STANFORD
COMPUTER
OPTICS

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

https://stanfordcomputeroptics.com

STANFORD
COMPUTER
OPTICS

4 Quik E ICCD camera

High speed intensified CCD camera

Based on more than 30 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.

More detailed information

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 100 kHz 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 red (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 100kHz (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 3.0 (standard), GigE (optional) output
- Remote interface for real time camera control
- Compact and light system design
- 4 Spec software

Optional features

- Nikon F-Mount Adapter
- Two discrete images with double frame mode (interframing time 500ns) with P46 posphor
- Adapters for various spectrometer
- Vacuum flange for UHV connection

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 high QE 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.

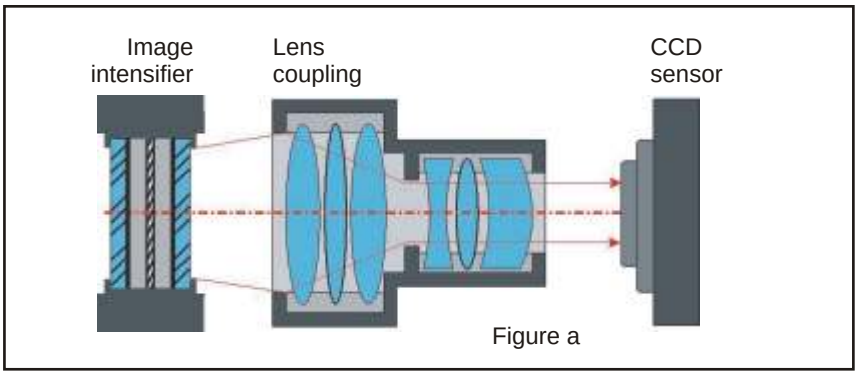


Figure a: Schematic sketch of the lens coupled intensified CCD camera. The appropriate coupling lens images the phosphor screen of the image intensifier to the CCD sensor.

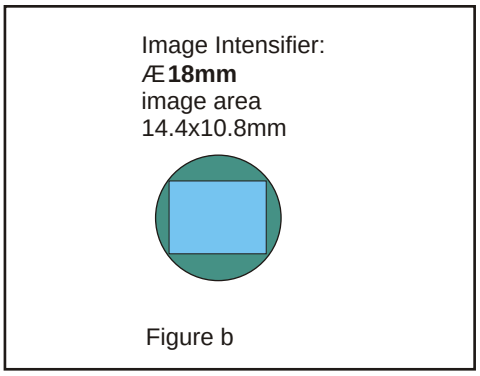


Figure b: Lens coupling provides full coverage of the CCD sensor (no dark corners) and highest image resolution.

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 NOT necessary
Intensified CCD cameras do not need actively cooled CCD sensors since the incident photon signal is pre-amplified by the image intensifier. Therefore, the SNR 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
Resolution	1360 x 1024	780 x 580
Pixel size [µm]	4.7 x 4.7	8.3 x 8.3
Camera interface	USB 3.0 (GigE optional)	USB 3.0 (GigE optional)
Binning options	full frame, 2 (2x2 binning), ROI (region of interest)	
Dynamic range	12 or 14 bit	12 or 14 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

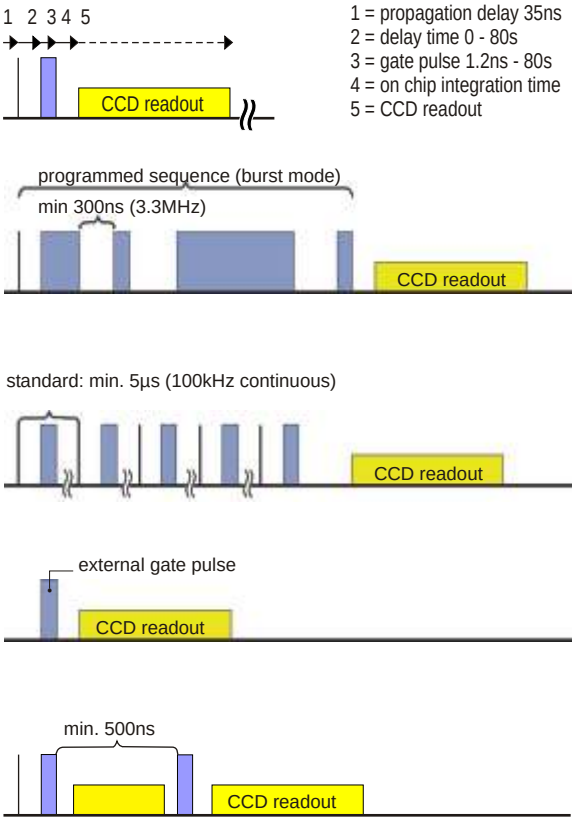
Single frame mode
The standard operational mode of our ICCD cameras allows the independent control of photocathode gating and CCD sensor.

