2. Overview

2.1. The APDCAM family

The APDCAM family of products are ultrafast avalanche photodiode (APD) matrix detector devices containing all detector infrastructure and data acquisition in one compact package, connecting to a computer via 1 or 10 Gbit Ethernet interface. This type of detector is designed for special applications where low light level has to be measured with extreme high speed (up to several MHz). The APDCAM family uses the Hamamatsu S8550 4x8 detector array having large area pixels (1.6x1.6 mm) compared to CCD sensors therefore they are easier to match to low f-number optics used in low light applications. For low light level applications Multi-Pixel Photon Counter (MPPC) detectors are also available on request. All pixels of the detector are read out simultaneously; therefore the throughput is not limited by readout time. The intrinsic gain of the detector allows measurement under conditions where photodiodes would not be applicable and stable gain is provided by the temperature stabilised detector.

APDCAM uses one 4x8 pixel detector and connects to the computer via 1 Gbit Ethernet, while APDCAM-10G can use up to 4 detector matrices, that is 32 to 128 pixels. Different arrangements are possible: 8x8, 4x16, 4x32, 8x16 all using the same 10 Gbit Ethernet interface.

2.2. Overview of APDCAM-10G

APDCAM-10G has a modular layout with detector amplifiers and digitizers available in 32 channel blocks. The detector arrangement, the amplifier analog parameters and many other options can be specified at order time, see in the Order options section. Each APD pixel has its individual analog amplifier and 14 bit digitizer which runs all the time. The resulting data stream can be digitally filtered and down-sampled before sending to the computer in UDP packets. At present only Linux operating system is supported as ordinary Windows systems cannot handle the maximum throughput rate. (The 32 channel APDCAM system is supported under Windows as well.) Data is transferred to the computer in real time, thus the amount of data is limited only by computer memory. The maximum data rate depends on the number of active channels, for the maximum configuration of 128 channels 3 MHz is available.

Although the S8550 detector matrix has a fill factor of 50% only, an optional micro-lens array can be mounted on it to increase detection efficiency close to 100%, depending on the optical input imaging.

Various triggering and sampling schemes are available for the data acquisition, including external, internal, post-trigger, external sample control. Optional fibre-to-electrical interfaces can be installed in the camera to be able to use triggering/sampling signals directly in digital optical format.

To help alignment and testing APDCAM-10G has an array of LEDs and optional optical fibres around its detectors. LEDs can be used for both alignment by back illuminating to the object space or for testing as calibration light source. Optical fibres lead light to the back of the camera where e.g. it can be connected to spectrometers.

Technical specifications of the system are shown in *Table 1.* and *Table 2*. *Figure 1.* shows photos of the APDCAM10G system.

Detector	
Detector type	Avalanche Photodiode array Hamamatsu S8550, 2 or 4 arrays/camera (micro-lens array optional)
Pixel arrangement	8 x 8, 4x16, 4x32, 8x16 (order option)
Pixel size	1.6 x 1.6mm
Pixel pitch	2.3 mm (2.6 mm between 2x8 sub-arrays inside detector, 4.3 mm between detectors)
Fill factor	50%
Spectral response range	300 to 1000 nm
Peak quantum efficiency	85% typical at 650 nm
Detector Gain	Typical 50, max 100
Temperature control range[1]	Typical 10...30 ºC
Temperature control type	Peltier, cooling/heating
Micro-lens array (Optional)	
Material	Zeonex
Arrangement	2x8 aspherical lens matrix
Mounting	Non-detachable with UV hardening optical glue. Each 2x8 array is adjusted to 2x8 detector sub-array
Lens height above detector surface	2.3 mm
Optical fibres in detector head (Optional)	
Diameter	1 mm, bunch of 10 micron optical fibres
Numarical Aperture (NA)	0.55
Typical detector sensitivity and noise	
Sensitivity @ Gain=100, 14 bit mode[2]	2.4 10^6 photon/s/digit
Noise equivalent photon flux @ no light[2]	Typical 8 10^7 photon/s
Analog bandwidth[2]	500 kHz
Digitizer	
Internal sampling rate / bits	10-25 MHz / 14 bits
Digital filter	5-point FIR + 1stage recursive
Output bits	14/12/8 (MSB from internal 14 bits)
Ring buffer	0...1024 samples/channel
Trigger	Internal/External TTL/software
Trigger delay	1µs....1000s
Resampling control	Internal fixed divider or external TTL input
Clock base	Internal 20 MHz or external

Table 1. Technical specifications of APDCAM-10G, part 1.

[1] Temperature range depends on ambient temperature.
[2] Standard setting. Sensitivity and bandwidth can be specified at order time. Selection affects noise level.

