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Superior imaging intensified CCD cameras

4 Quik E

High speed ICCD camera

1.2ns highest shutter speed
Best imaging quality
Single photon detection
Compact and light design

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4 Quik E ICCD camera

High speed intensified CCD camera

Based on more than 25 years of experience in the field of high speed intensified imaging, Stanford Computer Opitcs, is developing pioneering, fast-gated intensified CCD (ICCD) cameras. The 4 Quik E ICCD camera sets new standards of reliable and outstanding, nanosecond resolved imaging and spectroscopy.

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Down to 1.2ns flat top, optical gating time
The 4 Quik E ICCD camera is equipped with high resolution image intensifier which provide excellent temporal resolution and highest sensitivity down to single photon. Equipped with a high resolution CCD sensor the 4 Quik E camera provides exceptional performance and superior image quality. Long-lasting and reliable electronics ensure trouble-free and undisturbed intensified imaging experience.

High performance and reliable electronics
In-house developed, custom-built electronics provide extreme low jitter, low intrinsic delay, excellent timing control with 0.1ns accuracy and flat top, true optical gating time of down to 1.2ns. The adjustable MCP voltage, multiple trigger options and various operation modes make the 4 Quik E most flexible and versatile intensified CCD camera for any scientific or industrial application.

Multi-purpose camera with nanosecond resolution
Optionally, the 4 Quik E ICCD camera can be equipped with up to 2MHz (on request 5MHz) continuous photocathode gating repetition rate and and increased signal amplification using a V-stacked double multi-channel plate (MCP) image intensifier.

Images cover & backside: Positive streamer discharge in pure argon imaged with the 4 Quik E camera. Reprinted figure with permission from U. Ebert et al., 2011 Nonlinearity 24 C1. Copyright (2011) by IOP Publishing Ltd. The figure was published originally in figure 7 of S. Nijdam et al., 2010 J. Phys. D: Appl. Phys. 43 145204.

Highlights

Standard features and benefits

- Shortest shutter time 1.2ns
- Gating time from 1.2ns .. DC
- Internal delay times: 0 .. 80s
- Highly accurate timing control with step size of 0.1ns
- Extreme low jitter: 20ps
- High resolution image intensifiers with optical system resolution of >60lp/mm
- Spectral sensitivity from UV to IR (depends on type of image intensifier)
- Brilliant sensitivity providing single photon detection
- Adjustable MCP voltage for 50db dynamic range in signal amplification
- Multiple exposure operation with up to 3.3MHz (burst mode) and 200kHz (continuous) optical shutter repetition rate
- Customized f/0.8 distortion free lens coupling between image intensifier and CCD
- High dynamic range up to 14bit resolution
- Multiple trigger options: 3x input; 3x output
- USB 2.0 output
- Remote interface for real time camera control
- Compact and light system design

Optional features

- Two discrete images with double frame mode (interframing time 500ns) with P46 posphor
- High photocathode gating repetition rate up to 2MHz continuous; on request up to 5MHz available
- Adapters for various spectrometer
- Vacuum flange for UHV connection
- LabVIEW API

Fastest optical gating down to 1.2ns

Superior image quality by customized lens coupling

High system sensitivity with single photon detection

Long-lasting electronics (24 months warranty)

Compact and light design

Best performance CCD sensors

High resolution, high dynamic range imaging sensors

The 4 Quik E ICCD camera features high resolution intensified imaging for sharpest images with 1.2ns true optical gating. The 4 Quik E camera provides highest sensitivity with Gen II photocathodes and provides the best intensified image quality through customized lens coupling without compromising vignetting, distortion and coupling efficiency. All CCD sensors are front-illuminated types and provide best image quality with low noise and high fill factor.

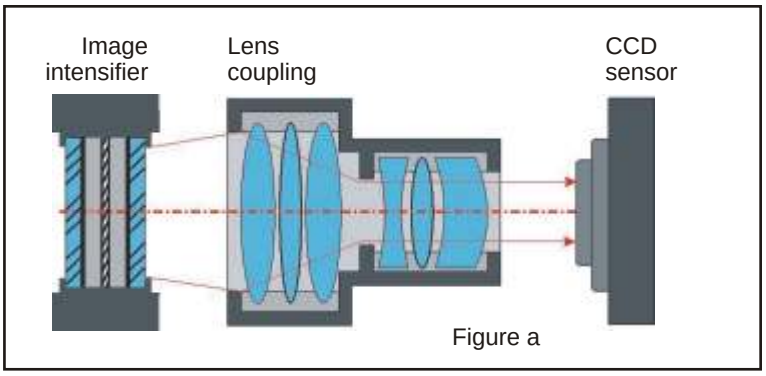


Figure a: Schematic sketch of the lens coupled intensified CCD camera. The appropriate coupling lens images the phosphor screen of the image intensifier to the CCD sensor.

