99%) | <200 ns |
| Settling time (99.9%) | <5 µs |
| Max. ON time: | 1 ms |
| Max. duty cyle (ON/OFF) | 100 |
| Switching noise | <10mV for <200 ns |
| High voltage range: | 750-850V |

**HV supply:**

| | |
|---|---|
| Voltage range: | -70...-1kV |
| Max. current: | 2 mA |
| Voltage ripple: | <1mV (DC to 20 MHz) |
| Remote HV control voltage | 0..+1V |

**Mechanics:**

| | |
|---|---|
| PMT module size: | 70 x 25mm |
| PMT module weight: | 50 g |
| Optical interface: | O-ring sealed mount or adapter for 1" Thorlabs lens tube system |
| High voltage supply: | 50.5x128.4x103mm 3 height units, 10 width units standard cassette |

**Connectors:**

| | |
|---|---|
| Gating Input: | Minax/BNC |
| Signal out: | Minax/BNC |
| HV to PMT: | Lemo Camac |
| HV power supply: | H11 connector |

**Power supply:** 15V DC, 250mA

**Environmental conditions:**

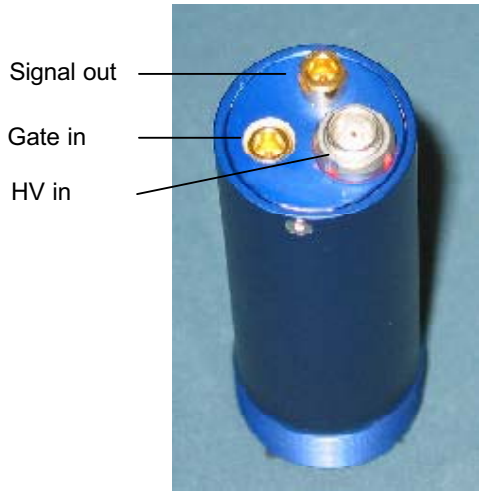
| | |
|---|---|
| Operating temperature: | 0°C to 30°C (non condensing) |
| Storage temperature: | -40°C to 70°C |

**System integration:**

Mating parts of Thorlabs Lens tube system
SM1L03, SM1L05,...1" stackable lens tubes
SM1NT Locking Nut
and other components of the SM1 series

# *Mechanical Specifications and Pinout*

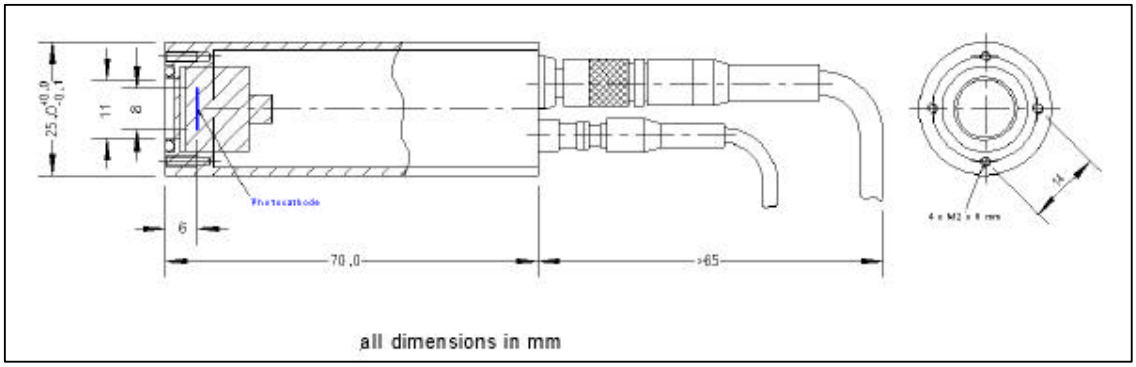
**Connectors:**




**H11 connector on HV power supply, rear side:**

| Pin | Description |
|---|---|
| 2 | +13...+15V in (max. 280mA) |
| 5 | Gnd |
| 8 | +5V Reference out |
| 11 | Gnd |
| 14 | HV Inhibit (high = off) |
| 17 | +12V Reference out |
| 20 | Gnd |
| 23 | Remote HV Control, 0..+1V into 100kOhm |
| 26 | Voltage Monitor (-5mV/V) |
| 29 | Current Monitor (2mA/V) |
| 32 | Protective Gnd (Case) |

