Si-Avalanche Photodiode module

Digital control

Licel GmbH

April 30, 2024

Operators manual

1 Principle of operation

The Licel Si-Avalanche Photodiode Module is based on the Excelitas E39056EH series of avalanche photo diodes. These Si-diodes are manufactured using a double-diffused "reach through" structure at the back side. 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. 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 40%.

The APD is operated in the linear mode below the Geiger threshold. This gives the required linear response for analog detection.

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. The x and y axis adjustment is done by the external screws, the z adjustment is done by turning the riffled ring in the middle.

Detector head

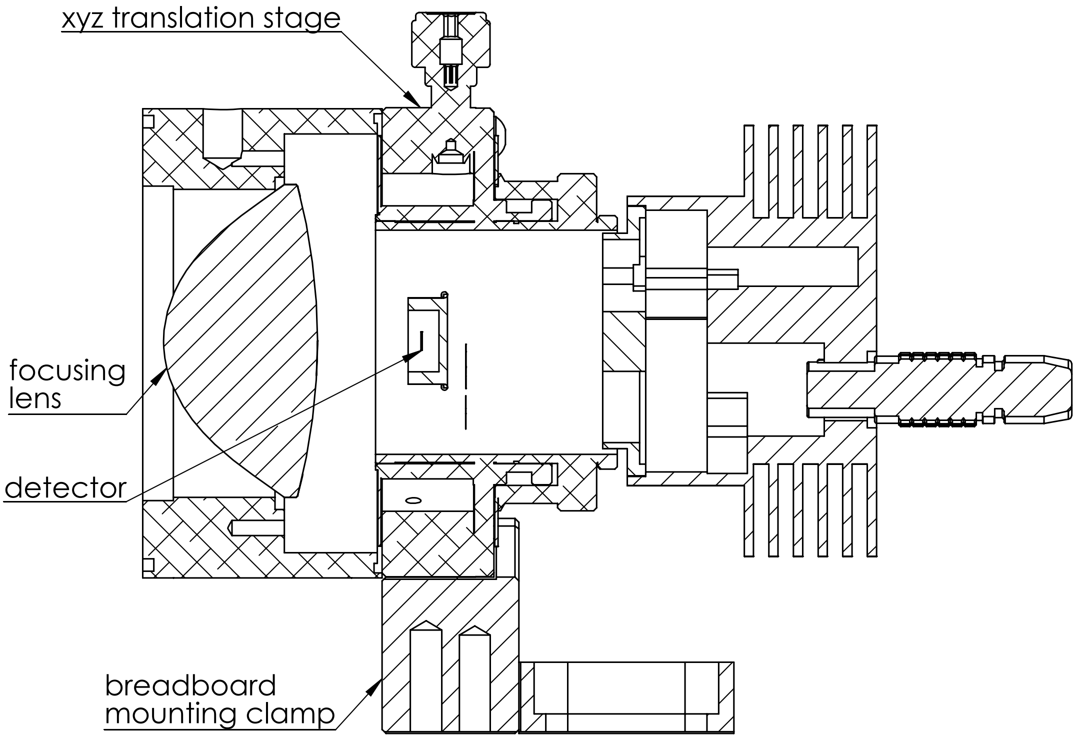


Fig. 1:

Schematic view of detector head

The power supply unit contains a linear regulated +5V and +/-15 V power supply and a 0...+550 V high voltage supply. This provides the voltages for the temperature controller and preamplifier as well as the variable reverse voltage for the APD.