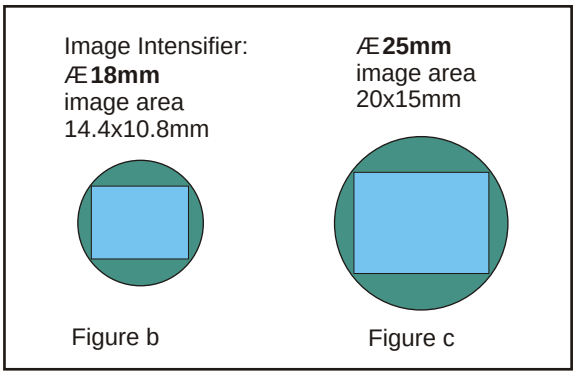


Figure b and c: Lens coupling provides full coverage of the CCD sensor (no dark corners) and highest image resolution.

Automatic continuous cleans
The CCD sensor is automatically cleared before triggering at trigger frequencies below 4Hz. This ensures the best and most efficient reduction of CCD sensor background noise.

High dynamic range
The CCD sensor provides up to 14bit dynamic range. Furthermore, the CCD sensor gain can be adjusted from 0 to 20db. In combination this results in 17bit dynamic range of the CCD sensor.

High fill factor
The interline CCD sensor provide highest fill factors using micro lens arrays on top of the active pixels.

CCD sensor cooling
Intensified CCD cameras do not need actively cooled CCD sensors, since, the incident photon signal is pre-amplified by the image intensifier. Therefore, the S/R ratio is rather limited by the image intensifier EBI and ion feedback than by the CCD sensor background current and readout noise.

CCD sensor options

Parameter	High resolution HR CCD sensor	Standard resolution SR CCD sensor	CCIR / EIA analog CCD sensor
Resolution	1360x1024	780x580	752x582 / 768x494
Pixel size [µm]	4.7x4.7	8.3x8.3	8.6x8.3 / 8.4x9.8
Camera interface	USB 2.0 or CameraLink (CL)	USB 2.0 or CameraLink (CL)	analog video, RS 232
Binning options	full frame, 2 (2x2binning), ROI (region of interest)		-
Dynamic range	12 or 14 bit	12 or 14 bit	8 or 10 bit
Video gain [dB]	full and ROI: 0..20db; 2x2: 0..25db		-
Chip readout	Correlated double sampling, dark current corrected		

Time settings

Superior timing control with on-board delay generator

The **on-board digital** delay generator provides accurate timing control of the photocathode gating. All true flat top optical gating times are measured in single shot measurements. These measurements do not include the positive influence of signal jitter in integrating measurements.

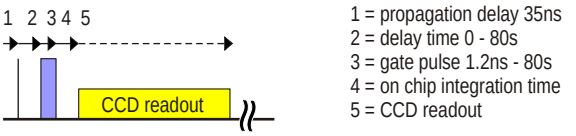
Time settings

Parameter	4 Quik E
Gate time [step size]	1.2ns … 80s [100ps]
Delay time [step size]	0.1ns … 80s [100ps]
Jitter	0.02ns
Minimal dead time between multiple exposures	300ns
Minimal interframing time (optional double frame mode*)	500ns
Trigger propagation delay	internal gate pulse: 60-65ns external gate pulse: 30-35ns

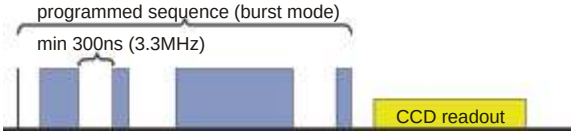
** image intensifiers with P46 phosphor screen*

Operation modes

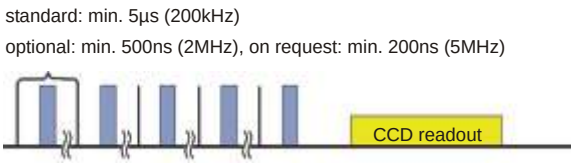
Single frame mode
The standard operational mode of our ICCD cameras allows the independent control of photocathode gating and CCD sensor.



Integrate-on-chip: Programmed sequence (burst mode)
Any time sequence consisting of multiple gate and delay times can be applied to the photocathode. The minimum delay time is 300ns corresponding to 3.3MHz gate repetition rate.

