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Stanford Computer Optics, Inc.
and Paul Hoess KG

ICCD cameras

200ps highest shutter speed
Best distortion free imaging quality
Up to eight intensified channels / 16 frames
Single photon detection
Compact and light design

How to assemble the optimum ICCD camera in four steps

www.stanfordcomputeroptics.com

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Based on more than30 years of experience in the development and progression of world-class, ultra high speed Intensified CCD (ICCD) cameras, Stanford Computer Optics sets new standards with superior distortion free intensified imaging technology.

The products from Stanford Computer Optics cover the complete range of intensified imaging. All-in-one-head ICCD cameras with high speed shutter systems providing gating times down to the picosecond regime.

15 Years ago, the ultra high speed framing camera, XXRapidFrame based on the 4 Picos or 4 Quik E ICCD camera technology, was introduced to our customers. Since 2014 this multi-channel camera is available with up to eight independently controllable channels in a compact housing.

Additionally to the hardware, Stanford Computer Optics offers the 4 Spec software as a perfect and highly comfortable tool for providing camera control, image editor, spectroscopy and data handling.

How to assemble the optimum ICCD camera in four steps

The Stanford Computer Optics ICCD cameras enable 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 your ICCD camera in 4 steps

Step 1: Minimum gate time

1.1 down to 0.2ns:
4 Picos is the “ICCD camera of your choice”

1.2 down to 1.2ns
4 Quik E is the “ICCD camera of your choice”

Step 2: ideal CCD sensor

3.1. Resolution
Standard Resolution SR
780 x 580 pixel
High Resolution HR (optional)
1360 x 1024 pixel

3.2. Dynamic range
12bit (standard)
14bit (optional)

3.3. Camera connection
USB 3.0 (standard)
GigE (optional)

Make your selection!

Step 3: Image intensifier

2.1. Photocathode
high QE UV (standard)
optional: high QE blue,
high QE green,
high QE red
standard input window: quartz
optional: MgF2 (UV)

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

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

Step 4: Selection of optional accessories and adapters

Item-No.	Name of product	Description
N1-LMA-F	lens mount adapter	F-Mount adapter providing full aperture and reduced stray light by black anodized aluminum
N1-SGA-...	spectrograph adapter	selection of adapter for the most common spectrograph manufacturer on request (e.g. Acton, Horiba, Jobin Yvon)
N1-SMB-BNC	SMB-BNC	SMB - BNC adapter cables in any length (12cm standard included)

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

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Step 1: minimum gate time

Ultra high speed ICCD cameras providing gating times of 0.2ns and 1.2ns

The 4 Picos-dig and 4 Quik E-dig ICCD cameras contain the very best from CCD sensor and gated image intensifier technologies. They achieve a superior combination of rapid acquisition rates and ultra-high sensitivity down to single photons. Exceptional detection performances are accessed through high quantum-efficiency (QE) image intensifiers, up to 3.3MHz photocathode gating rates.
Extreme low jitter, low insertion delay gating electronics and picosecond-scale optical gating provide excellent timing accuracy, allowing ultra-precise synchronisation of complex experiments through 4 Picos and 4 Quik E ICCD camera series.

ICCD camera technology
4 Picos and 4 Quik E

Standard features and benefits
4 Picos ICCD camera
✓200 picosecond fastest gating time
✓Gating time adjustable in 10ps steps
✓Jitter <10ps

4 Quik E ICCD camera
✓1.2 nanosecond fastest gating time
✓Gating time adjustable in 100ps steps
✓Jitter <20ps

General features and benefits
✓True optical flat top measurement
✓High resolution image intensifier
18mm: Image area 14.4 x 10.8mm
✓Customized 6-element f/0.8 relay coupling lens assures distortion free, vignetting free, honeycomb free imaging
✓Digital output : either USB 2.0 or USB 3.0 or GigE (make your choice with order)
✓Highest gating repetition rate
1MHz continuous (one hour max)
✓Free programmable gating sequence
✓Real-time remote control of all camera parameters
✓Incorporated Single Trigger Discriminator (STD)
✓Multiple gate repetition delay time 0.3µs
✓12V D/C power supply with cables
✓Weight: 3kg (all in one head)
✓Dimensions: 248 x 110 x 135mm (l x w x h)

Optional features
❑ 3MHz continuous photocathode gating
❑ Dual stage multi-channel plate (MCP) for highest S/N ratio and single photon detection
❑ P46 double frameing with 500ns interframing delay
❑ Choice of adapters for different lens mount systems
❑ Choice of adapters for all major spectrograph manufacturers on request

Applications
❑ Non scanning 3D laser scanner
❑ Ultra high speed lightning dynamics
❑ Fluoreszenz lifetime measurements
❑ Exponential decay measurements
❑ Combustion dynamics
❑ Time resolved spectroscopy

Note: 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.