Power supply unit

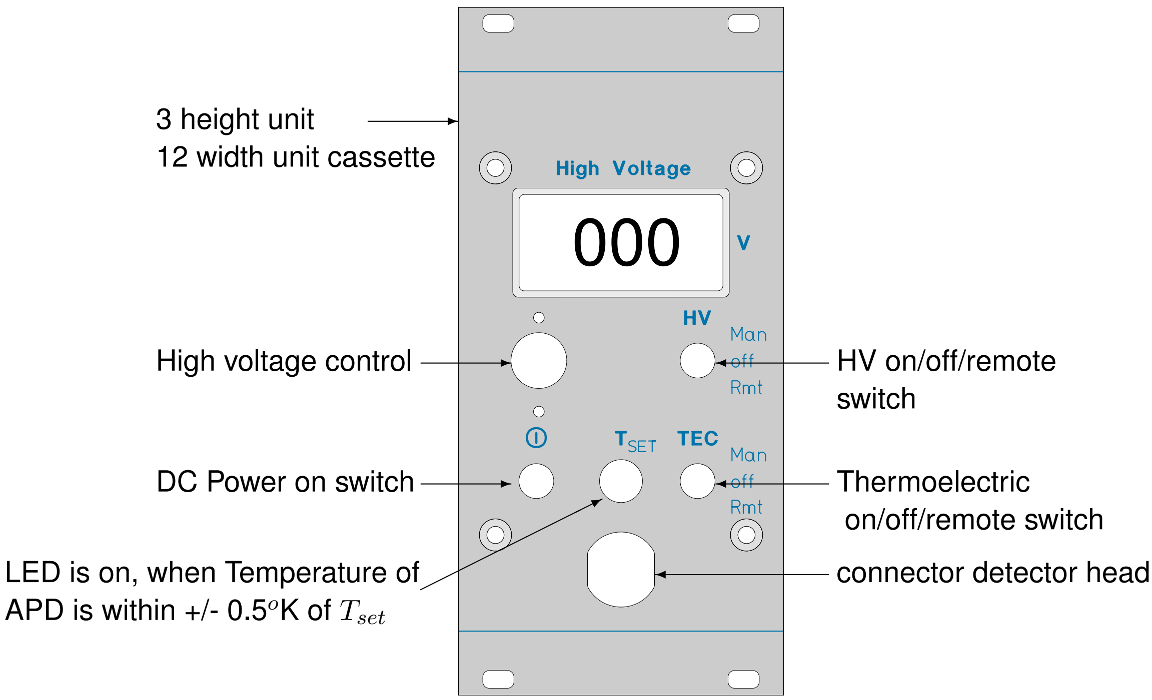


Fig. 2 Control and connector at power supply unit

3 Operating instructions

Avalanche photo diodes 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^o 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 data sheet supplied with your diode. At very low light levels (i.e. in lidar systems using narrow band daylight filters) 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 data sheet supplied with your diode.

Its general recommended to turn the TEC on and to wait for the green status LED to turn bright before turning the HV on. The cooling efficiently reduces the probability of a thermal damage to the detector.

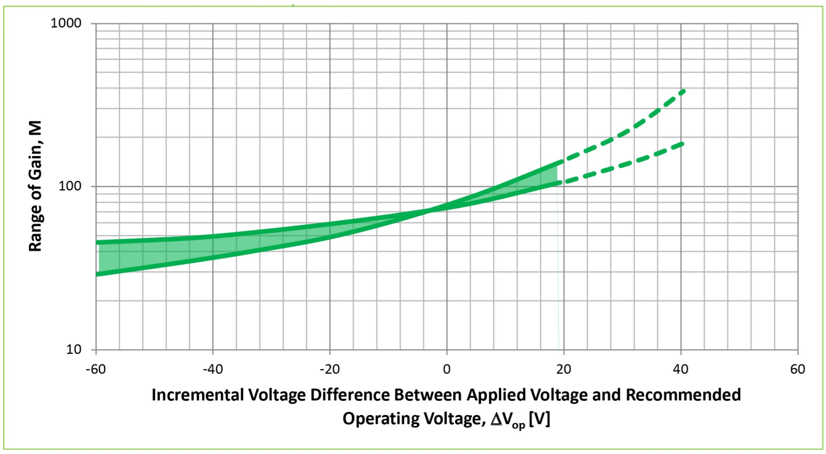


figure 3 : Variation of gain as a function of difference between actual applied operation voltage and recommended operation voltage (adapted from Excelitas E39056EH data sheeet).

The gain follows close the to breaktrough the Miller formula
S. L. Miller, Avalanche breakdown in germanium, Phys. Rev. 99, p. 1234 (1955)

$$M = \frac{1}{1 - \left(\frac{V}{V_b}\right)^n} \tag{1}$$

For a typical APD the lower bound of the recommend range the gain is around 200 and increases by factor of 10 to 2000 at the upper bound.

At HV 0 the APD has no amplification and behaves like a photodiode with gain of 1. A gain of 2 is typically reached around HV = 50V.

4 High Voltage Setting

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^oK 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 averaged over a time of 100 ms. (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).
If a very low voltage (<40V) is applied the HV ripples and this will create ripple in the signal.