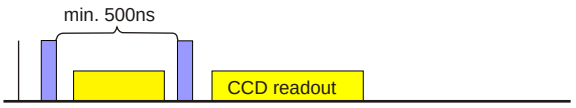


Integrate-on-chip: Multiple triggering (continuous)
This mode enables a continuous photocathode gating series on individual trigger signals with a predefined delay and gating time. The camera provides by default 200kHz, optionally 2MHz and on request 5MHz repetition rate. This mode is used e.g. for synchronization with high repetition rate lasers.



External gate control
Allows the direct control of the photocathode gating via an external TTL pulse and provides the shortest delay between external trigger and photocathode gating.

Optional: Double frame mode
Image intensifiers with P46 phosphor screen allow to capture two seperate full-size, full-resolution images with a interframing delay as short as 500ns. This mode is applied e.g. Particle Imaging Velocimetry (PIV) or particle size analysis.

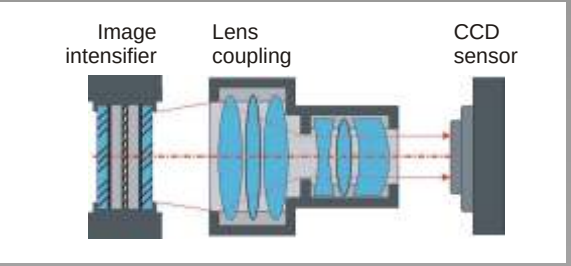
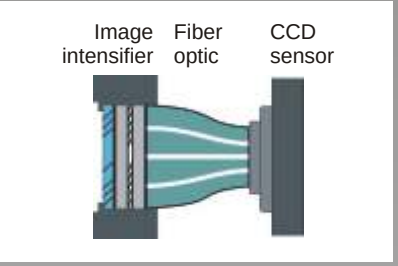
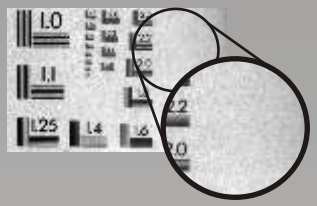


Lens coupling system

The lens coupled ICCD cameras provide superior image quality.

All 4 Quik E ICCD cameras are equipped with the in-house developed, customized f/0.8 lens coupling system. It provides superior imaging quality without compromising distortion, resolution and vignetting. In contrast to other claims the lens coupled ICCD camera systems provides single photon detection and high S/N ratio at low light environment. The stray light is reduced using convenient anti-reflex coatings which results in magnificent optical contrast. Furthermore, in combination with the adjustable MCP voltage it proves high dynamic range, large linearity and ensures a great life span of the imaging system.

Coupling image intensifier ® CCD sensor comparison

Parameter	F/0.8 lens coupled ICCD camera	Fiber-optic coupled ICCD camera
		
Example		
Advantages	+ excellent coupling efficiency by F/0.8 lens + superior image quality · highest modulation transfer function (cut off @ 180lp/mm) · **NO honeycomb pattern** · **NO vignetting** · **NO distortion** (<0.03%) + cost efficient + variable setup (e.g. easy repair and replacement of each single component, especially image intensifier)	+ good coupling efficiency + compact design
Disadvantages	- stretched design	- poor image quality · lower modulation transfer function · distortion > 3% · **CLEARLY visible honeycomb pattern** - cost intensive - fixed structure e.g. no repair or replacement

In summary the fiber-coupled ICCD camera systems provide lower image quality and less flexibility in combination and maintenance. Whereas the often claimed much better coupling efficiency diminish after taking into account the coupling loss, the core-cladding-ratio of the fibers and the significant loss of the fiber optic due to diameter reduction. On the other hand the customized F/0.8 lens coupling system provides best intensified image quality, high flexibility and excellent coupling efficiency.

4 Spec E software

4 Spec E provides the perfect tools for ICCD camera operation: camera control, image editor, spectroscopy analysis and data handling

Standard features and benefits
- ❑ Camera control, image editor, spectroscopic analysis and data handling
- ❑ Fastest acquisition of spectra
- ❑ Dynamic range up to 32bit
- ❑ Real time sequence to hard disk
- ❑ Data import/export curves as text, raw data, TIFF file, BMP file

Optional features
- ❑ LabVIEW API

Camera control
The camera control interface of the 4 Spec E software provides a comfortable and intuitive interface for the remote control of all ICCD cameras from Stanford Computer Optics.