Technical details for Step 2: ideal CCD sensor

CCD sensor options

Parameter	Standard resolution SR CCD sensor	High resolution HR CCD sensor (optional)
Resolution	780 x 580	1360 x 1024
Pixel size [µm]	8.3 x 8.3	4.7 x 4.7
Camera interface	optional USB 2.0 or USB 3.0 or GigE	optional USB 2.0 or USB 3.0 or GigE
Binning options	full frame, 2 (2x2binning), 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	

High speed ICCD camera specifications

Parameter	4 Picos-dig	4 Quik E-dig
Shortest gating time	0.2ns	1.2ns
Minimum delay steps	0.01ns steps	0.1ns steps
Image intensifier size	18mm	
Gate repetition rate	3.3MHz burst, 1MHz continuous (one hour max.); optional: 3MHz continuous	
Multiple exposures	free programmable sequence, min step 0.3µs	
Photocathode spectral range	120 - 900nm (not all in one, please see page 11 for more information)	
Frame rate frames/sec	up to 60fps	
Optical coupling	customized, distortion free, shading free, and vignetting free F/0.8 lens	
Delay and gate electronics	all integrated in the head (all in one)	
Weight / Dimensions	3kg; 6.6lb / 248 x 110 x 135mm	

Delay generator specifications

Parameter	4 Picos-dig	4 Quik E-dig
Gate pulse adjustable Software controlled	from 200ps to 80s in 10ps steps	from 1.2ns to 80s in 100ps steps
Gate delay adjustable Software controlled	from 0 to 80s in 10ps steps	from 0 to 80s in 100ps steps
Jitter	<10ps	<20ps
Trigger input	camera trigger neg/pos slope TTL pulse (-Trig/+Trig)	
External gate pulse	TTL input signal for direct control of photocathode gating (ExtGtP)	
Trigger output	multiple TTL output signals for synchronisation (Fsync, CCD-Busy) TTL output signal of photocathode gating pulse (IntGtP)	
Multiple exposures modes	double frame mode (two frames in 500ns interframing delay) multiple gating on single trigger multiple gating on multiple trigger free programmable gating sequence	
Trigger propagation delay	internal gate pulse: 60-65ns external gate pulse: 30-35ns	

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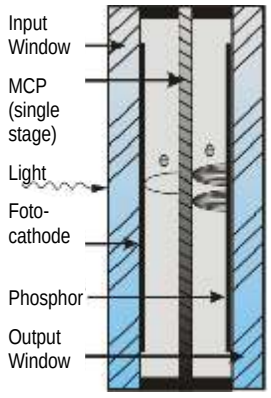
Technical details for Step 3:

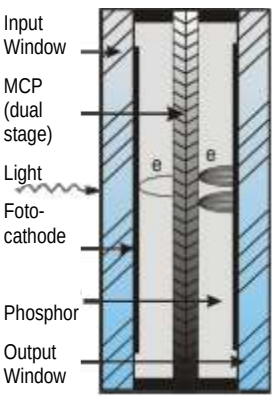
The image intensifier is a key component of each ICCD camera. This section deals with the fundamental characteristics of image intensifiers and their options.
Different applications of ICCD cameras have different demands and requirements on the camera and thus on the image intensifier.

Following questions need to be addressed

- How fast need to be the shutter/shortest gating time?
  1.2 ns or 0.2ns
- What are the spectral characteristics of the illumination?
  Does determine the suitable photocathode
- How much light is there?
  Dual stage MCP's have better performance at low light environments but lower sensitivity.
- High speed or low light imaging?
  Does determine the suitable phosphor screen, higher efficiency (P43) or fast double framing (P46).



single stage image intensifier



dual stage image intensifier

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.