5 Acquisition system requirements:

Due to the lower internal gain of an APD as compared to a photomultiplier, the performance of the acquisition electronics is a key factor for achieving an optimum signal/noise ratio. We recommend to use our Licel transient recorders. Special care should be taken to the analog input range of the transient recorder to prevent clipping of the signal. The following example demonstrates this effect: This description is focussed on users who use our transient recorders. However, for users using other acquisition systems, the same issues apply.

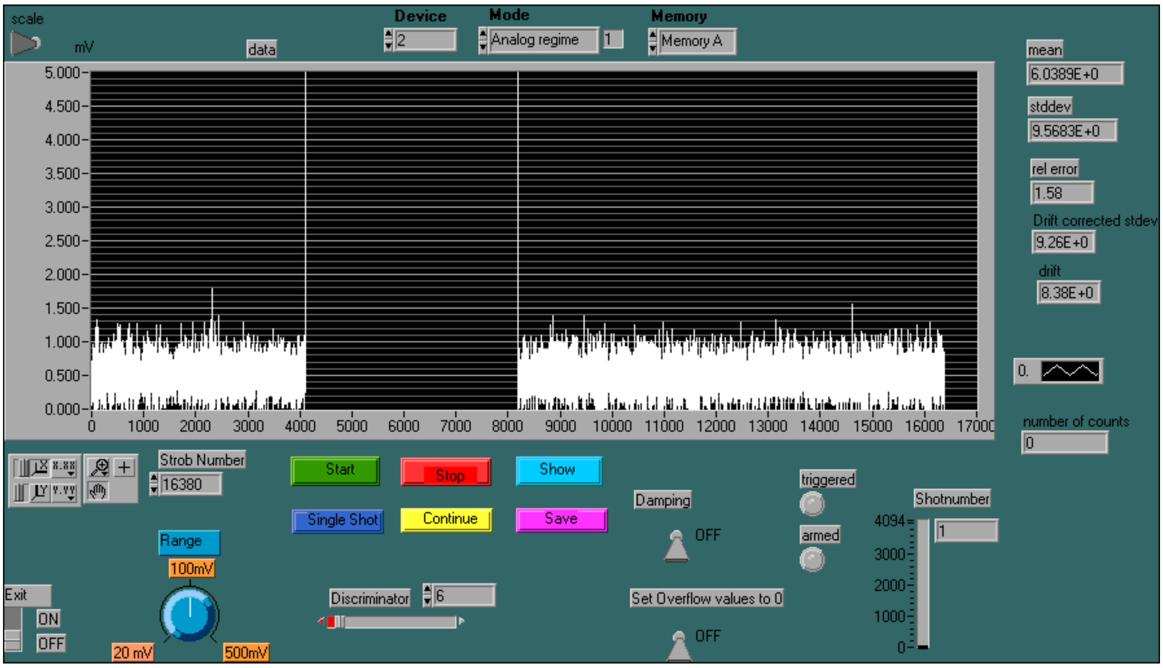


Fig. 4: Some samples of this single shot measurement are exceeding the lower input limit of the ADC.