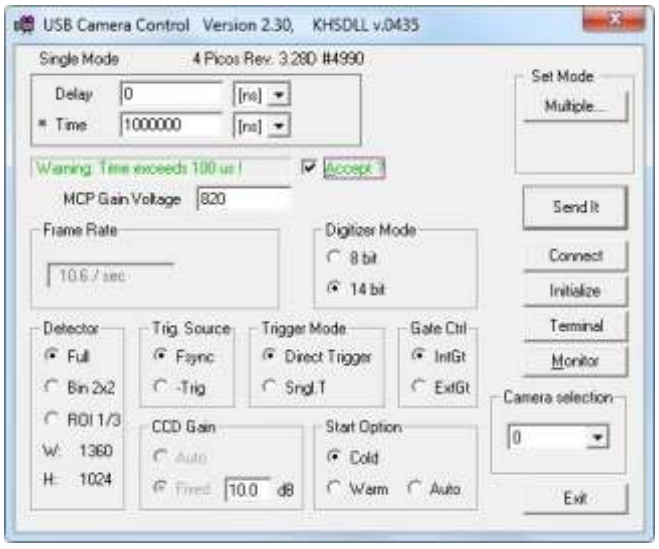
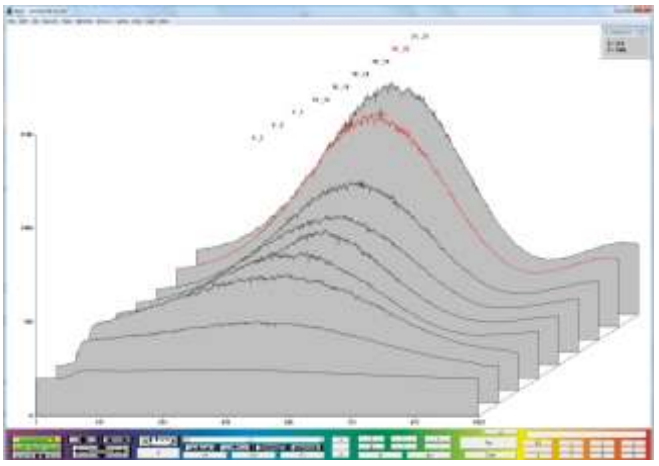


Image editor
The image editor gives direct access to the acquired images and allows basic image correction like background subtraction and flat field correction.

Spectroscopy analysis
4 Spec E software provides extended functions for spectroscopy applications. It enables the spectrum extraction from the 2D raw images, the spectrum handling and calibration. Moreover it provides multiple tools for data presentation and storage.



LabVIEW API for 4 Spec E
A LabVIEW API is available optionally to the 4 Spec E software. It is not a stand alone solution and uses the 4 Spec E basis. With this API the user gain full control of the ICCD camera within the LabVIEW environment.

4 Spec E software

Item-No.	Name of product	Description
LA-4SpecE	4 Spec E, Version 2.2	camera control, image-data acquisition and video spectroscopy software for the PC. Intel Pentium® or subsequent, Microsoft® Windows XP, Vista, Windows 7 (x32, x64 Version)
LA-LV	LabVIEW API	the LabVIEW API is no stand alone solution and uses the 4 Spec E basis for full control of the ICCD camera.