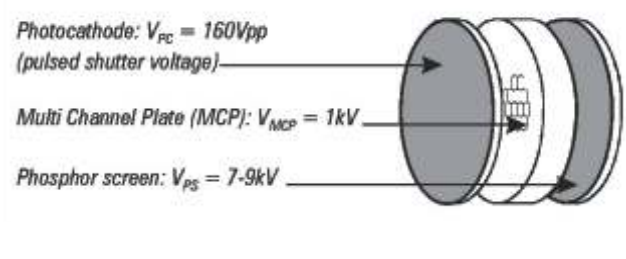
New:

Gen II High QE photo cathodes

The new Gen II high Quantum Efficiency photo cathodes are providing the best spectral responsibility performance.

Photocathodes

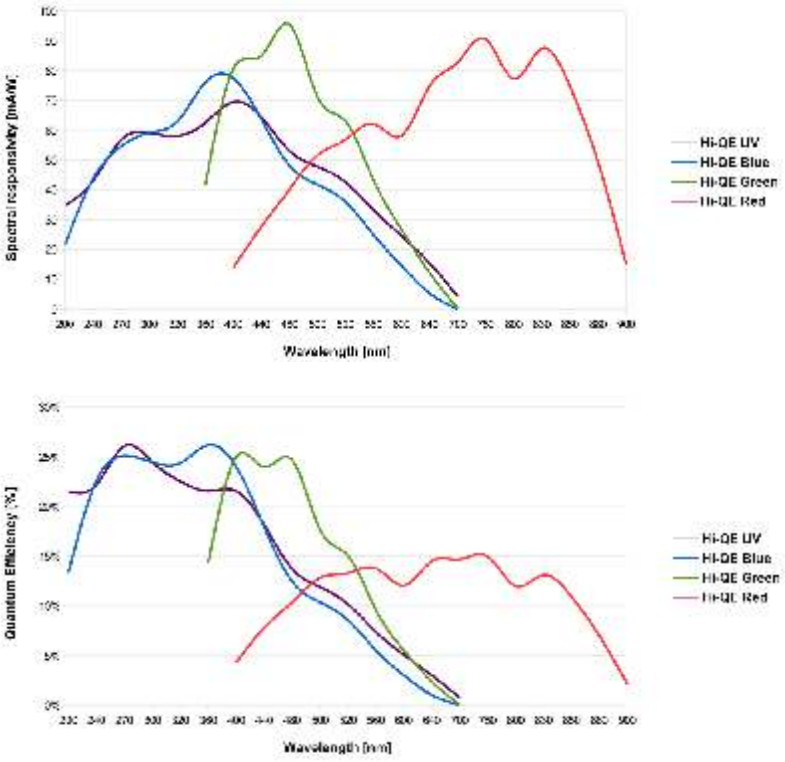
Type	Spectral range
Standard	
High QE UV	approx. 180 - 700nm
Optional	
High QE UV, MgF2	approx. 120 - 700nm
High QE blue	approx. 200 - 700nm
High QE green	approx. 360 - 700nm
High QE red	approx. 400 - 900nm



Choose the most suitable Image Intensifier

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. 120nm.



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

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4 Spec Vers. 3 software

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, BMP file

Camera control

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

Note

The new software involves changes in the hardware and therefore cannot simply be used as an upgrade.

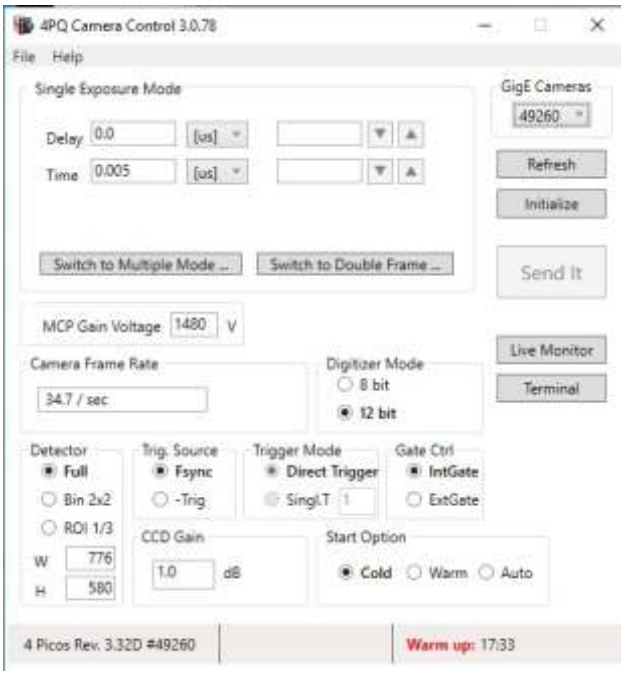
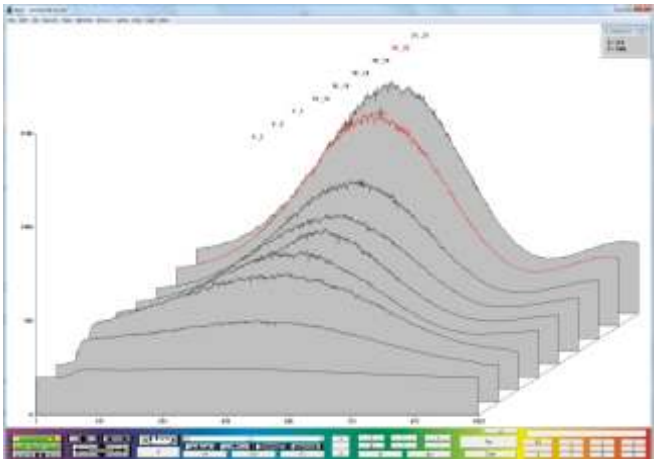