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 100kHz.

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.

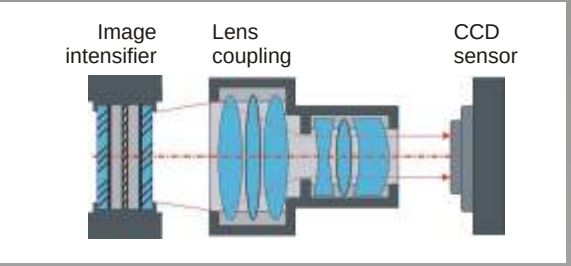
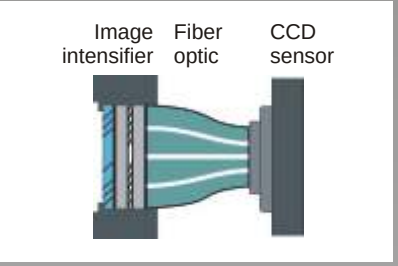
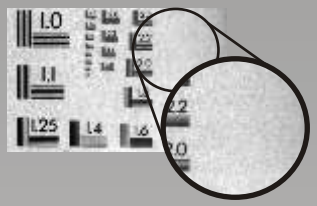


Lens coupling system

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 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 0.2ns.

2. Image intensifier

2.1. Photocathode
- high QE UV
- optional: high QE blue
  high QE red
  (see details on page 9)
  (high QE green cancelled)
- input window: quartz
  or MgF2 (UV) on request

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

2.3. Phosphor screen
- P43 standard
- P46 optional
  (requested for 500ns fast dual frame mode)

3. CCD sensor

3.1. Digital output
- standard: USB 3.0
- optional: GigE

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

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

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
F-Mount	lens mount adapter	selection of adapter for various lens mount systems (F-mount) providing full aperture and reduced stray light by black anodized aluminum
SGA-...	spectrograph adapter	selection of adapter for some spectrograph manufacturer standard Zolix, optional: e.g. Acton, Horiba and Jobin Yvon, on request
VF	vacuum flange	customized flange to connect the ICCD camera to any vacuum tube
SMB-BNC	SMB-BNC	SMB - BNC adapter (12cm standard), other length on request

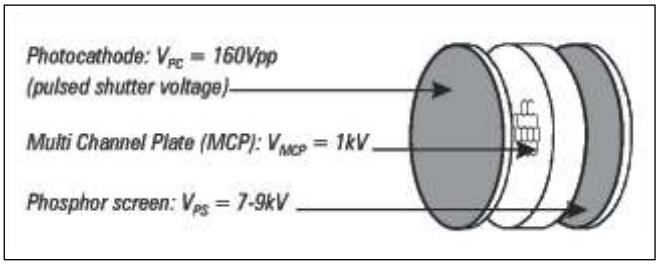
High performance image intensifier

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.

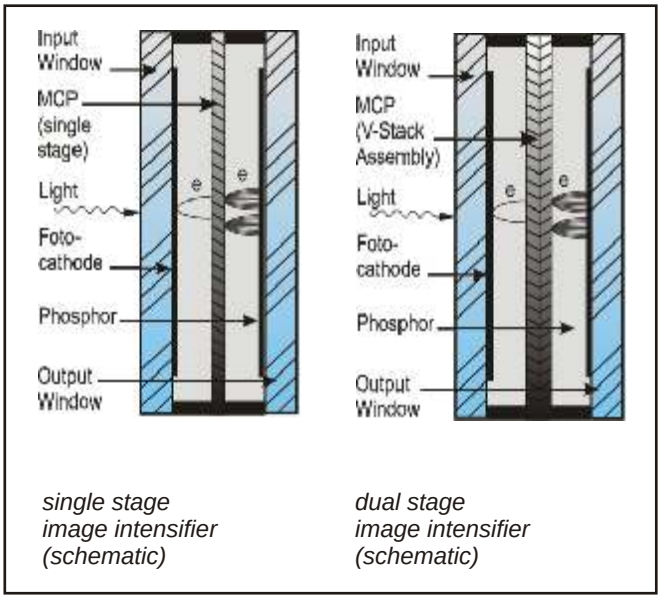
Following questions need to be addressed

- What are the spectral characteristics of the illumination?
  → Does determine the suitable photocathode.
- 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 but 30% less image resolution compared to single stage.
- High speed or low light imaging?
  → Does determine the suitable phosphor screen.