**Mechanical dimensions and location of photocathode:**



# Licel Euro Price List

| Order No. | Description | price, Euro |
|---|---|---|
| | **Transient recorder modules:** | |
| TR 20-16bit | Transient recorder, 16 Bit-20 Ms/s A/D and 250 MHz photon counting acquisition, up to 3278 µs signal length. (Available from December 2010) | 9 100.- |
| TR 40-xx* | Transient recorder, 12 bit-40 MHz A/D and 250 MHz photon counting acquisition, up to 0.4 ms signal length. | 8 600.- |
| TR 20-xx* | Transient recorder, 12 bit-20 MHz A/D and 250 MHz photon counting acquisition, up to 0.8 ms signal length. | 7 850.- |
| TR 20-xx*-AP | Transient recorder with 2 separate inputs for 12 bit-20 MHz A/D and 250 MHz photon counting acquisition, allows simultaneous use of 2 detectors. | 7 850.- |
| PR 20-160-P | Photon Counting system, 250 MHz max. photon count rate, signal trace: 819 µs - 122km, two channels fit into one cassette. | 5450.- |
| PR10-160-P | Photon Counting system, 250 MHz max. photon count rate, signal trace: 1 838 µs - 244km, two channels fit into one cassette. | 5450.- |
| | **Options and Accessories:** | |

| | | |
|---|---|---|
| Trig-Las | Optical trigger module for passive Q-switched laser | 600.- |
| Cab-2 | Data cable transient rack to interface card, shielded connectors with brackets, length 2 m. | 180.- |

**Rack and power supplies:**

| | | |
|---|---|---|
| Rack-1 | Housing and power supply for single transient recorder. +5.4 V, -5 V, linear power supplies, data interface, AC 230 V-50 Hz / 110V-60 Hz input. | 750.- |
| Rack-2 | Housing and power supply for 2 transient recorders. AC 230 V-50 Hz / 110V-60 Hz input. | 1 000.- |
| Rack-6 | Housing and power supply for up to 6 transient recorders. AC 230 V-50 Hz / 110V-60 Hz input. | 1 250.- |
| PMT-Rack3 | Rack for up to 3 pmt modules | 500.- |
| PMT-Rack8 | Rack for up to 8 pmt modules | 900.- |

**Ethernet Remote Control**

| | | |
|---|---|---|
| Ethernet-IO | Ethermet interface module option for transient recorder rack. Control and readout of up to 16 transient recorders | 950.- |
| PM-Remote-8 | Ethernet interface for remote control of up to 8 photomultipliers. Remote high voltage setting and high voltage monitor. incl. LabView routines. Mounted in 3 HU cassette. | 940.- |
| PM-Remote-4 | Ethernet interface for remote control of up to 4 photomultipliers. Remote high voltage setting and high voltage monitor. | 890.- |

| | | |
|---|---|---|
| | incl. LabView routines. Mounted in 3 HU cassette. | |
| APD-Remote-4 | Ethernet interface for remote control of up to 4 APD modules. Remote high voltage setting and TEC on/off control. incl. LabView routines. Mounted in 3 HU cassette. | 890.- |
| Trigger generator | Ethernet interface for active laser flashlamp, Q-switch, Gating and transient recorder control. Variable repetition rate and pretrigger delay. Incl. LabView routines. Mounted in 3 HU cassette. | 890.- |
| Laser Monitor | Ethernet laser monitor. Continous acquisition of laser pulse energy measured by laser power meter (not. incl.) or photodiode (included). | 1 350.- |

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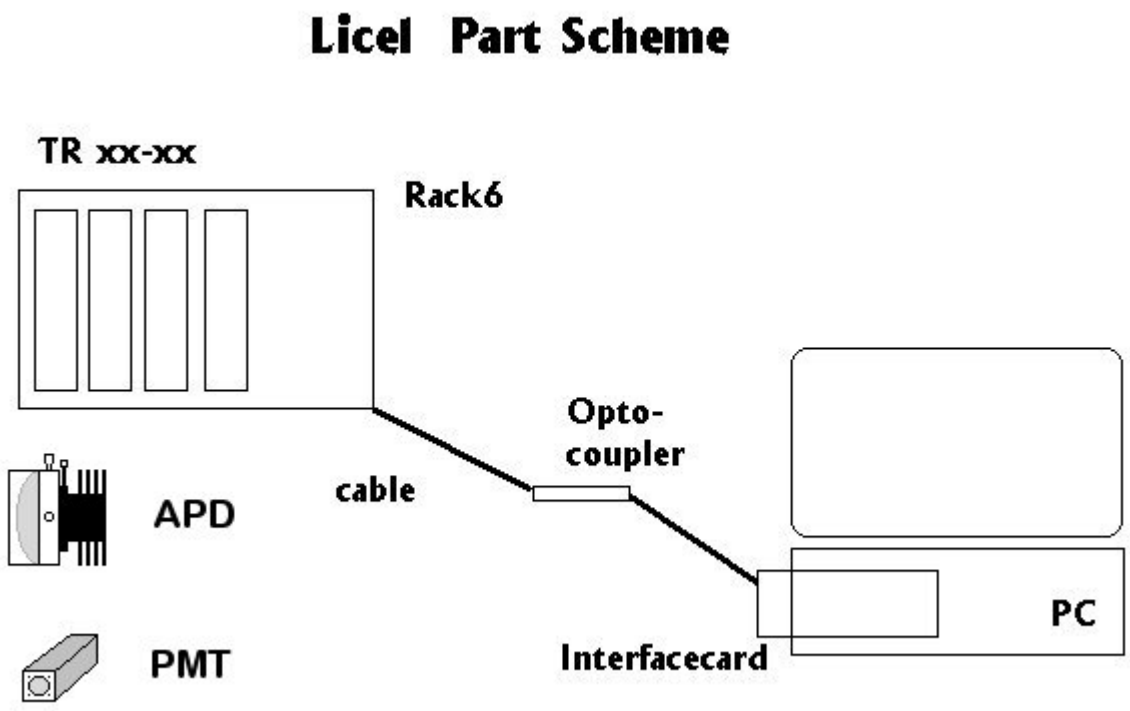
**Detectors:**