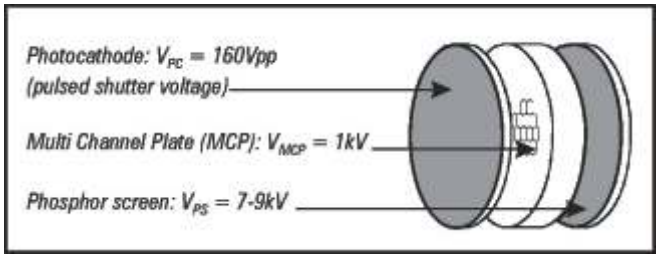
High performance image intensifier

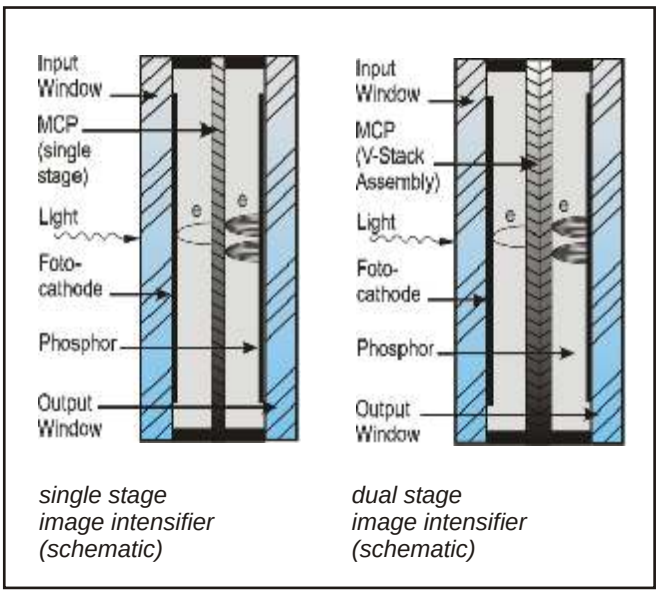
Guidance to make the right choices in order to get the most suitable image intensifier.

The image intensifier is a key component of each ICCD camera. This section deals with the fundamental characteristics of image intensifiers and their options.
Different applications of ICCD cameras have different demands and requirements on the camera and thus on the image intensifier.

Following questions need to be addressed

- What are the spectral characteristics of illumination?
  → Does determine the suitable photocathode.
- What spatial resolution is neccessary?
  → Does determine the size of the image intensifier.
- How fast need to be the shutter/shortest gating time?
  → Highest shutter speed does have some constrains to e.g. size of the image intensifier.
- How much light is there?
  → Dual stage MCP's have better performance at low light environments.
- High speed or low light imaging?
  → Does determine the suitable phosphor screen.





single stage image intensifier (schematic)

dual stage image intensifier (schematic)

First the incoming photon releases an electron in the photocathode, second the electron is accelerated and amplified to an electron avalanche within the multi-channel plate (MCP), third the accelerated electrons are converted into photons by the phosphor screen.

Photocathodes

	Type	Nb	Spectral range	
Standard	S20	I	UV - VIS	approx. 165 - 820nm
	S25	II	VIS - IR	approx. 350 - 920nm
Optional	S20 (MgF2)*	III	UV - VIS	approx. 110 - 820nm
	Broadband*	IV	UV - IR	approx. 190 - 920nm
	Solar Blind*	V	UV	approx. 180 - 340nm
	S1*	VI	IR	approx. 700 - 1300nm

** Please ask for availability in advance for 18 or 25mm MCP and 1.2ns minimum gate time.*

Image intensifier specifications

Diameter
The diameter of the image intensifier is one key parameter. The 18mm image intensifier provides high shutter speed and a higher specific resolution than the 25mm image intensifier. This makes the 18mm image intensifier to the standard and most suitable to many applications of ICCD cameras. If you are looking for the best spatial resolution with the drawback of slower shutter speeds the 25mm image intensifier is the preferred choice.

Shutter speed
The shutter speed is limited by the speed of light since any electromagnetic signal does not travel faster. Due to this physical constraint the shutter of the 25mm image intensifier is slower.

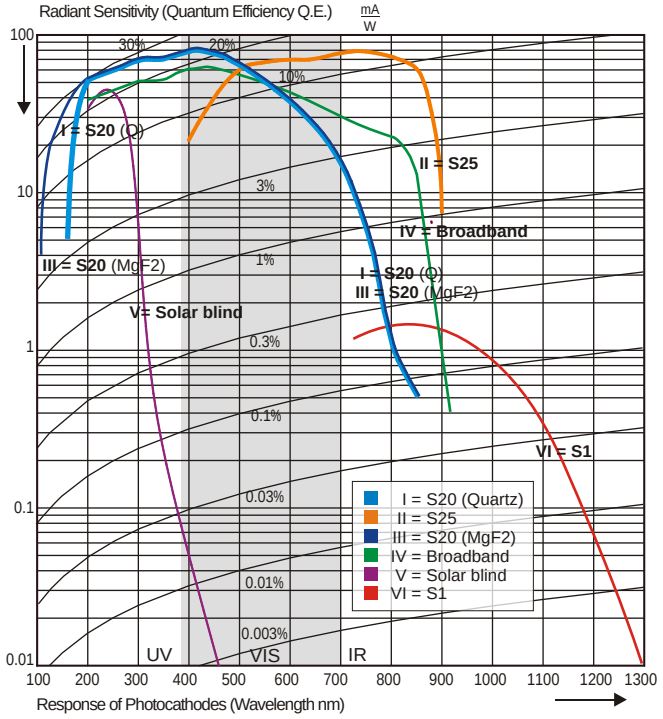
Input window
The standard input window is made of quartz. This limits the UV spectral range below 165nm. The optional Magnesium Fluoride (MgF2) window enables measurements down to 110nm.