GenII High QE photocathodes
Gen II high Quantum Efficiency photocathodes are providing the best spectral responsibility performance.

We do not use GenIII image intensifiers
because of the following disadvantages:
1. Service life is 50% less than for GenII image intensifier
2. GenIII are much more expensive than GenII
3. GenIII image intensifier have higher dark current
4. There may be more black spots in imaging



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.

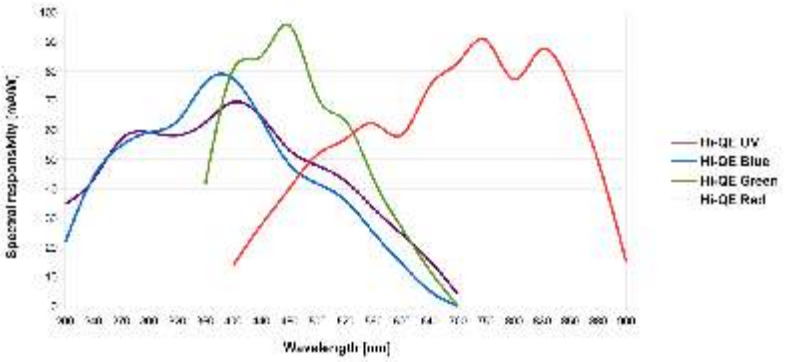
Photocathodes

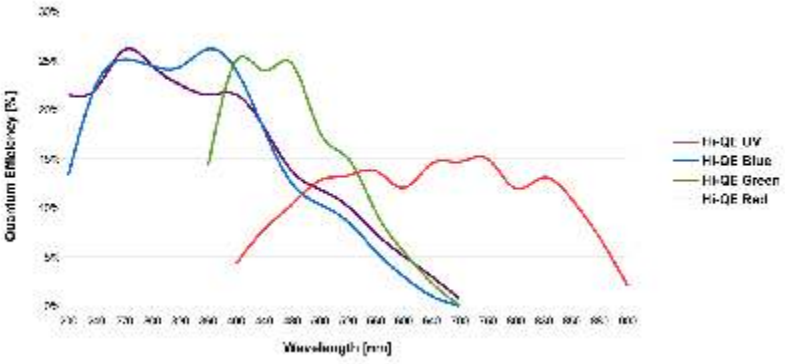
	Type	Spectral range
Standard	High QE UV	approx. 180 - 700nm
Optional	High QE UV, MgF2	approx. 110 - 700nm
	High QE blue	approx. 200 - 700nm
	High QE red	approx. 400 - 900nm
	(*High QE green cancelled in 2021)*	*approx. 360 - 700nm*

Image intensifier specifications

Shutter speed
The shutter speed is limited by the speed of light since any electromagnetic signal does not travel faster.

Input window
The standard input window is made of quartz. This limits the UV spectral range below 200nm. The optional Magnesium Fluoride (MgF2) window enables measurements down to approx. 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

Upper graph: Spectral responsitivity [mAW]
Lower graph: Quantum Efficiency [%]