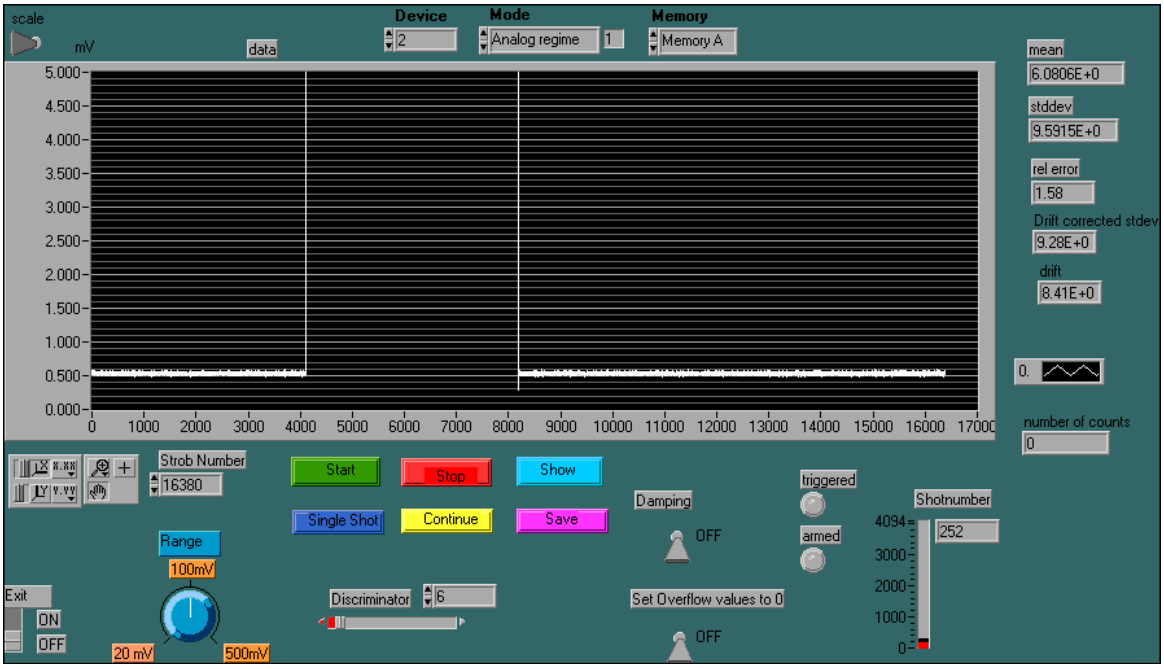


Fig. 5: In the averaged signal, the baseline of the measurements seems to be inside the analog input range, however the baseline value is incorrect since the samples beyond the ADC input range should have been averaged with a negative amplitude value, but have been actually averaged with a clipped value of 0mV.

The clipping of the signal can be detected in the averaged data by using the "Set overflow values to 0" function of the "track.vi" program as shown in the following plot. All data bins where the ADC input range was clipped at least once are set to 0mV in this plot to check the validity of the data.

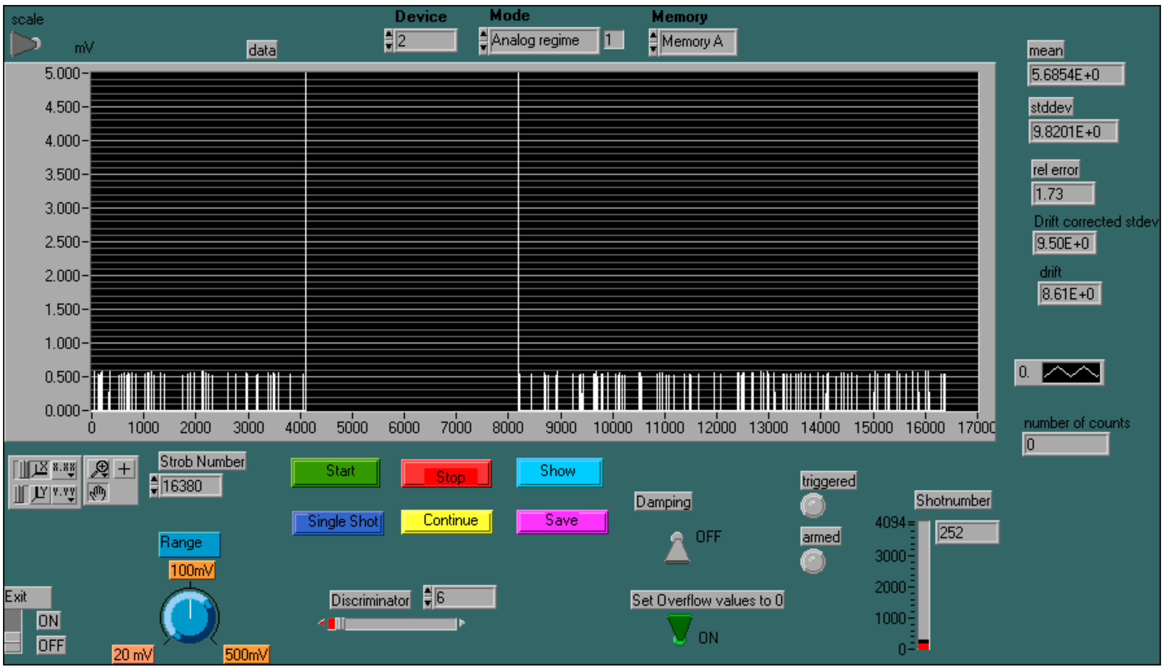


Fig. 6: Same measurement as before, Using the "Set overflow values to 0" function. This plot shows, that in most of the databins of the baseline, the ADC data have been clipped at least once. Therefore the averaged baseline value is not correct.