Photocathode
Photocathodes define the sensitivity and the spectral response of the image intensifier.

Phosphor screen
There are three important considerations in choosing a luminous (phosphor) output screen.

1. spectral emission range
2. efficiency
3. phosphor decay time

The P43 phosphor screen has a higher efficiency, however, a longer decay time. For fast applications e.g. double frame mode with interframing time of 500ns the P46 phosphor screen is neccessary to avoid gost images from the previous exposure.



Multi-channel-plate (MCP)
Image intensifiers can be equipped with single or double stage MCP's. The single stage MCP features excellent signal gain and fits most applications of the ultra high speed ICCD cameras.

The V-stacked double MCP's are especially used for extreme low light environments. The increased electron multiplication provide single photon detection with increased signal to noise ratio and reduced ion feedback noise. Therefore, the double MCP is mainly used for long exposure measurements and extreme low light applications

Phosphor screen

Type	Composition	Efficiency	Decay time		Emission spectral range
			90% to 10%	10% to 1%	
P43	$Gd_2O_2S:Tb$	185 ph/e @6kV	1.5ms	3.3ms	360 - 680nm
P46	$Y_3Al_5O_{12}:Ce$	90 ph/e @6kV	0.2µs	10µs	490 - 620nm

Micro-channel-plate (MCP)

Type	Electron multiplication	S/N ratio	Notice
Single stage	up to 10^3	very good	best image quality
Double stage	up to 10^6	excellent	highest sensitivity

Connection options

4 Quik E camera: Multi-purpose and user-friendly intensified imaging

The 4 Quik E ICCD camera is equipped with the most reliable and dependable electronics. This combines long-life cycle, easy handling and best performance with ultra low jitter and ultra low propagation delay. Multiple TTL input and output connectors enable a multi-purpose usage of the 4 Quik E ICCD camera. Due to this flexibility the 4 Quik E ICCD camera is valued and esteemed by researcher in many fields of study and engineers throughout different industries.

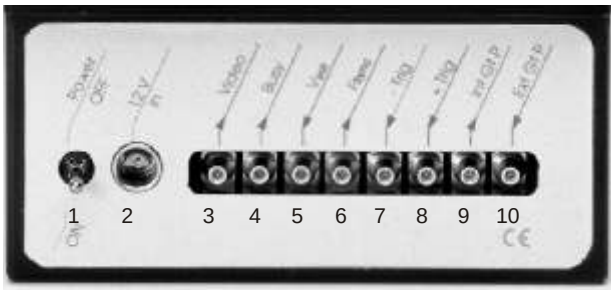
I/0 Connectors

1 Power Switch
ON/OFF

2 Power supply socket
Supply voltage of 12V approx. 1amp without cooling 2.5amp. max with cooling

3 Video
(only analog CCD sensor) Output analog video signal for the frame grabber card.

4 Busy
TTL output signal; this timing circuitry busy signal can be used as external trigger for a frame grabber or other instruments. It is an active low signal but on special request it can be changed to active high.



5 Vinit
(only analog CCD sensor) TTL input signal; Reset the analog CCD sensor for synchronisation purposes

6 FSync
TTL output signal; reference signal synchronous to the internal CCD sensor in free running mode.

7 -Trig
TTL input trigger; Input for external trigger on negative edge ±20V max. for short time periods transition at 1.3V.

8 +Trig
TTL input trigger; Input for external trigger on positive edge ±20V max. for short time periods transition at 1.3V.

9 IntGtP - TTL output signal
Gate monitor output provides reliable timing information on actual gating occurrence with internal time generator or external gating pulse.

10 ExtGtP - TTL input signal
Direct access of the photocathode gating via external TTL source. A negative logic CMOS signal is necessary (low for shutter open). The transition voltage level is 2.5V.