Data transmission	
Data and control interface	10 Gigabit Ethernet
Optical module form factor	XFP (camera provides 5V power but no clock for the transceiver)
Communication format	UDP, both directions
Max. data rate @ 128 channels	4 MHz/14bit
Max. data rate @ 64 channels	6 MHz/14bit
Power supply unit	
Power input	19-24 V DC, max. 180 W
Size (W,H,D)	32x22x27 cm
Camera mechanical dimensions	
Size (L,W,H)	497*160*185 mm
Weight without power supply[3]	8 kg

Table 2. Technical specifications of APDCAM-10G, part 2.

[3] Weight depends on order options

3. System components

The APDCAM-10G system consists of the camera, the power supply unit and a mains adaptor as shown in Fig. 1. The mains adaptor is a high-power laptop power supply or it can be substituted by any suitable 19-24 V DC power supply.

The APDCAM-10G power supply unit converts the single 19-24V input voltage from the mains adaptor to several voltages required by the camera. These voltages are connected to the camera through the power cable. The cable length can be between 1-10 m, specified at order. The power supply unit is set for the given camera configuration and cable length. Using a shorter cable is possible at the expense of increased camera temperature. Using longer cable might require adjustments in the power supply unit.

Connectors and indicators are located on the back of the camera, as shown in *Fig.2*. *Table 3*. contains brief information on these elements, more details are found in the following chapters.

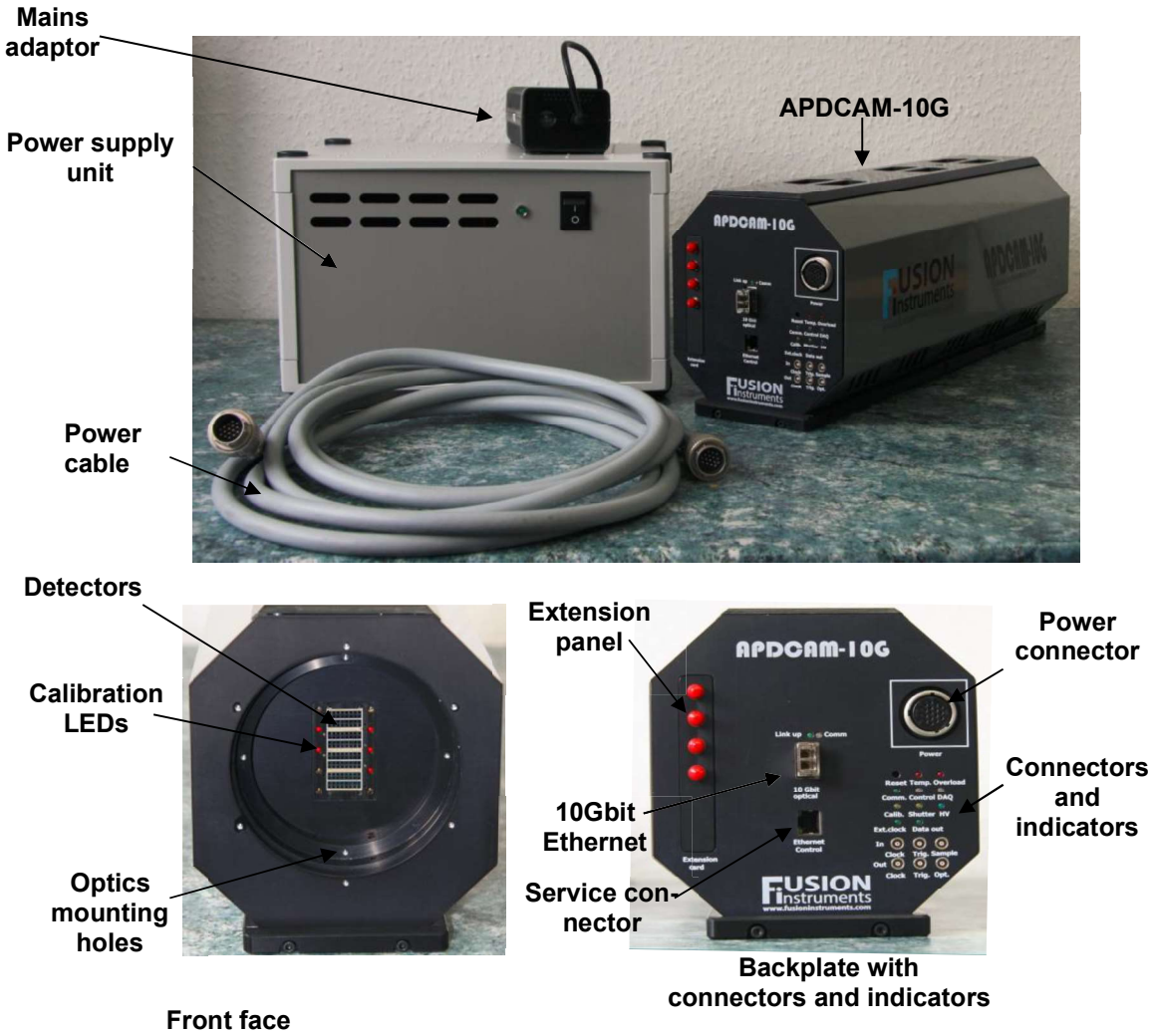

Figure 1. View of the APDCAM-10G system components.