Image editor

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 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.



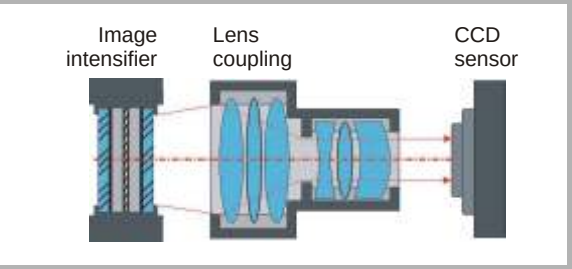
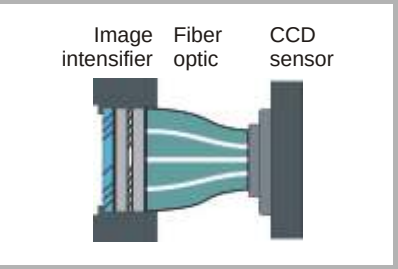
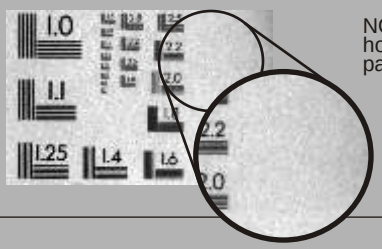
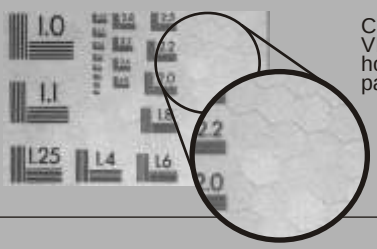
4 Spec software

Item-No.	Name of product	Description
N3-4Spec	4 Spec, Version 3	camera control, image-data acquisition and video spectroscopy software for the PC. Intel Pentium® or subsequent, Microsoft® Windows 10 (64bit)

The lens coupled ICCD cameras provide superior image quality

All Stanford Computer Optics ICCD cameras are equipped with the in-house developed f/0.8 lens coupling system. It provides superior imaging quality without compromising distortion, resolution and vignetting. The lens coupled ICCD camera system 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. In combination with the adjustable MCP voltage it proves high dynamic range, large linearity and ensures a great life span of the imaging system. In summary the fiber-coupled ICCD camera systems provide lower image quality and less flexibility. 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.

Coupling image intensifier → CCD sensor comparison

Parameter	F/0.8 lens coupled ICCD camera	Fiber-optic coupled ICCD camera
		
Example	 NO honeycomb pattern	 CLEARLY VISIBLE honeycomb pattern
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

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Superior imaging intensified CCD cameras

Multi-channel XXRapidFrame

The XXRapidFrame is a framing camera with up to eight ICCD channels.
The all-in-one-head design enables out of the box measurements and includes a single optical input, an image splitter unit and up to eight individually controllable channels.
It is available based on the 4 Picos or on the 4 Quik E ICCD camera technology with the shortest gating time down to 0.2ns and 1.2ns, respectively. The framing camera can take up to 8 images with an interframing delay as short as 10ps and 100ps, respectively.
This enables successive image sequences taken with a corresponding frame rate of up to 100 billion frames per second.
The custom optical design provides superior imaging without compromising resolution, shading, distortion or parallax. The mirror image splitter design ensures a constant intensity division over the entire spectral range. The optional UV enhanced splitting optics enables measurements from 200nm to 700nm (limited by the type of photocathode, page 6-7).