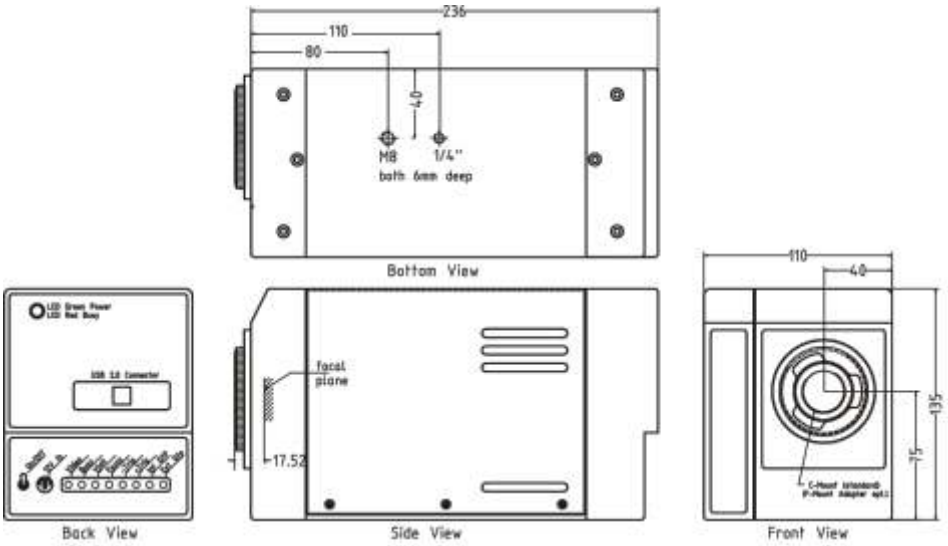
Multiple camera-PC connection types are available for the 4 Quik E ICCD camera. The USB 2.0 connection provides a convenient interface for laptops and integration of multiple cameras on a single workplace. Furthermore, the USB 2.0 connection enables the remote control of the ICCD cameras at large distances. The CameraLink connection provides highest frame rates with the drawback in limited flexibility due to the usage of a frame grabber. In addition to these digital connection types the 4 Quik E ICCD camera can be also equipped with a analog CCD sensor in combination with a frame grabber.

Camera PC connections

Description	USB 2.0	CL CameraLink	Analog
Additional required equipment	-	PCI CameraLink card	PCI analog card
Frame rate standard resolution	14.1 / 25.3 / 27.1fps	33.8 / 60.8 / 67.0fps	50/60 Hz (EIA/CCIR)
Frame rate high resolution	8.8 / 14.8 / 20.7fps	10.6 / 17.9 / 20.9fps	-
(1x1 / 2x2 / 1/3 ROI	full / bin / ROI	full / bin / ROI	-

Dimensions

Compact and light design



Mechanical and environmental data

Parameter	Description
Camera weight (all in one)	3kg / 6.6lb
Camera dimensions without lens	248 x 110 x 135mm (l x w x h)
Camera mount	1/2" and M8 mounting holes
Operating humidity	25..95%, non condensing
Operating temperature	0°C - 50°C / 32°F - 122°F
Performance specification	10°C - 40°C / 50°F - 104°F
Operating limits	-10°C - 50°C / 14°F - 122°F
Shock and vibration	60g accel. shock, 7g Vibration (11 - 200Hz), excludes MCP in direct frontal impact
Voltage	90..260VAC

Extended warranty on all products from Stanford Computer Optics

2 years
on mechanics and electronics
Stanford Computer Optics Inc. warrants all new products to be free from defects in materials and workmanship for 24 months from the date of dispatch.

1 year on image intensifier
Image intensifiers are subject to the original manufacturer's warranty conditions. It comprises a warranty of 12 months. In case of any defect the Paul Hoess KG or Stanford Computer Optics Inc. will assist for repair or replacement.

Warranty restriction
Warranties do not cover normal wear, misuse, negligence or accident. They do not apply to goods which have been misused, altered, inadequately maintained, stored incorrectly, or negligently installed or serviced.

4 Quik E family

Customize the optimum 4 Quik E ICCD camera for your application

The 4 Quik E ICCD camera enables the customization to the requirement and needs of your experiment. This guarantees best performance in combination with superior intensified imaging. Please follow the indicated four step process to get the best and most suiting ICCD camera for your application.

Customize the 4 Quik E camera in 4 steps:

1. Select the minimum gating time
2. Select the optimum image intensifier
3. Choose the ideal CCD sensor
4. Pick the required accessories

1. Minimum gate time

If the preferred minimum gate time is 1.2ns the 4 Quik E is the camera of your choice.

For shorter times please see our 4 Picos ICCD camera with min. gate time down to 200ps.

2. Image intensifier

2.1. Diameter
- 18mm or
- 25mm

2.2. Photocathode
- S20 (I) or S25 (II)
- others on request
  see details on page 8
- input window: quartz or MgF2 on request

2.3. Multi-channel plate (MCP)
- single or
- dual stage (optional)

2.4. Phosphor screen
- P43 standard
- P46 optional (for dual frame mode)

3. CCD sensor and camera connection

3.1. Digital
- with USB 2.0 or
- CameraLink (with frame grabber)

3.1.1. Resolution of CCD sensor
- standard resolution: 780 x 580 pixel
- high resolution: 1360 x 1024 pixel

3.1.2. Dynamic range of CCD sensor
- 12bit or
- 14bit

3.2. Analog
with frame grabber
- 25/50Hz (EIA) or
- 30/60Hz (CCIR)

Please contact our sales team to get assistance and further details to these options.