| | | |
|---|---|---|
| | Photomultiplier modules based on Hamamatsu mini PMT's, HV supply, stabilized dynodes, overcurrent protection, cables. | |
| PM-HV-06 | 160-650nm Bialkali | 2 650.- |
| PM-HV-03 | 185-650nm Bialkali | 2 550.- |
| PM-HV-02 | 300-880nm Multialkali | 3 070.- |
| PM-HV-20 | 300-900nm Multialkali | 3 340.- |
| PM-HV-SBA | 300-650nm Super Bialkali | 2 940.- |
| gating | optional gating circuit for the PMT modules shown above. The gated PMT version can only be used in gated mode, max. gate ON time = 1ms | add 850.- |
| Boresite | 4-quadrant boresite alignment system, detector, photon counter, Ethernet interface | 9 330.- |

| | | |
|---|---|---|
| SP32-xx | 32-channel Multi-Anode PMT single photon counting system, high voltage supply, Ethernet interface, max. count rate 100MHz | |
| xx = 01 | Multialkali photocathode 300-880nm | 18 400,- |
| xx = 03 | Bialkali photocathode 185-650nm | 17 000,- |
| xx = 20 | Multialkali photocathode 300-880nm | 19 600,- |
| xx = 110 | Super Bialkali (SBA) photocathode 230-700nm | 17 700,- |
| xx = 200 | Ultra Bialkali (UBA) photocathode 230-700nm | 18 700,- |
| Sp32-Power | External Power for Multispectral Lidar detector | 450.- |
| Fiber | Fiber Bundel for Multispectral Lidar detector | 900.- |
| | **NIR (1064nm) enhanced Si-APDs for analog detection:** | |
| APD-0.8 | Silicon APD detector module detector size 0.8 mm (dia.), responsitivity at 1060 nm typ. 34 A/W, peltier cooled, integrated preamplifier, 50 Ω output, integrated temperature control, HV supply (0...400V) and power supply. | 5 500.- |
| APD-1.5 | Silicon APD detector module detector size 1.5 mm (dia.), features as shown above. | 5 700.- |
| APD-3.0 | Silicon APD detector module detector size 3.0 mm (dia.), features as shown above. | 6 900.- |
| | **Standard Si sensitivity APDs for analog or p.c. detection:** | |

| | | |
|---|---|---|
| APD-C30902 | Silicon APD detector module detector size 0.5 mm (dia.), not infrared enhanced, lower dark count rate | 7 800.- |
| | **InGaAs APD module for eyesafe lidar** | |
| APD-InGaAs | InGaAs APD detector module, 0.2mm dia., sens. 1100-1700 nm, air cooled, incl. AC/DC power supply, HV supply, focussing and alignment optics | 7 800.- |
| | **Polarization measurements:** | |
| Polarotor | Rotating polarizing beamsplitter for alternating measurements of parallel and perpendicular polarized signals up to 50Hz laser rep. rate. Ethernet interface. | 8 900.- |
| | **Software:** | |
| Basic | Drivers for LabView routines (source code) to perform data acquisitions, display signals, combine analog and photon counting signals, analyze photon counting pulse height distribution. Additional low level C-routines (NI-DAQ based) for integration into existing software. | incl. |
| File | Customized file format and naming convention according to local standards. | 1 000.- |
| Develop | LabView drivers for off-line software development, simulating hardware behaviour of transient recorders and lidar systems. | 1 800.- |

**All Prices are EXW Berlin and excl. VAT and taxes**




Please note that the optocoupler is only optional and in most cases not necessary, but once you have strong electromagnetic interference, it helps to protect the National Instruments PCI-DIO-32HS interface card.