If you are using our transient recorders and the offset voltage is such, that the analog input clipping occurs it is necessary to adjust the input offset of the transient recorder preamplifier as described in the transient recorder manual.

5.1 Peak signal

The averaged peak signal should not exceed half of the input range, for a 500mV input this would be 250mV. The reason for this comes from the statistics. For Poisson statistics where the equals the mean for a steady signal. So between the signals that are accumulated for the sum, there signals where the peak by far exceeds the averaged peak. If one of those exceeding signal is larger then input range, the signal will be clipped there. These clipped signals will then participate in the computation of the sum and by this the sum will be compromised. Experience shows that this starts at 60 percent of the input range.

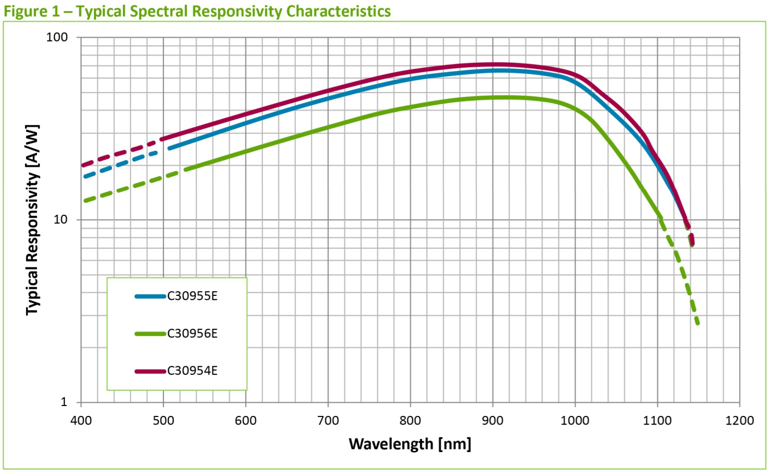
The clip LED is intentional red on the TR units to make clear that the sum will contain compromised values.

One can expect from an APD in combination with a TR 3.5 orders of magnitude as dynamic range. Starting from a 250mV signal this would be down to a 50 uV in the far field. If more dynamic range is required a near field + far field setup should be considered.

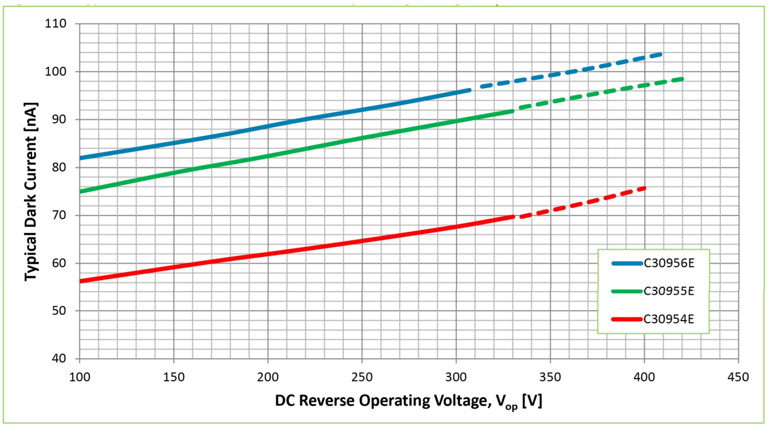
6 Spectral sensitivity data

The following data and figures are adapted from the Excelitas E39056EH datasheet:
Typical spectral responsivity characteristics:

Figure 1 – Typical Spectral Responsivity Characteristics

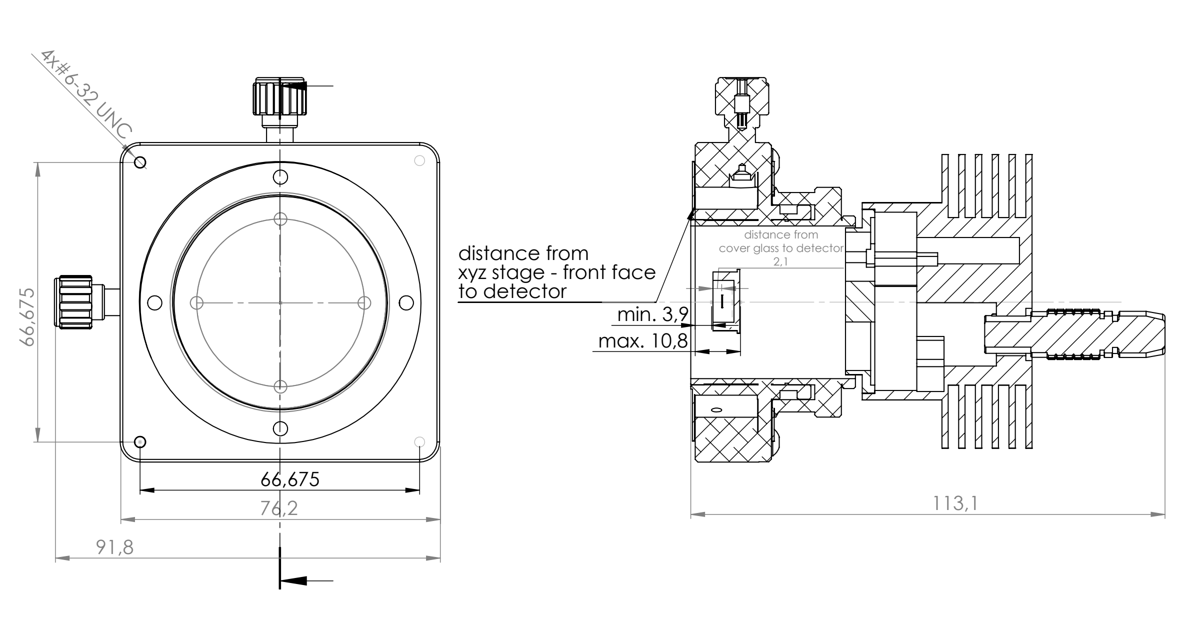


dark current:



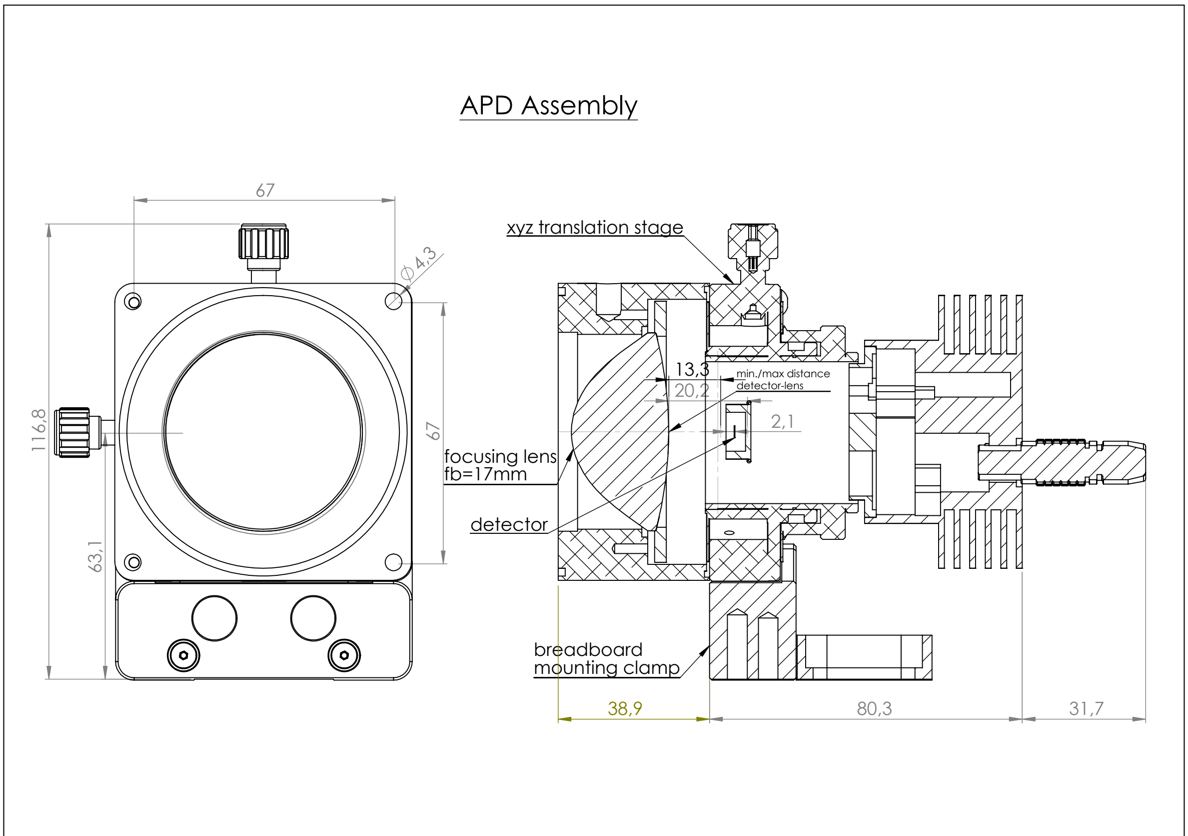
7 Mechanical specifications

7.1 Mounting the APD module without lens adapter

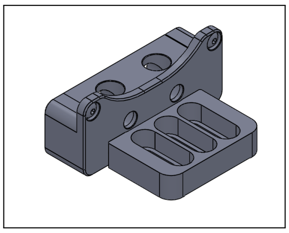


7.2 Mounting the APD module with lens adapter

The APD comes with lens adapter to focus parallel beams up to 48 mm onto the diode. The lens adapter is compatible with the Thorlabs lens tube system.



The detector ships with a mounting adapter for the breadboard.



7.3 Dimensions

APD HV-Cassette length:	232 mm
APD HV-Cassette width:	60 mm
APD HV-Cassette weight:	1425 g
APD detector head:	875 g
APD cable:	350 g
APD total:	1650 g
cable length :	1.5 m

8 Electrical specifications

The APD cassette comes with a AC power cord. The voltage system is specified on order (typical are 230V/50-60Hz, 115V/50-60Hz and 100V/50-60Hz)

9 Remote Control

The APD can be remote controlled. Licel offers a matching controller with the part number
APD-Remote-Dig (see https://licel.com/price_list_euro.html#APD-Remote-Dig)

9.1 Software interface

The APD-Remote-Dig controller comes with a software in LabView and a pre build executable.
The software can be downloaded from Licel Data Acquisition and Processing Software (http://licel.com/soft_tcp.html) web page.
The software usage is described in the Ethernet Manual (http://licel.com/manuals/ethernet_pmt_tr.pdf) in section 6.1 *The Combined APD and PMT Control Panel*.

The communication syntax of the remote controller is described in the *TCP/IP Command List and Syntax Appendix of the Ethernet Manual* .

In order to use the software, both switches **HV** and **TEC** on the front panel of the HV cassette must be in the remote position.

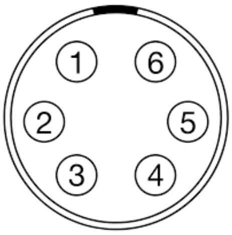
C Driver Further the C driver, which can be downloaded at http://licel.com/download/c-files/Ethernet/licel_tcpip_C_driver.zip supports the setting of the TEC controller, the APD HV and can retrieve a APD status. Thats the same basic functionality that is behind the LabVIEW programm.

The C Driver is described in the programming manual, which can be found at http://licel.com/manuals/programmingManual.pdf.

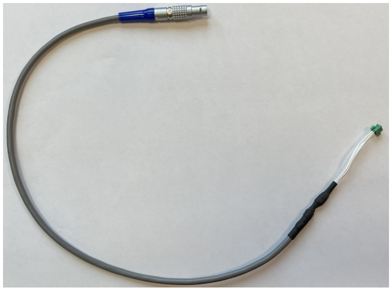
In the programming manual the flow of the example program `SetAPDHV` is shown in in section 7.9.

9.2 Electrical interface

The APD-Remote-Dig controller uses the 6 pin interface at the rear of the APD cassette.



Pin No.	Signal In/output	Voltage level
1	Vin	3V $<$Vin $<$5.5V
2	SPI CS	$<$1.25V =off, $>$1.5V =on
3	SPI MOSI	$<$1.25V =off, $>$1.5V =on
4	SPI MISO	$<$1.25V =off, $>$1.5V =on
5	SPI CLK	$<$1.25V =off, $>$1.5V =on
6	Gnd	



10 Individual test data