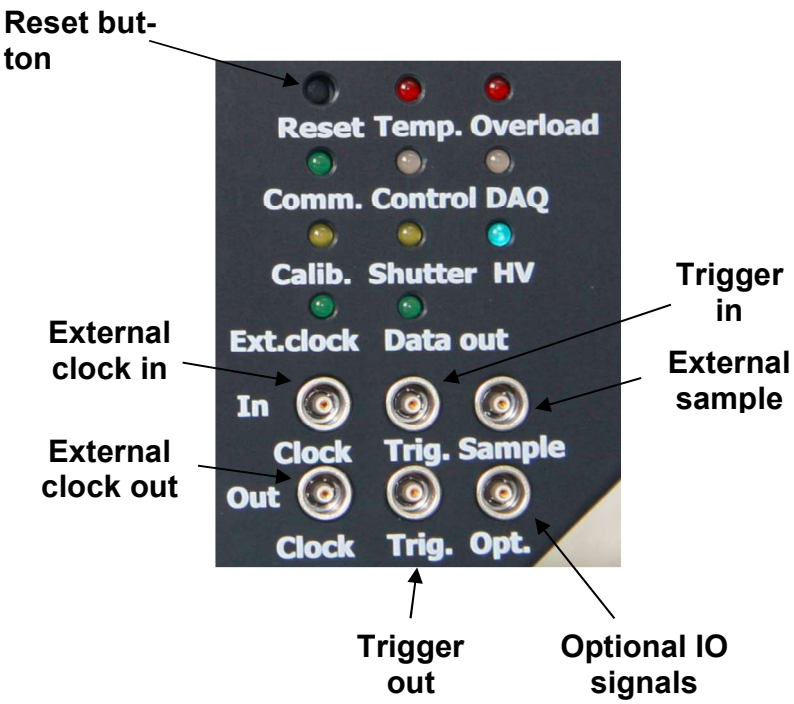

Figure 2. Connectors and indicators on the backside of the camera.

Controls	
Reset button	This depressed button can be operated with a pen or other pointed device. Pressing it causes the camera to return to factory default settings.
Connectors	
Power connector	Receives input power from the power module.
Clock in	Reference TTL clock input. Synchronises clock base of APDCAM to external source. (Signal standard 3.3 V CMOS)
Clock out	Reference clock output. Can be used to synchronize clock base of external device. (Signal standard 3.3 V CMOS)
Trigger in	Data acquisition start trigger signal input. (Signal standard 3.3 V CMOS)
Trigger out	Outputs High level while data transmission is active. (Signal standard 3.3 V CMOS)
Sample in	Input resample clock. (Signal standard 3.3 V CMOS)
Opt	Optional input-output. Can be selected among various internal signals in the factory.
Optical interface	An XFP form factor transceiver is installed in this place which provides 10Gbit optical Ethernet interface to the PC.
Ethernet UTP	UTP cable connection only for factory testing.
LEDs	
Temp.	Red light means temperature alarm. Some element of the camera is overheated.
Overload	Red light means overload condition occurred, detector bias voltage is switched off. (Optional)
Comm.	Green light flashes when control communication occurs between PC and camera
DAQ	Data acquisition module state: Green: normal state, red: error
Control	Control module state: Green indicates normal state, red means error condition.
Calib.	Yellow light means calibration light is on.
Shutter	Yellow light means shutter is open. (Shutter is optional.)
HV	Blue light means detector bias voltage is on.
Ext. Clock	Green light means external reference clock signal is accepted.
Data out	Green light indicates data output to PC.
Link Up	10Gbit communication established
Comm.	Communication to PC.
Extension card	
The extension card can hold SMA fibre connectors, optical-to-TTL repeaters and combinations of them.	
Optical fibre connectors	These are the (optional) SMA connections to the optical fibres installed in the detector head.
Optical receiver	These modules can be used for fibre connections to/from trigger and clock signals.

Table 3. List of controls, connectors and LED indicators of APDCAM-10G.

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