4. Selection of optional accessories and adapters

Item-No.	Name of product	Description
LA-LMA-...	lens mount adapter	selection of adapter for various lens mount systems (e.g. F-mount, EOS) providing full aperture and reduced stray light by black anodized aluminum
LA-SGA-...	spectrograph adapter	selection of adapter for all common spectrograph manufacturer e.g. Acton, Horiba and Jobin Yvon, others on request
LA-VF	vacuum flange	customized flange to connect the ICCD camera to any vacuum tube
LA-SMB-BNC	SMB-BNC	SMB - BNC adapter cables in any length
LA-IOL-...	input objective lens	various input objective lenses e.g. Pentax UV lens 25mm, F2.8-16; Pentax UV lens 78mm, F3.8-16F3.8-1, others on request

Applications

4 Quik E ICCD camera provides user-friendly intensified imaging for numerous, different applications

Hyper-Rayleigh measurements
e.g. by M. R. Beaudin from the Carleton UniVersity, Canada: Chem. Mater.,18,1079-1084, 2006

Combustion imaging
e.g. by I.Y. Ohm from the Seoul National University, South Korea: International Journal of Automotive Technology, Vol. 12, Issue 5, 2012

Electrical breakdown measurements
e.g. by K. Schoenbach from the Old Dominion University, United States:
Plasma Sources Sci. Technol., Vol. 17, Issue 2, 2008

Fluorescence spectroscopy
e.g. by S.E. Saari from the Tampere University of Technology, Finland:
Atmospheric Environment, Vol. 71, 2013

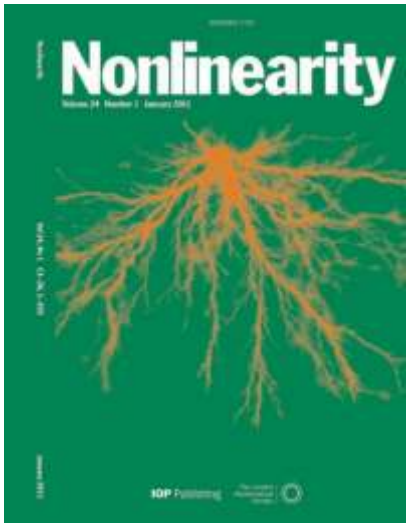
Spray and flow imaging
e.g. by H. K. Suh from the Hanyang University, South Korea: Atomization and Sprays, Vol. 17, Issue 7, 2007

Laser induced breakdown spectroscopy (LIBS)
e.g. by S. T. Järvinen from the Tampere University of Technology, Finland: Spectrochimica Acta Part B: Atomic Spectroscopy , Vol. 86, 2013

Raleigh scattering
e.g. by J. Campo from the University of Antwerp, Belgium:
Optics Express, Vol. 17, Issue 6, 2009

Time-resolved optical emission spectroscopy
e.g. by R. M. van der Horst from the Eindhoven University of Technology, The Netherlands:
J. Phys. D: Appl. Phys., Vol. 45, Issue 34, 2012

Streamer discharge research
e.g. by U. Ebert from the CWI Amsterdam, The Netherlands: Nonlinearity, Vol. 24, Issue 1, 2011



Feather-like structures in a positive streamer discharge in pure argon at room temperature and atmospheric pressure. The image is recorded with the 4 Quik E ICCD camera and represents about 40mm of the discharge gap with the electrode tip in the top center. The blurred structures are out of focus.

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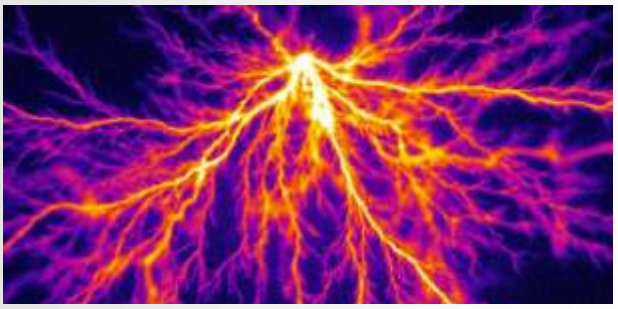

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