Standard Features and Benefits

- Multi-channel ICCD camera with 4, or 8 individual intensified CCD channels (the number of the channels must be decided with the order, later modifications are not possible)
- Based either on 4 Picos or 4 Quik E camera technology
- Total of 4, or 8 frames from one trigger
- Image sequences with up to 100 billion fps
- Trigger options: TTL, 100V or optical fiber
- Perfectly spectral flat image splitter
- Compact design: 625 x 325 x 375mm (body only)

Optional Features

- UV enhanced splitting optics from 200nm - 700nm
- Total of 8, or 16 frames from one trigger using double frame mode (with P46 phosphor)

Specifications of XXRapidFrame

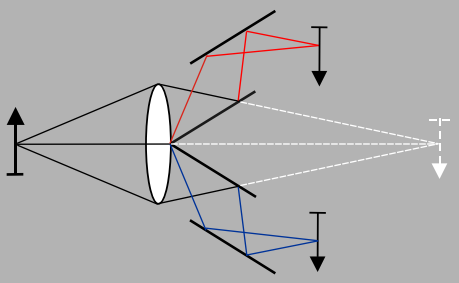
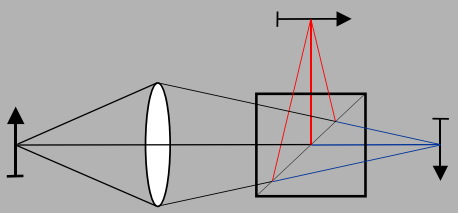
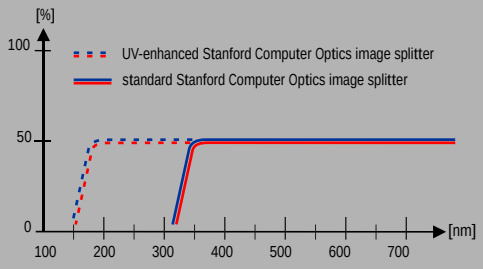
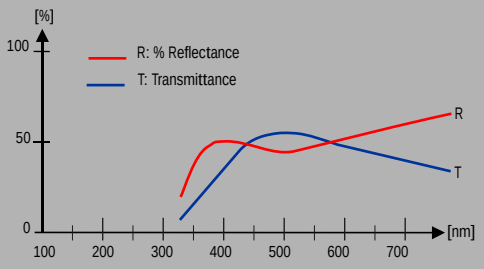
Parameter	based on 4 Picos technology	based on 4 Quik E technology
Shortest gating time	0.2ns	1.2ns
Minimum delay steps	10ps steps	100ps steps
Image intensifier size	18mm	
Spectral sensitivity	depends on image intensifier, standard: 380 - 700nm (limited by splitting optic) optional: 200 - 700nm (with UV enhanced splitting optic) Note: the system sensitivity is limited by the photocathode (see page 7)	
Delay and gate electronics	all integrated in the body (all in one)	
Dimensions (without objective lens)	4, 8 channels: 625 x 325 x 375mm (body only)	
Weight	4, 8-channel system: 32kg, 38kg	

based on 4 Picos or 4 Quik E technology

2014 PRISM AWARDS FINALIST

Stanford Computer Optics developed and designed the mirror based image splitter to provide the best optical resolution and imaging quality with the multi-channel ICCD camera, XXRapidFrame. This customized image splitter does provide spectral flat response over the UV, VIS and IR and splits the incoming light equally between the attached channels. Hence, the mirror based image splitter has numerous advantages in comparison to competing solutions.

Image splitter comparison

Parameter	customized mirror based image splitter	semi transparent mirror image splitter
Optical layout		
Spectral splitting characteristics		
Advantages	+ flat spectral response + expandable to UV + light and compact + multi-spectral imagery	+ multi-spectral imagery
Disadvantages		- spectral response depending on the characteristics of the mirror - not expandabel to UV - heavy and large

UV enhanced image splitter

The standard mirror based image splitter enables measurements down to 350nm. Even if the downstream ICCD cameras are sensitive in the UV the light below 350nm just does not pass the image splitter. The UV enhanced mirror based image splitter enables in combination with the adequate photo-cathode measurements down to 200nm. It consist of a customized, in-house developed lens system including 6 lenses made of UV capable material like MgF2 and adequate mirror coatings.

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