Phosphor screen

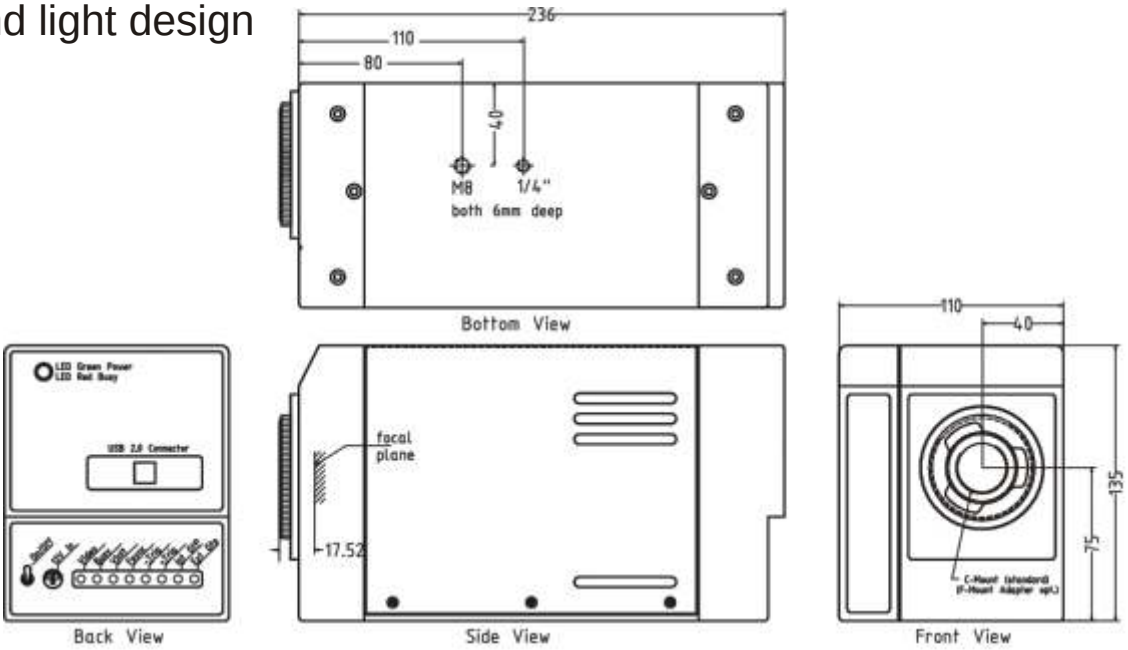
Type	Composition	Efficiency	Decay time		Emission spectral range
			90% to 10%	10% to 1%	
P43	Gd_2O_2S:Tb	185 ph/e @6kV	1.5ms	3.3ms	360 - 680nm
P46	$Y_3Al_5O_{12}$:Ce	90 ph/e @6kV	0.2µs	10µs	490 - 620nm

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

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.

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

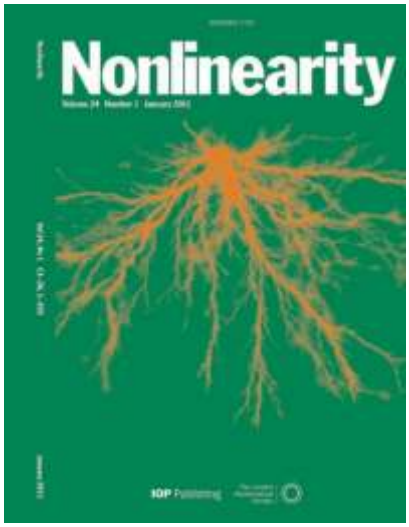
Spray and flow imaging
e.g. by H. K. Suh from the Hanyang University, South Korea: Atomization and Sprays, Vol. 17, Issue 7, 2007

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.

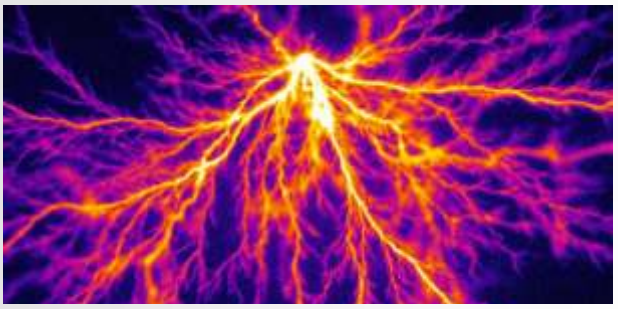
Reprinted figure with permission from U. Ebert et al., 2011 Nonlinearity 24 C1. Copyright (2011) by IOP Publishing Ltd. The figure appeared also on the cover of Nonlinearity Vol. 24 (2011) and was published originally in figure 7 of S. Nijdam et al., 2010 J. Phys. D: Appl. Phys. 43 145204.

STANFORD
COMPUTER
OPTICS

Superior imaging intensified CCD cameras

4 Quik E

High speed ICCD camera



1.2ns high shutter speed

Best imaging quality

Single photon detection

Compact and light design

Contact

Europe/Asia: Paul Hoess KG
Entenbachstr. 14 - 81541 Muenchen, Germany
Phone: +49 (0)89 652029 Fax: +49 (0)89 654817
E-mail: europe@stanfordcomputeroptics.com
https://stanfordcomputeroptics.com

USA/Canada: Stanford Computer Optics, Inc.
780 Cragmont Avenue - Berkeley, CA 94708, USA
Phone: +1(510) 527-3516 Fax: +1(510) 558-9582
E-mail: info@stanfordcomputeroptics.com